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Proceedings

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Forward & Executive Report

The organizers of the International Conference on Systematic Innovation (ICSI) and Global Competition on Systematic Innovation (GCSI) are pleased to present the proceedings of the conference and the Program of Innovative Project Exhibition which includes 72 papers/presentations and 17 finalist innovation projects.

This is the first time in the innovation field that two major international conferences are joining together. The Korean Global TRIZCON and the International Conference on Systematic Innovation are held together in all plenary events and separately administer in the break-up sessions. All participants will receive the same papers/presentation materials. The organizers of ICSI are greatly indebted to a number of people who gave their time to make the conference a reality. In particular, the greatest thanks should go to the Korean Academic TRIZ Association - especially Professor Kyeong Won Lee, Ms Shin, and KATA's organizing committee for their willingness to support many of the local affairs. Of course, on behalf of the ICSI & GCSI organizing committee, I would like to thank and welcome all participants. Without your participation, this joint conference will be meaningless. The list of organizations and working team who have contributed tremendous amount of time and efforts to create this conference are acknowledged at the end of this program brochure. There are more contributors who are beyond the list.

Besides the regular conference with many good papers, some special features of this event include three keynotes and three tutorials by world renown innovation experts. A very special feature of this conference is that the excellent papers from the conference will be invited to submit to the **International Journal of Systematic** Innovation (IJoSI). The Journal is the only scientifically oriented journal dedicated to the field of Systematic Innovation including TRIZ. You are also cordially invited to submit your regular papers to the IJoSI at www.ijosi.org.

Whether the papers included in the proceedings are work-in-progress or finished products, the conference and proceedings offer their authors an opportunity to disseminate the results of their research and receive early feedback from colleagues, without the long lead time associated with publication in peer-reviewed journals. On the other hand, the presentations and the proceedings do not preclude the option of submitting the work in an extended and finished form for publication in the IJoSI or another peer-reviewed journal.

Another special feature of this conference is that there is also an exhibition on Systematic Innovation taking on the corridor of this conference. This is an opportunity to showcase innovation projects in the international Arena. This Global Competition on Systematic Innovation (GCSI) is the ONLY innovation/invention competition in the world which not only concerns the results but also concerns the systematic methodical processes bringing about the results. Special Features of the Competition include: 1) Both “Opportunity Identification” and “Problem Solving” types of projects are valued; 2) Both results and idea generating processes are accounted for in the evaluation of each project. You will see the 16 finalist projects in the conference exhibition site this year. The first place winner will be awarded USD 1,000 in addition to a Gold medal and a certificate. All the Gold, Silver, and Bronze medal projects will be published on the GCSI web and the awards will be presented to the winners in the closing ceremony of the ICSI conference. You are invited to submit your innovation next year. The next year's ICSI will be held in Hsinchu, Taiwan in conjunction with the IFIP International Conference on Computer-aided Innovation during June 27-29, 2013. One day free tour will be offered to first 40 international participants. There will also be the final round of Global Exhibition on Systematic Innovation on the conference site. Again, **the first place winner will have USD 1,000 award and Gold medal.** There are multiple Gold, Silver, and Bronze medals available. You are most welcome to participate in these synergized events.

We are confident that you will find the participation in this conference rewarding. If there is anything that you need assistance, please feel free to inform the attendant(s) at the service desk. We are here to serve you.

With best regards,

D. Daniel Sheu, Ph.D., MBA, CMfgE
General Chair & Chair of Organizing Committee
The International Conference & Global Competition on Systematic Innovation
President, the Society of Systematic Innovation
Editor-in-Chief, the International Journal of Systematic Innovation

Paper List

Part 1. Full Papers in English

Part 2. Full Chinese Papers Preceded by English Title and Abstract

Paper ID: 13

Development of Vibrating Plates and Innovative Planar Loudspeakers

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Abstract

The 3C products of thin speaker technology have been gradually paid with great attention. This creation of planar loudspeakers have the properties of light weight, thin exciter, and broad response of frequency. One flat-panel is able to play from the tweeter to the woofer, and it also has the live sound quality and clear. Exciter has a damper device to inhibit the high-frequency distortion. The strip-shaped exciter can be changed for length according to various product sizes, and its width does not need to enlarge. The thickness can be less than 8~13 mm which it is much thinner than the current market product of flat speaker (22mm) about 40%. Excitation device using braided carbon fiber. Exciter and magnet are produced modularly and easy to assemble. The membranes used carbon fiber prepreg layers (or nano-carbon tube) and foam boards (or Balsa) to combine the sandwich membranes, which were then applied to the planar loudspeakers. The primary purpose of this paper is to determine the optimal design method for manufacturing gamut planar loudspeakers by developing a membrane, producing the exciter, and selecting the surround. The paper employed analysis method to determine the sound pressure curves at 100 Hz to 20KHz for planar loudspeakers. The study of planar loudspeakers can be equipped in portable DVD players and plane crafts ... and other flat electronics. The technology developed here is expected to become the new trend of future.

Keywords: 3C product, planar loudspeakers, nano-carbon tube, sandwich membrane, sound pressure curve

1. Introduction

This article mainly introduces that sandwich planar loudspeakers are invented with the sound pressure emulation analysis, optimal design, assembly and measurement of entities. The simulation analysis and design optimization of the sound pressure curves of the sandwich planar loudspeakers are discussed firstly in this article. Utilize the optimization to assemble the components and entities of the

planar loudspeakers and measure of the sound pressure curves. The paper used carbon fiber prepreg layers (or nano-carbon tube) and foam boards (or Balsa) to combine the sandwich membranes, which were then applied to the planar loudspeakers. An optimal sandwich membrane, which includes a stiffed pattern, minimum weight, and stiffness, affects the high-frequency sound quality and sound pressure curve. That is using carbon fiber to get the effect of stiffening for planar loudspeakers and using finite element analysis and Fortran software to determine the smooth sound pressure curves at 100 Hz to 20KHz. During experiments, we measured the sound pressure curves to verify the value of the proposed theory. The experimental results are used to verify the accuracy of the proposed analysis. At last, the sound pressure curves of experimental measurement and simulation analysis is compared and confirmed to ensure the consistency the simulation data and experimental data.

2. Research methods

Research methods in the implementation section of this article contains mainly the patterns of the design and production of the loudspeaker plates, the development of the surrounded fixtures, and the assembly and measure of the loudspeakers; the software includes ANSYS and Fortran; the design and development of the planar loudspeakers are undertaken from above directions. First of all, exercising ANSYS establishes the analysis model for the calculation of the amplitude and phase angle on each Node and integrates the data into equation. Lastly, this is using Fortran software and solving for the best manufacturing parameters in this article obtain the SPL modeling. In the entity manufacture, after the planar loudspeakers assembled, CLIO Spectrum Analyzer of sound pressure measurement is used to measure the SPL within 20Hz~20KHz and ORIGIN6.0 draws theoretical and experimental values of the pressure curves to contrast; then the results are compared and confirmed for the accuracy of the theory.

▪2.1 Reference

The literature of the calculation and optimization method of the sound pressure curves, Morse (1968) drove the sound pressure equations through audio source in air delivery. Mingsian and Bowen's (2004) manipulation of genetic algorithms in the development of the effectiveness of full frequency range of planar loudspeakers not only earned optimal manufacturing parameters but also had a better effectiveness on the planar loudspeakers. Lee (2006) had developed the small flat-panel speaker, which could reduce the effect of median frequency gap efficiently by enhance stiffness of the flat-panel speaker. The sound pressure level (SPL) can be calculated by finite element method (FEM), Takeo (1980). This project used Fortran and ANSYS software to simulated the SPL by calculating the frequency (20Hz to 20KHz) and phase angle.

▪2.2 Components manufacturing

The main entity manufacturing in the first part is the spring system; second part is the membranes and the final part is the exciter production. Figure 1 shows conformation of sandwich planar loudspeakers. The illustrations of flat-panel speakers processing are as follows:

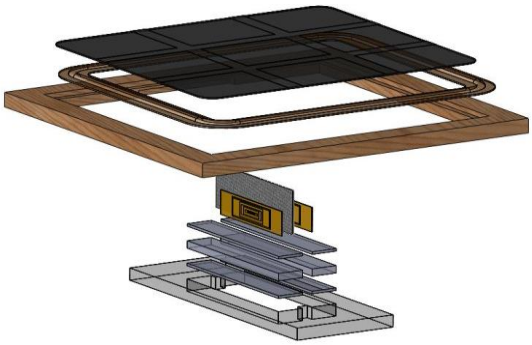


Figure 1. Illustration of Sandwich planar loudspeakers.

(i) The production of the spring systems

The main function of the spring system (Figure 2) to support the vibration of the membranes and stick the membranes to a fixed position; the irregular swings won't occur when vibration motion happens; besides, the spring system has to be stable under the vibration of the maximum power. In this way, the *fo* value of the first resonance could be reduced.

Figure 2. Illustration of the spring system.

(ii) The production of the composite sandwich membranes

Two kinds of processing of the membranes forming can been seen in this article. One is that the foam board is used to be the substrate; the foam board testing is cut into the dimension 265 mm×18 mm×1.8 mm and then the prepreg carbon fiber material is cut into the dimension 265 mm×18 mm×1.8 mm; the top and bottom side of the prepreg carbon fiber material is pressed by steel plates and put it into the oven. After baking, apply the AB silicone to the foam board evenly; attach the prepreg carbon fiber material to the foam board and the production is completed after pressed for two hours by weight (Figure 3).

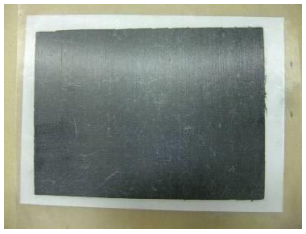


Figure 3. Completing membranes of the carbon fiber.

(iii) The production of the exciter

The exciter is mainly made up of voice coil and exciter plates(Figure 4). The material of exciter has to be high-temperature-proof and unfragile. The material of the exciter plates is woven carbon fiber prepreg. Because of the preferable mechanical properties of high stiffness and lightweight, the exciter is light in weigh and strong but easily damaged.

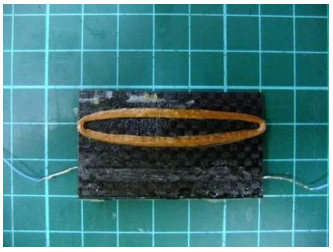


Figure 4. Finished version of a exciter.

(iv) Planar-loudspeaker entity assembled

First, twin adhesive is adhered to the four-side interior of a spring, and apply the resin to the spring; membranes are attached to the inside of the spring; then magnets are plugged into the frame. Chisel two small holes close to the magnet frame (thread using) and attach the springs and membranes to the frame. Apply the silicon to the junction of the frame and the spring. After the silicon dried, bond the exciter and membranes with AB silicon. For sticking the exciter to the center precisely, measure the central point before sticking it. Position the magnet frame exactly in order that the coil won't scratch the magnet and keep equal distance between two ends. After positioning is done, apply silicon to the junction of the magnet frame and exterior frame. The planar loudspeakers are set up after all junctions are checked and one-day solidification. Figure 5 shows the assembly.

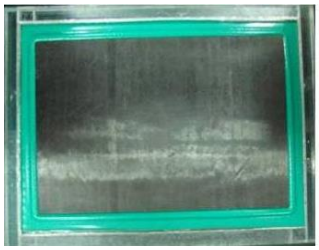


Figure 5. Finished version of a planar – loudspeaker entity.

(v) Measurement of a planar loudspeaker

The surroundings must be in anechoic chamber, measurement must be with spectrum analyzer of sound pressure of CLIO, and measured distance is 50cm when the sound-pressure curves of the sandwich material are measured. Figure 6 shows the assembly.

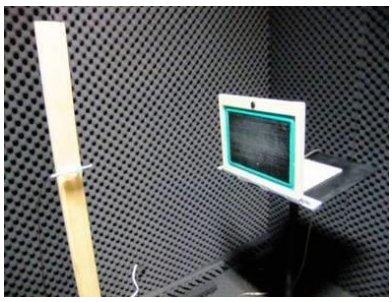
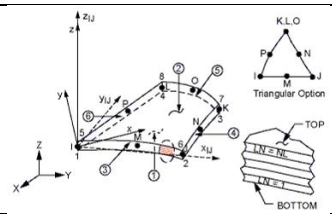
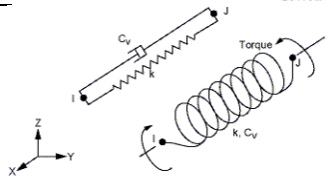
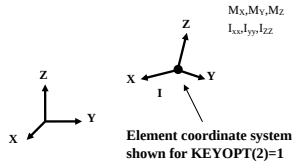
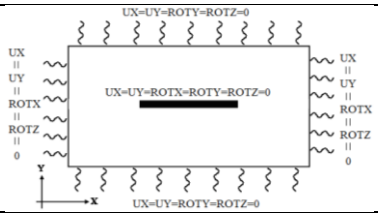


Figure 6. A illustration of the measurement of a planar loudspeaker.

▪2.3 Finite element analysis

This study uses ANSYS software to modeling the completing membranes of the foam board and carbon fiber material problems, in which the Shell 99 (Table 1) are employed. The Shell 99 element has eight nodes that each node has six degrees. Table 1 shows the boundary conditions of membrane are taken for the membrane.

Table 1. This is an example a table caption.

Element	Figure	Abstract
Plane element (Shell99)		Sandwich structure model of the diaphragm, mainly used to build the laminated plate elements can enter the stack number, angle and thickness of this element for the 8 node (NODE) elements, each node has six degrees of freedom.
Spring elements (Combin14)		Spring element, this element is constituted by two nodes, you can enter the spring constant (K).
Elements of mass node (Mass21)		Mass elements is used in the surround and voice coil, and can enter the mass of single node.
Boundary constions		Fixed the UX, UY, ROTY, ROTZ for X direction and fixed UX, UY, ROTX, ROTZ for Y direction. The vibration area is fixed the UX、UY、ROTX、ROTY、ROTZ。

3. Result and Disussion

In order to verify the correctness_of theoretical analysis of sound pressure curves, comparison between the experiment and analysis of the sound pressure curves. The PVC is used to produce spring system, foam boards and prepreg carbon fiber material are adopted to make membranes, and planar loudspeakers with dimension 265mm×180mm×1.8mm (LxWxT) of composite sandwich material are assembled. Figure 4-2 compares the experiment and analysis of the sound pressure curves, and the *f*o value of the experiment and analysis of the sound pressure curves is very close. Accordingly, the model of theoretical analysis is feasible. The material properties of foam boards and prepreg carbon fiber material are shown in Table 2. .

Table 2. This is mechanical properties.

Materials / Properties	Foam board	Prepreg carbon fiber material
E_1	1.89 Gpa	147.503Gpa
$E_2=E_3$	1.89 Gpa	9.223Gpa
$\nu_{12}=\nu_{13}$	0.25	0.306
ν_{23}	0.25	0.25
$G_{12}=G_{13}$	0.756 Gpa	6.8533Gpa
G_{23}	0.756 Gpa	1.1229Gpa
ρ	46.2Kg/m^3	1747Kg/m^3

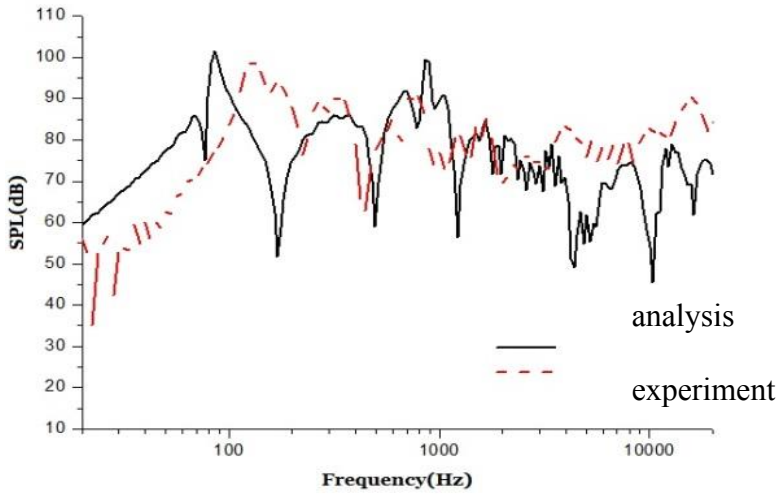


Figure 7. The experiment and analysis of the sound pressure curves.

4. Conclusion

This study provides a useful procedure for manufacturing innovative planar loudspeakers. The paper is developed sandwich membrane, which includes a stiffed pattern, minimum weight, and stiffness, affects the high-frequency sound quality and sound pressure curve. The finite element analysis using ANSYS shell99 model for planar loudspeakers reveals the correct results of modal analysis, so these models are enable to analyze the further mechanical behaviors. The experimental results are used to verify the accuracy of the proposed analysis.

▪Reference

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Lee, T. Y. , Optimal Design of Stiffened Composite Flat-Panel Speakers by Nano-Carbon Tube", Master paper, Industrial Engineering and Technology Management, Da-Yeh University, 2006.

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Paper ID: 15

ANALYSIS OF THE BEHAVIOR OF KURTOSIS BY UTILIZING TRIANGLE MODEL

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Abstract

Among many dimensional and dimensionless amplitude parameters, Kurtosis(4-th normalized moment of probability density function) is recognized to be the sensitive good parameter for machine diagnosis. Kurtosis has a value of 3.0 under normal condition and the value generally goes up as the deterioration proceeds. But there are cases that kurtosis value goes up and then goes down when damages increase as time passes. In this paper, simplified calculation method of kurtosis is introduced for the analysis of impact vibration including affiliated impact vibration. One of the TRIZ methods is extended and applied. Affiliated impact vibration is approximated by triangle and simplified calculation method is introduced. Varying the shape of triangle, various models are examined and above phenomenon is traced and its reason is clarified by the analysis. Utilizing this method, the behavior of kurtosis is forecasted and analyzed while watching machine condition and correct diagnosis is executed.

Key Words: impact vibration, Kurtosis, deterioration

1. Introduction

In mass production firms such as steel making that have big equipments, sudden stops of production processes by machine failure cause great damages such as shortage of materials to the later processes, delays to the due date and the increasing idling time.

To prevent these troubles, machine diagnosis techniques play important roles. So far, Time Based Maintenance (TBM) technique has constituted the main stream of the machine maintenance, which makes checks for maintenance at previously fixed time. But it has a

weak point that it makes checks at scheduled time without taking into account whether the parts still keeping good conditions or not. On the other hand, Condition Based Maintenance (CBM) makes maintenance checks by watching the condition of machines. Therefore, if the parts are still keeping good condition beyond its supposed life, the cost of maintenance may be saved because machines can be used longer than planned. Therefore the use of CBM has become dominant. The latter one needs less cost of parts, less cost of maintenance and leads to lower failure ratio.

However, it is mandatory to catch a symptom of the failure as soon as possible of a transition from TBM to CBM is to be made. Many methods are developed and examined focusing on this subject. In this paper, we propose a method for the early detection of the failure on rotating machines which is the most common theme in machine failure detection field.

So far, many signal processing methods for machine diagnosis have been proposed (Bolleter, 1998). As for sensitive parameters, Kurtosis, Bicoherence, Impact Deterioration Factor (ID Factor) were examined (Yamazaki, 1977; Maekawa et al.1997; Shao et al.2001; Song et al.1998; Takeyasu, 1987,1989). In this paper, we focus our attention to the index parameters of vibration.

Kurtosis is one of the sophisticated inspection parameters which calculate normalized 4th moment of Probability Density Function (PDF). Kurtosis has a value of 3.0 under normal condition and the value generally goes up as the deterioration proceeds. But there were cases that kurtosis values went up and then went down when damages increased as time passed which were observed in our experiment in the past (Takeyasu,1987,1989).

In this paper, simplified calculation method of kurtosis is introduced for the analysis of impact vibration including affiliated impact vibration. One of the TRIZ methods is extended and applied. Affiliated impact vibration is approximated by triangle and simplified calculation method is introduced.

Varying the shape of triangle, various models are examined and we try to clarify the reason of above stated phenomenon. If the new model states the observed facts well, this new method would be utilized effectively in making machine diagnosis.

Extended analysis method is stated in section 2. We survey each index of deterioration in section 3. Simplified calculation method of Kurtosis including affiliated impact vibration is introduced in section 4. Numerical example is exhibited in section 5. Section 6 is a summary.

2. Extended Analysis Method

Boris Zlotin & Alla Zusman proposed the concept of "Trends" in TRIZ CON 2006 (Boris Zlotin et al., 2006). We can further develop this concept as shown in Figure 1.

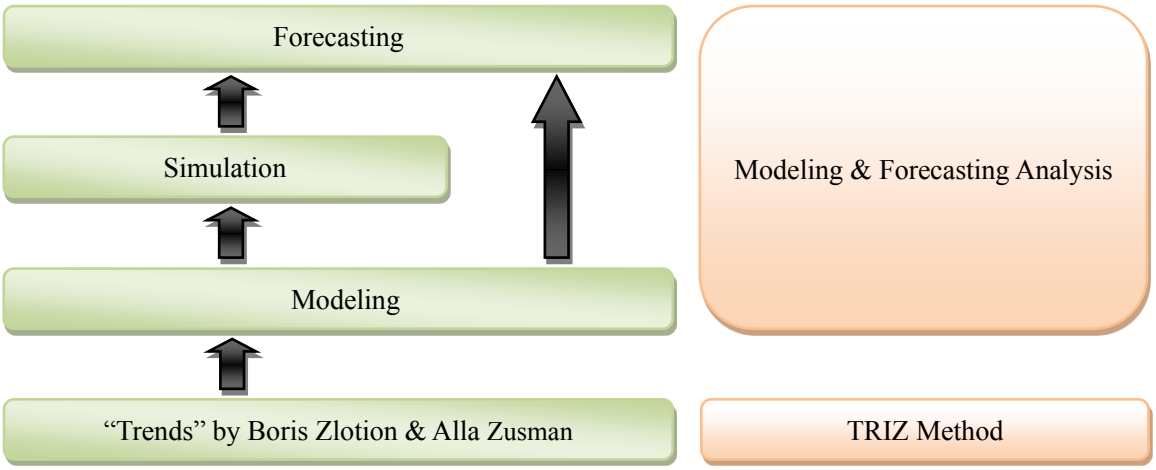

Figure 1. Extended Analysis Method

Based on the TRIZ method, modeling and forecasting analysis method is developed. Extending "Trends", modeling is constructed first. Then we can make simulation by utilizing them. We can make forecasting utilizing the simulation function or directly from the utilization of the model built. These are the process of "Modeling & Forecasting Analysis" based upon TRIZ "Trends" analysis method. Detailed inspection is executed in section 4 and 5.

3. Factors for Vibration Calculation

In cyclic movements such as those of bearings and gears, the vibration grows larger whenever the deterioration becomes bigger. Also, it is well known that the vibration grows large when the setting equipment to the ground is unsuitable (Yamazaki, 1977). Assume the vibration signal is the function of time as $x(t)$. And also assume that it is a stationary time series with mean 0. Denote the probability density function of these time series as $p(x)$. Indices for vibration amplitude are as follows.

$$X_{root} = \left[\int_{-\infty}^{\infty} |x|^{\frac{1}{2}} p(x) dx \right]^2 \tag{1}$$

$$X_{rms} = \left[\int_{-\infty}^{\infty} x^2 p(x) dx \right]^{\frac{1}{2}} \tag{2}$$

$$X_{abs} = \int_{-\infty}^{\infty} |x| p(x) dx \tag{3}$$

$$X_{peak} = \lim_{n \to \infty} \left[\int_{-\infty}^{\infty} x^n p(x) dx \right]^{\frac{1}{n}} \tag{4}$$

These are dimensional indices which are not normalized. They differ by machine sizes or rotation frequencies. Therefore, normalized dimensionless indices are required. There are four big categories for this purpose.

A. Normalized root mean square value
B. Normalized peak value
C. Normalized moment
D. Normalized correlation among frequency domain

A. Normalized root mean square value

a.Shape Factor : SF

$$SF = \frac{X_{rms}}{\overline{X}_{abs}} \tag{5}$$

($\overline{X}_{abs}$: mean of the absolute value of vibration)

B. Normalized peak value

b.Crest Factor : CrF

$$CrF = \frac{X_{peak}}{X_{rms}} \tag{6}$$

(X_{peak} : peak value of vibration)

c.Clearance Factor : ClF

$$ClF = \frac{X_{peak}}{X_{root}} \tag{7}$$

d.Impulse Factor : IF

$$IF = \frac{X_{peak}}{\overline{X}_{abs}} \tag{8}$$

e.Impact Deterioration Factor : ID Factor

$$ID = \frac{X_{peak}}{X_c} \tag{9}$$

(X_c : vibration amplitude where the curvature of PDF becomes maximum)

C. Normalized moment

f.Skewness : SK

$$SK = \frac{\int_{-\infty}^{\infty} x^3 p(x)dx}{\left[\int_{-\infty}^{\infty} x^2 p(x)dx\right]^{\frac{3}{2}}} \tag{10}$$

g.Kurtosis : KT

$$KT = \frac{\int_{-\infty}^{\infty} x^4 p(x)dx}{\left[\int_{-\infty}^{\infty} x^2 p(x)dx\right]^{2}} \tag{11}$$

D. Normalized correlation in the frequency domain

h.Bicoherence

Bicoherence means the relationship of a function at different points in the frequency domain and is expressed as

$$Bic,_{xxx}(f_1, f_2) = \frac{B_{xxx}(f_1, f_2)}{\sqrt{S_{xx}(f_1)\cdot S_{xx}(f_2)\cdot S_{xx}(f_1+f_2)}} \tag{12}$$

Here

$$B_{xxx}(f_1, f_2) = \frac{X_T(f_1)\cdot X_T(f_2)\cdot X_T^*(f_1+f_2)}{T^{\frac{3}{2}}} \tag{13}$$

means Bispectrum and

$$X_T(t) = \begin{cases} x(t) & (0 < t < T) \\ 0 & (else) \end{cases}$$

T : Basic Frequency Interval

$$X_T(f) = \int_{-\infty}^{\infty} X_T(t) e^{-j2\pi ft} dt \tag{14}$$

$$S_{xx}(f) = \frac{1}{T} X_T(f) X_T^*(f) \tag{15}$$

Range of Bicoherence satisfies

$$0 < Bic,_{xxx}\left(f_1, f_2\right) < 1 \tag{16}$$

When there exists a significant relationship between frequencies f_1 and f_2, Bicoherence is near 1 and otherwise comes close to 0. These indices are generally used in combination and machine condition is judged totally. Among them, Kurtosis is said to be superior index (Noda, 1987) and many researches on this have been made (Maekawa et al.1997; Shao et al.2001; Song et al.1998). Judging from the experiment we made in the past, we may conclude that Bicoherence is also a sensitive good index (Takeyasu, 1989, 1989).

In Maekawa et al.(1997), ID Factor is proposed as a good index. In this paper, we focusing on the indices of vibration amplitude, simplified calculation method of Kurtosis including affiliate impact vibration is introduced.

4. Simplified Calculation Method of Kurtosis

4.1 Several Facts on Kurtosis

KT is transformed into the one for discrete time system as

$$\begin{aligned} KT &= \frac{\int_{-\infty}^{\infty} x^4 p(x)dx}{\left[\int_{-\infty}^{\infty} x^2 p(x)dx\right]^2} \\ &= \lim_{N\to\infty} \frac{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^4}{\left\{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2\right\}^2} \end{aligned} \tag{17}$$

Here,

$$\{x_i\} : i = 1, 2, \cdots, N$$

are the discrete signal data. $\bar{x}$ is an average of $\{x_i\}$

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$$

Here the variance, the mean, *KT* of N amount of data are stated as

$\sigma_N{}^2$, $\overline{x_N}$, KT_N

4.2 Simplified Calculation Method of Kurtosis

When there arise failures on bearings or gears, peak value arise cyclically. In the early stage of the defect, this peak signal usually appears clearly. Generally, defects will injure another bearing or gears by contacting the inner covering surface as time passes. When defects grow up, affiliate impact vibration arises.

Assume that the peak signal which has p times magnitude from normal signals arises during m times measurement of samplings. As for determining sampling interval, sampling theorem is well known (Tokumaru et al.1982). But in this paper, we do not pay much attention on this point in order to focus on our proposal theme.

Suppose that affiliate vibration can be approximated by triangle and set sampling count as d, then we can assume following triangle model (Figure 2).

When $d=1$, the peak signal which has p times magnitude from normal signals arises.

When $d=i$, the peak signal which has $p-(i-1)\frac{p-1}{q}$ times magnitude from normal signals arises ($i=1,\cdots,q$).

When $d \geq q+1$, normal signal.

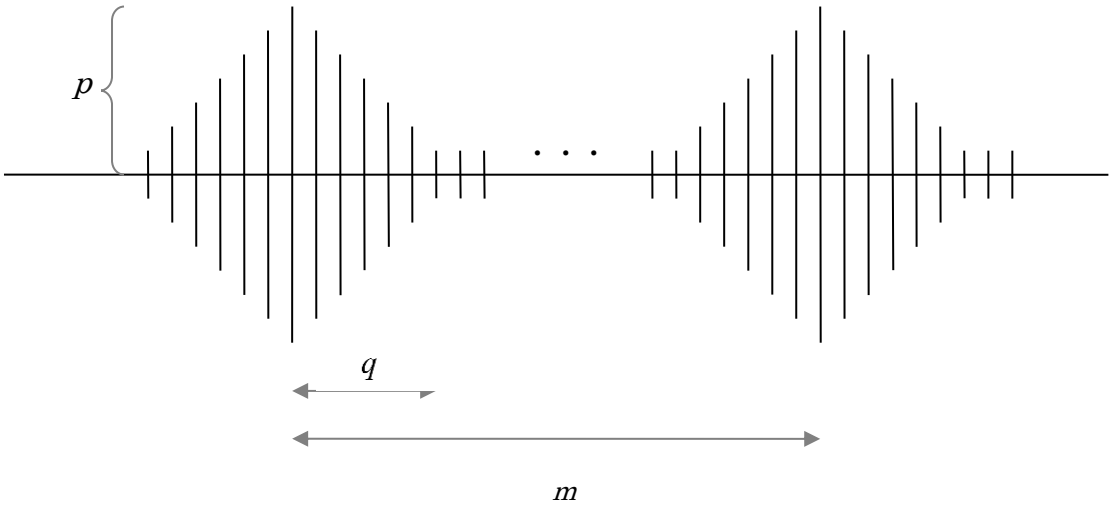

Figure 2. Impact Vibration and Affiliated Vibration

Let $\sigma_N{}^2$ state as $\overline{\sigma_N}^2$ when impact vibration occurs. As for 4th moment and Kurtosis, let them state as $\overline{MT_N}(4)$, $\overline{KT_N}$ in the same way. $\overline{\sigma_N}^2$ can be calculated as follows.

$$\begin{aligned}\overline{\sigma_N}^2 &= \frac{1}{m-1}\sum_{i=1}^{m}\left(x_i-\bar{x}\right)^2 \\ &= 2\left[\sum_{i=1}^{q}\left\{p-(i-1)\frac{(p-1)}{q}\right\}^2\right]\frac{\sigma_N{}^2}{m-1}+(m-1-2q)\frac{\sigma_N{}^2}{m-1} \\ &= \sigma_N{}^2+\frac{\sigma_N{}^2}{m-1}(q+1)(p-1)\left\{2+\frac{(p-1)(2q+1)}{3q}\right\}\end{aligned} \tag{18}$$

As for $\overline{MT_N}(4)$, utilizing

$$\begin{aligned}\sum_{i=1}^{n} i^3 &= \left\{\frac{n(n+1)}{2}\right\}^2 \\ \sum_{i=1}^{n} i^4 &= \frac{n}{30}(n+1)(2n+1)(3n^2+3n-1)\end{aligned} \tag{18}$$

$\overline{MT_N}(4)$ can be calculated as follows.

$$\begin{aligned}\overline{MT_N(4)} &= \frac{1}{m-1}\sum_{i=1}^{m}\left(x_i-\bar{x}\right)^4 \\ &= \frac{2}{m-1}\left[\sum_{i=1}^{q}\left\{p-(i-1)\frac{(p-1)}{q}\right\}^4\right]MT_N(4)+\frac{m-1-2q}{m-1}MT_N(4) \\ &= \left[1+\frac{2}{m-1}(q+1)(p-1)\left\{\frac{1}{30}(p-1)^3\frac{1}{q^3}(2q+1)(3q^2+3q-1)+(p-1)^2\frac{1}{q}(q+1)+(p-1)\frac{1}{q}(2q+1)+2\right\}\right]MT_N(4)\end{aligned} \tag{19}$$

Then we get $\overline{KT_N}$ as

$$\overline{KT_N} = \frac{\left[1+\frac{2}{m-1}(q+1)(p-1)\left\{\frac{1}{30}(p-1)^3\frac{1}{q^3}(2q+1)(3q^2+3q-1)+(p-1)^2\frac{1}{q}(q+1)+(p-1)\frac{1}{q}(2q+1)+2\right\}\right]KT_N}{\left[1+\frac{1}{m-1}(q+1)(p-1)\left\{\frac{2q+1}{3q}(p-1)+2\right\}\right]^2} \tag{20}$$

Here we introduce the following number. Each index is compared with normal index as follows.

$$F_a = \frac{P_{abn}}{P_{nor}} \tag{21}$$

Here,

P_{nor} : Index at normal condition

P_{abn} : Index at abnormal condition

We get F_a as

$$F_a = \frac{\overline{KT_N}}{KT_N}$$
$$= \frac{1+\frac{2}{m-1}(q+1)(p-1)\left\{\frac{1}{30}(p-1)^3\frac{1}{q^3}(2q+1)(3q^2+3q-1)+(p-1)^2\frac{1}{q}(q+1)+(p-1)\frac{1}{q}(2q+1)+2\right\}}{\left[1+\frac{1}{m-1}(q+1)(p-1)\left\{\frac{2q+1}{3q}(p-1)+2\right\}\right]^2} \tag{22}$$

5. Numerical Example

If the system is under normal condition, we may suppose $p(x)$ becomes a normal distribution function. Under this condition, KT is always

$KT = 3.0$

Under the assumption of 3, let $m = 12$. Considering the case $p = 1,2,\ldots,6$ and $q = 1,2,3,4$, we obtain Table 1 from the calculation of (22).

Table 1. F_a by the variation of p, q

		p					
		1	**2**	**3**	**4**	**5**	**6**
q	**1**	1.0	1.561	2.580	3.409	3.978	4.361
	2	1.0	1.421	2.030	2.477	2.775	2.988
	3	1.0	1.320	1.709	1.971	2.142	2.251
	4	1.0	1.235	1.482	1.644	1.749	1.821

	5	1.0	1.157	1.311	1.412	1.480	1.527

As $KT_N \cong 3.0$, we show Table 2 as an approximation of $\overline{KT_N}$ by multiplying 3.0 for each item of Table 1.

Table 2. $\overline{KT_N}$ for each case

		p					
		1	**2**	**3**	**4**	**5**	**6**
q	**1**	3.0	4.683	7.740	10.227	11.934	13.083
	2	3.0	4.263	6.090	7.431	8.325	8.964
	3	3.0	3.960	5.127	5.913	6.426	6.753
	4	3.0	3.705	4.336	4.932	5.247	5.463
	5	3.0	3.470	3.935	4.238	4.440	4.582

As p increases, F_a and $\overline{KT_N}$ increase. On the other hand, F_a and $\overline{KT_N}$ decrease as q increases when p is the same. When damages increase or transfer to another place, peak level grows up and affiliate impact vibration spread. This means that $\overline{KT_N}$ value shift from left-hand side upwards to right-hand side downwards in Table 2. For example, following transition of $\overline{KT_N}$ can be supposed.

When $q=1,\ p=1,\ \overline{KT_N}=3.0$

When $q=1,\ p=2,\ \overline{KT_N}=4.683$

When $q=4,\ p=3,\ \overline{KT_N}=4.336$

When $q=5,\ p=6,\ \overline{KT_N}=4.582$

We made experiment in the past (Takeyasu(1987),Takeyasu(1989)). Summary of the experiment is as follows. Pitching defects are pressed on the gears of small testing machine.

Small defect condition: Pitching defects pressed on 1/3 gears of the total gear.

Middle defect condition: Pitching defects pressed on 2/3 gears of the total gear.

Big defect condition: Pitching defects pressed on whole gears of the total gear.

RMS and Kurtosis in this case are exhibited in Table 3.

Table 3. Experiment Result

	Kurtosis	RMS
Normal	2.961	289.212
Small Defect	3.747	671.175
Middle Defect	2.970	833.592
Big Defect	3.310	855.375

RMS values grow up as damages increase. Kurtosis value responds to the damage in the small defect level. But it is rather close to normal level under middle and goes up again in big defect. We thought damages became rounded, so Kurtosis had fallen. Considering the above stated model which includes the affiliate impact vibration, we can explain the case that Kurtosis is big initially and then fall and goes up again. Though the score may differ by the adjustment of parameter, we can analyze the behavior of Kurtosis principally by utilizing this simplified model and calculation method.

We can easily calculate (20) watching the waveform at the maintenance site, and we can get much more correct estimation of Kurtosis than the method presented by Takeyasu et al. 2003.

Changing the variable set (p,q) by 0.1 for each variable from (1.0, 1.0) to (7.0, 8.0), following results are obtained. We show the summary version in Table 4, Table 5 and the detailed version in Appendix.

Table 4. The variable set (p,q) which is close to the value in Table3

	Experiment results Kurtosis	(p,q)	Kurtosis value under the set(p, q)
Normal	2.961	(1,1)	3.000
Small Defect	3.747	(1.7,1.7)	3.755
Middle Defect	2.970	(1.8,7.3)	3.013
Big Defect	3.310	(6.0,7.4)	3.308

Table 5. The variable set (p,q) which is close to the value in Table3 (exhibited by range)

Small Defect	(p,q)	(1.7,1.5)~(1.7,2.0)	(1.8,2.5)~(1.8,3.0)	(1.9,3.2)~(1.9,3.6)	(2.0,3.3)~(2.0,4.0)	(2.1,4.0)~(2.1,4.3)
	Kurtosis	3.786~3.712	3.795~3.703	3.789~3.701	3.780~3.705	3.791~3.708
Middle Defect	(p,q)	(1.7,6.1)~(1.7,7.6)	(1.9,6.3)~(1.9,7.6)	(2.1,6.6)~(2.1,7.7)	(2.3,6.7)~(2.3,7.7)	(2.7,6.9)~(2.7,7.7)
	Kurtosis	3.194~2.970	3.190~2.974	3.181~2.966	3.176~2.978	3.189~2.983
Big Defect	(p,q)	(5.2,7.1)~(5.2,7.3)	(5.6,7.2)~(5.6,7.3)	(6.0,7.2)~(6.0,7.4)	(6.4,7.3)~(6.4,7.4)	(6.8,7.3) ~(6.8,7.5)
	Kurtosis	3.376~3.300	3.363~3.324	3.386~3.308	3.367~3.328	3.386~3.307

6. Conclusion

We proposed a simplified calculation method of Kurtosis for the analysis of impact vibration including affiliated impact vibration. One of the TRIZ methods was extended and applied. Affiliated impact vibration was approximated by triangle and simplified calculation method was introduced. Varying the shape of triangle, various models were examined and the phenomenon that Kurtosis went up and down as the deterioration proceeded was traced and its reason was clarified by the analysis.

Utilizing this method, the behavior of Kurtosis would be forecasted and analyzed while watching machine condition and correct diagnosis would be executed.

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Appendix.

As the table becomes so large, table is divided into three for the corresponding part of the defect condition. Kurtosis shown by range in Table 5 is indicated with boldface.

Table 6. The variable set (p,q) which is close to the value in Table3

(Small Defect)

		p										
		1.5	**1.6**	**1.7**	**1.8**	**1.9**	**2.0**	**2.1**	**2.2**	**2.3**	**2.4**	**2.5**
	1.0	3.463	3.659	3.883	4.131	4.398	4.682	4.977	5.282	5.592	5.906	6.220
	1.1	3.453	3.643	3.859	4.097	4.354	4.624	4.906	5.195	5.490	5.786	6.083
	1.2	3.445	3.630	3.838	4.068	4.314	4.573	4.842	5.117	5.396	5.678	5.958
	1.3	3.438	3.617	3.820	4.041	4.278	4.526	4.783	5.045	5.311	5.578	5.844
q	**1.4**	3.431	3.606	3.802	4.016	4.244	4.482	4.728	4.979	5.232	5.486	5.738
	1.5	3.425	3.595	**3.786**	3.993	4.212	4.442	4.677	4.917	5.159	5.400	5.639
	1.6	3.419	3.585	**3.770**	3.970	4.182	4.403	4.629	4.858	5.089	5.319	5.547
	1.7	3.413	3.575	**3.755**	3.949	4.154	4.366	4.583	4.803	5.023	5.242	5.459
	1.8	3.407	3.565	**3.740**	3.929	4.126	4.331	4.539	4.750	4.960	5.169	5.376
	1.9	3.401	3.556	**3.726**	3.908	4.100	4.296	4.497	4.699	4.900	5.100	5.297

	2.0	3.395	3.546	**3.712**	3.889	4.073	4.263	4.456	4.649	4.842	5.033	5.221
	2.1	3.390	3.537	3.698	3.870	4.048	4.231	4.416	4.602	4.787	4.969	5.148
	2.2	3.384	3.528	3.684	3.851	4.023	4.199	4.378	4.556	4.733	4.907	5.078
	2.3	3.378	3.518	3.671	3.832	3.998	4.169	4.340	4.511	4.680	4.847	5.010
	2.4	3.372	3.509	3.657	3.813	3.974	4.138	4.303	4.467	4.630	4.789	4.945
	2.5	3.366	3.499	3.643	**3.795**	3.950	4.108	4.267	4.425	4.580	4.733	4.882
	2.6	3.360	3.490	3.630	**3.776**	3.927	4.079	4.232	4.383	4.532	4.678	4.821
	2.7	3.354	3.480	3.616	**3.758**	3.903	4.050	4.197	4.342	4.485	4.625	4.761
	2.8	3.347	3.471	3.602	**3.740**	3.880	4.022	4.163	4.302	4.439	4.573	4.703
	2.9	3.341	3.461	3.589	**3.722**	3.857	3.994	4.129	4.263	4.395	4.523	4.647
	3.0	3.334	3.451	3.575	**3.703**	3.834	3.966	4.096	4.225	4.351	4.473	4.593
	3.1	3.327	3.441	3.561	3.685	3.812	3.938	4.064	4.187	4.308	4.425	4.539
	3.2	3.321	3.431	3.547	3.668	**3.789**	3.911	4.032	4.150	4.266	4.378	4.487
	3.3	3.314	3.421	3.534	3.650	**3.767**	**3.884**	4.000	4.114	4.225	4.333	4.437
	3.4	3.307	3.410	3.520	3.632	**3.745**	**3.858**	3.969	4.078	4.185	4.288	4.387
	3.5	3.299	3.400	3.506	3.614	**3.723**	**3.832**	3.939	4.043	4.145	4.244	4.339
	3.6	3.292	3.390	3.492	3.596	**3.701**	**3.806**	3.908	4.009	4.106	4.201	4.292
	3.7	3.285	3.379	3.478	3.579	3.680	**3.780**	3.879	3.975	4.068	4.158	4.246
	3.8	3.277	3.369	3.464	3.561	3.658	**3.755**	3.849	3.941	4.031	4.117	4.200
	3.9	3.270	3.358	3.450	3.544	3.637	**3.729**	3.820	3.908	3.994	4.077	4.156
	4.0	3.262	3.348	3.436	3.526	3.616	**3.705**	**3.791**	3.876	3.958	4.037	4.113
	4.1	3.255	3.337	3.422	3.509	3.595	3.680	**3.763**	3.844	3.923	3.998	4.071
	4.2	3.247	3.326	3.408	3.491	3.574	3.656	**3.735**	3.813	3.888	3.960	4.029
	4.3	3.239	3.315	3.394	3.474	3.553	3.631	**3.708**	3.782	3.853	3.922	3.989
	4.4	3.231	3.305	3.380	3.457	3.533	3.608	3.681	3.751	3.820	3.886	3.949
	4.5	3.223	3.294	3.367	3.440	3.512	3.584	3.654	3.721	3.787	3.850	3.910
	4.6	3.215	3.283	3.353	3.423	3.492	3.561	3.627	3.692	3.754	3.814	3.872
	4.7	3.207	3.272	3.339	3.406	3.472	3.537	3.601	3.663	3.722	3.779	3.834
	4.8	3.199	3.261	3.325	3.389	3.452	3.515	3.575	3.634	3.691	3.745	3.798
	4.9	3.191	3.250	3.311	3.372	3.433	3.492	3.550	3.606	3.660	3.712	3.761
	5.0	3.183	3.239	3.297	3.355	3.413	3.470	3.525	3.578	3.629	3.679	3.726

Table 7. The variable set (p,q) which is close to the value in Table3

(Middle Defect)

		p											
		1.6	**1.7**	**1.8**	**1.9**	**2.0**	**2.1**	**2.2**	**2.3**	**2.4**	**2.5**	**2.6**	**2.7**
q	**6.0**	3.130	3.161	3.194	3.226	3.258	3.289	3.319	3.349	3.378	3.405	3.432	3.458
	6.1	3.119	**3.148**	3.178	3.208	3.238	3.267	3.295	3.323	3.350	3.376	3.402	3.426
	6.2	3.108	**3.135**	3.163	3.190	3.218	3.245	3.272	3.298	3.323	3.348	3.371	3.394
	6.3	3.097	**3.122**	3.147	**3.173**	3.198	3.224	3.249	3.273	3.297	3.320	3.342	3.364
	6.4	3.086	**3.109**	3.132	**3.155**	3.179	3.202	3.226	3.248	3.270	3.292	3.313	3.333
	6.5	3.075	**3.096**	3.117	**3.138**	3.160	3.181	3.203	3.224	3.245	3.265	3.284	3.303
	6.6	3.064	**3.083**	3.102	**3.121**	3.141	**3.161**	3.180	3.200	3.219	3.238	3.256	3.274
	6.7	3.053	**3.070**	3.087	**3.104**	3.122	**3.140**	3.158	**3.176**	3.194	3.212	3.229	3.245
	6.8	3.043	**3.057**	3.072	**3.087**	3.104	**3.120**	3.137	**3.153**	3.169	3.186	3.202	3.217
	6.9	3.032	**3.044**	3.057	**3.071**	3.085	**3.100**	3.115	**3.130**	3.145	3.160	3.175	**3.189**
	7.0	3.021	**3.031**	3.042	**3.054**	3.067	**3.080**	3.094	**3.107**	3.121	3.135	3.149	**3.162**
	7.1	3.010	**3.018**	3.028	**3.038**	3.049	**3.061**	3.073	**3.085**	3.098	3.110	3.123	**3.135**
	7.2	3.000	**3.006**	3.013	**3.022**	3.031	**3.041**	3.052	**3.063**	3.074	3.086	3.097	**3.109**
	7.3	2.989	**2.993**	2.999	**3.006**	3.014	**3.022**	3.032	**3.041**	3.052	3.062	3.072	**3.083**
	7.4	2.979	**2.981**	2.985	**2.990**	2.996	**3.003**	3.011	**3.020**	3.029	3.038	3.048	**3.057**
	7.5	2.968	**2.968**	2.970	**2.974**	2.979	**2.985**	2.991	**2.999**	3.007	3.015	3.024	**3.032**
	7.6	2.958	**2.956**	2.956	**2.958**	2.962	**2.966**	2.972	**2.978**	2.985	2.992	3.000	**3.008**
	7.7	2.947	2.944	2.942	2.943	2.945	**2.948**	2.952	**2.957**	2.963	2.970	2.976	**2.983**
	7.8	2.937	2.931	2.929	2.927	2.928	2.930	2.933	2.937	2.942	2.947	2.953	2.959
	7.9	2.926	2.919	2.915	2.912	2.911	2.912	2.914	2.917	2.921	2.925	2.930	2.936
	8.0	2.916	2.907	2.901	2.897	2.895	2.895	2.895	2.897	2.900	2.904	2.908	2.913

Table 8-1. The variable set (p,q) which is close to the value in Table3

(Big Defect)

		p										
		5.0	**5.1**	**5.2**	**5.3**	**5.4**	**5.5**	**5.6**	**5.7**	**5.8**	**5.9**	**6.0**
q	**7.0**	3.401	3.409	3.416	3.423	3.430	3.437	3.444	3.450	3.456	3.463	3.469
	7.1	3.362	**3.369**	3.376	3.383	3.390	3.397	3.403	3.409	3.415	3.421	3.427
	7.2	3.324	**3.331**	3.338	3.344	3.351	3.357	**3.363**	3.369	3.375	3.381	**3.386**
	7.3	3.286	**3.293**	3.300	3.306	3.312	3.318	**3.324**	3.330	3.336	3.341	**3.347**
	7.4	3.250	3.256	3.263	3.269	3.275	3.281	3.286	3.292	3.298	3.303	**3.308**
	7.5	3.214	3.220	3.226	3.232	3.238	3.244	3.249	3.255	3.260	3.265	3.270
	7.6	3.179	3.185	3.191	3.197	3.202	3.208	3.213	3.218	3.223	3.228	3.233
	7.7	3.145	3.151	3.156	3.162	3.167	3.172	3.178	3.183	3.188	3.192	3.197
	7.8	3.111	3.117	3.122	3.128	3.133	3.138	3.143	3.148	3.153	3.157	3.162
	7.9	3.079	3.084	3.089	3.094	3.099	3.104	3.109	3.114	3.118	3.123	3.127
	8.0	3.046	3.052	3.057	3.062	3.066	3.071	3.076	3.080	3.085	3.089	3.094

Table 8-2. The variable set (p,q) which is close to the value in Table3

(Big Defect)

		p									
		6.1	**6.2**	**6.3**	**6.4**	**6.5**	**6.6**	**6.7**	**6.8**	**6.9**	**7.0**
q	**7.0**	3.474	3.480	3.486	3.491	3.496	3.502	3.507	3.512	3.517	3.521
	7.1	3.433	3.438	3.444	3.449	3.454	3.459	3.464	3.469	3.474	3.478
	7.2	3.392	3.397	3.402	3.408	3.413	3.418	3.422	3.427	3.432	3.436
	7.3	3.352	3.357	3.362	**3.367**	3.372	3.377	3.382	**3.386**	3.391	3.395
	7.4	3.313	3.318	3.323	**3.328**	3.333	3.337	3.342	**3.346**	3.351	3.355
	7.5	3.275	3.280	3.285	3.290	3.294	3.299	3.303	**3.307**	3.311	3.316
	7.6	3.238	3.243	3.248	3.252	3.256	3.261	3.265	3.269	3.273	3.277
	7.7	3.202	3.206	3.211	3.215	3.220	3.224	3.228	3.232	3.236	3.240
	7.8	3.166	3.171	3.175	3.179	3.184	3.188	3.192	3.196	3.200	3.203
	7.9	3.132	3.136	3.140	3.144	3.148	3.152	3.156	3.160	3.164	3.168
	8.0	3.098	3.102	3.106	3.110	3.114	3.118	3.122	3.125	3.129	3.133

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Surface Digitization Technology of Reverse Engineering based on TRIZ

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Abstract

Surface digitization is the key step in Reverse Engineering (RE), the digitization accuracy and efficiency can hardly be improved simultaneously. TRIZ theory is used to analysis the contradictory information, and universal technology character parameters are used to describe problem, then the invention theory are found from the contradiction matrix to solve this problem. According to the division and the advance operation of the invention principle, and combining the digital equipment and the characteristics of the measured parts, the solution of measuring surface base on the multi-sensor integration is obtained. The experimental results show that this evolution scheme can effectively solve the problem of surface digitization in reverse engineering, which can improve the accuracy and efficiency of surface digitization in the current equipment technology conditions.

Keywords: reverse engineering; surface digitization; TRIZ ; inventive theory; contradiction matrix

1. Introduction

Reverse Engineering (RE) is a very important branch of geometrical design and manufacturing application area, which has been widely recognized as an important step in the product development cycle. The use of RE will reduce the manufacturing time and cost significantly. The process of RE is usually subdivided into three stages, surface digitization of the part, processing of measured data and CAD modeling. Surface digitization is a key step in RE. Surface digitization of the part in RE can be achieved by utilizing either touch probing or non-contact sensors. The touch probing is generally more accurate but slow in data acquisition[1]. Vision sensor, used wildly among non-contact sensors, is able to obtain dense point cloud data quickly, and has high measuring efficiency. However, its accuracy cannot meet the applications with higher accuracy requirements[2]. Its accuracy and efficiency are still difficult to improve simultaneously. How to improve the accuracy of surface digitization while improving its efficiency has been a hot issue among the scholars from various countries.

Easy to learn and use, TRIZ is an innovative theoretical system, characterized with universality, practicality and operability. TRIZ tool can analyze the contradictions that exist in design and manufacture. Inventive principles of TRIZ can put forwards reasonable methods and directions to solve these contradictions[3]. In this paper, TRIZ is used to analyze the existing contradictions of surface digitization in reverse engineering, in order to seek a viable solution.

2. TRIZ theory and contradiction matrix

TRIZ was developed in the former Soviet Union by G. Altshuller. It is a series of tools, methods and strategies developed through over 1500 person-years of research and the study of over four hundred thousand of the world's most successful patents[4]. The basic constituents of TRIZ are the contradictions, 40 inventive principles, the matrix, and the laws of evolution, the substance-field analysis modeling, ideal final result, substance field resources, scientific effects and ARIZ.

These tools are developed on the basis of the experience of human innovation and a large number of patents. The application of these methods to solve many problems in product and guide the innovation process[5].

Altshuller selected about 40,000 patents at Level 2 and above, from the several hundred thousand patents issued in the USSR, USA, Germany, and other countries. He extracted from them 40 Inventive Principles and 39 Engineering Parameters that are generic for many engineering fields. The contradiction matrix is a 40*40 matrix, which includes 39 standard engineering parameters describing the contradiction uniformly and 40 innovative principles offering the possible solutions.

To solve specific problems, first of all using the common engineering parameters to express the problems in order to identify the contradiction, It means to transform the specific problem into a TRIZ issue. The corresponding inventive principles will be found through the contradiction matrix. According to the specific problem, the appropriate invention principles can be selected to generate a specific solution[6].

3. Application of contradiction matrix in the reverse engineering

The accuracy and efficiency of surface digitization are still difficult to improve simultaneously. Applying TRIZ theory to solve these conflicts, first of all, needs problem analyzing. It can get improved engineering parameter *39 'productivity' and worsened engineering parameter *28 'accuracy of measurement'. The corresponding inventive principles #01, #10, #34, #28 can be found in the contradiction matrix, as shown in Table 2,3.

Table 1. surface digitization contradiction matrix.

Worsening Engineering Parameter / Improving	28 Accuracy of measurement
29	

Engineering Parameter	
39 Productivity	1、10、34、28

Table 2. invention principle to the contradiction

inventive principles	sub–Principles
1 Segmentation	①Divide an object into independent parts
	②Make an object modular
	③Increase the degree of fragmentation or segmentation
10 Prior action	①Perform, before necessary, a required change of an object (either fully or partially).
	②Pre-arrange objects so that they can act from the most convenient place and without losing time for their delivery
34 Rejecting and regenerating parts	①Discard (by dissolving, evaporating, etc.) portions of an object that have fulfilled their functions or modify these directly during operation.；
	②Conversely, restore consumable parts of an object directly in operation
28 Replacement of a mechanical system	①Replace a mechanical means with a sensory (optical, acoustic, taste,or olfactory) means.
	②Use electric, magnetic, and electromagnetic fields to interact with the object.
	③Change from static to movable fields, from unstructured fields to those having structure.
	④Use fields in conjunction with field-activated particles (e.g., ferromagnetic).

After analysis, #1 'segmentation' and #10 'prior action' are selected. After the study of #10, the vision sensor is used before the touch probing. The initial information of surface is obtained by vision sensor rapidly with low accuracy. The initial information intelligently guides the touch probing to measure with the purpose of improving accuracy. After the study of #1, the part is measured in sections. The section where the curvature of the surface has little change is measured by vision sensor. To measure a complicated part accurately and completely, the touch probe is adopted to measure the key features and the blind areas on a part. Ultimately the measurement scheme of the multi-sensor integration has been shown in Fig. 1.

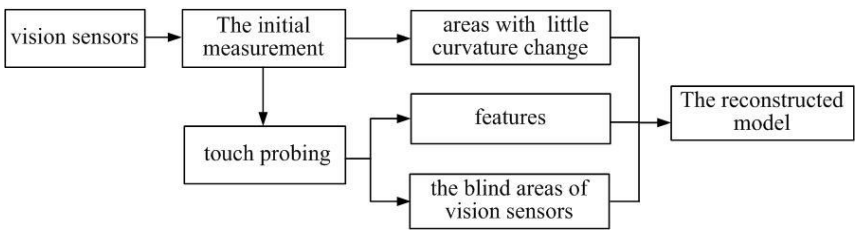


Figure 1. measurement scheme of the multi-sensor integration

The part is tested, as shown in Fig. 2. The laser scanning sensor of articulated arm measuring machine scans the part firstly. Then the point cloud data are obtained, as shown in Fig. 3. The CAD model Ⅰ is reconstructed, as shown in Fig. 4. According to the measurement scheme of the multi-sensor integration, with the touch probing of articulated arm measuring machine, measuring twenty points in two free-form surface area respectively, as shown in Fig.5. The CAD model Ⅰ is amended with the help of the points. CAD model Ⅱ is obtained with the use of surface deformation technology, as shown in Fig. 6.

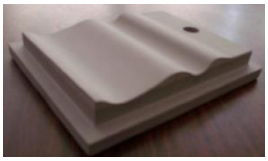


Figure 2. tested part

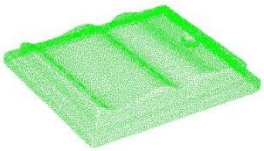


Figure 3. point cloud data

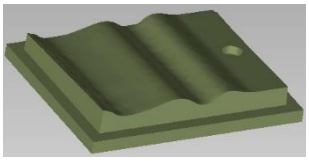


Figure 4. reconstructed CAD model Ⅰ

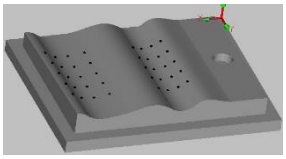


Figure 5. the contact probing points

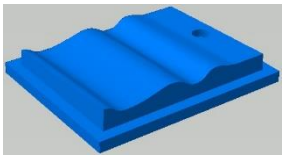
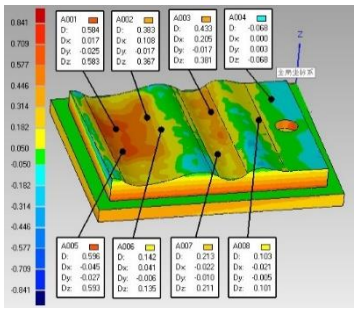
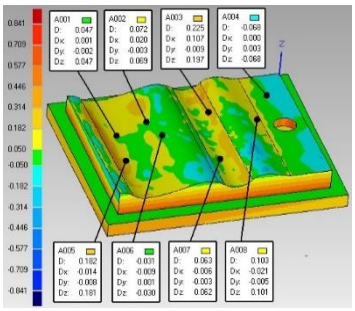


Figure 6. reconstructed CAD model Ⅱ

Geometric Qualify software is used to detect the deviation between the reconstructed model and the original model. The 3D comparative analyses of the deviation between CAD model Ⅰ and the original model are shown in Fig. 7(a), the average deviation is 0.126 mm, the standard deviation is 0.186. The 3D comparative analyses of the deviation between CAD model Ⅱ and the original model are shown in Fig. 7(b), the average deviation is 0.064mm, the standard deviation is 0.13.The deviation of model Ⅱ decreased significantly in the 3D color deviation map. Good experiment results are obtained to demonstrate the merits of surface digitization based on multi-sensor integration. The results prove TRIZ theory to be effective guidance to solve engineering problems.



(a) model Ⅰ



(b) model Ⅱ

Figure 1. 3 D comparisons between reconstruction CAD model and the original CAD model

4. Conclusions

To solve the problem that the accuracy and efficiency of surface digitization in RE can hardly be improved simultaneously, we can use the TRIZ theory to do analysis and construct universal technology character parameters (parameters of improvement and depravation) based on the contradictory. After that we can use the contradiction matrix to find out the inventive principles. Through segmentation and pre-operation of the selected crucial inventive principle and combination of the features of the specific digital device and the object to be measured, we can get the solution of the integrated measurement. Results show that the TRIZ theory plays a directing role in solving problems of the field of engineering.

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Packaging Innovation Design of Red Wine Based On TRIZ

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Abstract

Through market research towards the red wine, red wine system function model was established to find the problems and their causes. The conflict was determined by TRIZ conflict resolution theory, then the conflict was generalized and the improved engineering parameters and worsened engineering parameters were determined. The innovative structure of red wine was designed according the invention theory No.1 division and No.3 local quality and NO.32 change color provided by the conflict matrix. This structure has good buffer function and strength and the function of drawer and display is full developed. This system has both functions of protecting product and promoting sale.

Key words： TRIZ, Structure Design, Innovation, Red wine

Red wine packaged by glass bottle is very breakable. The sales package of red wine mainly uses fixed carton, wood box and carton. The cost of fixed carton is very high and the fixed carton is made mainly by handwork, so the product efficiency is very low. The wood box is also not easily to produce, similar to fixed carton. And these tow packing boxes are very heavy, so the cost of storage and transportation is very high. TRIZ was put forward by Genrich S.Altshuler (1926-1998) and a series of researchers in 1946, based on analyzing and researching more than 250,000 patents all over the world. The package of red wine is innovative designed according to the invention theory provided by the conflict matrix. The new design uses corrugated board, so it is very easily produced and the cost is relative low. The design is so ingenious, that the performance of strength and cushion is very good, and the structure also has the function of showing.

1. Introduction of TRIZ

TRIZ theory is considered as a kind of innovative theory, whose main function is on the side solving invention problem. This system includes technical evolution models, theory of

solving conflict, 39 general engineering parameters, 40 inventive principles, 39×39 solving contradiction matrix, 76 standard solutions, the algorithm of inventive problem solving (ARIZ), computer aided innovation and so on. TRIZ has become the study hotspot in the engineering field of Europe and America during these sixty years and many famous companies introduced TRIZ to solve technical innovation[1-4].

TRIZ theory considers that solving conflict is the core of invention problem and the design will not be innovation design if never conquer conflict[1,5]. The conflict of TRIZ includes technical confliction and physical confliction. Technical confliction means that in the system when one aspect is improved, another one will appear bad result, for example, if increasing the engine power of the airplane, accordingly, its weight will absolutely increase, which is not the expectable result. The physical confliction is the two aspects of the one parameter. For example, we want improve the speed of filter net which require the net is big, but at the same time we want improve the quality of the product, which require the net is small. The process of solve technical conflict problem is shown in Figure.1[6].

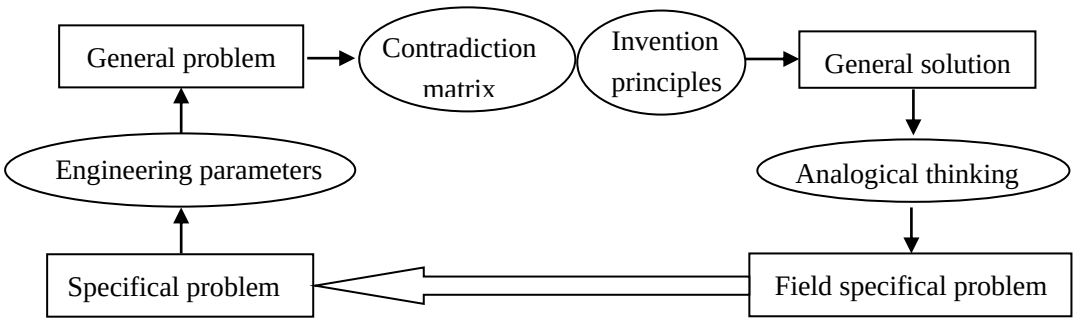

Figure.1 Process of solve technical conflict.

2. Function model of red wine package

2.1 Description of problem

The sales package of red wine mainly uses fixed carton, wood box and carton. The cost of fixed carton is very high and the fixed carton is made mainly by handwork, so the product efficiency is very low. The wood box is also not easily to produce, similar to fixed carton. The red wine is laid on the show stand or the box cover is opened when the red wine is sailing. The current package is not easily to produce and the cost is very high and it is not environmental friendly.

2.2 Function model of red wine package

Products are usually composed of many elements and the interactions between the

components. The function analysis is to establish the connection between the product structure and the interaction of product [7]. The problem can be easily found by function analysis, then the methods for further improvement can be put forward. The function model of red wine package is firstly established, and showed in Figure.2.

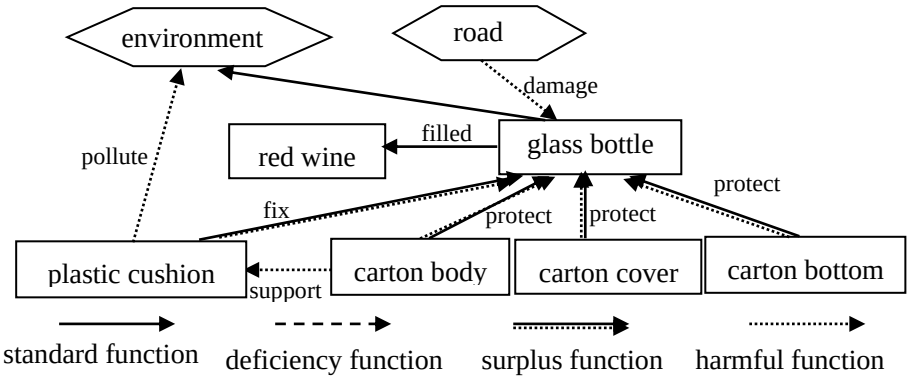

Figure.2 Function model of system.

From this function model, we can know that plastic cushion have harmful function to super system and will pollute environment. The super system road will damage the product and it is harmful function to red wine. The fixed carton have surplus function to red wine bottle and it is not easily produced. We should weaken the surplus function, and get rid of harmful function, and make up deficiency function.

3. Packaging Innovation Design of Red Wine Based On TRIZ Conflict Resolution Theory

3.1 Determining the principles of invention

We hope that the cost can be reduced, meanwhile the strength is adequate, and the design is easily produced. But it means we must change the type of package structure and use folding carton, which will make the strength of package reduce. It can be known that one function make two results include useful and harmful synchronously, so the conflict can be determined as technology conflict.

After determining the type of conflict, the conflict was generalized according to the 39 engineering parameters[1,8]. The improved parameter is NO.32 manufacturability and the worsened parameter is No.14 strength according to the table of engineering parameters. The corresponding principles of invention include No.1 division, No.3 local quality, No.10 pre operation, NO.32 change color, and showed in Figure.3.

	Worsening Engineering Parameters				
Improving Engineering Parameters		Weight of moving object 1	Weight of static object 2	Length of moving object 3	Strength 14
	1. Weight of moving object	+	-	15,8, 29,34	28,27,18,40
	4.Length of static object		28,35,29,40	-	15,14,28,26
	32. Manufacturability	28,29,15,16	1,27,36,13	1,29,13，17	**1,3, 10,32**

Figure.3 Conflict matrix

3.2 Find the Field specifical problem

Through the analysis, No.1 division, No.3 local quality and NO.32 change color are selected.

（1）No.1 division

One object is divided into some independent parts, or easy disassembly and assembly parts, which is called division. So the carton body made up of two pieces is designed according to the principle No.1 division, which is different to current carton and is innovating.

（2）NO.3 local quality and No.32 change color

Local quality principle means add asymmetric structure and make different parts finish different function and maximize the function of every part. Change color means change the color of the object or change the visibility and transparency of the object. The inner and bottom cushion pads are designed according to the principles No.3 local quality and NO.32 change color. The windowed structure of inner cushion pad is made up of non-uniform geometric figures, as shown in Fig.4. The innovation package structure of red wine is shown in Figure.4 according to these principles of invention.

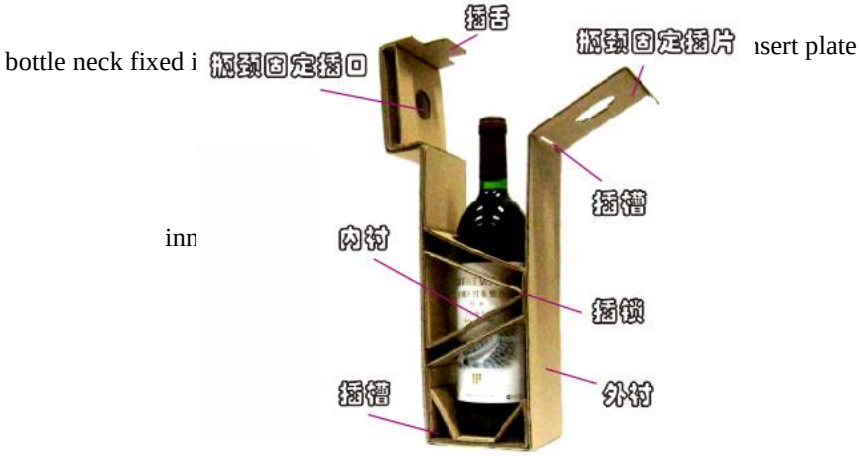

Figure.4 Effect drawing of packaging structure.

The material of this structure is corrugated board, which is easily to produce and the cost is relative low. The carton body is made up of two parts and the inner cushion pad is made up of non-uniform geometric figures, which make the cushion pad have enough strength and at the same time it is aesthetic. In a word, this structure has the function of protecting product and showing. This design shows that TRIZ theory has an effective guidance to the innovation design of package structure.

4. Conclusion

TRIZ is the theory of inventive problem solving, and TRIZ theory helps people break through the inertia thinking and analyze the problem in one innovative perspective, consequently attains a new field specifical solution. The innovative package of red wine is designed in this text according to the invention principle of TRIZ. The package is easily to produce and the cost is relative low and the package have the function both transportation and sale. The problem of package design is often translated to conflict, so the theory of TRIZ can help the designers easily find the innovative design.

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Questionnaire Investigation on Jewelry / Accessory and its Sensitivity Analysis Utilizing Bayesian Network

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Abstract

Recently, the numbers of jewelry/accessories buying via the Internet are increasing, especially for young people. They often have difficulty deciding what kinds of jewelry/accessories, because there are many kinds of jewelry/accessories to choose from. Consulting service to support decisions is required for these matters. In this paper, a questionnaire investigation is executed for the purchasing on-line network, used for jewelry/accessory purchasing in order to get instructions for an on-line network consulting service. Nearly 500 sample data are collected. In this research, we construct the model utilizing Bayesian Network and causal relationship is sequentially chained by the characteristic of customer, the purchase budget and the accessory type. One of the TRIZ methods is extended and applied. We analyzed them by sensitivity analysis and some useful results were obtained. These are utilized for constructing a much more effective and useful on-line network consulting service.

Keywords: jewelry, questionnaire investigation, Bayesian Network

1. Introduction

Owing to the prevailing Internet, new businesses such as jewelry selling via Internet with on-line consultation, what kind of jewelry/accessory for gift purchasers would be better to choose, is becoming a big trend. Purchasers via Internet have various purchasing patterns and they may have significant relationship with their characteristics and the circumstances they are in. Therefore, if we can make clear the relationship between these, we would be able to make a much more effective marketing plan and execute efficient sales promotion for each of them.

For these purposes, we created a questionnaire investigation of jewelry/accessory purchasing. In recent years, Bayesian Network is highlighted because it has the following good characteristics (Neapolitan, R.E., 2004).

- Structural Equation Modeling requires normal distribution to the data in the analysis. Therefore it has a limitation in making analysis. But Bayesian Network does not require specific distribution type to the data. It can handle any distribution type.
- It can handle the data which include partial data.
- Expert's know-how can be reflected in building Bayesian Network model.
- Sensitivity analysis can be easily executed by settling evidence. We can estimate and predict the prospective purchaser by that analysis.
- It is a probability model having network structure. Related items are connected with directional link. Therefore understanding becomes easy by its visual chart.

In this research, it is suitable to utilize Bayesian Network to analyze jewelry / accessory purchasing because each variable does not necessarily have normal distribution. Reviewing past researches, there are some related researches as follows. Takahashi et al. (2008) made analysis for the future home energy utilizing Bayesian Network. Tsuji et al. (2008) made analysis concerning preference mining on future home energy consumption. There are some papers concerning purchase behavior in the shop (Tatsuoka et al.,2008-a, Tatsuoka et al., 2008-b). But we can hardly see the analysis concerning jewelry / accessory purchasing utilizing Bayesian Network.

In this paper, a questionnaire investigation is executed for the purchasing on-line network used for jewelry/accessory purchasing in order to get instructions for an on-line network consulting service. One of the TRIZ method is extended and applied. These are analyzed by using Bayesian Network.

The analysis utilizing Bayesian Network enabled us to visualize the causal relationship among items. Furthermore, sensitivity analysis brought us estimating and predicting the prospective purchaser.

Some interesting and instructive results are obtained. These are utilized for constructing a much more effective and useful on-line network consulting service.

The rest of the paper is organized as follows. Extended analysis method is stated in section 2. Outline of questionnaire research is stated in section 3. In section 4, an analysis by cross tabulation is executed. In section 5, Bayesian Network analysis is executed which is followed by the sensitivity analysis in section 6. Section 7 is a summary.

2. Extended Analysis Method

The function "Moves" is a fundamental function of TRIZ [6],[7].
We can further develop this concept as shown in Figure 1.

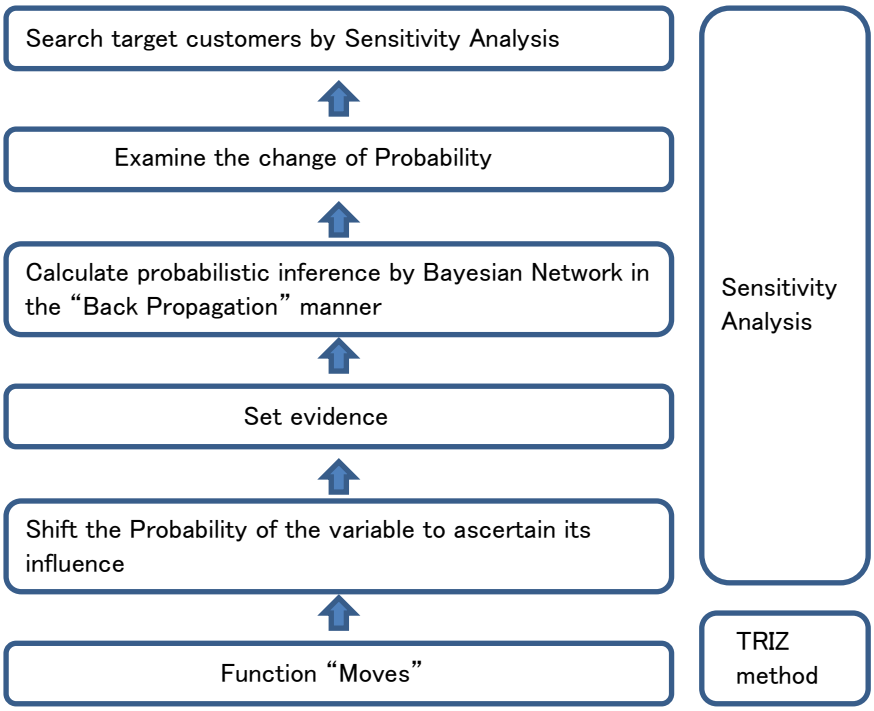

Figure1. Extended Analysis Method

Based on the TRIZ method, sensitivity analysis is developed utilizing Bayesian Network. Applying "Moves" function, shift the probability of the variable to ascertain its influence. Set evidence to, for example, "1.0" to the variable, calculate probabilistic inference by Bayesian Network in the "Back Propagation" manner. Then, examine the change of probability.
These are the process of "Sensitivity Analysis" based upon TRIZ "Moves" method. Detailed inspection is executed in section 6.

3. Outline of Questionnaire Research and Examinees

3.1. Outline of Questionnaire Research

Outline of questionnaire research is as follows.
Scope of investigation: Young Persons, Japan

Period : May 2008～June 2009
Method : Mail and self writing
Collection : Number of distribution 1,500, Number of collection 421 (collection rate 28.1%)

Analysis methods are as follows.

Questionnaire results are analyzed in four methods. First, summary by single variable is explained in 4.1 in order to examine the pattern of responding about items. Second, analysis by Cross Tabulation is executed in 4.2 in order to confirm hypotheses. Third, analysis by Bayesian Network is executed in 4.3 in order to clarify and visualize the causal relationship among the items. Fourth, analysis by sensitivity analysis is executed in 4.4 in order to predict the prospective purchaser as is shown in Table 1.

Table 1. Analysis Procedure

Step	Aim of analysis	Used Method
①	Confirm hypotheses	Cross Tabulation
②	Build Bayesian Network in order to clarify and visualize the causal relationship among items	Bayesian Network Analysis
③	Predict the prospective purchaser	Sensitivity Analysis

3.2. Outline of Examinees

①Sex (Q45)
- Male : 67%
- Female : 33%

②Age (Q46)
- Under 18 : 1%
- 18～22 : 36%
- 23～27 : 15%
- 28～32 : 12%
- 33～37 : 14%
- 38～42 : 10%
- 43～47 : 4%
- More than 48 : 8%

③Occupation (Q47)
- Student : 39%
- Officer : 2%
- Company Employee : 46%
- Clerk of Organization : 1%
- Independents : 6%
- Miscellaneous : 6%

④ Address (Q48)
- Osaka : 57%

- Hyogo : 7%
- Kagawa : 6%
- Wakayama : 5%
- Fukui : 5%
- Nara : 4%
- Others : 16%

4. Analysis by Cross Tabulation

4.1. Hypotheses and Their Cross Tabulation Analysis

We set 10 Themes as follows. These are extracted from the experience of the professionals. We can consider many other themes, but we focus mainly upon monetary, frequency, character, and purchasing goods.

Theme 1	Female would esteem coupon much better than male does.
Theme 2	Those who make stress upon material or quality have rather high budget amount.
Theme 3	There are not so much utilization of Internet shopping for the people who like sports and shopping.
Theme 4	Those who like indoor lifestyle use Internet frequently.
Theme 5	Company employee uses Internet Shopping much more frequently than student or housewife.
Theme 6	Those who like shopping esteem brand, trend and design.
Theme 7	Budget amount is large when he / she has someone to consult with in making present.
Theme 8	Those who like shopping do not hesitate to consult with sales clerk.
Theme 9	Those who often use Internet shopping live far from urban.
Theme 10	Those who like shopping also like Internet shopping.

The results of statistical hypothesis testing are as follows.

Theme1. Female esteems coupon much better than male does.
Null hypothesis: Female esteems coupon as male does.

Table 2. Cross Tabulation result 1

		Q35 (%)					
		Very important	Slightly important	Ordinary level	Not so important	Not important	Total
Q45	Male	0.208	0.384	0.220	0.107	0.082	1.000
	Female	0.321	0.346	0.233	0.057	0.044	1.000
Sum		0.245	0.371	0.224	0.090	0.069	1.000

Real number	Important	Not important	Sum
Male	188	60	248
Female	106	16	122
Sum	294	76	370

Expectation	Important	Not important	Sum
Male	197.0594595	50.94054	248
Female	96.94054054	25.05946	122
Sum	294	76	370

Statistic	6.149465
Rejection region	3.84146

The hypothesis is rejected with 5% significance level.
Therefore it can be said that “Female esteems coupon much better than male does”.
Shop owner has an impression that many women respond to the promotion or campaign of coupon.
It is only women to inquire about campaign of coupon. Women seek the best timing to buy, while men often buy the goods when they need, whether the campaign is held or not.

Theme2 Those who do not make stress upon material or quality have rather low budget amount.
Null hypothesis: There is not so much difference in esteeming material or quality whether the budget is high or not.

Table 3. Cross Tabulation result 2

		Q12 (%)							
		～5000	～10000	～15000	～20000	～25000	～30000	more	Total
Q5	Very important	0.123	0.262	0.139	0.197	0.033	0.172	0.074	1.000
	Slightly important	0.145	0.271	0.187	0.182	0.019	0.131	0.065	1.000
	Ordinary level	0.149	0.175	0.193	0.228	0.009	0.123	0.123	1.000
	Not so important	0.214	0.143	0.143	0.286	0.107	0.071	0.036	1.000
	Not important	0.000	0.333	0.000	0.167	0.000	0.333	0.167	1.000
Sum		0.143	0.240	0.171	0.202	0.025	0.138	0.081	1.000

Real number	0～20,000（Cheap）	20,000～（High）	Sum
Important	256	80	336
Not Important	25	9	34
Sum	281	89	370

Expectation	0～20,000（Cheap）	20,000～（High）	Sum
Important	255.18	80.8216	336
Not Important	25.822	8.17838	34
合計	281	89	370

Statistic	0.1197
Rejection region	3.8415

The hypothesis is not rejected.

It cannot be said that budget is not necessarily high even though consumers esteem material or quality. In particular, consumers cannot confirm the goods holding at their hands, therefore they confirm the explanation of material or quality at the site.

We often hear from many shop owners that they have experience of what consumers who buy only price deducted goods are severe in selecting goods. It can be said that those who are severe for price are also severe for quality.

Theme3 There are not so much utilization of Internet shopping for the people who like sports and shopping.

Null hypothesis: There is little difference in the frequency of utilization of Internet shopping among those who like sports/shopping and those who do not.

Table 4.1 Cross Tabulation result 3

		Q38 (Internet Shopping) (%)				
		Very often	Sometimes	Rarely	Never	Total
Q21 (Sports)	Very important	0.139	0.376	0.171	0.314	1.000
	Slightly important	0.071	0.473	0.161	0.295	1.000
	Ordinary level	0.125	0.458	0.139	0.278	1.000
	Not so important	0.250	0.438	0.094	0.219	1.000
	Not important	0.286	0.286	0.000	0.429	1.000
Sum		0.130	0.415	0.156	0.299	1.000

Real number	use	Not use	Sum
Like	187	170	357
Dislike	26	13	39
Sum	213	183	396

Expectation	use	Not use	Sum
Like	192.023	164.9773	357
Dislike	20.977	18.02273	39
Sum	213	183	396

Statistic	2.886697
Rejection region	2.874374

The hypothesis is rejected with 1% significance level.

Table 4.2 Cross Tabulation result 3

		Q38 (Internet Shopping) (%)				
		Very often	Sometimes	Rarely	Never	Total
Q23 (Shopping)	Very important	0.167	0.395	0.111	0.327	1.000
	Slightly important	0.124	0.513	0.133	0.23	1.000
	Ordinary level	0.119	0.396	0.208	0.277	1.000
	Not so important	0.081	0.243	0.27	0.405	1.000
	Not important	0	0	0	1.000	1.000
Sum		0.133	0.41	0.161	0.296	1.000

Real number	use	Not use	Sum
Like	163	112	275
Dislike	12	27	39
Sum	175	139	314

Expectation	use	Not use	Sum
Like	153.264	121.7357	275
Dislike	21.736	17.26433	39
Sum	175	139	314

Statistic	11.24787
Rejection region	6.634897

The hypothesis is rejected with 9% significance level.

It can be said that there are not so much utilization of Internet shopping for the people who like sports and shopping.

There who like sports and shopping would easily go out and search goods at real shop. It may be considered that they do not think highly of net shop.

Theme4 Those who like indoor lifestyle use Internet frequently.
Null hypothesis: There is not so much difference in the frequency of using Internet whether those who like indoor lifestyle or not.

Table 5. Cross Tabulation result 4

		Q37 (%)				
		Very often	Sometimes	Rarely	Never	Total
Q30	Outdoor	0.571	0.276	0.100	0.053	1.000
	Indoor	0.755	0.123	0.065	0.058	1.000
	Either	0.597	0.264	0.069	0.069	1.000
Sum		0.638	0.223	0.079	0.060	1.000

Real number	Use	Not use	Sum
Outdoor	144	26	170
Indoor	136	19	155
Sum	280	45	325

Expectation	Use	Not use	Sum
Outdoor	146.462	23.53846	170
Indoor	133.538	21.46154	155
Sum	280	45	325

Statistic	0.626487
Rejection region	3.84146

The hypothesis is not rejected.

There is not so much difference in the frequency of using Internet whether those who like indoor lifestyle or not.

Once, there was an image that indoor typed people often use Internet. But nowadays, it became common to use Internet whenever and wherever.

Theme5 Company employee uses Internet Shopping much more frequently than student or housewife.

Null hypothesis: There is not so much difference in the frequency of using Internet whether they are company workers or not.

Table 6. Cross Tabulation result 5

		Q47 (Occupation) (%)						
		Student	Officer	Company Employee	Clerk of Organization	Independents	Miscellaneous	Total
Q38	Very often	0.238	0.016	0.540	0.000	0.127	0.079	1.000
	Sometimes	0.293	0.005	0.571	0.005	0.066	0.061	1.000
	Rarely	0.446	0.036	0.422	0.012	0.024	0.060	1.000
	Never	0.559	0.021	0.301	0.000	0.049	0.070	1.000
Sum		0.390	0.016	0.462	0.004	0.062	0.066	1.000

Real number	Student	Worker	Sum
Use	90	171	261
Not use	132	94	226
Sum	222	265	487

Expectation	Student	Worker	Sum
Use	118.977	142.0226	261
Not use	103.023	122.9774	226
Sum	222	265	487

Statistic	27.948
Rejection region	6.6349

The hypothesis is rejected with 1% significance level.
It can generally be said that company employee uses Internet shopping much more frequently than student or housewife.
Company employees are accustomed to use Internet and they have hard time to go out shopping while in week days.
Therefore they may use Internet for shopping. Actually, the most frequent access times to Cherish Co. Ltd. are around 21 o'clock. They may be making Internet shopping at home after work.

Theme6. Those who like shopping esteem brand, trend and design.
Null hypothesis: There is not so much difference in esteeming brand, trend and design whether those who like shopping or not.

Table 7. Cross Tabulation result 6

		Q4 (Fad) (%)					
		Very important	Slightly important	Ordinary level	Not so important	Not important	Total
Q23 (Shopping)	Very important	0.5 88	0.267	0.097	0.036	0.012	1.000
	Slightly important	0.318	0.473	0.118	0.091	0.000	1.000
	Ordinary level	0.297	0.506	0.127	0.063	0.006	1.000
	Not so important	0.270	0.378	0.216	0.135	0.000	1.000
	Not important	0.500	0.000	0.500	0.000	0.000	1.000
Sum		0.403	0.403	0.123	0.066	0.006	1.000

Real number	important	Not important	Sum
Like	228	18	246
Dislike	25	5	30
Sum	253	23	276

Expectation	important	Not important	Sum
Like	225.5	20.5	246
Dislike	27.5	2.5	30
Sum	253	23	276

Statistic	3.0599
Rejection region	2.8744

The hypothesis is rejected with 9% significance level.
It can generally be said that those who like shopping esteem brand, trend and design. Those who like shopping are accustomed to go shopping and generally have information about brand, trend and design therefore thy have own standard what to buy.

Theme7. Budget amount is large when he / she has someone to consult with in making present.
Null hypothesis: There is not so much difference for the budget amount whether they have someone to consult with or not in making present.

Table 8. Cross Tabulation result 7

		Q12 (%)							
		～5000	～10000	～15000	～20000	～25000	～30000	more	Total
Q15	Boy(Girl)friend	0.061	0.210	0.144	0.238	0.022	0.193	0.133	1.000
	friend	0.196	0.346	0.215	0.121	0.028	0.075	0.019	1.000
	clerk	0.141	0.250	0.156	0.266	0.047	0.141	0.000	1.000
	Do not consult with anybody	0.205	0.197	0.189	0.220	0.016	0.102	0.071	1.000
	Miscellaneous	0.200	0.000	0.000	0.000	0.000	0.200	0.600	1.000
Sum		0.140	0.240	0.171	0.209	0.025	0.136	0.079	1.000

	～5000	～10000	～15000	～20000	～25000	～30000	more	Total
Consult with somebody	0.118	0.255	0.165	0.204	0.028	0.148	0.081	1.000
Do not consult with any-body	0.214	0.136	0.175	0.243	0.019	0.126	0.087	1.000
Sum	0.139	0.228	0.167	0.213	0.026	0.143	0.083	1.000

Real number	0～20,000（Cheap）	20,000～（High）	Sum
Important	265	92	357
Not Im-portant	79	24	103
Sum	344	116	460

Expectation	0～20,000（Cheap）	20,000～（High）	Sum
Important	266.97391	90.026087	357
Not Im-portant	77.026087	25.973913	103
Sum	344	116	460

Statistic	0.25847
Rejection region	3.84146

The hypothesis is not rejected.
It cannot be said that the budget is high for those who have someone to consult with in making present compared with those who do not have.

Theme8. Those who like shopping do not hesitate to consult with sales clerk.
Null hypothesis: There is not so much difference whether they like shopping or not, for those who do not hesitate to consult with sales clerk.

Table 9. Cross Tabulation result 8

		Q45 (%)					
		Boy(Girl) friend	Friend	Clerk	Do not consult with anybody	Miscel-laneous	Total
Q23 (Shop ping)	Very important	0.315	0.321	0.117	0.241	0.006	1.000
	Slightly im-portant	0.330	0.259	0.098	0.313	0.000	1.000
	Ordinary level	0.433	0.121	0.172	0.255	0.019	1.000
	Not so important	0.371	0.171	0.143	0.286	0.029	1.000
	Not important	1.000	0.000	0.000	0.000	0.000	1.000
Sum		0.365	0.226	0.132	0.265	0.011	1.000

Real number	Consult	Not consult	Sum
Like	30	74	104
Dislike	5	10	15
Sum	35	84	119

Expecta-tion	Consult	Not consult	Sum
Like	30.58824	73.41176	104
Dislike	4.411765	10.58824	15
Sum	35	84	119

Statistic	0.127137
Rejection region	6.634897

The hypothesis is not rejected.
Generally, there are few people to consult with sales clerk while shopping. It may be because they hear the request before making present. Sales talk of sales clerk may be backed away at any rate.

Theme9. Those who often use Internet shopping live far from urban. Null hypothesis: There is not so much difference among those who live urban and those who do not live, in the use of Internet shopping.

Table 10. Cross Tabulation result 9

		Q48 (Address) (%)							
		Aichi	Ibaragi	Kyo-to	Kagawa	Kouchi	Saitama	Yamagu-chi	Shiga
Q38	Very often	0.016	0.032	0.016	0.129	0.016			0.016
	Some-times		0.010	0.026	0.052		0.010	0.005	0.005
	Rarely		0.026	0.039					
	Never		0.044	0.007	0.015		0.007		
Sum		0.002	0.026	0.021	0.043	0.002	0.006	0.002	0.004

		Akita	Chiba	Nara	Sizuoka	Osaka	Tokyo	Kanagawa	Fu-kui
Q38	Very often		0.048	0.032	0.016	0.403	0.032	0.016	0.065
	Some-times		0.021	0.073	0.021	0.578	0.005	0.010	0.031
	Rarely	0.013				0.701			0.039
	Never		0.007	0.030	0.007	0.659	0.007		0.030
Sum		0.002	0.017	0.043	0.013	0.599	0.009	0.006	0.036

		Oita	Hy-ougo	Mie	Fukuoka	Naga-no	Hirosi-ma	Wakaya-ma	Total
Q38	Very often		0.081		0.016			0.065	1.000
	Some-times		0.094	0.005	0.016	0.021		0.036	1.000
	Rarely	0.013	0.078		0.026	0.021		0.065	1.000
	Never		0.074	0.007	0.030	0.021	0.007	0.059	1.000
Sum		0.002	0.084	0.004	0.021	0.021	0.002	0.052	1.000

Real num-ber	urban	far	Sum
use	139	115	254
Not use	144	68	212
Sum	283	183	466

Expectation	urban	far	Sum
use	154.2532	99.74678	254
Not use	128.7468	83.25322	212
Sum	283	183	466

Statistic	8.44255
Rejection region	6.634897

The hypothesis is rejected with 1% significance level.

It is generally assumed that residents in urban area have less need to use Internet because shops are near.

But the actual order number is many for the residents in urban area. It does not depend upon the place where they live but lifestyle and/or hobby may have correlation for the utilization of Internet for shopping.

Theme10. Those who like shopping also like Internet shopping.
Null hypothesis: There is not so much difference whether those who like shopping also like Internet shopping or not.

Table 11. Cross Tabulation result 10

		Q38 (%)				
		Very often	Sometimes	Rarely	Never	Total
Q23 (Shopping)	Very important	0.167	0.395	0.111	0.327	1.000
	Slightly important	0.124	0.513	0.133	0.230	1.000
	Ordinary level	0.119	0.396	0.208	0.277	1.000
	Not so important	0.081	0.243	0.270	0.405	1.000
	Not important	0.000	0.000	0.000	1.000	1.000
Sum		0.133	0.410	0.161	0.296	1.000

Real number	Use	Not use	Sum
Like	163	112	275
Dislike	12	27	39
Sum	175	139	314

Expecta-tion	Use	Not use	Sum
Like	153.26433	121.73567	275
Dislike	21.735669	17.264331	39
Sum	175	139	314

Statistic	11.2479
Rejection region	6.6349

The hypothesis is rejected with 1% significance level.

It can generally be said that those who like shopping also like Internet shopping. Internet shopping became popular and it is one of the style of shopping in general.

In particular, those who like shopping may feel convenient in selecting goods as there are so many goods sold in Internet shop.

5. Bayesian Network Analysis

In constructing Bayesian Network, it is required to set an outline of the model reflecting the causal relationship among groups of items. Concept chart in this case is exhibited in Figure 2.

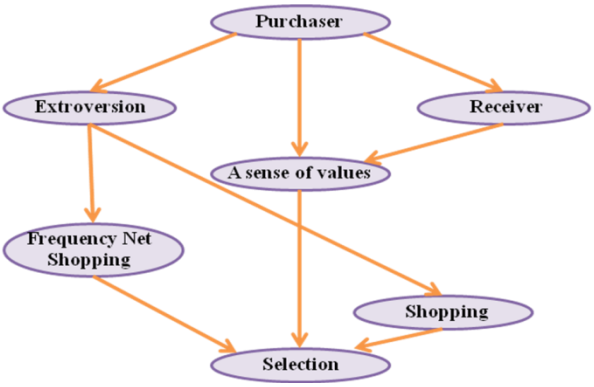

Figure 2. Node and Parameter

Based on this, model is built as is shown in Figure 3.

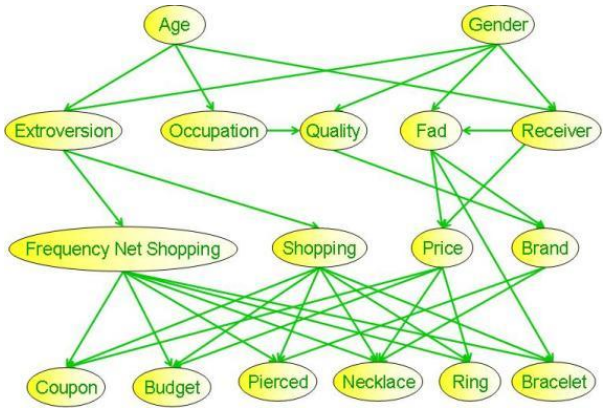

Figure 3. Built Model

We used BAYONET software (http://www.msi.co.jp/BAYONET/). When plural nodes exist in the same group, it occurs that causal relationship is hard to set a priori. In that case, BAYONET system set the sequence automatically utilizing AIC standard. Node and parameter of Figure 3 are exhibited in Table 12.

Table 12. Node and Parameter

Group Name	Node in Group	Parameter				
		1	2	3	4	5
Purchaser	Age	Under22	23~32	33~42	Over43	
	Gender	Male	Female			
	Occupation	Students	Employee	Independent	Others	
Receiver	Receiver	Lover	Parents	Sweet Heart	Myself	Others
Extrover-sion	Extroversion	Outdoor	Indoor	Not Either		
A sense of values	Fad, Brand, Praice, Quality	Important	Ordinary	Not Either		
Internet Shopping	Frequency_Net Shopping	Often	Sometimes	Rarely	Never	
Shopping	Shopping	Important	Ordinary	Not Either		
Selection	Budget	~10000	~20000	~30000	Over 30000	
	Ring, Necklace, Pierced, Bracelet	Buy	Not			
	Coupon	Important	Ordinary	Not		

"Very important" and "Slightly important" are condensed into one as "Important" in order to decrease node number.

6. Sensitivity Analysis

Now, let's confirm whether the results of Cross Tabulation and the results of probabilistic inference by Bayesian Network coincide or not. We take up Hypothesis 1 as a case. Posterior probability is calculated by setting evidence as, for example, 1.0. Comparing Prior probability and Posterior probability, we can seek the change and confirm whether the Hypothesis is appropriate or not. In Hypotheses 1, set evidence as 1.0 for the "Male" in the group of "Gender". Generally, we can obtain more clear result when we set evidence to the contraposition item. We assume that "Female would esteem coupon much better than male does", therefore setting evidence 1.0 to "Male" would be suitable in this case. Table 13 shows the result of this attempt.

Table 13. Sensitivity Analysis for Hypothesis 1

Node	Parameter	Prior Probability	Posterior Probability	
			Male	Important
Gender	Male	0.681	1.000	0.680
	Female	0.319	0.000	0.320
Receiver	Lover	0.547	0.624	0.542
	Myself	0.076	0.038	0.060
Extroversion	Outdoor	0.340	0.371	0.342
	Indoor	0.325	0.284	0.324
Frequency_Net Shopping	Sometimes Never	0.284	0.284	0.335
		0.257	0.257	0.245
Shopping	Important	0.395	0.395	0.446
Fad	Important	0.756	0.745	0.758
	Not	0.098	0.099	0.094
Price	Important	0.377	0.377	0.418
	Not	0.280	0.287	0.224
Quality	Important	0.683	0.662	0.683
Budget	~20000 Over 30000	0.319	0.319	0.330
		0.149	0.150	0.134
Ring	Buy	0.507	0.508	0.501
Necklace	Buy	0.553	0.553	0.555
Pierced	Buy	0.323	0.323	0.314
Bracelet	Buy	0.228	0.229	0.225
Coupon	Important	0.526	0.525	1.000
	Not	0.215	0.215	0.000

Hatched parts show the setting of evidences. We examined two cases. One is setting evidence 1.0 to “Male” and another one is to “Important” for coupon. Table 14 shows the Cross Tabulation result for Hypothesis 1.

Table 14. Cross Tabulation result for Hypothesis 1

	Coupon			
Gender	Important	Ordinary	Not	Total
Male	176	61	50	287
Female	86	34	14	134
Sum	262	95	64	421

It is clear that female esteems coupon better than male by Table 14. We can see that female esteems coupon on the change of the probability, though the change is little. It is often seen that the change of the probability becomes small when the hierarchical data cluster is distant. To this point, reinforcement learning, for example, may be one of an improving method to

cope with this. For another improving method is to make shallow the depth of the hierarchy of the model. For another attempt of setting evidence 1.0 to "Male", we can observe that male does not esteem coupon. The value of Posterior Probability slightly decreased. This can also be made much more clear by introducing such as reinforcement learning method. Looking over other parameters, we can find that those who esteem coupon think it important about "Price " and we can also find that those who like shopping, and/or Internet shopping esteem coupon and those purchasers buy for themselves. We can derive the findings from these results that we would be better to focus upon "Female with small budget" while issuing coupon. In this way, we can utilize sensitivity analysis to focus target consumers in marketing.

7. Conclusion

Jewelry/accessory buying via the Internet is increasing, especially for young people. They often had difficulty deciding what kind of jewelry/accessory, because there were many kinds of jewelry/accessories to choose from. Consulting service to support decision was required for these matters. In this paper, a questionnaire investigation was executed for purchasing on-line network, used for jewelry/accessory purchasing in order to get instruction for an on-line network consulting service. These were analyzed by using Bayesian network. One of the TRIZ methods was extended and applied. Some interesting and instructive results were obtained. These would be utilized for constructing a much more effective and useful on-line network consulting service. Examining such trials should be traced hereafter.

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APPENDIX: Questionnaire Concerning the Purchasing of Jewelry/ Accessories for Gifts

Please answer the following questions. Please write down ○ to the answering items. Plural selection is allowed for Question 1, 13, 14, 17, 20, 39, 40, 43, 44. Select ①～⑤ of the right column for the Question 2～11, 21～29, 32～36.

1. When you make a gift of jewelry/ accessory to someone, what point do you stress? (Plural Answers Allowed)

Q1 ①Price ②Brand ③Trend/Design ④Raw Materials/Quality ⑤Kind/Items ⑥Response of the shop members ⑦Existence of Certification ⑧Relatively Cheap ⑨Desire of the receiver of the gift ⑩ Miscellaneous ( )

2. When you choose, how is the importance of each item?

Importance	Very important	Slightly important	Ordi-nary level	Not so important	Not important
Q2 Price	①	②	③	④	⑤
Q3 Brand	①	②	③	④	⑤
Q4 Trend/Design	①	②	③	④	⑤
Q5 Raw Materials/Quality	①	②	③	④	⑤
Q6 Kind/Items	①	②	③	④	⑤
Q7 Response of the shop members	①	②	③	④	⑤
Q8 Existence of Certification	①	②	③	④	⑤
Q9 Relatively Cheap	①	②	③	④	⑤
Q10 Desire of the receiver of gift	①	②	③	④	⑤
Q11 Miscellaneous ( )	①	②	③	④	⑤

3. How much do you spend for one gift? [Unit: yen]

Q12 ①～5,000 ②～10,000 ③～15,000 ④～20,000 ⑤～25,000 ⑥～30,000 ⑦more than that

4. What kind of jewelry/accessory have you given? (Plural Answers Allowed)

Q13 ①Ring ②Necklace/ Pendant ③Pierced earrings ④Bracelet/Bungle ⑤Brooch ⑥Necktie Pin ⑦ Miscellaneous ( )

5. Why did you select them? (Plural Answers Allowed)

Q14 ①Desire of the receiver ②Trend ③Because it was popular ④Famous entertainers have them ⑤ Recommendation of the sales person in the shop ⑥Budget ⑦Special Sales ⑧Miscellaneous ( )

6. Who do you consult with when you choose?

Q15 ①Lover ②Friend ③Sales person of the shop ④Do not consult with anybody ⑤Miscellaneous ( )

7. Where do you buy gifts?

Q16 ①Department Store ②Jewelry/Accessory Shop ③Remote Sales by Catalogue ④Internet Shop ⑤ Miscellaneous ( )

8. Why is it? (Plural Answers Allowed)

Q17 ①Desire of the receiver ②Reliability of the shop ③Plenty of items ④There are favorite brands ⑤ Specified shop to buy(Always buy from the shop) ⑥Friends often shop there ⑦Rather cheap compared

with quality ⑧Able to get additional points when using a credit card ⑨There is DM(Direct Mail) guidance when gift seasons come ⑩Miscellaneous ( )

9. Whom do you make a gift to?

Q18 ①Lover ②Father/Mother ③Children ④Sweet heart ⑤Myself ⑥Miscellaneous ( )

10. How many times do you make gifts in a year?

Q19 ①Once ②Twice ③Three times ④Four times ⑤More than that ⑥None (Reason:)

11. On what occasions do you give presents? (Plural Answers Allowed)

Q20 ①Birthday ②Xmas ③Valentine day ④White day ⑤Grown up anniversary ⑥Wedding Anniversary ⑦Congratulate for birth ⑧Congratulate for getting job ⑨Congratulate for commencement of studying at school ⑩Miscellaneous ( )

12What is your hobby?

Importance	Very important	Slightly important	Ordinary level	Not so important	Not important
Q21 12-1 Sports: ①Baseball ②Football ③Tennis ④Miscellaneous ( )	①	②	③	④	⑤
Q22 12-2 Reading Books: ①Novel ②Business Affair ③Weekly Magazine ④Comic ⑤Miscellaneous ( )	①	②	③	④	⑤
Q23 12-3 Shopping	①	②	③	④	⑤
Q24 12-4 Traveling: ①Sightseeing ②Hot Springs ③Gourmet ④Miscellaneous ( )	①	②	③	④	⑤
Q25 12-5 Music: ①Classic ②Western POPS ③Japanese POP ④Miscellaneous ( )	①	②	③	④	⑤
Q26 12-6 Movie: ①Love ②Action ③Comedy ④Miscellaneous ( )	①	②	③	④	⑤
Q27 12-7 Theater: ①Song ②Dance/Ballet ③Drama ④Miscellaneous ( )	①	②	③	④	⑤
Q28 12-8 Drinking: ①Beer ②Wine ③Japanese wine-sake ④Japanese liquor-shochu ⑤Miscellaneous ( )	①	②	③	④	⑤
Q29 12-9 Miscellaneous: ( )	①	②	③	④	⑤

13. What kind of lifestyle do you like?

Q30 13-1 Pleasure: ①Outdoor ②Indoor ③Not either

Q31 13-2 Work: ①Desk Work ②Outdoor activity such as visiting sales ③Not either

14. Which method of payment do you want to choose?

Importance	Very important	Slightly important	Ordinary level	Not so important	Not important
Q32 14-1 ①Cash/Cash on Delivery	①	②	③	④	⑤
Q33 14-2 Credit Card	①	②	③	④	⑤
Q34 14-3 Discount	①	②	③	④	⑤
Q35 14-4 Point Card/Coupon	①	②	③	④	⑤
Q36 14-5 Miscellaneous ( )	①	②	③	④	⑤

15.How often do you use the Internet?

Q37①Very often ②Sometimes ③Rarely ④Never

16. How do you use Internet?

Q38 16-1 How often do you use Internet Shopping?: ①Very often ②Sometimes ③Rarely ④Never

Q39 16-2 If you have answered "Yes"(16-1①②), tell us the reason why. (Plural Answers Allowed)
①Convenient ②Able to compare goods easily ③Cheap ④Plenty of goods ⑤Able to consult with other people ⑥Miscellaneous ( )

Q40 16-3 If you have answered "No"(16-1③④), tell us the reason why. (Plural Answers Allowed)
①Difficult to buy ②anxious ③Can not observe actual goods ④Can not identify which shop is good ⑤Can not get goods immediately ⑥Miscellaneous ( )

Q41 16-4 If you have answered "Yes", which method do you use? ①PC ②Mobile Phone ③Miscellaneous ( )

Q42 16-5 Do you want to buy jewelry/Accessory via the Internet? ①Yes ②Perhaps ③No ④I do not know

Q43 16-6 If you have answered "Yes"(16-5①②), tell us the reason why. (Plural Answers Allowed)
①Convenient ②Able to compare goods easily ③Cheap ④Plenty of goods ⑤Able to consult with other people ⑥Miscellaneous ( )

Q44 16-7 If you have answered "No"(16-5③④), tell us the reason why. (Plural Answers Allowed)
①Difficult to buy ②anxious ③Can not observe actual goods ④Can not identify which shop is good ⑤Can not get goods immediately ⑥Miscellaneous ( )

17. Ask about yourself?

Q45 17-1 Sex: ①Male ②Female

Q46 17-2 Age: ①Under 18 ②18～22③23～27④28～32 ⑤33～37⑥38～42⑦43～47⑧More than 48

Q47 17-3 Occupation: ①Student ②Officer ③Company Employee ④Clerk of Organization ⑤Independents ⑥Miscellaneous

Q48 17-4 Address: ①Prefecture( ) ②City( )

Paper ID: 19

BRAND SELECTION IN THE CASE OF AUTOMOBILE
-Expansion to the Second Order Lag and its Forecasting Accuracy-

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Abstract

Focusing that consumers' are apt to buy superior brand when they are accustomed or bored to use current brand, a new analysis method is introduced. Before buying data and after buying data is stated using liner model. When above stated events occur, transition matrix becomes upper triangular matrix. In this paper, equation using transition matrix is extended to the second order lag and the method is newly re-built. These are applied to the automobile purchasing case and are confirmed by numerical examples. It is expected that forecasting accuracy would be improved compared with those of the former one. Some interesting results are obtained. This approach makes it possible to identify brand position in the market and it can be utilized for building useful and effective marketing plan.

Keywords: brand selection, matrix structure, automobile industry, brand position

1. Introduction

It is often observed that consumers select the upper class brand when they buy the next time. Focusing the transition matrix structure of brand selection, their activities may be analyzed. In the past, there are many researches about brand selection [1-5]. But there are few papers concerning the analysis of the transition matrix structure of brand selection. In this paper, we make analysis of the preference shift of customer brand selection and confirm them by the questionnaire investigation for automobile purchasing case. If we can identify the feature of the matrix structure of brand selection, it can be utilized for the marketing strategy.

Suppose that the former buying data and the current buying data are gathered. Also suppose that the upper brand is located upper in the variable array. Then the transition matrix

becomes an upper triangular matrix under the supposition that the former buying variables are set input and the current buying variables are set output. If the top brand were selected from the lower brand in jumping way, corresponding part in the upper triangular matrix would be 0. These are verified by the numerical examples with simple models.

If the transition matrix is identified, a S-step forecasting can be executed. Generalized forecasting matrix components' equations are introduced. Unless planner for products does not notice its brand position whether it is upper or lower than another products, matrix structure make it possible to identify those by calculating consumers' activities for brand selection. Thus, this proposed approach enables to make effective marketing plan and/or establishing new brand.

A quantitative analysis concerning brand selection has been executed by [4, 5]. [5] examined purchasing process by Markov Transition Probability with the input of advertising expense. [4] made analysis by the Brand Selection Probability model using logistics distribution. In [6], matrix structure was analyzed for the case brand selection was executed toward upper class.

In this paper, equation using transition matrix is extended to the second order lag in order to improve model accuracy and thereby forecasting accuracy, and confirm them by the questionnaire investigation for automobile purchasing case. It is expected that forecasting accuracy would be improved compared with those of the former one. Such research is quite a new one.

Hereinafter, extended analysis method is stated in section 2. Matrix structure is clarified for the brand selection in section 3. Extension of the model to the second order lag is executed in section 4. Forecasting is formulated in section 5. A questionnaire investigation to Automobile Purchasing case is examined and its numerical calculation is executed in section 6. Forecasting is executed and compared with the former one in section 7. Remarks are described in 8. Section 9 is a summary.

2. Extended Analysis Method

Boris Zlotin & Alla Zusman proposed the concept of "Trends" in TRIZ CON 2006 (Boris Zlotin et al., 2006). We can further develop this concept as shown in Figure 1.

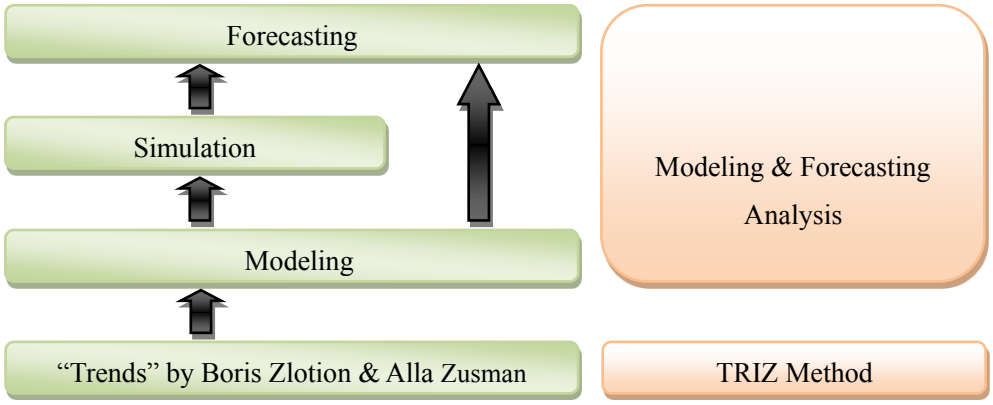

Figure 1. Extended Analysis Method

Based on the TRIZ method, modeling and forecasting analysis method is developed. Extending "Trends", modeling is constructed first. Then we can make simulation by utilizing them. We can make forecasting utilizing the simulation function or directly from the utilization of the model built. These are the process of "Modeling & Forecasting Analysis" based upon TRIZ "Trends" analysis method. Detailed inspection is executed in Section 5 through 7.

3. Brand Selection and Its Matrix Structure

3.1 Upper Shift of Brand Selection

It is often observed that consumers select the upper class brand when they buy the next time. Now, suppose that x is the most upper class brand, y is the second upper brand, and z is the lowest brand. Consumer's behavior of selecting brand would be $z \to y$, $y \to x, z \to x$ etc. $x \to z$ might be few.

Suppose that x is the current buying variable, and x_b is the previous buying variable. Shift to x is executed from x_b, y_b, or z_b. Therefore, x is stated in the following equation.

$$x = a_{11}x_b + a_{12}y_b + a_{13}z_b$$

Similarly,

$$y = a_{22}y_b + a_{23}z_b$$

And

$$z = a_{33} z_b$$

These are re-written as follows.

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ 0 & a_{22} & a_{23} \\ 0 & 0 & a_{33} \end{pmatrix} \begin{pmatrix} x_b \\ y_b \\ z_b \end{pmatrix} \tag{1}$$

Set :

$$\mathbf{X} = \begin{pmatrix} x \\ y \\ z \end{pmatrix}, \quad \mathbf{A} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ 0 & a_{22} & a_{23} \\ 0 & 0 & a_{33} \end{pmatrix}, \quad \mathbf{X_b} = \begin{pmatrix} x_b \\ y_b \\ z_b \end{pmatrix}$$

then, $\mathbf{X}$ is represented as follows.

$$\mathbf{X} = \mathbf{A}\mathbf{X_b} \tag{2}$$

Here,

$$\mathbf{X} \in \mathbf{R}^3, \mathbf{A} \in \mathbf{R}^{3\times 3}, \mathbf{X_b} \in \mathbf{R}^3$$

$\mathbf{A}$ is an upper triangular matrix. To examine this, generating the following data, which are all consisted by the upper brand shift data.

$$\mathbf{X^i} = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} \quad \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} \quad \cdots \quad \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} \tag{3}$$

$$\mathbf{X_b^i} = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} \quad \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} \quad \cdots \quad \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} \tag{4}$$

$$i = 1, \quad 2, \quad \cdots \quad N$$

parameter can be estimated using least square method. Suppose

$$\mathbf{X}^i = \mathbf{A}\mathbf{X}_\mathbf{b}^i + \boldsymbol{\varepsilon}^i \tag{5}$$

Where

$$\varepsilon^i = \begin{pmatrix} \varepsilon_1^i \\ \varepsilon_2^i \\ \varepsilon_3^i \end{pmatrix} \qquad i = 1,2,\cdots,N$$

And

$$J = \sum_{i=1}^{N} \boldsymbol{\varepsilon}^{iT} \boldsymbol{\varepsilon}^i \rightarrow Min \tag{6}$$

$\hat{\mathbf{A}}$ which is an estimated value of $\mathbf{A}$ is obtained as follows.

$$\hat{\mathbf{A}} = \left(\sum_{i=1}^{N} \mathbf{X}^i \mathbf{X}_\mathbf{b}^{iT} \right) \left(\sum_{i=1}^{N} \mathbf{X}_\mathbf{b}^i \mathbf{X}_\mathbf{b}^{iT} \right)^{-1} \tag{7}$$

In the data group of the upper shift brand, estimated value $\hat{\mathbf{A}}$ should be an upper triangular matrix. If the following data, that have the lower shift brand, are added only a few in equation (3) and (4),

$$\mathbf{X}^i = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix}, \qquad \mathbf{X}_\mathbf{b}^i = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}$$

$\hat{\mathbf{A}}$ would contain minute items in the lower part triangle.

3.2 Sorting Brand Ranking by Re-arranging Row

In a general data, variables may not be in order as x, y, z. In that case, large and small value lie scattered in $\hat{\mathbf{A}}$. But re-arranging this, we can set in order by shifting row. The large value parts are gathered in an upper triangular matrix, and the small value parts are gathered in a lower triangular matrix.

$\hat{\mathbf{A}}$ $\hat{\mathbf{A}}$

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} \begin{pmatrix} \bigcirc & \bigcirc & \bigcirc \\ \varepsilon & \bigcirc & \bigcirc \\ \varepsilon & \varepsilon & \bigcirc \end{pmatrix} \quad \xleftarrow{\text{Shifting}} \quad \begin{pmatrix} z \\ x \\ y \end{pmatrix} \begin{pmatrix} \varepsilon & \varepsilon & \bigcirc \\ \bigcirc & \bigcirc & \bigcirc \\ \varepsilon & \bigcirc & \bigcirc \end{pmatrix} \tag{8}$$

3.3 Matrix Structure Under the Case Intermediate Class Brand is Skipped

It is often observed that some consumers select the most upper class brand from the most lower class brand and skip selecting the middle class brand. We suppose v, w, x, y, z brands (suppose they are laid from the upper position to the lower position as $v > w > x > y > z$). In the above case, the selection shifts would be

$$v \leftarrow z, \qquad v \leftarrow y$$

Suppose there is no shift from z to y, corresponding part of the transition matrix is 0 (i.e. a_{45}=0). Similarly, if there is no shift from z to y, from z to w, from y to x, form y to w, from x to w, then the matrix structure would be as follows.

$$\begin{pmatrix} v \\ w \\ x \\ y \\ z \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} \\ 0 & a_{22} & 0 & 0 & 0 \\ 0 & 0 & a_{33} & 0 & 0 \\ 0 & 0 & 0 & a_{44} & 0 \\ 0 & 0 & 0 & 0 & a_{55} \end{pmatrix} \begin{pmatrix} v_b \\ w_b \\ x_b \\ y_b \\ z_b \end{pmatrix} \tag{9}$$

4. Extension of The Model to The Second Order Lag

We extend Eq.(2) to the second order lag in this section. We have analyzed the automobile purchasing case ([6]). In that case, we could obtain the data (current buying data, former buying data, before former buying data). We have analyzed them by dividing the data (current buying data, former buying data) and (former buying data before former buying data), and put them to Eq.(5) to apply the model.

But this is a kind of a simplified method to apply to the model. If we have a further time lag model and we can utilized the data as it is, the estimation accuracy of parameter would be more accurate and the forecasting would be more precise. Therefore we introduce a new model which extends Eq.(2) to the second order lag model as follows.

$$\mathbf{X}_t = \mathbf{A}_1 \mathbf{X}_{t-1} + \mathbf{A}_2 \mathbf{X}_{t-2} \tag{10}$$

Where

$$\mathbf{X}_t = \begin{pmatrix} x_1^t \\ x_2^t \\ \vdots \\ x_p^t \end{pmatrix} \quad t = 1,2\cdots$$

$$\mathbf{A}_1 = \begin{pmatrix} a_{11}^{(1)}, & a_{12}^{(1)}, & \cdots, & a_{1p}^{(1)} \\ a_{21}^{(1)}, & a_{22}^{(1)}, & \cdots, & a_{2p}^{(1)} \\ \vdots & \vdots & & \vdots \\ a_{p1}^{(1)}, & a_{p1}^{(1)}, & \ldots, & a_{pp}^{(1)} \end{pmatrix}$$

$$\mathbf{A}_2 = \begin{pmatrix} a_{11}^{(2)}, & a_{12}^{(2)}, & \cdots, & a_{1p}^{(2)} \\ a_{21}^{(2)}, & a_{22}^{(2)}, & \cdots, & a_{2p}^{(2)} \\ \vdots & \vdots & & \vdots \\ a_{p1}^{(2)}, & a_{p1}^{(2)}, & \ldots, & a_{pp}^{(2)} \end{pmatrix}$$

$$\mathbf{X}_t \in \mathbf{R}^p \left(t = 1,2,\cdots\right) \quad \mathbf{A}_1 \in \mathbf{R}^{p\times p}, \mathbf{A}_2 \in \mathbf{R}^{p\times p}$$

In order to estimate $\mathbf{A_1}, \mathbf{A_2}$, we set the following equation in the same way as before.

$$\mathbf{X}_t^i = \mathbf{A}_1\mathbf{X}_{t-1}^i + \mathbf{A}_2\mathbf{X}_{t-2}^i + \boldsymbol{\varepsilon}_t^i \quad \left(t = 1,2,\cdots,N\right) \tag{11}$$

$$J = \sum_{i=1}^{N} \boldsymbol{\varepsilon}_t^{\ iT} \boldsymbol{\varepsilon}_t^{\ i} \rightarrow Min \tag{12}$$

Eq.(11) is expressed as follows.

$$\mathbf{X}_t^i = \left(\mathbf{A}_1, \quad \mathbf{A}_2\right) \begin{pmatrix} \mathbf{X}_{t-1}^i \\ \mathbf{X}_{t-2}^i \end{pmatrix} + \boldsymbol{\varepsilon}_t^i \tag{13}$$

$\left(\hat{\mathbf{A}}_1, \quad \hat{\mathbf{A}}_2\right)$ which is an estimated value of $\left(\mathbf{A}_1, \quad \mathbf{A}_2\right)$ is obtained as follows in the same way as Eq.(7).

$$\left(\hat{\mathbf{A}}_1, \quad \hat{\mathbf{A}}_2\right) = \left(\sum_{i=1}^{N} \mathbf{X}_t^i \left(\mathbf{X}_{t-1}^{iT}, \quad \mathbf{X}_{t-2}^{iT}\right)\right)\left(\sum_{i=1}^{N} \begin{pmatrix} \mathbf{X}_{t-1}^i \\ \mathbf{X}_{t-2}^i \end{pmatrix} \left(\mathbf{X}_{t-1}^{iT}, \quad \mathbf{X}_{t-2}^{iT}\right)\right)^{-1} \tag{14}$$

This is re-written as :

$$\left(\hat{\mathbf{A}}_1, \quad \hat{\mathbf{A}}_2\right) = \left(\sum_{i=1}^{N} \mathbf{X}_t^i \mathbf{X}_{t-1}^{iT}, \quad \sum_{i=1}^{N} \mathbf{X}_t^i \mathbf{X}_{t-2}^{iT}\right) \begin{pmatrix} \sum_{i=1}^{N} \mathbf{X}_{t-1}^i \mathbf{X}_{t-1}^{iT}, & \sum_{i=1}^{N} \mathbf{X}_{t-1}^i \mathbf{X}_{t-2}^{iT} \\ \sum_{i=1}^{N} \mathbf{X}_{t-2}^i \mathbf{X}_{t-1}^{iT}, & \sum_{i=1}^{N} \mathbf{X}_{t-2}^i \mathbf{X}_{t-2}^{iT} \end{pmatrix}^{-1} \tag{15}$$

We set this as :

$$\left(\hat{\mathbf{A}}_1, \quad \hat{\mathbf{A}}_2\right) = \left(\hat{\mathbf{B}}, \quad \hat{\mathbf{C}}\right) \begin{pmatrix} \hat{\mathbf{D}} & \hat{\mathbf{E}} \\ \hat{\mathbf{E}}^T & \hat{\mathbf{F}} \end{pmatrix}^{-1} \tag{16}$$

In the data group of upper shift brand, $\hat{\mathbf{E}}$ becomes an upper triangular matrix. While $\hat{\mathbf{D}}$ and $\hat{\mathbf{F}}$ are diagonal matrix in any case. This will be made clear in the numerical calculation later.

5. Forecasting

After transition matrix is estimated, we can make forecasting. We show some of them in the following equations.

$$\hat{\mathbf{X}}_{t+1} = \hat{\mathbf{A}}_1 \mathbf{X}_t + \hat{\mathbf{A}}_2 \mathbf{X}_{t-1} \tag{17}$$

$$\hat{\mathbf{X}}_{t+2} = \left(\hat{\mathbf{A}}_1^{\,2} + \hat{\mathbf{A}}_2\right)\mathbf{X}_t + \hat{\mathbf{A}}_1 \hat{\mathbf{A}}_2 \mathbf{X}_{t-1} \tag{18}$$

$$\hat{\mathbf{X}}_{t+3} = \left(\hat{\mathbf{A}}_1^{\,3} + \hat{\mathbf{A}}_1 \hat{\mathbf{A}}_2 + \hat{\mathbf{A}}_2 \hat{\mathbf{A}}_1\right)\mathbf{X}_t + \left(\hat{\mathbf{A}}_1^{\,2} + \hat{\mathbf{A}}_2\right)\hat{\mathbf{A}}_2 \mathbf{X}_{t-1} \tag{19}$$

$$\begin{aligned} \hat{\mathbf{X}}_{t+4} = & \left(\hat{\mathbf{A}}_1^{\,4} + \hat{\mathbf{A}}_1^{\,2}\hat{\mathbf{A}}_2 + \hat{\mathbf{A}}_1 \hat{\mathbf{A}}_2 \hat{\mathbf{A}}_1 + \hat{\mathbf{A}}_2 \hat{\mathbf{A}}_1^{\,2} + \hat{\mathbf{A}}_2^{\,2}\right)\mathbf{X}_t \\ & + \left\{\hat{\mathbf{A}}_1\left(\hat{\mathbf{A}}_1^{\,2} + \hat{\mathbf{A}}_2\right) + \hat{\mathbf{A}}_2 \hat{\mathbf{A}}_1\right\}\hat{\mathbf{A}}_2 \mathbf{X}_{t-1} \end{aligned} \tag{20}$$

6. A Questionnaire Investigation and Numerical Calculation

A questionnaire investigation for automobile purchasing case is executed.

<Delivery of Questionnaire Sheets>

- Delivery Term : July /2008 to July / 2009
- Delivery Place : Tokyo, Osaka, Hyogo, Nara, Kyoto, Wakayama in Japan
- Number of Delivered Questionnaire sheets: 700

<Result of collected Questionnaire Sheets>

- Collected Questionnaire Sheets:160
- Collected data sets:237

The questionnaire includes the question of the past purchasing history. Therefore the plural data may be gathered from one sheet. For example, we can get two data such as (before former automobile, former automobile), (former automobile, current automobile). As a result, we obtained 237 data sets. 94 cases are the upper shifts, 89 cases are the same rank movement, and 54 cases are the lower shifts. Lower shift is consists of 23% in whole cases and the transition matrix corresponds to these facts on the whole. Fundamental statistical result is exhibited in Table 1.

Table 1. Summary for 160 sheets

Age		Sex		Occupation		Annual income (Japanese Yen)		Marriage		Kids	
Teens	19	Male	129	Student	52	0-3 million	56	Single	81	0	98
Twenties	54	Female	31	Officer	18	3-5 million	21	Married	75	1	15
Thirties	31			Company employee	76	5-7.5 million	21	Not filled in	4	2	36
Forties	28			Clerk of Organization	5	7.5-10 million	12			3	17
Fifties	25			Independents	1	10-15 million	5			4	10
Sixties and over	3			Miscellaneous	6	15 million or more	0			5	1
Not filled in	0			Not filled in	2	Not filled in	45				
Sum	160		160		160		160		160		160

Analyzing collected sheets based on Model ranked Table (Appendix1, Appendix2), we obtained the following 237 data sets. Appendix shows the ranking Table for this calculation.

	$<\mathbf{X}_{t-2}$ to $\mathbf{X}_{t-1}>$		$<\mathbf{X}_{t-1}$ to $\mathbf{X}_{t}>$	
1.	Shift from 5 brand to 5 brand	10	Shift from 5 brand to 5 brand	10
2.	Shift from 5 brand to 5 brand	3	Shift from 5 brand to 4 brand	3
3.	Shift from 5 brand to 5 brand	3	Shift from 5 brand to 3 brand	3
4.	Shift from 5 brand to 5 brand	5	Shift from 5 brand to 2 brand	5
5.	Shift from 5 brand to 5 brand	4	Shift from 5 brand to 1 brand	4
6.	Shift from 5 brand to 4 brand	3	Shift from 4 brand to 5 brand	3
7.	Shift from 5 brand to 4 brand	1	Shift from 4 brand to 4 brand	1
8.	Shift from 5 brand to 4 brand	2	Shift from 4 brand to 3 brand	2
9.	Shift from 5 brand to 4 brand	1	Shift from 4 brand to 1 brand	1
10.	Shift from 5 brand to 3 brand	1	Shift from 3 brand to 4 brand	1

11.	Shift from 5 brand to 2brand	1	Shift from 2 brand to 4 brand	1
12.	Shift from 5 brand to 2brand	2	Shift from 2 brand to 2 brand	2
13.	Shift from 5 brand to 1brand	1	Shift from 1 brand to 3 brand	1
14.	Shift from 4 brand to 5 brand	2	Shift from 5 brand to 5 brand	2
15.	Shift from 4 brand to 5 brand	1	Shift from 5 brand to 4 brand	1
16.	Shift from 4 brand to 5 brand	3	Shift from 5 brand to 3 brand	3
17.	Shift from 4 brand to 5 brand	1	Shift from 5 brand to 2 brand	1
18.	Shift from 4 brand to 4 brand	1	Shift from 4 brand to 5 brand	1
19.	Shift from 4 brand to 4 brand	1	Shift from 4 brand to 4 brand	1
20.	Shift from 4 brand to 4 brand	1	Shift from 4 brand to 3 brand	1
21.	Shift from 4 brand to 3 brand	2	Shift from 3 brand to 4 brand	2
22.	Shift from 4 brand to 3 brand	1	Shift from 3 brand to 3 brand	1
23.	Shift from 4 brand to 3 brand	4	Shift from 3 brand to 2 brand	4
24.	Shift from 4 brand to 3 brand	2	Shift from 3 brand to 1 brand	2
25.	Shift from 3 brand to 5 brand	1	Shift from 5 brand to 5 brand	1
26.	Shift from 3 brand to 3 brand	1	Shift from 3 brand to 1 brand	1
27.	Shift from 3 brand to 2 brand	2	Shift from 2 brand to 3 brand	2
28.	Shift from 3 brand to 2 brand	1	Shift from 2 brand to 2 brand	1
29.	Shift from 3 brand to 2 brand	1	Shift from 2 brand to 1 brand	1
30.	Shift from 3 brand to 1 brand	1	Shift from 1 brand to 2 brand	1
31.	Shift from 2 brand to 5 brand	1	Shift from 5 brand to 5 brand	1
32.	Shift from 2 brand to 5 brand	2	Shift from 5 brand to 2 brand	2
33.	Shift from 2 brand to 4 brand	1	Shift from 4 brand to 5 brand	1
34.	Shift from 2 brand to 4 brand	1	Shift from 4 brand to 2 brand	1
35.	Shift from 2 brand to 3 brand	1	Shift from 3 brand to 3 brand	1
36.	Shift from 2 brand to 3 brand	1	Shift from 3 brand to 2 brand	1
37.	Shift from 2 brand to 2 brand	2	Shift from 2 brand to 2 brand	2
38.	Shift from 2 brand to 2 brand	1	Shift from 2 brand to 1 brand	1
39.	Shift from 2 brand to 1 brand	1	Shift from 1 brand to 3 brand	1
40.	Shift from 1 brand to 3 brand	1	Shift from 3 brand to 2 brand	1
41.	Shift from 1 brand to 3 brand	1	Shift from 3 brand to 1 brand	1
42.	Shift from 1 brand to 2 brand	1	Shift from 2 brand to 3 brand	1
43.	Shift from 1 brand to 1 brand	1	Shift from 1 brand to 4 brand	1
44.	Shift from 1 brand to 1 brand	1	Shift from 1 brand to 2 brand	1
45.	-		Shift from 5 brand to 5 brand	18
46.	-		Shift from 5 brand to 4 brand	7
47.	-		Shift from 5 brand to 3 brand	6
48.	-		Shift from 5 brand to 2 brand	6

49.	-	Shift from 5 brand to 1 brand	3
50.	-	Shift from 4 brand to 5 brand	4
51.	-	Shift from 4 brand to 4 brand	3
52.	-	Shift from 4 brand to 3 brand	1
53.	-	Shift from 4 brand to 2 brand	1
54.	-	Shift from 4 brand to 1 brand	1
55.	-	Shift from 3 brand to 5 brand	4
56.	-	Shift from 3 brand to 4 brand	2
57.	-	Shift from 3 brand to 3 brand	5
58.	-	Shift from 3 brand to 2 brand	1
59.	-	Shift from 3 brand to 1 brand	1
60.	-	Shift from 2 brand to 5 brand	3
61.	-	Shift from 2 brand to 3 brand	2
62.	-	Shift from 2 brand to 2 brand	5
63.	-	Shift from 2 brand to 1 brand	1
64.	-	Shift from 1 brand to 5 brand	1
65.	-	Shift from 1 brand to 4 brand	2
66.		Shift from 1 brand to 1 brand	2

Vector $\mathbf{X}_t, \mathbf{X}_{t-1}, \mathbf{X}_{t-2}$ in these cases are expressed as follows.

1. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ 2. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$

3. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ 4. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$

5. $\mathbf{X}_t = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ 6. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$

7. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$

8. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$

9. $\mathbf{X}_t = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$

10. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$

11. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$

12. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$

13. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$

14. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

15. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

16. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

17. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

18. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

19. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

20. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

21. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

22. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

23. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

24. $\mathbf{X}_t = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

25. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$

26. $\mathbf{X}_t = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$

27. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$

28. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$

29. $\mathbf{X}_t = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$

30. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$

31. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

32. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

33. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

34. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

35. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

36. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

37. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

38. $\mathbf{X}_t = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

39. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

40. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

41. $\mathbf{X}_t = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

42. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

43. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

44. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-1} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X}_{t-2} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

45. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$

46. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$

47. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$

48. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$

49. $\mathbf{X}_t = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$

50. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

51. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

52. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

53. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

54. $\mathbf{X}_t = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

55. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$

56. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$

57. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$

58. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$

59. $\mathbf{X}_t = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$

60. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

61. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

62. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

63. $\mathbf{X}_t = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

64. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

65. $\mathbf{X}_t = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

66. $\mathbf{X}_t = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \quad \mathbf{X}_{t-1} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

Substituting these to equation (14), we obtain the following equation.

$$\left(\hat{\mathbf{A}}_1,\ \hat{\mathbf{A}}_2\right) = \left(\begin{array}{ccccc:ccccc} 2 & 3 & 5 & 2 & 7 & 1 & 1 & 2 & 2 & 5 \\ 2 & 10 & 7 & 2 & 14 & 2 & 6 & 2 & 5 & 7 \\ 2 & 5 & 7 & 4 & 12 & 1 & 2 & 2 & 5 & 6 \\ 3 & 1 & 5 & 5 & 11 & 1 & 0 & 0 & 4 & 6 \\ 1 & 3 & 4 & 9 & 32 & 0 & 2 & 1 & 3 & 13 \end{array}\right) \left(\begin{array}{ccccc:ccccc} 10 & 0 & 0 & 0 & 0 & 2 & 1 & 1 & 0 & 1 \\ 0 & 22 & 0 & 0 & 0 & 1 & 3 & 4 & 0 & 3 \\ 0 & 0 & 28 & 0 & 0 & 2 & 2 & 1 & 9 & 1 \\ 0 & 0 & 0 & 22 & 0 & 0 & 2 & 0 & 3 & 7 \\ 0 & 0 & 0 & 0 & 76 & 0 & 3 & 1 & 7 & 25 \\ \hdashline 2 & 1 & 2 & 0 & 0 & 5 & 0 & 0 & 0 & 0 \\ 1 & 3 & 2 & 2 & 3 & 0 & 11 & 0 & 0 & 0 \\ 1 & 4 & 1 & 0 & 1 & 0 & 0 & 7 & 0 & 0 \\ 0 & 0 & 9 & 3 & 7 & 0 & 0 & 0 & 19 & 0 \\ 1 & 3 & 1 & 7 & 25 & 0 & 0 & 0 & 0 & 37 \end{array}\right)^{-1} \quad (21)$$

As we have seen before, we can confirm that

$\hat{\mathbf{E}}$ part in Eq.(16) is an upper triangular matrix and

$\hat{\mathbf{D}}, \hat{\mathbf{F}}$ part in Eq.(16) are diagonal matrices.

$\hat{\mathbf{E}}^T$ part is there by a lower triangular matrix.

We can find that if $\hat{\mathbf{E}}$ part becomes an upper triangular matrix, then the items compose upper shift or the same level shift. Calculation results of $\left(\hat{\mathbf{A}}_1,\ \hat{\mathbf{A}}_2\right)$ become as follows.

$$\left(\hat{\mathbf{A}}_1,\ \hat{\mathbf{A}}_2\right) = \begin{pmatrix} 0.171 & 0.099 & 0.175 & 0.078 & 0.075 & 0.042 & -0.018 & 0.169 & -0.017 & 0.052 \\ 0.115 & 0.390 & 0.167 & 0.026 & 0.142 & 0.208 & 0.355 & 0.002 & 0.128 & 0.049 \\ 0.195 & 0.214 & 0.225 & 0.173 & 0.151 & -0.011 & -0.008 & 0.082 & 0.074 & -0.001 \\ 0.342 & 0.102 & 0.192 & 0.244 & 0.156 & -0.034 & -0.181 & -0.157 & 0.023 & -0.012 \\ 0.174 & 0.195 & 0.241 & 0.479 & 0.476 & -0.205 & -0.148 & -0.096 & -0.208 & -0.088 \end{pmatrix} \quad (22)$$

7. Forecasting Accuracy

Forecasting accuracy of this model is examined and compared with the former one. We make forecasting by the following method.

7.1 First Order Lag Model

$$\hat{\mathbf{X}}_t = \hat{\mathbf{A}}\mathbf{X}_{t-1} \quad (23)$$

7.2 Second Order Lag Model

$$\hat{\mathbf{X}}_t = \hat{\mathbf{A}}_1 \mathbf{X}_{t-1} + \hat{\mathbf{A}}_2 \mathbf{X}_{t-2} \tag{24}$$

As we already have the realized value $\mathbf{X}_t$, we can calculate the variance of forecasting error as follows.

$$\sigma_j^{\ 2} = \frac{1}{N_2 - N_1} \sum_{i=N_1}^{N_2} \left(\hat{x}_j^i - x_j^i \right)^2 \quad (j = 1,2 \cdots ,5) \tag{25}$$

Where x_j^i means j-th column of $\mathbf{X}_t$ for i-th data set, and N_1 through N_2 are testing data period. Forecasting accuracy may be evaluated as follows.

$$F_a = \frac{1}{5} \sum_{j=1}^{5} \sigma_j^{\ 2} \tag{26}$$

The calculation results are as follows.

7.1 First Order Lag Model

$$\sigma_1^{\ 2} = 3.797$$
$$\sigma_2^{\ 2} = 10.711$$
$$\sigma_3^{\ 2} = 8.765$$
$$\sigma_4^{\ 2} = 6.939$$
$$\sigma_5^{\ 2} = 20.631$$
$$F_a = 10.169$$

7.2 Second Order Lag Model

$$\sigma_1^{\ 2} = 0.522$$
$$\sigma_2^{\ 2} = 0.934$$
$$\sigma_3^{\ 2} = 0.625$$
$$\sigma_4^{\ 2} = 0.436$$
$$\sigma_5^{\ 2} = 1.300$$
$$F_a = 0.763$$

Forecasting accuracy has apparently improved by this new model. This method should be examined in various cases.

8. Remarks

Based on these data, we can clarify the shift among car makers.

- In the upper shift data, the number of the shifts from Toyota to Toyota is 23. This is the greatest number and takes the share of 25% of the total in the upper shift data. Next, the number of the shifts from Matsuda to Toyota is 7. This has the share of 8% of the total.
- In the lower shift data, the number of the shifts from Toyota to Toyota is 10. This is the greatest number and takes the share of 25% of the total in the lower shift data. Next, the number of the shifts from Nissan to Nissan is 5. This has the share of 9% of the total.

In both of the upper and the lower shift data, the number of the shifts to Toyota is the most. Meanwhile, the number of the shifts to Nissan occupies the majority in the lower shift data.

9. Conclusion

Consumers often buy higher grade brand products as they are accustomed or bored to use current brand products they have.

Formerly we have presented the paper and matrix structure was clarified when brand selection was executed toward higher grade brand. In [6], matrix structure was analyzed for the case brand selection was executed for upper class. In this paper, equation using transition matrix was extended to the second order lag and the method was newly re-built. One of the TRIZ methods was extended and applied. Matrix structure's hypothesis was verified by the questionnaire investigation for automobile purchasing case. We can utilized the data as it is for the data in which time lag exist by this new model and estimation accuracy of parameter becomes more accurate and forecasting becomes more precise. The expansion to the third order lag of this model would be our future works to be investigated.

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Appendix. Model Ranking Table

	Sedan	Coupe·Sports car	One box·Minivan	Wagon	SUV	Compact car	Light car	Truck
Ⅰ	525i BMW Crown hybrid Crown majesta Celsior Benz Lexus Lexus ES Lexus LS	GTR M3 NSX Audi Countach Corvette Boxster Porsche Volvo Lexus SC			Hummer Land-cruiser Lexus GX Range rover			
Ⅱ	C4 MS-9 VW golf VW vento Accord Aristo Altezza Inspire Windom Camry Cadillac Crown Crown royalsaloon Gloria Cima Chanson Skyline Cedric Cedric cube Fuga Peugeot207 Bora Mark Ⅱ Mark Ⅱ blit Lancer evolution x Lexus IS	MR-S RX-7 RX-8 S2000 Integra type-R Cosmo Skyline coupe Fairlady Z	MPV Astro Alphard Alphard hybrid Vellfire Estima Elysion prestige Elgrand Odyssey Delica space gear Lucida	Accord tourer Mark x zio Airwave	Kluger Safari Bighorn Prado			
Ⅲ	Impreza Cresta Sigma Civic type-R Cefiro Diamante Beetle Vigor Prius Mark X Legacy Leopard Laurel	Levin	Ipsum Stepwgn Stepwgn-spada Spacio Serena Delica Hiace Regius	Accord wagon Golf wagon Stagea Primera wagon Legacy touring-wagon Legnum	CRV OUtlander X-trail Surf Terrano Hilux surf Pajero Harrier			

Ⅳ	SX4 seedan Ascot Insight Integra Impreza anesis Exiv Capella Carina ED Galant fortis Cronus Civic Chaser Vista Vista ardeo Primera Bluebird Bluebird sylphy	180SX Cavalier Silvia Supra Smart Celica Prelude	Isis Wish Voxy Edix Caravan Sienta Chariot Stream Noah Freed Premacy Bongo	Avenir Caldina Mark Ⅱ wagon	RAV-4 Airtrek Cami Tribute Forester	RVR Corolla rumion Mini cooper Raum Rumion		
Ⅴ	CR-X Axela Aerio Carina Corolla Corolla Ⅱ Cruze Corsa Corona Sunny Gemini City Tercel Tiida Pulsar Familia Festiva Platz Mirage Lancer sedan Leone Logo	MR2 Corolla levin Sprinter Sprinter- trueno	Acty van Every Chariot Townace Hijet Prairie Masterace Liteace	Sprinter carib Demio Lancer cedia- wagon Libero	Chevrolet Pajero Jr Rasheen	bB iQ Vitz Cube That's Swift Note Pyzar Passo Fun cargo Fit March	eK wagon MAX MR- wago Atrai- wagon Alto Vivio Every- wagon Otti Opti Jimny Scrum Stella Street Sonica Tanto Bistor Pino Minica Mira Move Moco Life Lapin Rex Wagon R	Acty truck High bit- truck Mighty boy

Paper ID: 20

Discussion on the pattern of popularization and application of TRIZ theory towards Chinese enterprises

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Abstract

TRIZ theory is an advanced innovation method, which is strongly popularized by the government of China in recent years. But TRIZ theory is still unfamiliar to most Chinese enterprises due to a very short period of time for the introduction of TRIZ, and how to popularize TRIZ theory effectively in Chinese enterprises is still being probed. This paper aims at the research of popularization pattern of TRIZ theory in Chinese enterprise based on the analysis of successful application experience in the United States, Germany and South Korea. According to the present situation and the existing problems during the popularization of TRIZ in Chinese enterprises, some suggestions have been proposed.

Keywords: Innovation method, TRIZ theory, Pattern of popularization and application, Chinese enterprise

1. Introduction

TRIZ theory has its origins in the former Soviet Union, where it was founded by Genrich Saulovich Altshuller. He obtained the principle of invention and solving problem based on the research of 2.5 million patents. In the case of contradictions or conflicts, TRIZ theory does not compromise, but thoroughly solve the contradictions or conflicts. Accordingly, TRIZ theory can help people quickly find the essence of problems, and inspire people's innovative thinking, as well as break the limit of knowledge, thus achieve a technical breakthrough[1-4]. Visibly, TRIZ theory is a kind of scientific methodology system with operability.

Recently, TRIZ theory, as a kind of advanced innovation method, in some developed countries and famous companies has a good application. Therefore, the popularization and application of TRIZ theory is widely concerned in the whole world. How to promote TRIZ

theory more effectively, and make more enterprises benefit from it, is the governments' common issue of concern. But so far, there are few literatures about the pattern of popularization and application of TRIZ theory. Therefore, this paper endeavors to probe an effective popularization and application pattern of TRIZ theory toward Chinese enterprises through the analysis of the successful experiences for some top 500 enterprises.

2. The successful application experiences of TRIZ theory

TRIZ theory was unknown outside the Soviet Union until 1990s, and it became possible for Soviet experts to travel abroad and for some to emigrate. Its popularity in the US, Japan and the Pacific Rim, and Western Europe is now growing rapidly. These countries actively introduce the TRIZ experts, and establish the research institutes and teams of TRIZ theory to carry out their research and application, which have achieved remarkable effects. Many Fortune 500 companies have cited a phenomenal increase in productivity, and they credit TRIZ for the breakthrough ideas and quality solutions to tough engineering problems. Great success has been achieved for some top 500 enterprises such as Boeing company of the United States, Siemens company of Germany, Samsung electronic company of South Korea and etc., which applied TRIZ theory in product's innovation[5-7].

(1) Boeing company of the United States

In the United States, TRIZ theory was introduced in the early 1990s. Since the Altshuller research institute was established in 1999, the work for the popularization and application of TRIZ theory accessed to a formal stage. The Boeing Company always adhere to the independent innovation, pay attention to team cooperation innovation, its CEO think that innovation is a team's project, not an individual one. In 2001, the Boeing Company invited 25 TRIZ experts from the former Soviet to conduct the training for 450 engineers for about two weeks. Using TRIZ theory, the Boeing Company successfully solved the key technology problem by adding the gasoline to the Boeing 767 aircraft in the sky, thus defeated the airbus company of France, and won a $1.5 billion's order for the company. The popularization experience of the Boeing company can be contributed to the leadership' attention, good innovation atmosphere and the team's cooperation spirit.

(2) Siemens company of Germany

TRIZ theory was introduced to Germany in 1973, and the course of TRIZ theory was open in the universities of science and engineering in the 1990s. Siemens company of Germany attached great importance to the advanced innovation method, and began to apply TRIZ theory in product's development in the 1990s. Siemens company hired some TRIZ theory experts and engineers from the former Soviet to carry out the international exchange and cooperation, and imported the computer aided innovation software to enhance the efficiency of solving problems. In addition, Siemens also emphasized the integration of resource advantages by reinforcing the cooperation with universities and research institutes. Therefore, TRIZ theory in Siemens got

very good application and produced a lot of innovation achievements with independent intellectual property. In 2004, Siemens realized about 9000 inventions, and applied for more than 6000 patents, among which more than 3800 patents were converted to products. The Siemens popularization experience can be summarized as great attentions of the company's leadership, and the integration of resource advantages as well as the application of innovation tools.

(3) Samsung company of South Korea

Since TRIZ theory was imported to South Korea in 1997, it has got positive responses of some famous enterprises such as Samsung, LG, and etc., and was widely used in product's development. Samsung began TRIZ theory in 1997, and imported some TRIZ experts from the former Soviet Union to instruct product's innovation, who also conducted the training course of TRIZ theory for the company employees. In this way, Samsung developed TRIZ masters independently and obtained remarkable economic benefits. In 2003, Samsung saved the product's cost of $1.5 billion using TRIZ theory, and among 67 research projects there were 52 ones successfully applied for patents. In 2004, Samsung created a global market share of the first grade. In 2006, Samsung gained 2453 patents of invention in the United States, and its market value broke through $100 billion, $41 billion more than SONY. The popularization experience of Samsung may owe to the introduction of external TRIZ experts to foster TRIZ masters independently, the establishment of research teams of TRIZ and good innovation atmosphere.

3. The present popularization situation of TRIZ theory in China

The research work and application of TRIZ theory has just begun in China. Since 2007, the Ministry of Science and Technology of the P.R. China has approved the provinces of Heilongjiang, Sichuan, Guangdong and Jiangsu and etc. as the pilot ones for innovative method. For several years, the pilot provinces take the government-driven as the leading popularization pattern, and spread TRIZ theory to the society and the enterprises. Multi-levels and various forms of TRIZ training class have been carried out to enhance the enterprises' awareness of TRIZ and foster the creative talents.

Although the work for the popularization and application of TRIZ theory has made some achievements, there still exist many problems as follows due to the early stage of the popularization of TRIZ in China.

(1) The enterprises' awareness of TRIZ theory is inadequate, and most of them are still in trying to stage. Some enterprises introduce TRIZ theory mainly because of the government's advocacy and financial support, but lack of initiative.

(2) TRIZ has been introduced to Chinese mainland only for a very short period of time, no matter whether the quantity or quality of TRIZ trainers is quite weak. Besides, the TRIZ experts with engineering background and experience are very few, and cannot

satisfy the enterprises' actual demand at all, which greatly restricts the popularization and application of TRIZ theory.

(3) Few high-level achievements have been produced for the pilot enterprises using TRIZ theory, and the effect of typical demonstration for the application cases is unobvious. Besides, the innovation atmosphere of the society has not been formed, and the independent innovation consciousness of the enterprises still needs to be further enhanced.

(4) The existing popularization pattern of TRIZ theory, which mainly depends on the government's promotion, is immature and needs to be further probed.

4. Proposals for the popularization pattern of TRIZ in Chinese enterprises

TRIZ theory comes from industry, so it is an invention theory facing to engineering field. The value of TRIZ theory mainly manifests that it can provide the innovative solutions of technical problems for the enterprises. Therefore, the popularization of TRIZ theory is greatly dependent on its application in enterprises. China is an industrial manufacturing country, how to combine the actual situation of Chinese enterprises and explore an effective popularization pattern of TRIZ theory is a hot topic worthy of being discussed. In view of the problems during the popularization of TRIZ, some proposals are put forward as follows:

(1) The publicity and popularization of TRIZ theory should be strengthened, and various forms of training class of TRIZ theory may be held in enterprises so as to let the enterprises' executive leaders and core technology staffs know about TRIZ theory.

(2) The teams of the trainers and consultants should be fostered and their professional skill needs to be enhanced. In order to provide high-level service for the enterprises, it is recommended to import excellent TRIZ experts in the early stage of the popularization of TRIZ, meanwhile, the teams of local trainers and consultants should be developed.

(3) Pilot enterprises should be carefully selected before being cultivated because their outcome by applying TRIZ theory directly affects the subsequent popularization of TRIZ theory. Some successful cases of the pilot enterprises may be publicized to drive other enterprises to learn and apply TRIZ theory initiatively.

(4) Consultative companies should be vigorously developed, which can provide more comprehensive and thoughtful service for the enterprises due to being profit-making organizations.

(5) Resource integration for universities, research institutes and enterprises should be carried out. Through the cooperation of Industry, Education and Academy, the public service platform of technology can be built to provide technical support and service for the enterprises.

5. Summary

In this paper, the experiences of TRIZ theory applied in the famous enterprises such as Boeing Company of the United States, Siemens Company of Germany, and Samsung Electronics Company of South Korea, have been analyzed. In view of the current situation of the application of TRIZ theory in Chinese enterprises, some proposals for the popularization of TRIZ theory toward Chinese enterprises were put forward, which include strengthening the publicity of TRIZ theory in Chinese enterprises, fostering the trainer teams, developing the consultative companies, building the public service platform and etc..

Acknowledgement

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A TRIZ-based Strategic Reference Model for New Product Development

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Abstract

New product development (NPD) is a core function of any manufacturer facing competition. However, there is a significant amount of uncertainty involved. Managers think that there isn't any systematic approach required because there are too many uncertainties present in the process. However, if there was a process which could identify the trends and driving forces, possible futures could be envisaged and virtually experienced, with inventive problem solving throughout the process. This would help to overcome the uncertainties. A TRIZ-based Strategic Reference Model (SRM) has been developed. This model is divided into five building blocks: Idea Generation Block (IGB), Strategy Formulation Block (SFB), Strategy Determination Block (SDB), Problem Solving Block (PSB) and Learning Support Block (LSB). Integrated Definition (IDEF0) is used as the key modelling technique of the SRM. Although it has limitations due to its theoretical assumptions, the TSRM is a new approach to tackling the uncertainties connected with new product development. When walking through the process, managers in the organisation are provided with a continuous learning experience, which simulates their thinking and results in the further enhancement of future products.

Keywords: IDEF0, new product development, Reference model, TRIZ,

1 Introduction

It is beneficial for an organization to develop new products. Doing so can help them to establish a strong position in the market. They can set an industry standard that is so high that it is a barrier to competitors; they can capitalize on investments in R&D and manufacturing; they can build up their image and nurture the organization with product development efforts thereby capturing the commitment, innovation and creativity of the entire organization. However, the business environment is continually changing, therefore it is also necessary for strategic planning to continually change in order to maintain a "balance" or "fit' with the external environment. The turbulent environment is affected by both technology and market changes. Technological innovations cause environmental turbulence by accelerating the rate of change. Market turbulence results in continuous changes in customers' preferences/demands, in

price/cost structures, and in the composition of competitors. Robert (1995) did a survey on best practice companies. The results showed that 'none of them could give an answer on how new products are developed because whatever process they used, they were practicing it by osmosis.!. 'It could not be codified, cannot be explained rationally nor can it be transferred'. McGrath(1996) supported this and said that traditionally, product development had been looked upon as an art; that products were created by a mixture of genius and inspiration therefore it could not be 'managed'. Moreover, to meet the competitive environment companies have to create product ideas in a more innovative way.

TRIZ was founded by Genrich Altshuller as a systematic and creative approach towards reaching innovative results with the help of various tools. It is not purely a theory: the principles were developed based on in-depth analysis of numerous past patents. The basis of the approach is to extract the problem-solving knowledge of patent inventors to enhance practitioners' domain knowledge and invent problem-solving skills.

To fill this gap, the author developed a TRIZ-based strategic reference model (TSRM) for new product development strategic planning, based on the modeling technique of IDEF0.

2 New product development strategic planning

There are three paradigms for how to formulate strategies: the rationalist, the evolutionary and the processual (van der Heijden,2005).

The *rationalist* paradigm assumes that there is one 'best solution' of strategy (optimal strategy). It assumes predictability with no interference from outside; clear intentions; implementation follows formulation; a full understanding throughout the organization; and reasonable people will do reasonable things. The *evolutionary* paradigm (emergent strategy) is based on the assumption that many phenomena taking place in nature are unpredictable. It is not because we lack the knowledge and capacity to analyze them but just because they are unpredictable by their very nature. This paradigm assumes that strategy emerges and can only be understood in retrospect. The *processual* paradigm lies between the rationalist and the evolutionary paradigms. It assumes that the business environment is neither predictable nor non-predictable. The organization has a process to mobilize the brain power of the people to strengthen their skills. The process is to make room for ideas. Any idea which can be directed towards improving the link between the organization's competencies and the business environment will surface and be considered. Therefore when there are a lot of uncertainties, success is more related to having a good process than to having found the 'optimal strategy'. New products are developed in a turbulent business environment therefore it could never be developed by a purely rational approach; nor through a passive approach as the environment is unpredictable. If there is a process that the organization can follow, new product development becomes a processual strategic planning activity.

Product strategy plays a critical role in most companies, in that they depend on a continuous stream of new products for their livelihood. Product strategy is the most important element of the entire business strategy and it is tightly integrated with product development strategy because it defines the plan for new products that a company intends to develop. There are four main purposes of a new product development strategy (Wheelwright and Clark,1992):

- Creating, defining, and selecting a set of development projects that will provide superior products.
- Integrating and coordinating functional tasks, technical tasks, and organizational units involved in development activities over time.
- Managing development efforts so they converge to achieve business purposes as effectively and efficiently as possible.
- Creating and improving the capabilities needed to make development a competitive advantage over the long term.

It should focus around the expectations of the customers by developing products through research and development efforts. It should be able to position the company effectively against its competitors in the competing markets to ensure the success of the company.

Conventional NPD strategic planning started from technology and market assessment and then moved to project management. Wheelwright and Clark pointed out that it failed to set boundaries and focus to provide sufficient up-front planning to link projects and strategies. He improved the new product framework as shown in Figure 1.

Although there is some improvement in the new product development strategy, several weaknesses can still be observed:

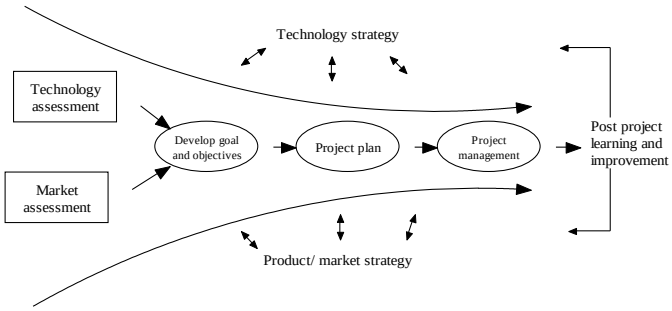

Figure 1: Improved new product development strategy by Wheelwright and Clark.

- It is based on rational strategic planning, assuming that there is a best solution while going through different stages of the framework. It has not taken the continuously changing environment into consideration so as to be responsive It does not clearly explain how to handle the idea and concept generation ‘proactively’. Although in their

later work, they developed the 'development funnel' and described the generation of ideas as "encouraging certain sources of new ideas and selecting which of those to support in development projects" (Wheelwright and Clark, 1992). It still did not cover how to create ideas for further development.

- Post project learning can provide an opportunity to learn from experience. However, every new product project is different and while experience can prevent similar mistakes occurring again, it may not automatically generate new concepts that are 'adaptive' enough to cope with the turbulent changing environment.
- Missing of idea creation and problem solving in an innovative way throughout the whole NPD process.

To fill up this gap, the author has developed a reference model for new product development strategic planning that can tackle the above weaknesses. This will be explained in more details in the coming sections.

3 Research design

3.1 Questionnaire survey on new product development

The hypotheses testing will test the characteristics of the key components of the model. Questionnaire surveys were sent to manufacturers in Hong Kong. Responses from non-manufacturers were discarded. Names of the companies were obtained from the membership list of the Federation of Hong Kong Industries which is the representative association of Hong Kong Industries. Electrical and Electronic consumer product manufactures were chosen.

The first survey was concerned with the way the organization prepared its strategic plan for new product development. The second survey was a follow up survey about the actual performance of the new product. In the first survey 387 questionnaires were sent with 45 respondents which represented an 11.6 % response rate. The second batch of questionnaires was sent to the 45 respondents and asked for the actual new product performance. Respondents were reminded to respond by follow up calls. As a result, 35 questionnaires were returned representing a 77.8% response rate. A follow up survey were sent to the 45 respondents again to verify the problem solving practices of the organizations.

The objectives of the survey were two folds:-

1. To identify the practices being used by manufacturers to determine new product development strategic planning and problem solving.

2. To verify the practices by comparing them with the actual achievement of the manufacturers.

4 TRIZ-based Strategic reference model development

4.1 Rationale of using a reference model

A reference model is a pre-defined partial model, in several parts that may be reused and customized to facilitate the development of a particular model pertinent to an individual organization. It should provide decision makers with a rational and holistic basis for decision making and evaluation. It can be shared and reused. Through the modeling process, it is possible to map activities and their interrelationships, resources and organizational units, as well as the flow of information through operational and supporting processes. It provides a graphical description of business activities. The value of the outcome document can illustrate the big picture, and act as a vehicle for development and communication.

Since the main objective of the present research is to construct a practical tool to help manufacturers in planning a strategy for new product development, a Reference Model with the advantages mentioned above would be suitable for the proposed strategic planning process. It is appropriately named the Strategic Reference Model (SRM).

There are many model construction techniques for business process modeling some of which are mentioned below: Structured analysis design technique (SADT); ICAM Integrated Definition (IDEF); Structure-Conduct-Performance (SCP),; Market Structure-Market Conduct-Market Performance (MMMP); Architecture for Integrated Information Systems (ARIS); Unified Modeling Language (UML); Group de Recherché en Automatisation Integrere (GRAI); Generalized Enterprise Reference Architecture and Methodology (GERAM); Soft System Methodology (SSM); Viable System Methodology (VSM).

IDEF0 conforms to the CIMOSA modeling framework which is a diagrammatic representation of modeling dimensions. It is able to provide a simple method for communicating easily with understanding of the subject of the strategic reference model. It was chosen because it has the following advantages:

- Simple for non-experts to use
- Easily interpreted and discussed
- Used as a basis for further developments
- Able to identify opportunities for system improvements
- Agile and concise so that continuous maintenance may be viable
- It is a functional model popular with the industry

- It is a de facto international standard, and a US Federal Information Processing standard

An example of an IDEF0 diagram is shown in Figure 3 in which the arrow from the left is 'input', the arrow to the right is 'output', the arrow from the top is 'control' and the arrow from the bottom is 'mechanism.'

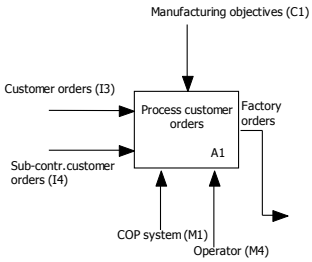

Figure 2: Example of an IDEF0 diagram

4.2 Framework infrastructure

Competitive sense-making (CSM)

The competitive sense-making process is the starting point of the NPD strategic planning. Competitive sense-making (CSM) is one of the competitive intelligence activities to 'proactively' search for information about the competitive elements of product, market, competitor, technology and customer. Through this competitive sense-making searching process, ideas are developed which can be turned into product ideas for development. This competitive sense-making process is 'proactive' and also forward looking as it is used to search for information and opportunities. The starting point of new product development is to generate ideas. Rarely do organizations have a systematic way of corralling ideas, nor is anybody responsible for their identification (Wheelwright and Clark, 1992). Some researchers suggest listening to customers for ideas, however, customers tend to express their needs in terms of past and current experience so that blindly listening to customers' needs is not reliable

H1: The collection of sense-making intelligence for new product development is positively related to the performance of new products.

Constructing scenarios

Scenario planning with sense-making in the organization will bridge the gap between strategy implementation and early warning processes (Fink, Siebe and Kuhle.,2004). It is an instrument that enables the organization to discuss futures with strategic planning issues when facing uncertainties. The power of scenarios as a process tool to handle uncertainty in the strategic area has been covered in many text books (van der Heijden, 2005; Walsh, 2005;

Lindgren and Bandhold, 2003; Schwartz, 1996; Schoemaker, 1995). Scenarios enable managers to experience the future world ahead of time, creating memories which serve as guidelines to make sense of environmental signals and to act on them ahead of competitors. During the thinking process, the managers of the organization think through what will be happening in the future which is what Peter Schwarz (1996) called the rehearsing of the future. It allows the managers to rehearse the future by imagining different events which will lead to alternative futures. Scenarios can also identify 'trigger points' to indicate whether the market is moving in or away from a specific direction (Jennings, 2000). Research has also reported a positive relationship between scenario planning applications and business performance gains (Phelps, Chan and Kansalis, 2001). Based on these benefits, and taking into consideration that new product development is for products in a future in which a lot of uncertainties are involved, scenario planning is justified as a strategic planning tool for new product development strategic planning.

H2: The practice of competitive trend development for new product development is positively related to the performance of new products.

Identify trends

New products require a time span in which to develop, some need longer, some shorter. Anyhow, they are developed for the future not for today. The better the prediction of the changes in market, customers, technologies, competitors, the better the chance of success the new product has (Lindgren and Bandhold, 2003). The information for the prediction does not come from nothing, but from the competitive sense making for which intelligence from many customers, competitors, markets, and technologies should have been on hand, for evaluation.

H3: The practice of trend analysis for new product development is positively related to the performance of new products.

Strategic learning

Product life cycles are becoming shorter and shorter. Today's new products become old products tomorrow; so the companies have to seek more ideas for new products in order to survive. Product development therefore needs to develop new competences continuously due to changes of customers' expectations. Many articles in the literature have stated that organizational learning is believed to be important to the competitive performance of the business. De Geus (1997) has stated that learning more quickly than competitors, is vital for a company's survival. Organizations are now competing on their ability to change more quickly and more effectively than their rivals. Learning in new product development is therefore vital in today's competitive, uncertain and turbulent environments. Even more important, learning faster to launch new products more quickly, will increase the probability of success.

New product development is not aimed at today's product; instead it carries the task of constantly developing products for tomorrow through continuous organizational learning and knowledge creation. Product innovation that draws on that knowledge has a higher chance of success. It builds on the accumulation of previous knowledge. Strategic learning is concerned with the processes by which organizations learn about themselves and their environment. It consists of discussions, debates and conversations during the competitive sense-making, idea generation, trend development, driving force development, scenario construction, strategy formulation, performance evaluation, ending in strategic decisions. This forms a strategic learning cycle (Figure 4) in the strategic planning process.

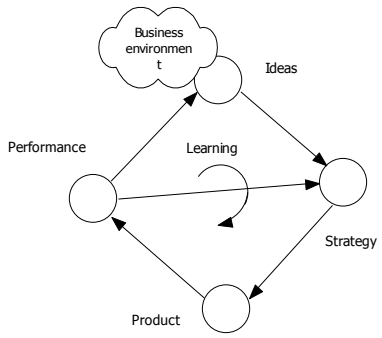

Figure 3: Strategic learning cycle

H4: The degree of learning in the organization is positively related to the performance of new products.

Problem Solving Ability

Throughout the new product development process, ongoing problems appear starting from customer requirements, product definition, concept design, product testing, market response, product launch to the markets. The performance of the new product is heavily related to the ability of the organization to continuously solving the problems with creative ideas. By doing this, it could keep the product development going in a smooth and faster way.

H5: The practice of problem solving ability is positively related to the performance of new products.

Performance measures

Performance metrics for NPD (Appendix 1) will be used in the SRM for consequent testing and actual performance measurements. Each strategic alternative will be evaluated against these three dimensions. The overall performance index (PI) is computed for comparing the performance project by project. The performance measures are grouped into three

dimensions identified by Leavitt (2003) as the Objective dimension, the Success dimension and the Opportunity dimension.

The Objective dimension is to measure how well the new product:

- Meets sales objectives
- Meets profit objectives
- Meets market share objectives
- Meets budget control

The Success dimension measures how well the new product:

- Meets return on investments in the project
- Achieves customer satisfaction
- Is developed on time

The Opportunity dimension measures how well the new product opens an:

- Opportunity window on new categories
- Opportunity window on new markets
- Opportunity window on new technologies
- Opportunity window on learning

These performance metrics can also be used to evaluate the actual performance of a project if a particular strategy alternative has been chosen by the metrics for a product that has been put into real production.

5 Strategic process and architecture

The TRIZ-based Strategic Reference Model (TSRM) applies the techniques of scenario planning with the addition of a starting point for competitive sense-making (CSM) activities as well as the Performance Measurement concepts mentioned in section 4. The Model proactively searches for information as a function of sense-making, develops the intelligence to identify trends and driving forces, develops scenarios, proposes success factors and strategy alternatives, performs consequent testing by performance metrics and confirms the final determination of strategies. The heart of the Model (Figure 5) is to solve problems continuously with inventive solution and the creation of organizational learning throughout the entire process in order to achieve an adaptive nature for future product development.

5.1 Idea generation block (IGB)

The 'Idea Generation Block' (IGB) consists of step one through step three of the NPD strategic planning process.

Step 1- *Idea generation by competitive sense-making (CSM)*: There are specific areas that the company needs to 'sense' constantly in order to convert them into product opportunities. The specific areas are unexpected successes, unexpected failures, unexpected external events, process weaknesses, industry/market structure changes, high growth of industry, converging technologies, demographic changes, perception changes, and new knowledge.

Step 2- *Identify trends*: There is no single rule to identify trends; Delphi, a focus group or an expert panel can be used. The outcome is a list of identified trends, product trends, market trends, customer trends, competitor trends and technology trends.

Step 3- *Identify driving forces* : Driving forces are the underlying and impacting factors that set the pattern of events and determine outcomes. They are the forces that make things happen. Therefore understanding the driving forces could uncover the reasons why the trends are as they are. The outcome from this step is a list of driving forces corresponding to the trends.

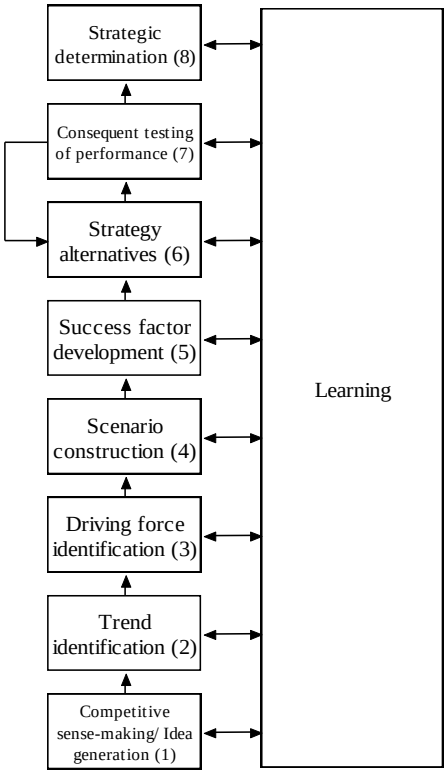

Figure 4: Strategy determination of SRM

(Numbers inside brackets are the steps of the SRM process)

This block provides intelligence for decision makers so that they can have further strategy development. It also opens up eyes and ears for scenario planning in the second block.

5.1 Strategy formulation block (SFB)

The 'Strategy Formulation Block' consists of steps four through six of the NPD strategic planning process. It is the block where scenarios are drawn from the ideas created in the IGB. Success factors of the scenarios are determined and finally strategy alternatives are proposed. It is the block in which strategy alternatives are proposed for further evaluation. It is constituted partly from the product development strategy phase of the NPD process.

Step 4- *Constructing scenarios*: Scenarios are constructed by adapting the methodology of Lindgren and Bandhold (2003) based on the uncertainties uncovered. This is the step that the team takes to make sense of complexity. It is a process of inclusion, where all previous thinking on trends, driving forces and competitive sense-making is combined with the thinking developed in the generation of the different 'types of futures'. It is a group scenario generation process that involves conversations among the people involved. The conversation couples the people together and it becomes a joint learning process. When this mental model has been built up over time within the group, it creates a common language that makes strategic conversation possible. The outcome from this step is a list of scenarios.

Step 5- *Developing success factors:* Key success factors are those capabilities of the organization which differentiate it from its competitors. For each of the scenarios developed in step 4, a list of required key success factors are determined by the team. The outcome from this step is a list of success factors corresponding to each scenario.

Step 6- *Generating strategy alternatives*: Strategy is related to survival and success and is used to steer actions to drive the success. To generate strategies, the mission and vision of the organization, the ideas from CSM, trends and driving forces, scenarios and key success factors are all the inputs for the strategy formulation. In addition, the expectations of stakeholders and resource limitations of the organization are considered. The strategies thus developed have to consider the internal perspective, the organizational capability and the external perspective, and the business portfolio (Van der Heijden, 2005) which are available from previous steps. It is a group dialogue addressing the questions the organization needs to answer when it faces the uncertainties of the future. The strategies being defined need to match with the unique characteristics of the organization. The outcome from this step is a list of strategic alternatives for further evaluation, so the most appropriate choice can be decided on.

5.3 Strategy determination block (SDB)

Activities of the 'Strategy Determination Block' include reviewing the performance metrics that were determined, consequent testing of each proposed strategy alternative and

finally the strategic decision. This block consists of step seven through eight of the NPD strategic planning process. It complements the 'Strategy Formulation Block' to constitute the rest of the product development strategy.

Step 7: *Consequent testing of strategy alternatives:* Each alternative is tested by pre-set performance metrics (explained in previous section). The purpose of this consequent testing is to evaluate each alternative by forecasting the performance before an actual decision is made. The performance metrics are evaluated in a portfolio of objective, success, and opportunity dimensions. A performance index (PI) is calculated for each strategic alternative for evaluation.

Step 8: *Strategic choice*: Step 4 to 7 can be repeated several times if the expected performance index from step 7 is not satisfactory, or if it does not match the objectives, expectation of stakeholders or limitations of the resources. Alternative scenarios will be generated again for consideration until a final strategic decision is made.

5.4 Problem solving block (PSB)

Activities of the 'Problem Solving Block' include problem identification and problem solving. TRIZ problem identification tools such as Function Analysis, Flow Analysis, Technology Trend Analysis, Trimming Analysis are used continuously throughout the various stages of the product development process. TRIZ problem solving tools such as Contradiction Analysis, Substance-Field Analysis, Inventive Principles and ARIZ are used to solve the problems throughout the process. The determination of the problem identification and problem solution are feeding to the organizational learning of the company for future use.

5.5 Learning support block (LSB)

Activities of the 'Learning Support Block' involve identification and prioritizing of organizational learning dimensions and processes. It is the block which supports a long-term NPD strategic plan through continuous learning, and eventually results in knowledge generation in the organization. Throughout the eight-step process, learning has been generated to support the long-term growth of product development. Learning is generated during competitive sense-making (CSM), identifying trends and driving forces, creating scenarios, proposing strategy alternatives, testing of performance and making strategic choices. Discussion and agreement during the eight-step process improves communication and further enhance the thinking process of the team.

6 Hypotheses testing results

All the respondents had manufacturing facilities either in China or the Far East. The number of their employees was more than 100 in each company with significant product development every year.

The performance measure was categorized into: Objective dimension performance, Success dimension performance and Opportunity dimension performance. The reliability of the scales for these three dimensions was evaluated using Cronbach's α using SPSS 10 statistical software for analysis. For each scale, a value of α >0.75 was found, (Table 1) suggesting that the scales were reliable (Nunnally,1988).

Correlation of the practices of the respondents to formulate the new product development strategies vis-à-vis the Objective dimension, Success dimension and Opportunity dimension was evaluated by Bivariate correlation. Pearson's correlation coefficient with two-tailed significance of the SPSS 10 statistical software was used for analysis. The result of the correlation is shown in Table 1.

H1: The collection of sense-making intelligence for new product development is positively related to the performance of new products is thus supported. Sense-making intelligence can provide valuable information for the entire new product development process from idea generation through to product realization. This intelligence includes competitor intelligence, customer intelligence, marketing intelligence, technology intelligence, as regular input which can serve as a knowledge database for immediate use.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.Use sense making intelligence	1.000							
2.Use trend analysis	0.445	1.000						
3.Use scenario thinking	0.626*	0.786*	1.000					
4. Problem solving analysis	0.543	0.765*	0.808*	1.000				
5.Organizational learning culture	0.353	0.350	0.740*	0.518*	1.000			
6.Objective performance	0.626	0.372	0.367	0.624	0.393	1.000		
7.Success performance	0.714*	0.468*	0.487	0.732**	0.562	0.876*	1.000*	
8.Opportunity performance	0.803*	0.477*	0.404	0.508	0.404	0.800*	0.809*	1.000

Table 1: Correlation analysis of NPD strategic planning practices and performance dimensions

* Correlation is significant at the 0.05 level (2-tailed)

H2: The practice of competitive trend development for new product development is positively related to the performance of new products, is also supported. New products are developed for the future not for now. Therefore the managers look into the future to see what the market will need, what the customer will want, what technological changes there will be, and what

competitors will do. However, the many uncertainties ahead create questions that are complicated to answer. Using the developed trend to identify driving forces could give managers some insight as to what the underlying factors are and to what degree of impact such factors might have.

H3: The practice of scenario analysis for new product development is positively related to the performance of new products, is also supported. Scenario analysis can handle uncertainties (Schwarz,1996). It does not focus on the existing 'status quo' like the conventional forecasting, nor is it a simulation model. While working out the scenarios, the managers develop and test the strategies by thinking through the situation, then build ideas around it. This memory of the future (van der Heijden *et.al*.,2002) provides strong support to new product development to develop products for future use. Besides, scenarios encourage people to think, to communicate, to deal with complex situations; and eventually, the organization learns.

H4: The degree of learning in the organization is positively related to the performance of new products is supported. Traditionally organizational learning is seen to be a supporting function to the entire new product development. There is a misconception that experience is already learning, therefore learning itself is not planned. Michael and Palandjia (2004) showed that the organizations do not learn from experience at all. When experience accumulates, the organization learns more and more about a specialized routine and this makes it difficult to assess new experience accurately. Therefore entirely relying on experience in order to learn would not result in improvement. Since new product development requires new ideas and new inputs, organized learning at each phase is required. Formal reviews of the products including the business environment, company's products and competitors' products, the whole strategy formulation process and the performance, are desirable.

H5: The practice of problem solving techniques in the organization is positively related to the performance of new product development. It is very obvious that organization to keep solving problems evolving throughout the product development process, it could enhance the speed of the development as well as the outcome of the product.

7 Conclusion

Although the success of new product development is critical to the making of profit in a manufacturing organization, it was found through an extensive literature review that no research study has focused on the generation of a strategy for new product development by using a Reference Model including solving problem inventively. Since the investment in the research and development for producing a new product is expensive, fast decision making in choosing the right target product to match the anticipated market needs, is essential. TRIZ has been identified as a powerful tool for problem identification and problem solving. Involving TRIZ in the TSRM could enhance the speed, quality and performance of the product outcome.

Therefore, the author attempted to identify the distinct features that need to be considered when formulating a strategy for new product development and presented it as a Reference Model in such a way that facilitates direct application by manufacturing organizations. Through an extensive literature review and study of real life practices employed by local manufacturing organizations, the author identified the conceptual framework of the eight strategic planning steps. To enable this strategy planning tool to be applicable to different organizations with their unique characteristics, the TRIZ-based Strategic Reference Model (TSRM) was presented by the technique known as Integrated Definition (IDEF0) that allows different organizations to fit in their data for assessment and for making choices. The architecture of the TSRM is mainly composed of five blocks: the 'Idea Generation Block', the 'Strategy Formulation Block', the 'Strategy Determination Block', the 'Problem Solving Block' and the 'Learning Support Block'.

While walking through the steps of the TSRM, problem solving capability and organizational learning are created for the long-term success of continuous new product development which can enhance the development of strategies to confront the uncertainties in the business environment in a proactive, adaptive and responsive way to meet the competition.

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Exploring the Critical factors of Innovate Design System Structure for Alloy Manufacturing Equipment Based on Combing QFD and TRIZ with Hybrid MCDM Model

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Abstract

Overview of the highly competitive environment with shorten product life cycle, the company operates including many potential factors with new product development (NPD), technology, equipment and materials have progressed rapidly. Here, we probed the patented technology of existing magnesium alloys manufacturing equipment that found some technical problems in its production system. In this paper, we focus the problems on manufacturing equipment which are divided into “axial force”, “the infusion process of magnesium”, and “equipment structure” to probe the problems and improvements in order to find the critical factors of innovate design system, then propose an effective reforming and design approach for a new patented technology of manufacturing equipment system of magnesium alloys within a case study.

First, DEMATEL is used to structure the network relationship map (NRP) of design assessment indexes. Second, DANP is used to find the influential weights that provide the priority of problem-solving. Third, correlation matrix of QFD is used to structure the relationship of customer needs and engineering technical. And then, the results combine with TRIZ that is used to find technical methods of problem-solving. Finally, the proposed model can be used to provide specific improvement strategies and a new patented technology for improving the manufacturing equipment system of magnesium alloys. The result of study provides project team guidance to continuously improve, track and meet the quality assurance of production.

Keywords: DEMATEL, DANP, Magnesium alloys, Manufacturing equipment, NRP, QFD, TRIZ

1. INTRODUCTION

Overview of the highly competitive and dynamic change environment with shorten product life cycle, new product development (NPD), technology, equipment and materials have progressed rapidly (Levitt, 1965). The company operates including many potential factors which contents personnel, equipment, material, cost and limit time to product its products. Garvin (1984) thinks quality improvement is beneficial for market expansion and cost reduction. Manager not only intends to achieve the highest customer satisfaction, product value and product continuity, but also requires in low cost, high quality, and time to market in customization. Based on practical operation, we probed the patented technology of existing magnesium alloys manufacturing equipment that found some technical problems in its production system. It is extremely important to make a systematic approach to design decisions in the early phase of design. The concept of trade-off, or conflicting parameters is a core element of design where speed and reliability, or quality and cost are readily acknowledged. Therefore, the re-engineering designs in order to achieve engineering optimization for a particular application (Li and Huang, 2009).

In this paper, we focus the problems on manufacturing equipment which are divided into “axial force”, “the infusion process of magnesium”, and “equipment structure” to probe the problems and improvements in order to find the critical factors of innovate design system, then propose an effective reforming and design approach for a new patented technology of manufacturing equipment system of magnesium alloys within a case study. Numerous researchers have applied the concept of equipment design trade-offs from theory of inventive problem solving (TRIZ) to find problem-solving methods or idea points; QFD is applied to analysis the interactive relationship between customer needs and engineering technical. So, we used the concept of QFD to structure the relationship of customer needs (the requirement of reforming equipment) and engineering technical. Then, we used TRIZ and QFD tool combine with multi-criteria decision making (MCDM) model to find the critical factors of innovate design system that propose the design improvement strategies in order to help acknowledge and evaluate the conflicting parameters associated with manufacturing equipment of magnesium alloy.

Consequently, the purpose of this study is through the decision making model to solve the complex problems of existing that propose to find critical factors of problem-solving and combine the technical skills with customer opinions. As a result, through effectiveness reform of manufacturing equipment becomes the critical success factors of production.

2. LITERATURE REVIEW

The MCDM model refers to making decisions in the presence of multiple, and often simultaneously faced / managed multiple criteria / objectives with conflicting and non-commensurable criteria in real world. The problems of MCDM can be broadly classified into two categories including multiple objective decision making (MODM) for plan and multiple attribute decision making (MADM) for evaluation and selection. Here, we will use MCDM model combine QFD with TRIZ in order to find optimal improvements for innovative design.

2.1 Constructing the Network Relationship Map by DEMATEL

A decision-making trial and evaluation laboratory (DEMATEL) is an analytical method for establishing the system structural model. It is mainly used to solve all kinds of complex problems to clarify the essential problems. It uses matrix and related math theories to find the cause and effect on each element in the degree. This technique is widely used to solve various types of complex studies that can effectively understand the complex structure and provide viable options of problem-solving (Tzeng et al. 2007).

DEMATEL is divided into five steps. The first step is to confirm the system has n elements and develop the evaluating scale, using pair of dimensions to compare and also using evaluating scale 0, 1, 2, 3, 4, which in turn represents no effect (0), low effect (1), medium effect (2), high effect (3), and extremely high effect (4) as measuring standard. The second step is to calculate initial matrix, using pair of degree of interaction to obtain directly influential matrix $\boldsymbol{Z}$ $[z_{ij}]$, where z_{ij} represents the degree of effect on i factor effects j factor (Lin et al. 2009; Lin et al. 2010; Chen et al. 2010).

$$\boldsymbol{Z} = \begin{bmatrix} z_{11} & \cdots & z_{1j} & \cdots & z_{1n} \\ \vdots & & \vdots & & \vdots \\ z_{i1} & \cdots & z_{ij} & \cdots & z_{in} \\ \vdots & & \vdots & & \vdots \\ z_{n1} & \cdots & z_{nj} & \cdots & z_{nn} \end{bmatrix} \tag{1}$$

When the elements of i have a direct effect on the elements of j, then $z_{ij} \neq 0$, otherwise $z_{ij} = 0$. The third step is to normalize the matrix. It can be obtained from Eqs. (2) and (3). Its diagonal is 0, and maximum sum of row or column is 1.

$$\boldsymbol{X} = s \times \boldsymbol{Z} \tag{2}$$

$$s = \min\left[\frac{1}{\max_i \sum_{j=1}^{n} |z_{ij}|}, \frac{1}{\max_j \sum_{i=1}^{n} |z_{ij}|}\right], \; i,j = 1,2,\ldots,n \tag{3}$$

The forth step is to obtain the total effect matrix $\boldsymbol{T}$. It can be obtained by $\boldsymbol{T} = \lim_{h\to\infty}(\boldsymbol{X} + \boldsymbol{X}^2 + \cdots + \boldsymbol{X}^h)$ is equal to $\boldsymbol{X}(\boldsymbol{I} - \boldsymbol{X})$ where I is the identity matrix. The fifth step is to obtain prominence and relation. To sum of each row and column of the total influential matrix $\boldsymbol{T} = [t_{ij}]$. It will obtain the sum of all rows (vector $\boldsymbol{r} = (r_1,\ldots,r_i,\ldots,r_n)$) and the sum of all columns (vector $\boldsymbol{d} = (d_1,\ldots,d_j,\ldots,d_n)$). If r_i represents the sum of all rows of the total influential matrix $\boldsymbol{T}$, meaning directly or indirectly affects degree; d_j represents the sum of all columns of the total effect matrix $\boldsymbol{T}$, meaning affected by other criteria. Where r_i represents the factor i which affect all other factors, d_j represents the factor j that is affected by all other factors. According to the definition, $r_i + d_j$ presents the degree of relationship between the factors, meaning "prominence"; $r_i - d_j$ presents the degree of effect and effected for the factors, meaning "relation" (Tzeng et al. 2007; Tamura et al. 2002)

2.2 Calculating the Influential Weights by DANP

In this Section, we not only use DEMATEL to confirm the interacting relationship with each factor, but also want to obtain the most accurate influential weights. Then, we found ANP that can serve this purpose (Saaty, 1996). The purpose of ANP is to solve the dependent and feedback problems of criteria. Ou Yang et al. (2008) propose to apply the characteristics of ANP to combine with DEMATEL to solve this kind of problems that is the DEMATEL-based analytic network process (DANP) (Ou Yang et al. 2008). This novel / new method focus on how to improve the gap for achieving the aspired level in each criterion and given priority for improvement. It will yield a more practical result that the procedures of DANP as shown in Figure 1 (Ou Yang et al. 2008; Chen et al. 2011; Lee et al. 2009; Liu et al. 2011).

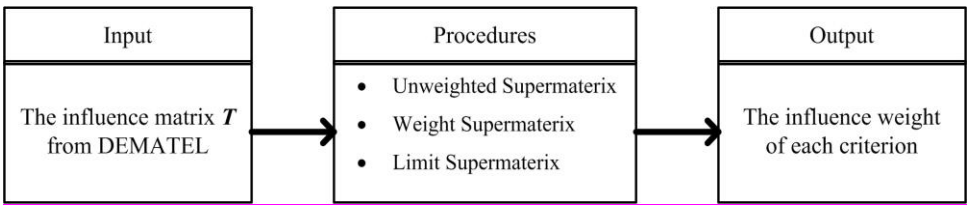

Figure 1. The concept of DANP approach

2.3 The Concept of QFD

The global markets changes very fast with short life-cycles and dynamic competition, QFD provides a comprehensive and systematic approach to development new product, ensuring that new products meet customers' expectations and satisfy customers' needs. Since 1966, Quality function deployment (QFD) was developed in Japan that was first used successfully in product development project by Japanese manufacturers of consumer electronics, home appliances, clothing, construction equipment and agricultural engines before American and European (Matzler and Hinterhuber, 1998). QFD is a useful tool for divining customer needs to design quality of new product development, to deploy the functions forming quality, and to deploy methods for achieving the design quality that uses a series of structured management processes to translate the customers' needs into efficient communication through the various stages of product planning, design, engineering, and manufacturing (Vezzetti and Kretli, 2011; Hauser and Clausing, 1998).

2.4 The Application of TRIZ

"Teoriya Resheniya Izobretatelskikh Zadatch (TRIZ)" means "Theory of Inventive Problem Solving (TIPS)" that began in 1946. It was developed by Genrich Altshuller that is widely used to solve the technical contradiction and offer innovative product structures for the existing problems (Altshuller, 1999; Maarten Bonnema, 2011).

. By 1969 Altshuller had employed a knowledge base built from approximately million patents in order to find out in what way the innovation had taken place and developed the concept of technical contradictions, primarily on mechanical design who proposed the 40 inventive principles and the contradiction matrix with 39 engineering parameters that is basic engineering parameters of common objects. Finding the ideal solution to a needed function or effect with no harmful or negative effects is referred to in TRIZ (Li and Huang, 2009; Altshuller, 1999; Stratton and Mann, 2003). This theory mentions about the technical contradiction and physical contradiction widely used in many application.

The technical contradiction means that in the system when one aspect is improved, another one will appear bad result (Jing and Jie, 2010). It is usually happens into two sub-systems of the same system. Furthermore, the technical contradiction could be presented as two extremes of one feature, which is called physical contradiction. It is requires mutually exclusive states as they relate to a function, performance or a components. TRIZ presents a systematic approach for analyzing the kind of challenging problems where inventiveness is needed and provides a range of strategies and tools for finding inventive solutions. It is emphasis on improving functionality that central purpose of TRIZ based analysis is to

systematically apply the strategies and tools to find superior solution that overcome the need for trade-off between the two elements (Li and Huang, 2009).

3. PROPOSED METHODOLOGY

Few studies have presented a holistic approach to develop an evaluation model for reforming the manufacturing equipment. The corresponding purpose of this study is to address this problem, using the method of hybrid MCDM to examine the dependent relationships among various dimensions and criteria of reforming manufacturing equipment and, ultimately, to suggest an optimal improvement plan for innovative design. The model is useful in identifying both an influential network and a priority sequence of dimensions/criteria related (Tamura et al. 2002; Liu et al. 2011). This section illustrate the theory and application of research tools that data is collected, selected, analyzed, simulated and tested by the literature of the past equipment improvement with expert questionnaires to find problems and improvements as a basis.

3.1 The Assessment Indexes of Manufacturing Equipment

The main survey objects engage for the new equipment development, materials research, and quality control audits within related areas of experts or scholars who have more than ten years project management experience of average within the person of company A. We proposed a design assessment system hierarchy with five dimensions to evaluate the manufacturing equipment according to the literature review and expert experiences. Through the expert questionnaires, the design assessment indexes are screened and selected that is divided into fifteen criteria, the result as shown in Table 1.

Table 1. The assessment indexes

Dimensions	Criteria
D_1 Productivity	C_1 production and yield rate
	C_2 the time-efficiency of production
	C_3 the usable efficiency of equipment
D_2 Reliability	C_4 the feasibility of equipment operation
	C_5 The quality of raw material input and output
	C_6 the stability of equipment operation
D_3 Stability	C_7 the consistency for the output and input flow of raw materials
	C_8 the lift change of equipment activity
	C_9 the composition status of crystallization

D_4	C_{10} the safety of equipment operation
Dimensions	Criteria
Safety & Environment	C_{11} the safety of personnel operation
	C_{12} the safety of production environment
D_5 Cost	C_{13} the cost loss of equipment failure and maintenance
	C_{14} the loss rate of electric motor power
	C_{15} the loss rate of raw materials

3.2 Combing Customer Needs with Innovative Design by QFD and TRIZ

This section is in order to deal with the existing-problem of manufacturing equipment that considered the technical skill and customer needs. Here, QFD provides a comprehensive and systematic approach to development new product, ensuring that new products meet customers' expectations and satisfy customers' needs. Furthermore, TRIZ theory can offer the useful systematic definition and the framework for solving problems both in technical and mechanical perspective (Altshuller, 1999).

. In this section, we integrate TRIZ innovative principles and QFD concept to structure the relationship of customer needs (the requirement of reforming equipment) and engineering technical (Jing and Jie, 2010; Xinjun et al. 2005). The concept of QFD combines with TRIZ as shown in Figure 2.

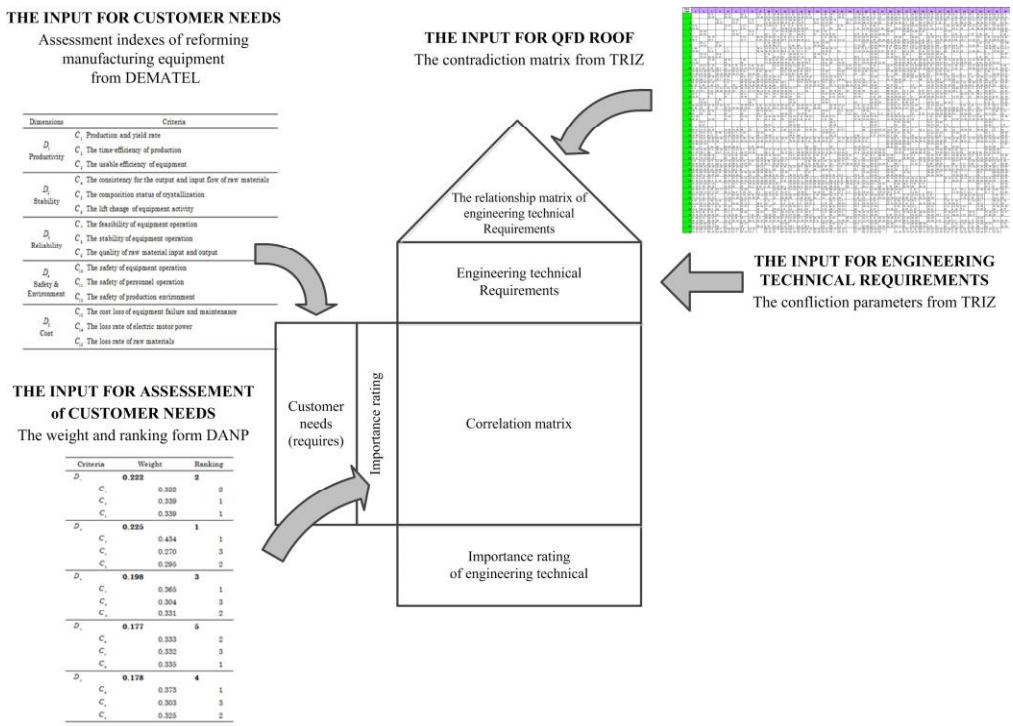

Figure 2. The concept of QFD combine with TRIZ

4. EMPIRICAL ANALYSIS FOR A CASE STUDY

According to the past literatures, we probed the patented technology of US6345964B1 in manufacturing magnesium alloys as a case study. First, we used the expert questionnaires to select the assessment indexes. Second, DEMATEL is employed to construct the NRP, which is used to illustrate the influential network of the manufacturing equipment improvement model. Third, DANP is adopted to evaluate the influence weights that provide the priority sequence of problem-solving. Finally, QDF is supported to connect the relationship of customer needs and technical that the results combined with TRIZ to find the inventive solutions for reforming design.

4.1 The Existing Manufacturing Equipment within Problems

The main problems in existing manufacturing equipment of magnesium alloy are divided into the three parts which critical components are including “axial force”, “the infusion process of magnesium”, and “equipment structure”. The impeller is an extremely critical component for the manufacturing equipment. The component of centrifugal impeller is in existing equipment which is divided into (a) type of closed; (b) type of half-closed; (c) type of opened as shown in Figure 3.

(a) (b) (c)

Figure 3. The component of centrifugal impellers

The first problem is “axial force” which uses the impeller whirling to swing the magnesium liquid. It uses the bump force to generate the centrifugal force. Due to the impeller is not fixed, that swing in different central points and bump force to cause the resonance effect which can’t operate in high speed of 2000 turns/per minute. Furthermore, the impeller inconsistencies swing the liquid of magnesium alloy to cause it generating the different size of irregular crystals of branches type. It is seriously to damage the quality and performance of casting. The second problem is “the infusion process of magnesium” which is exiting the small flow for axial modus with the high lift at the same time. The infusion process of magnesium is as shown in Figure 4.

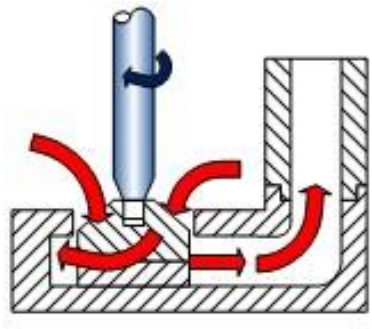

Figure 4. The infusion process of centrifugal pump

Under the effect of centrifugal force, the liquid of magnesium was thrown from the center of the outer edge of the impeller to generate the force for upgrading the liquid of magnesium as shown in Figure 5. This force is violation to manufacture the magnesium alloys that causes the output and input flow of raw materials are instability and generates the tremor to make equipment damage.

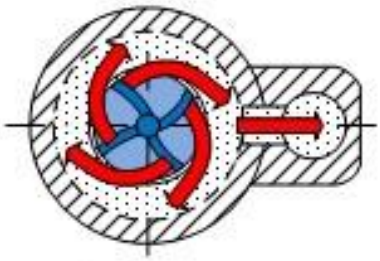

Figure 5. The force of centrifugal impellers

The impeller is a critical component for the liquid of metal to operate in manufacturing equipment combine with mercury to generate the force. The characteristic of existing manufacturing equipment through the flow of mercury to increase the power but it can't exceed the limit of flow. Furthermore, this production process exist the unsafe factors for the personnel and environment; the high temperature magnesium combines with air which can generate the combustion of severe oxidation to burn down the component. Moreover, it can generate the harmful gas and intensive white light that can cause the seriously harmful to the operator.

The third problem is "equipment structure" which exists the seriously defect to damage the alloy organization. The impeller operation doesn't use regular centrifugal force. Due to the impeller structure is the type of scroll and the impeller components has special arc line which can cause the electric motor power is highly loss, and lift and flow decrease in production process. Moreover, the tremor and rumble can cause the harmful for the components.

4.2 Constructing the Network Relationship Map by using DEMATEL

Due to the existing manufacturing equipment have many worsening factors to cause the quality and performance of production come down. In this section, DEMATEL is used to construct the model of network relationship map with five dimensions and fifteen criteria in order to provide the strategy of problem-solving. According to the expert questionnaires obtain the total influential matrix $\boldsymbol{T}$ of dimensions and criteria such as shown in table 4 to table 6. We can find the cognition and opinion of experts in five dimensions and the relationship between the extents of the impact can be found that compared to other dimensions.

According to the prominence ($+r\,d_{ii}$) , "productivity (D_1) " is the highest impact of the strength of relation that means the most important influencing factors; in addition, "Reliability (D_2) " are all the factors that affect the least degree of other factors.

According to the relation ($r_i \quad d_i$), we also can find "cost (D_5) " is the highest degree of impact relationship that affects other factors directly. These dimensions also have the interact characteristics. Opposite, "Stability (D_3) " is the most vulnerable to impact that compare with other dimensions, this result is shown in Table 2 and the relationship map as shown in Figure 6.

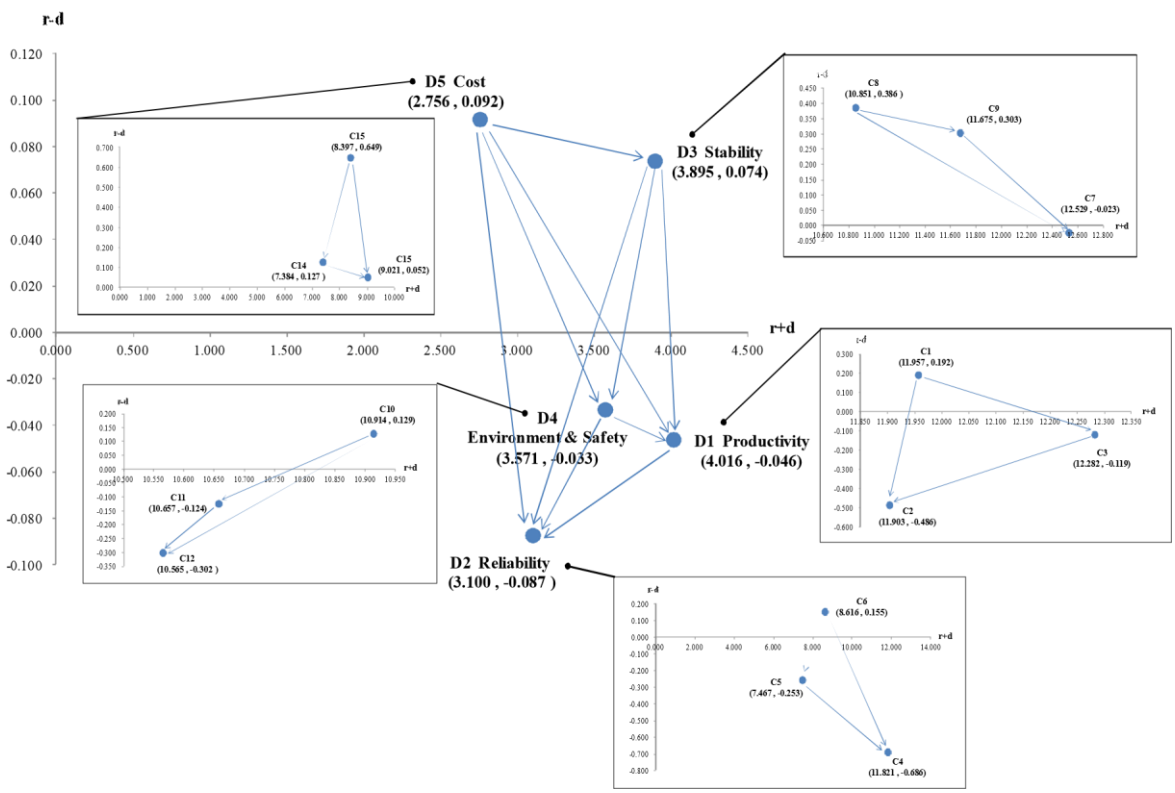

Figure 6. The total network relationship map

Table 2. The effect degree for each dimension

	D_1	D_2	D_3	D_4	D_5	r	d	$r+d$	$r-d$
D_1	0.446	0.372	0.447	0.418	0.302	1.985	2.031	4.016	-0.046
D_2	0.360	0.278	0.337	0.299	0.233	1.507	1.594	3.100	-0.087
D_3	0.474	0.367	0.418	0.419	0.307	1.984	1.910	3.895	0.074
D_4	0.420	0.318	0.389	0.367	0.275	1.769	1.802	3.571	-0.033
D_5	0.330	0.259	0.320	0.299	0.215	1.424	1.332	2.756	0.092

Base on these empirical results, we construct the network relationship map of each dimension as shown in Figure 6. It illustrate the critical problems in existing manufacturing equipment including "Productivity (D_1) ", "Reliability (D_2) " and "Environment and safety (D_4) " which are easily impacted by other factors. Therefore, this model provide the direction of problem-solving from "Stability (D_3) " and "Cost (D_5) ".

In this section, we find some factors are easily affected by other factors from DEMATL that is including "the time-efficiency of production (C_2) ", "the feasibility of equipment operation (C_4) ", "the consistency for the output and input flow of raw materials (C_7) ", "the safety of production environment (C_{12}) ", and "The cost loss of equipment failure and maintenance (C_{13})". Moreover, we find some factors are easily to affect with other factors from DEMATEL that is including "production and yield rate (C_1) ", "the stability of equipment operation (C_6) ", "the lift change of equipment activity (C_8) ", "the safety of equipment operation (C_{10}) ", and "The loss rate of raw materials (C_{15}) ".

Besides, we combine the result with DEMATEL and DANP that turn "AFFECTED FACTORS" into "worsen parameters" and turn "AFFECT FACTORS" into "improving parameters" according the result from DANP to evaluate the priority of problem-solving. First, "AFFECTED FACTORS" converted to "worsen parameters" means that characteristic of factors is easily affected by other factors, and these factors can cause other factors worsening; second, "AFFECT FACTORS" converted to "improving parameters" means that characteristics of factors is easily to affect with other factors and these factors has feature of problem-solving. We explore the problem solving method according to the concept from affect factors to vulnerable impact factors to find optimization principles for solving the existing problems. Consequently, we used QFD to integrate these design characteristics to apply in the contradiction matrix of TRIZ.

4.3 Calculating and Ranking the Weight by Using DANP Model

We use DEMATEL to confirm the interfering relationship with the design criteria as shown in Figure 6, but also expect to obtain the most accurate weights of theses design criteria. Since the purpose of ANP is used to solve the relaying and feedback problems of each criterion **0**. Therefore, we structure the evaluation model by DEMATEL and combine with DANP model to obtain the weight of each criterion as shown in Table 3.

Table 3. The effect degree, weight and ranking for each criterion

Criteria		***R***	***D***	***r + d***	***r – d***	Weight	Ranking
D_1						**0.234**	**1**
	C_1	6.074	5.882	11.957	0.192	0.322	2
	C_2	5.709	6.194	11.903	-0.486	0.339	1
	C_3	6.081	6.201	12.282	-0.119	0.339	1
D_2						**0.220**	**2**
	C_4	6.253	6.276	12.529	-0.023	0.365	1
	C_5	5.989	5.686	11.675	0.303	0.331	2
	C_6	5.619	5.232	10.851	0.386	0.304	3
D_3						**0.184**	**4**
	C_7	5.567	6.253	11.821	-0.686	0.436	1
	C_8	4.386	4.230	8.616	0.155	0.295	2
	C_9	3.607	3.860	7.467	-0.253	0.269	3
D_4						**0.208**	**3**
	C_{10}	5.521	5.393	10.914	0.129	0.333	2
	C_{11}	5.267	5.391	10.657	-0.124	0.332	3
	C_{12}	5.132	5.433	10.565	-0.302	0.335	1
D_5						**0.154**	**5**
	C_{13}	4.537	4.485	9.021	0.052	0.374	1
	C_{14}	3.756	3.628	7.384	0.127	0.303	3
	C_{15}	4.523	3.874	8.397	0.649	0.324	2

Therefore, we can find the critical factors for reforming the manufacturing equipment which is including "the time efficiency of production(C_2)", "the usable efficiency of

equipment (C_3) ", "the feasibility of equipment operation (C_4) ", "the consistency for the output and input flow of raw materials (C_7) ", "the safety of production environment (C_{12}) ",and "The cost loss of equipment failure and maintenance (C_{13}) " according to the priority sequence of these factors from DANP.

Consequently, we input the empirical results from DANP in QFD for importance of customers needs (requires) to evaluate the sequence of problem-solving. Here, we used correlation matrix of QFD to structure the relationship of customer needs (requires) and engineering technical by the expert questionnaires that is in order to selection the critical engineering technical. Based on these results, the worsen design characteristics and improving design characteristics can find corresponding inventive principles with contradiction matrix.

4.4 Applying the correlation matrix by using QFD combine with TRIZ

Certainly contradiction matrix is more efficient to find idea for solving problems, there are 39 engineering parameters respectively corresponding to different conflictions and establishment of relation between the parameters and inventive principles. The contradiction matrix consist the horizontal line that represents worsen parameters, and the vertical line that represents the improving parameters. Besides these, using the 39 horizontal lines and 39 vertical lines compose the contradiction matrix which shows the number of inventive principles to find the characteristics corresponding to the worsen parameter and improving parameters.

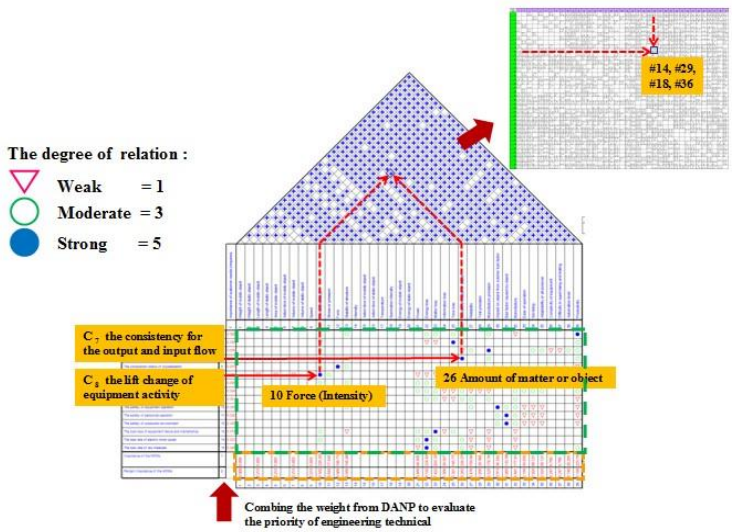

Figure 7. The relationship of customer needs and engineering technical

Here, QFD is a useful tool for divining customer needs to design quality of new product development, to deploy the functions forming quality, and to deploy methods for achieving the design quality in order to translate the customers' needs into efficient communication through the various stages of product planning, design, engineering, and manufacturing 00. Therefore, we used QFD to integrate the relationship of customer needs (requires) from DEMATEL / DANP and engineering technical of TRIZ that is divided into three parts, the result as shown in Figure 7.

In this section, we found the ranking of technical requirements from the results of QFD that combined customer needs and product effective with engineering technical as shown in Table4. Here, the results illustrated the priority sequence of engineering technical that found improving parameters of "no. 10 Force" and "no.22 Energy loss" are critical technical requirements according to the results from QFD.

Table 4. The weight of critical technical requirements from QFD

	Criteria	DANP Weights	Ranking	Technical Requirements from TRIZ	QFD Weight	Ranking
Improving parameters	C_1	0.322	3	**39**	0.070	**4**
	C_6	0.304	4	**13**	0.071	**3**
	C_8	0.295	5	**10**	0.079	**1**
	C_{10}	0.333	1	**30**	0.049	**5**
	C_{15}	0.324	2	**22**	0.072	**2**
Worsen parameters	C_2	0.339	**4**	**25**	0.036	5
	C_4	0.365	**3**	**27**	0.059	3
	C_7	0.436	**1**	**26**	0.059	3
	C_{12}	0.335	**5**	**31**	0.066	2
	C_{13}	0.374	**2**	**23**	0.078	1

Consequently, we combined these result in TRIZ matrix to find the inventive principles for problem-solving according to the relationship from NRP of DEMATEL. We can find different design ideas of engineering technical based on TRIZ inventive principles. Based on these inventive principles, we found the critical factors of innovate design in order to reform the manufacturing equipment of magnesium alloys for solving problems, the result as shown in Table 5.

In "Stability D_3", the worsen design characteristic of "the consistency for the output and input flow of raw materials (C_7) " correspond to the improving characteristic of "the lift

change of equipment activity (C_8)" which used the correlation matrix to find the engineering technical with worsen parameter of "no. 26 Amount of matter or object" and improving parameter of "no. 10 Force"; Here, we find the inventive principles as #14 Curved surface, #29 Gas or liquid driving structure, #18 Shaking, #36 Transformation.

In "Cost D_5", the worsen design characteristic of "The cost loss of equipment failure and maintenance (C_{13})" correspond to the improving design characteristic of "The loss rate of raw materials (C_{15}) " which used the correlation matrix to find the engineering technical with worsen parameter of "no. 23 Matter loss" and improving parameter of "no. 22 Energy loss"; Here, we find the inventive principles as #35 Parameter change, #27 Cheap substitution, #2 Extracting, #37 Hot expanding.

Table 5. The result of DEMATEL combine with QFD and TRIZ

Weights from QFD				1	5	3	3	2
Weights from DANP				2	4	1	3	5
Criteria		AFFECTED FACTORS		C_{13}	C_2	C_7	C_4	C_{12}
Weights from QFD	AFFECT FACTORS	Worsen parameter / Improving parameter		Matter loss	Time loss	Amount of matter or object	Reliability	Bad factor caused by object
				23	25	26	27	31
1	C_8	10	Force (Intensity)	#8,#35, #40,#5	#10,#37, #36	#14,#29, #18,#36	#3,#35, #13,#21	#13,#3, #36,#24
3	C_6	13	Stability of structure	#2,#14, #30,#40	#35,#27	#15,#32, #35		#35,#40, #27,#39
2	C_{15}	22	Energy loss	#35,#27, #2,#37	#10,#18, #32,#7	#7,#18, #25	#11,#10, #35	#21,#35, #2,#22
5	C_{10}	30	Impact on object from exterior bad factor	#33,#22, #19,#40	#35,#18, #34	#35,#33, #29,#31	#27,#24, #2,#40	
4	C_1	39	Productivity	#28,#10, #35,#23		#35,#38	#1,#35, #10,#38	#35,#22, #18,#39

5. RESULT AND DISCUSSION

According to the result from contradiction matrix, we find the inventive principles of #14 Curved surface and #29 Gas or liquid driving structure is used to change the force about "the bump force to generate the centrifugal force", the use of axial with liquid magnesium to generate the thrust for lift fluid to the exit with axial-in and axial-out. We mainly change the structure of liquid pressure that uses the vertical downward pressure. This design will change the infusion process in large flow for axial with the low lift which is closely suitable for the characteristics of magnesium.

Then, the inventive principles of #18 Shaking and #2 Extracting is used to increase the stability of the equipment operation. We design an axis-connecter to connect the axis with the component in order to keep the quite stable flow of output and to decrease the loss of electric motor power. This axis-connecter have the design characteristics of cancellation the shaking, easy to assemble and solve the impeller isn't operation in the same central points with irregular centrifugal force. This design will change stability of manufacturing equipment which is operate in high speed of 3000 rev / min. Due to improve the stability, the axis-connecter can cut off the irregular crystals of branches type. In new design, this component can make the crystals of ball type which is upgrade the quality and performance of casting. Furthermore, this new design can support the alloy operating in "semi-solid" processing, which is a great breakthrough for improving the existing magnesium alloy production. This technique has been confirmed that can improve the overall effectiveness of net shape forming (Patel, 2010).

Consequently, it is an important idea for the inventive principles of #27 Cheap substitution, we use the easy structure, easy maintain, and easy for production to redesign the system structure of alloy manufacturing equipment. Then, the inventive principles of #36 Transformation and #35 Parameter change is used to add the function for the safety. We design a component about the overflow hole that is used to release the high temperature liquid magnesium. This component is a one-way valve that can prevent the high temperature liquid magnesium to contact with the air. It is effectively decrease the harmful for equipment and the operator.

In this research, the entire result is proved by the empirical analysis as show in Figure 6 to Figure 8 and Table 5. Figure 6 shows the network relationship map of each dimension and criterion; the Fig. 8. Illustrates the relationship of customer needs (requires) and engineering technical by using QFD; Figure 8 illustrates the concept structure of innovative design that is significant to improve existing manufacturing equipment. According to these results, we proposed an evaluation model for the innovation design of magnesium alloy manufacturing equipment as shown in Table 5.

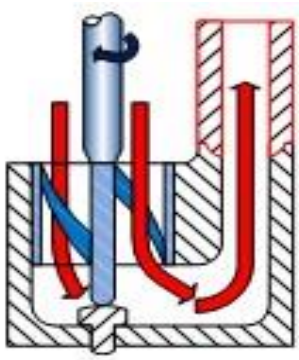

Figure 8. The axial flow pump for axial-in and axial-out

The result of this research finds the critical inventive principles that can effectively improve the existing manufacturing equipment including the six inventive principles with #14 Curved surface; #29 Gas or liquid driving structure; #18 Shaking; #36 Transformation; #35 Parameter change; and #2 Extracting as shown in Table 4. The present research work will continue to test in practical situations. Finally, we applied the result to reform the existing manufacturing equipment in order to design suitable manufacturing equipment for various applications base on the innovative design knowledge.

According to this model, we compared centrifugal pump and axial flow pump with a simulation experiment to support this result. First, we calculate the average of axial flow pump with the liquid reaction time $\bar{v}$ which carried out in a glass tank with a storage capacity of 25L. The motor frequency is 30Hz, axial flow pump with the liquid reaction time T is 90 seconds, and the liquid volume V is 9.65L, as shown in Eq. (13).

$$\bar{v}_{\text{axial flow pump}} \quad \frac{V \quad 9.65\ 10 \quad {}^{3}ml}{T \qquad 90s} \quad 110.7ml\ s/ \qquad (13)$$

Here, magnesium liquid consistency similar to water that the density of magnesium is $1.74g\ ml/\ {}^{3}$. We can estimate per second of the volume of output magnesium as shown in Eq. (14).

$$m\ pv \quad 1.74\ 110.7 \quad 192.6g\ s/ \qquad (14)$$

Consequently, we tested the motor carrier situation at different frequencies (this electric current is amplified 10-fold after the electric current value) as shown in Table 6.

Table 6. The test of axial flow pump

Frequency (Hz)	10	15	20	25	30	35	40	45	50
Electric current (A)	4.4	5.0	5.3	5.6	5.9	6.4	6.8	7.4	8.4

Second, we calculate the average of centrifugal pump with the liquid reaction time $\bar{v}$ in the same conditions which carried out in a glass tank with a storage capacity of 25L. The motor frequency is 30*Hz*, centrifugal pump with the liquid reaction time *T* is 150 seconds, and the liquid volume *V* is 9.88L, as shown in Eq. (15).

$$\bar{v}_{\text{centrifugal pump}} \quad \frac{V \quad 9.88\ 10 \quad {}^{3}ml}{T \qquad 150s} \quad 65.9ml\ s/ \qquad (15)$$

Here, magnesium liquid consistency similar to water that the density of magnesium is $1.74g\ ml/^{3}$. We can estimate per second of the volume of output magnesium as shown in Eq. (16).

$$m\ pv \quad 1.74 \quad 65.9 \quad 114.7g\ s/ \qquad (16)$$

Consequently, we tested the motor carrier situation at different frequencies (this electric current is amplified 10-fold after the electric current value) as shown in Table 7.

Table 7. The test of centrifugal pump

Frequency (Hz)	10	15	20	25	30	35	40	45	50
Electric current (A)	4.4	5.0	5.3	6.2	7.0	8.5	9.6	11.3	13.4

According to the experimental results, the axial flow pump and centrifugal pump are the same carrier when the frequency is less than 20Hz, and after the frequency is greater than 20Hz, (50Hz when the motor speed can reach 2800 rev / min) centrifugal pump set flow increased dramatically; opposite, axial flow pump carrier is slowly increasing as shown in Figure 9.

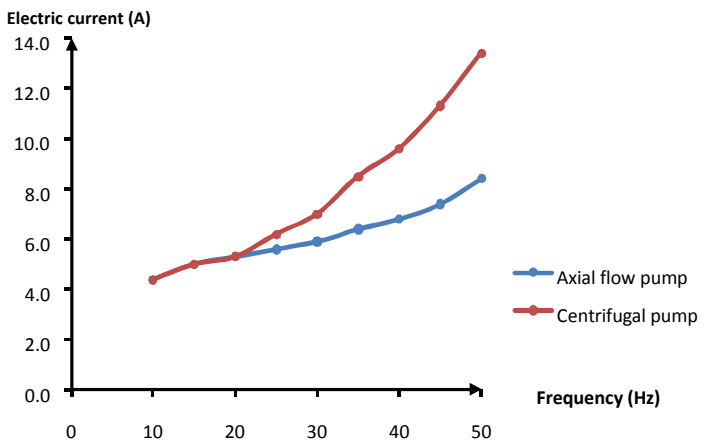

Figure 9. The simulation experiment result of axial flow pump and centrifugal pump

In the slow speed of the motor, the carrier of axial flow pump is not too large, and its blade of impeller is designed to the mix styles. The blade contacts the fluid with a large area. In the fluid, the force is proportional relationship to the size of speed. Furthermore, the damping coefficient of blade is also proportional relationship to cross-sectional area of fluid.

When the centrifugal pump speed increased, opposite the resistance is also rapidly increased. At the same time, because of the resistance increases rapidly, the surface of liquid is formed a large vortex that is greatly damaged for protection the surface of liquid. Moreover,

the vortex can bring the impurities spin into the magnesium and cause the structure alloy crystal disrupted. These reasons can affect the quality performance of casting product.

Besides, we proposed an innovative design to solve these problems. The impeller of axial flow pump is designed in parabolic surface and has the small cross section with liquid magnesium to increase the contact surface that can ensure a stable delivery of a large number of liquid magnesium. This kind of impeller can be greatly reduced the damping coefficient and increase the stability of equipment. Axial flow pump is used to pressure transmission process with axial-in and axial-out, but also is die cutting process of magnesium alloy. According to the result of empirical analysis, the innovative design of axial flow pump has these advantages including the alloy organization can be refined, grain growth can be controlled and the density of cast parts can be improved.

6. CONCLUSION

The research described in this paper demonstrates that development of innovative design for manufacturing equipment is within the realms of possibility. This design project is including different contradiction structure to be overcome. For this purpose, an idea generation method has been proposed in which the contradiction matrix of TRIZ is adopted based on the many fields knowledge. Here, we employed with an innovative method, TRIZ; multi-criteria decision making, DEMATEL and DANP combing with QFD tool for handling with many potential uncertainty factors which is able to evaluate and provide the most suitable strategies for reforming the design problems. Finally, the result of this study provides project team a guidance to continuously improve, track and meet the quality assurance of production; consequently, the needs can be satisfied. In this case study, these technical is apply to magnesium alloy manufacturing equipment in the real world.

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Development of Portable Lighting Products through NPD Approach based on TRIZ

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Abstract

Portable lighting products are well mature products around for many years. Traditional portable lighting products use conventional light bulb as light source for years. Some years ago, the light source has been gradually changed to Light Emitted Diode (LED) which is more dynamic, consume less energy, and compatible with most electronic components. The introduction of LED has given a new life to portable lighting products, however, there has been no breakthrough on the overall design of the products. This paper introduces the utilisation of common management and new product development techniques in line with the TRIZ inventive problem solving tools to develop a NPD process. The author will demonstrate the application of this NPD process for development of portable lighting products.

Keywords: contradiction, portable lighting products, TRIZ

1. Introduction

The change of developing a new product has gone through stages from conventional to innovative. Customer expectation would be factor that the developer has to take care. The trend of a new product is innovative. Customers expect new things that could be more value, many functions and interesting. For portable lighting products, this type of products has been around for many years as old as the birth of human being. In the very old days, the people used fire torch, oil lamps which are also examples of portable lighting products. After the invention of dry battery cells and vacuum light bulb, people started to use batteries to drive light bulb to produce light. This is what we call conventional electricity driven portable lighting products.

This paper aims to develop the viability of applying TRIZ to develop products. The author will develop a portable lighting product using TRIZ based new product development methods.

2. Portable Lighting Products

2.1 History of Portable Lighting Products

Conventional portable lighting products connect the electricity circuitry with the vacuum lighting bulb. The current passing the filament of light bulb burns the filament and produces both heat and light. Light is the part of function that we expect and use; while heat is the part of function that wastes energy of the batteries. This system has been around for almost one hundred years although there were slight changes of light bulb as well as the battery design. However the basic theory and design have not been changed at all.

Colored Light Emitted Diode (LED) has been around for more than fifty years. However the white color LED appeared only until year 2000. A Japanese company called Nichia invented a new process to turn blue color LED to white LED by adding some additives to the electronic chip so that when a current passing through the chip, the blue color becomes pale and looks like white color. At that time, the price of this white LED was very high. Portable lighting product is assumed to be a consumer product that could not afford a very high price. Until middle of year 2000 more and more companies produced white LED that drove the price down a lot. Then portable lighting product started to create real products around LED as lighting source.

2.2 Major Differences between Light Bulb and LED as Light Source of Portable Lighting Products

Conventional light bulb produces light by burning a filament at inert gas environment. The efficiency is in fact very low because part of the energy (from the dry batteries) lost at generating heat. Life of the filament is also relatively short at around 15 hours continuous burning. Although efforts have been put to prolong the life of the light bulb by burning the filament in inert gas, the life could only improve some percentage. The deficiency of low efficiency did not improve at all due to the basic physics of the system. The power drain of light bulb is high thus the batteries are drained very fast.

The birth of white LED completely changed the rule of the system. LED produces light not by burning but by electronic ‘sparkling’. This ‘sparkling’ effect does not ‘burn’ the chip of the LED to produce light therefore the life of a LED is much longer than conventional light bulb. It does produce heat during the electronic ‘sparkling’ effect but the percentage is much lower than the conventional light bulb. Moreover, the power consumption of LED is very low compared to the conventional light bulb.

Lower light output is the biggest deficiency of white LED. One piece of conventional light bulb is much brighter than one piece of white LED. To compensate this low light output, usually more than one piece of white LED are used which creates the same problem that one piece LED uses less energy but many piece LEDs would consume more energy.

3. TRIZ Introduction

3.1 TRIZ Basics

TRIZ was developed by Genrich Altshuller and his colleagues in former USSR starting in 1946. The basic principle of TRIZ research is that there are universal principles of inventions which are basics for innovation. If these principles are identified and codified, they could be learned and taught so that it becomes a process that we can use to predict innovative ideas. Altshuller studied more than 2 million patents to identify innovation patterns and laws of solving contradictions. He found that problems and solutions are similar across industries once they are at the generic positions. He also found that technology evolution also follow a pattern across industries. One of the key finding of Altshuller was to create inventive ideas from solving contradictions. When solving one contradiction, one inventive idea appears. After studying million of patents, he formulated a unique method to solve contradiction and thus simulate inventive ideas.

There are two types of contradictions, technical and physical contradictions. Technical contradiction has two parameters that one parameter is improved and at the same time another parameter would be worsened. Physical contradiction does not have two parameters. It happens at different time and space that sometimes the parameter should be A but at other situations the parameter must be B. Contradiction is a straight forward methodology to solve problem at different stages using inventive thinking.

Trimming is another TRIZ tool that could simplify the product by reducing the number of components yet the basic functions of the product is not affected. The value of Trimming is more than simplification of the product but more importantly cutting costs through the trimming exercise.

3.2 Application of TRIZ to NPD of Consumer Products

The key success factor of new product development (NPD) is to meet the expectation of customers. Nowadays customers expect many things for the product but they expect to pay lesser. Application of TRIZ for consumer product development would be the application of the two major tools, solving problems at the customer expectation stage by contradiction methods; and trimming of parts to reduce costs at concept stages.

4. New Product Development Framework

4.1 General Product Development Process

New product development is not an easy process. Most of the companies use a structured and well-highly organized approach for new product development. It needs an incredible amount of time and research. First off, the idea is generated based on the needs of the customers. The idea then gets transformed into concept, then it is tested to evaluate the characteristics of the product along with feasibility, target market and production cost. After this sale, the most important step is based on the customers' feedback. Customer needs are more important than the quality of the

product. After this step, profitability evaluation is done and then prototype of the product is made. It is then market tested and changes are made accordingly.

To summarize, the basics of new product development (Fig 1) starts from stage 1: the 'need' of the customers, a product is thus created to meet their need which is stage 2. Stage 3 is to realize the product through production to sell in the market.

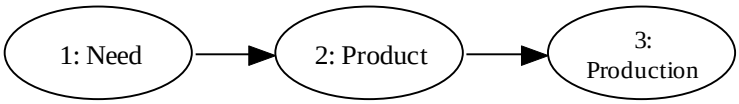

Fig 1: General Product Development Process

The whole product development process is to realize the need of the customers and turn it to a real product selling in the market.

4.2 Applying TRIZ to the NPD Process

Research said if there is a problem in the new product development process, the problem would be solved with $1 at the pre-product stage while it would be $1,000 at the post-product stage. It is clearly identified that if the problem could be solved as early as possible before more investment is injected into the project, it would save a big amount of investment for changes and delays. Therefore the application of TRIZ in the NPD process would be more effective between the 'need' and 'product' stage (Fig 2).

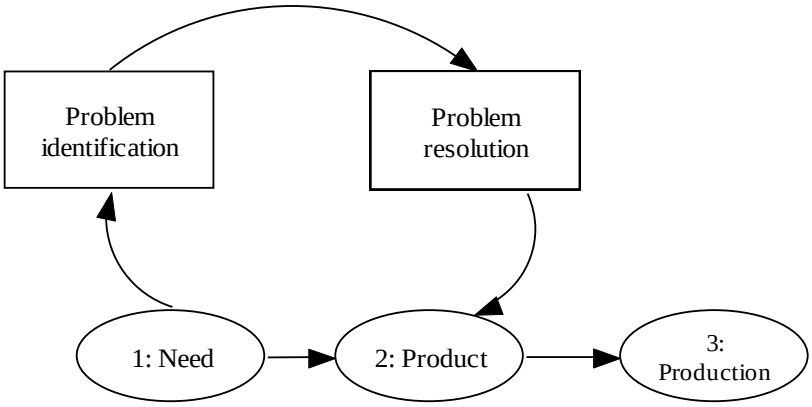

Fig 2: Application of TRIZ tools to the NPD Process

4.3 Problem Identification

The objective is to translate the problem information from the customer into the language of TRIZ . Problem identification starts from Function Analysis, Flow Analysis and Cause Effect Chain Analysis of the problem. Once the function diagram is built up, it would clear up the many 'whys' of the problem, or in other way, why we need to do this. Along the problem identification, the useful (desirable) function and harmful (non-desirable) function are identified. The aim for the service development is to increase (or improve) more useful functions and decrease (or eliminate) harmful functions. By doing this, it is

actually increasing the benefits for our customers and decreasing the harmful things such as wasting their time and money.

The next step of the problem identification is Trimming. Priority of trimming is to eliminate harmful functions by delegating the function either to itself or to other components. After the trimming process, the whole operation will be simpler and cheaper.

4.4 Problem Resolution

Objective of Problem Resolution is to identify and eliminate contradiction through contradiction analysis. There must be contradiction in any system. The problem is formulated in a form of a contradiction with two conflicting components. Contradictions could appear in the system level, or at the sub-system level. To effectively tackle the problem, the contradiction must be identified from the 'center' of the problem so that once the contradiction is eliminated; the problem would be solved completely. To eliminate the contradictions effectively, one may use the knowledge-based tools from TRIZ including the 40 inventive principles, contradiction matrix, 76 standard solutions and the Algorithm of Inventive Problem Solving (ARIZ). The 40 inventive principles and contradiction matrix are considered as simple and useful TRIZ problem resolution techniques among the various tools. It is effective in eliminating contradictions for both technical and non-technical problems. With the use of the contradiction methodology, contradictions can be eliminated with solutions generated for further evaluations.

5. Portable Lighting product Development

5.1 Problem Identification by Function Analysis

There are expectations from customers about lighting products:

- Could be used anytime when needed
- The power is always ready (no need to look for batteries)
- Bright enough for different applications
- Should not be heavy (when it is used for a longer time)

It could be converted to be useful and harmful functions of a conventional portable lighting product as Table 1. The desired function benefit of a portable lighting product is to produce light for human being at a moving situation, for instance, outdoor applications, or critical maintenance applications. However there are some harmful functions of a lighting product: use portable energy (batteries), size, weight, etc.

Useful functions	Harmful functions
Produce enough light	Need portable power
	Tired when being hold for long time

Table 1: Useful and harmful function of a conventional portable lighting product

5.2 Problem Resolution by Contradiction Tool and Inventive Principles

A major contradiction of a conventional portable lighting product is the durable of the power. Since the conventional lighting product uses light bulb that has low efficiency and high power drain. On the other hand, if the light source is changed to LED, the power consumption is reduced drastically, however the light output is not enough to provide enough brightness to the customers. These are technical contradiction that contradiction models could be built as Figure 3.

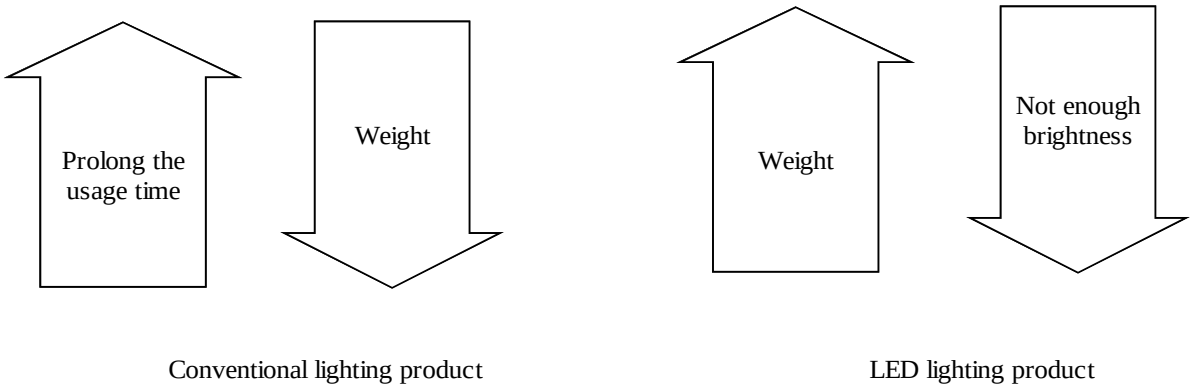

Fig 3: Technical contradiction Model of conventional and LED lighting products

The technical contradiction is solved by using contradiction matrix for both the conventional and LED type portable lighting products.

Inventive principles for solving contradiction of Conventional lighting products

- #6: Multifunctionality: make a system perform multiple functions
- #27 Cheap disposables: replace an expensive object with multiple inexpensive objects.
- #19 Periodic action: use periodic or pulsating actions.
- #16 Partial or excessive actions: make slightly less or slightly more

Inventive principles for solving contradiction of LED type lighting products

- #19 Periodic action: use periodic or pulsating actions
- #32 Optical property changes: change the color or transparency of an object
- #35 Parameter changes: change an object's physical state

The next step of the process is to create ideas from the inventive principles. The process is to think the inventive principles and develop ideas to get around the contradictions. There is no limitation how to apply the principle, it is a triggering process to force the team to think through different directions around the principle and eventually produce ideas. When there is an idea produced, Trimming tool is used to reduce cost to a minimum by critically study the components, combining components and eliminating components to achieve a lowest possible cost.

6. Conclusion

TRIZ is a force thinking methodology. It forces the user to think through the basic functions, contradiction, system limitation etc and applying the TRIZ tools to get the problem solved while running through the process. It is a unique way of systematic thinking. With a powerful knowledge-base such as the contradiction matrix as its foundation, TRIZ contrasts with other problem solving approaches by its distinct capabilities to generate new ideas and deliver solutions without compromise. TRIZ can be applied to engineering problems and service problems as well. The author demonstrates how to apply the Function Analysis and the Contradiction Analysis to stimulate new ideas of developing portable lighting products.

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Approach of course development for cultivation of innovative capability of students at university

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Abstract

Course design and development need to be considered in many aspects such as goals, features, resources and constraints of each institution. Furthermore, it should conform to society's needs and should be improved according to the advances of knowledge. In order to cultivate students' capabilities required by the needs of industry so that they can better cope with the severe competition in today's knowledge economy era, schools should have the responsibility and endeavor to instruct students how to acquire innovative knowledge rapidly. In this paper, a framework of the corresponding method of course development for cultivating the innovative capability of students at university was proposed based on knowledge chain model. An example implemented at Far East University in Taiwan was used to illustrate the feasibility of the proposed method. The concept and framework proposed in this paper might be used as a reference and guideline to promote the education of TRIZ and patent related courses in university.

Keywords: Course Development, TRIZ (Theory of Inventive Problem Solving), IDEF0 System Analysis, Knowledge Chain Model, Engineering Innovation Education.

1. Introduction

The cultivation of student's innovative capability has become more important for promoting his competitiveness in this knowledge economy era. However, due to the diversity of student's background and interest, how to effectively elicit the interest and excavate the potential of student is a indispensible prerequisite to approach the above-mentioned goal and this is also a problem worthwhile to study. Though there are many courses which provide various tools and methods to cultivate the creative or innovative capability for the students, it is still insufficient to ensure whether the teaching objective of the course and the learning performance of student have been achieved, especially for the advanced creative courses or project-oriented courses. Therefore, in order to elicit the student's innovative potential based on his prior interest and experience, it is necessary to systematically analyze, plan and design a framework or method to reinforce engineering innovative education from a context-oriented perspective considering prior professional knowledge, basic creative knowledge, advanced creative knowledge, individual interest, etc.

For engineering innovation education, TRIZ [1] has provided a systematic innovation method along with philosophic thinking and a variety of useful tools such as 40 inventive principles and the matrix of contradictions, laws of technical system evolution, substance-field analysis, and ARIZ (algorithm of inventive problems solving). Sheu [2] illustrated an overview of the classical TRIZ (Theory of Inventive Problem Solving) body of knowledge with a TRIZ Knowledge Map and Problem Solving Model. Ogot and Okudan [3] introduced TRIZ in a first-year engineering design course and the research result indicated that TRIZ makes it easier for students to generate feasible concepts to design problems. Turner [4] proposed the 'Advanced Systematic Inventive Thinking' (ASIT) method as a problem solving strategy for education. Sokol et al. [5] implemented an empirical study on the efficacy of the Thinking Approach (TA) to language teaching and learning for foreign language education.

The innovative education has become more imperative in this knowledge era. However, there is little paper to explore how to develop course with systematic method. Therefore, in this paper, we focused on engineering innovative education and proposed systematic approach to develop the framework and method for cultivation of innovative capability of students at university. Based on the above-mentioned argument, it reveals that the plan, design and implementation for a new advanced course need to face to many problems such as prerequisite courses, prior background and knowledge of student, cultivation of teacher's expertise, adaptive selection of the teaching materials, availability and affordance of teaching equipment, application of e-learning platform, design of teaching tools and method. Therefore, a framework to provide the regulations and criteria for the plan, implementation, control and evaluation of an innovative course is essential.

The objective of this paper is to propose a framework and method of course development for cultivation of innovative capability of students at university based on IDEF0 model and knowledge chain model for engineering education. The rest of the paper is laid out as follows. Section 2 describes

the research method including the analysis for prerequisite courses of engineering innovative education, the plan of innovation-eliciting course, and the generation of a systematic framework and method for cultivation of innovative capability of students. Section 3 illustrates the application of the proposed method with a case study. Final section is the discussion and conclusions to illustrate the limitations, contribution and future step of this paper.

2. Research Method

The approach of the course development includes three steps: analyze the prerequisite courses of engineering innovative education, plan an innovation-eliciting course based on knowledge chain model, and generate a systematic potential eliciting and inspiring method. The detailed process was illustrated as follows.

2.1 Analysis of Prerequisite Courses

The analysis of the prerequisite courses of engineering innovative education was presented in this section. The IDEF0 is a structural analysis and modeling technique specially designed for the modeling of decisions, actions, and activities of organizations or for the complex and interrelated systems [6]. The result of an IDEF0 functional modeling is a hierarchical, functional decomposition of process functions, each of which consists of five basic elements: functional block, input, output, control, and mechanism. Fig. 1 shows the system analysis diagram for the prerequisite courses of engineering innovative education with the IDEF0 structural analysis model. The purpose of the process analysis is to fully understand the context of course development processes, including the activities and tasks involved, their constrains, and supporting resources, as well as the information flow in the process.

The activities in the Fig. 1 include (1) domain knowledge courses such as the professional course, (2) basic creative knowledge courses such as creative thinking and introduction to intellectual property rights, (3) advanced creative knowledge courses such as TRIZ and patent practices, and (4) integrated knowledge courses such as project-oriented or topic research courses. All of the activities, as shown in Fig. 1, involve many constraints such as course objective, prior knowledge of students, expertise and practice of teachers, affordance of equipment, diversity of students. Furthermore, each activity involves plenty of iterative modification or refinement for course development. However, there are also various resources available such as teaching assistant, encouraging regulations, e-learning platform, Internet resources, funds of project from government. By way of the IDEF0 analysis for prerequisite courses, it provides the visibility and direction of the innovative course development for eliciting student's interest and excavate student's expertise.

2.2 Innovative Course Development based on Knowledge Chain

The concept of knowledge chain model proposed by Holsapple and Jones [7] includes two groups of activities. One is the primary activities containing knowledge acquisition, knowledge selection, knowledge generation, knowledge assimilation, and knowledge emission. Another is the

second activities comprising leadership, coordination, control, and measurement. This framework could provide a guideline to approach the problem solving of course development from a systematic and context-based perspective.

As the knowledge chain model can provide guidelines and it gives a context-based perspective to manage, control, and implement the knowledge management activities, this paper adopted it as a basis to propose a framework of course development for eliciting innovative potential as shown in Fig. 2. The primary activities of the knowledge chain framework are acquisition, selection, generation, assimilation, and emission. They focus on a sequential process and comprise acquiring knowledge from related courses, selecting needed knowledge to adapt student with different background, inspiring student to produce various new ideas by way of suitable course design, encouraging students to write document such as a patent specification or achieve a prototype based a feasible idea, and supporting students to participate competition, to apply patents, to write a paper, etc.

The secondary activities are leadership, coordination, control, and measurement. They focus on planning the foresight strategies for teacher cultivation, curriculum plan, encouraging method; resolving disputes and reasonably allocating resources such as course arrangement, equipments, and funds; ensuring teaching quality and learning performance; and constructing objective evaluation criteria and mechanism. In order to effectively proceed the activities in the framework, it is necessary to consider the influence of resource and environment which are similar to the resources and constraints in the IDEF0 model. The final goal of overall activities is to enhance the competitiveness of student, school, and even society.

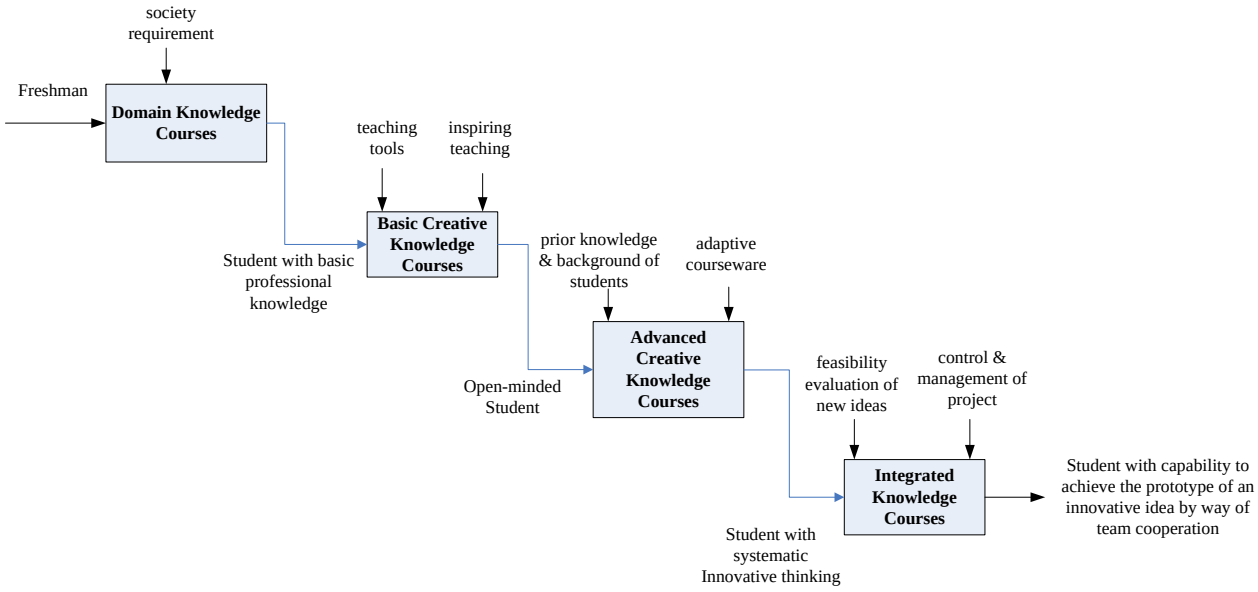

Fig. 1. IDEF0 system analysis diagram for the prerequisite courses of engineering innovative education.

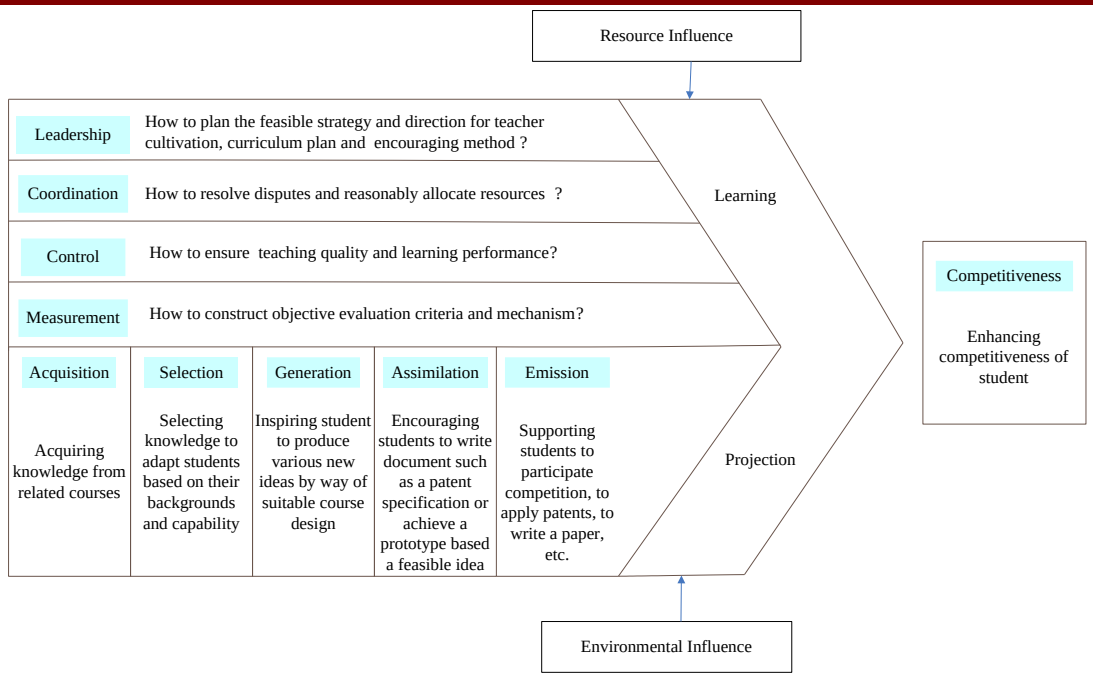

Fig. 2. Framework of course development for eliciting innovative capability based on knowledge chain model.

3. Case Study

In this paper, we adopted a project implemented by Department of Computer Science and Information Engineering of Far East University at Taiwan in 2008 as an example to illustrate the proposed method. Fig. 3 shows course development flowchart including course plan, course design, course implementation and evaluation along with the related resources and constraints. Fig. 4 shows a snapshot of course management with e-learning platform and Fig. 5 shows a snapshot of collaborative evaluation of students' reports with industrial expert. In Fig.3, the course plan module includes some activities such as to cultivate teachers, to analyze resources and constraints, to coordinate related members and to write projects to apply budgets. The course design module includes some activities such as to design teaching activities, to teach with industrial experts, to teach with the assistance of e-learning platform and to design homework and reports. The course implementation and evaluation module includes some activities such as to teach patent knowledge, to analyze student's background, to demand mid-term proposal submission and presentation, to demand final-term report submission and presentation, and to collaboratively evaluate students' reports with industrial experts.

Besides the three main modules, there are also two modules, resources and constraints, needed to consider during the course development. The resources module includes some important elements such as industrial experts, teaching assistants, courseware provided by ministry of education, e-learning courseware, e-learning platform, and encouraging methods and mechanisms provided by schools. The constraints module includes some important elements such as background and knowledge of teacher, background and capability of student, selection of feasible courseware, control of teaching activities, and quality control of final report.

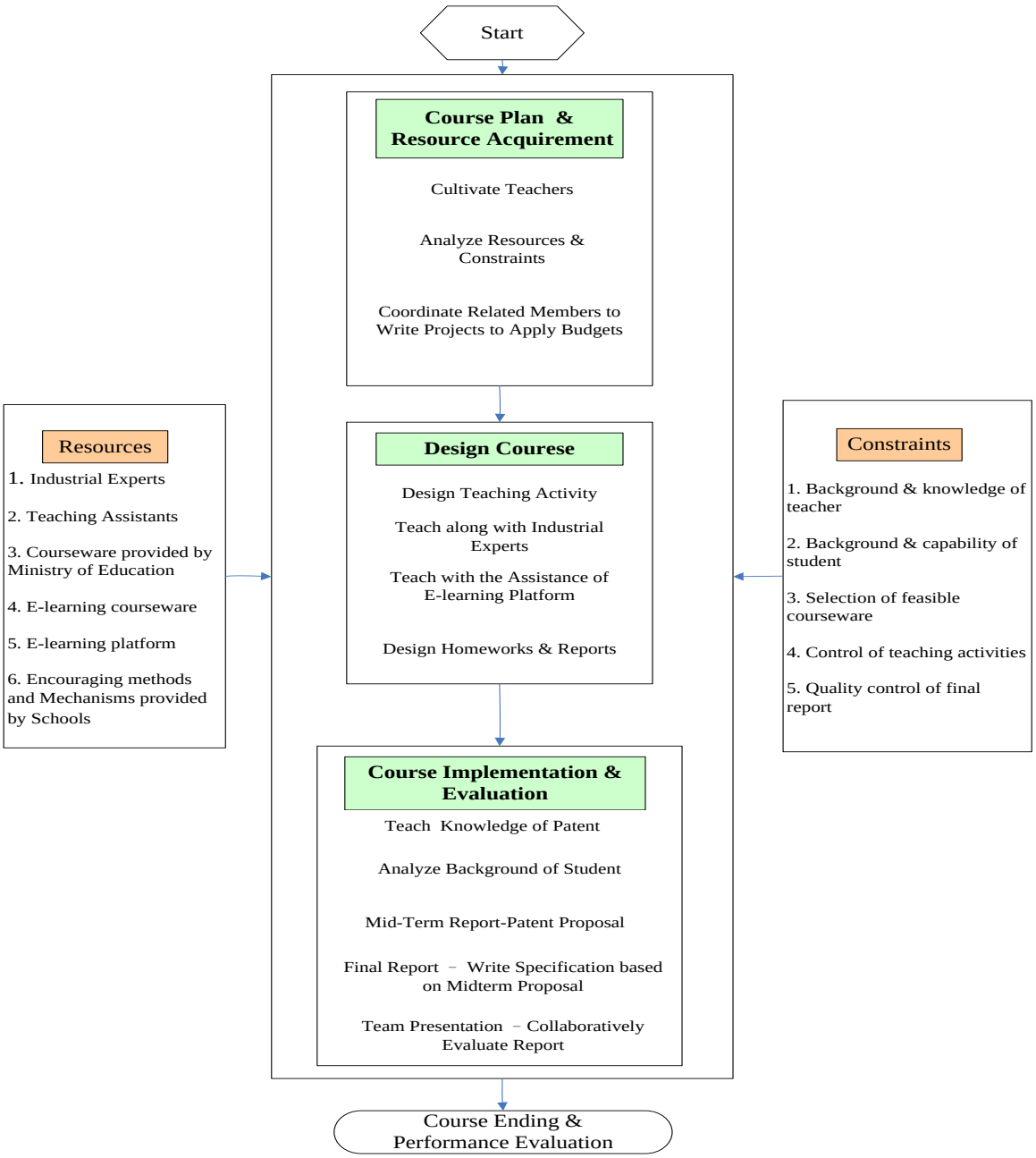

Fig. 3. The flowchart of plan, design, implementation and evaluation of course development.

Fig. 4. A snapshot of course management with e-learning platform.

Fig. 5. A snapshot of collaborative evaluation of students' reports with industrial expert.

4. Conclusions

In this paper, we have analyzed the inputs, outputs, resources and constraints of a course development with IDEF0 system analysis. Subsequently, a framework of course development was proposed based on knowledge chain model. Furthermore, A case study were used to illustrate the implementing method and process based on proposed framework. The authors expects this research could provide a guideline or reference for enhancing engineering innovation education and the method proposed in this paper is general in form to be applied for the other disciplines.

Acknowledgement

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Verification in Forecasting Projects. Specific features.

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Abstract

Verification is one of the important final stages of TRIZ forecasting project because it affects the quality of final concept and further decision-making in managerial activity. Due to the predicted new generations of technology and machinery, the verification is complicated by the absence of prototypes. The main function of developed verification block, as opposed to existing ones, is the specification (improvement) of working forecasting concept. We have developed the algorithm of forecast verification and final concept creation rules.

Keywords: concept, forecast, project, rules, verification

Verification in Forecasting Projects

Verified forecasts provide the executives with reliable information for managerial decision making. Besides, such forecasts are economically and politically effective thus justifying the labour and financial costs for its development.

The verification of the forecast means the determination of its credibility, accuracy and reasonableness. During the verification we analyze the compliance of forecast concept with the law, technology development trends and real possibilities of modern technologies.

The author's way to perform the forecast of engineering systems (ES) development includes: signing the contract, setting a work group; data collection, database creation for the forecasting project; analysis of problems and discrepancies of ES; sorting out the discrepancies, creation of solutions database; unifying the solutions into the concept of new ES; verification of the forecast concept; concept preparation and submittal to the customer; analysis of the forecast development process and improvement of the forecast methods.

Problems in Forecast Verification

The verification procedures are compulsory in the developed forecasting method. However, the known verification practice has some disadvantages:

- High labour input;
- Involvement of outside experts which is hardly possible due to the confidentiality of works;
- Absence of distinct procedures of work performance;

- The practice is based on experience and focused specialization of the experts, thus resulting in poor reliability of its methods in new groundbreaking areas;
- As a rule, the methods of verification do not imply the variability of ES performance;
- In the verification process we face the absence of real prototypes.

Methods of Forecast Verification

The suggested method of forecasting project verification is closely connected with the previous and following steps of forecast performance. It implies the following tests of forecast concept: experimental methods; patent stock; thesis works database; articles in literature and Internet; "Grand master method"; and in some cases diversionary analysis.

The results of the verification stage might be as follows: identification of technical, patent and scientific novelty and industrial feasibility of the concept; results of the experimental test which validate or disprove the forecasting concept; coming back to the previous stages in order to improve the concept; tested concept submittal to the customer.

Specific features of the Developed Verification Method:

- The forecasting concept is prepared as an application for a discovery;
- During the verification, the concept is checked in patent stocks of the leading countries, in the in-house patent stock, in thesis works on the same subject, in the Internet;
- If possible, the main ideas of the concept are subjected to the experimental test and the information detected is further analyzed;
- After verification of the concept it returns to the conceptual, informational, analytical or decision-making stage;
- The initial concept is specified in view of the detected information and then documented in the updated version of the concept which is subjected to the second verification stage;
- Only verified concept is submitted to the customer;

The suggested verification method has the following properties:

- Succession: use of the well known patent and information testing methods of good quality;
- Reliability: the verification is supported by the results of the completed scientific research, published patents, innovative activity;
- Cyclicity: return to the conceptual stage (informational, analytical or decision-making stages if necessary) and modification of the forecasting concept;

- Cost effectiveness: preparation of the forecasting concept as an application for a discovery reduces the customer's expenses on the further patent protection;
- Novelty: verification is based on the completed scientific and patent research, cutting-edge technology with regard to the law and technology development trends;
- Simplicity: the verification is carried out by simple procedure formalized in patent practice;
- Collective work: verification of the certain ideas of the concept is carried out by different members of the team, concept is improved by group discussion and then finalized;

Advantages of the Suggested Method

The forecasting practice has revealed the following advantages of the suggested method:

- Well-defined algorithm of concept writing and testing for novelty and industrial feasibility using well-proven letters of patent;
- Concept testing is characterized by lower labour input and can be performed by several members of the forecasting group which results in the promptness of the verification stage;
- Available software products, procedural guidelines and rules reducing the labour input yet more and facilitating the test of solutions and concepts;
- The forecast verification is objective because the patent information and thesis works are generally several years ahead of the state-of-the-art;
- The verification partly uses the results of recently completed patent and information search;
- Neither involvement of outside experts nor using other forecast methods is required;

Forecasting and verification methods has been applied in number of projects in various technological areas in Belarus, Russia, Great Britain and South Korea.

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TRIZ & Lean methodology synergy In Misplacement Prevention

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Abstract

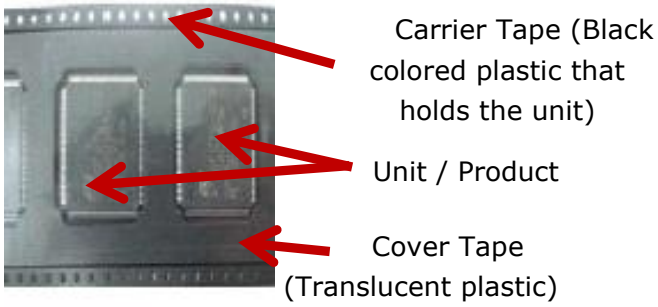
The paper discusses on the problems faced by the Assembly, Test Manufacturing (ATM) plants of Intel Corporation for a certain Tape and Reel Process and is generic across the other sister factories around the world. The complexity and high occurrence of the problem makes it more susceptible to customer returns and complaints. The problem was looked at by using Lean and TRIZ and we came up with a potential solution that was elegant and at the same time potentially solve the menacing issue that is a worry among the factories and at the same time surprisingly yields good returns.

Keywords: ICOS, Lean, Tape and Reel, component misplacement

1. Introduction

Component misplacement in the Tape and Reel process especially for small form factor products are very tricky as the tendency for units to be misplaced, out of pocket or totally missing is much higher compared to the bigger form factor products. This is due to design limitations of the tool used as the products being manufactured these days are getting smaller and smaller at a faster rate compared to the tool that operates it stays the same relatively for the next 5-10 years. This is a known dilemma that is faced by many organizations and this is no stranger to Intel manufacturing as well.

Component misplacement leads to empty pocket scenario that is caught at the customer's Incoming Quality Control (IQC) side. The customer receives inaccurate quantity of purchased material and this doesn't help Intel's case of retaining its customer when the customer's are not getting what they purchase. There have been numerous improvement efforts that have been carried out by the tool manufacturer as well as Intel but till today no one has successfully solved this intermittent issue from reoccurring.



Picture 1: Unit inside the carrier tape

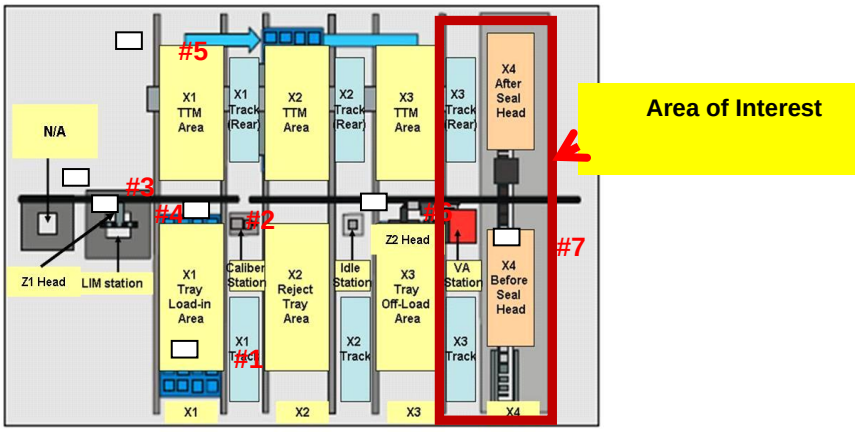
On an average component misplacement is triggered approximately 25 times/tool/day and in some cases the issue is genuine as at times it is a false alarm. However there is still a process in place to follow when this tool given an alarm for this type of problem. This serves as a temporary solution to address the component misplacement issue but it is still not fool proof.

By coupling TRIZ and LEAN, we have come out with a way to model the problem and look at the root cause by performing numerous Direct Observation (DO) and validating all the findings and uncertainties by experiments to differentiate the actual root cause vs. the symptoms of the problems. The process of transferring the units from the tray after inspection (CO, RO, etc….) and placing the units onto the carrier tape was scrutinized using DO and then TRIZ was used to analyze the Process and mechanism of the overall Tape and Reel process. The details of the findings will be discussed in the following sections of the paper.

2. Challenges/Problems

The fact of the matter is that the Tape and Reel process is a simple process on paper but the many customer excursions that have come as a result of inconsistencies of the process shows that it is a concern that needs to be addressed quickly. The main types of issues are component misplacement/ missing issues and sealing inconsistencies that lead to component missing or drop.

Across the different Intel Manufacturing sites around the world, these are the 2 main issues as well that is seen for the Tape and Reel manufacturing process. Focus on the sealing of the cover tape onto the carrier tape becomes relevant when the quality is not there i.e. the cover tape doesn't completely hold onto the carrier tape. This can potentially cause units to drop out off the carrier tape.



Picture 2: Overview of ICOS tool layout

The criticality of the issue is seen when this type of missing units are detected at the customer's side as this will trigger a chain of events for investigation and RC determination and Action plans that must be put in place quickly to fix the problem at least a temporary measure.

In the manufacturing line on the other hand, there are many occurrences of error message trigger for this tool and about 30% - 40% are all false alarm. False alarm happens due to the fact that the design of the sensor and position of it causes debris from the units to easily accumulate.

3. Lean & Process Analysis

We had to look objectively on the overall process and see what was working fine and what was not. The detection process on the overall looked sufficient as there was a detection point before the units is placed into the carrier tape, there is another detection system after the unit is placed into the carrier tape as well as another detection point after the unit is sealed into the carrier tape before the unit is being rolled into the reel but still there was escapees of missing units to the end customer.

By using the a strong element from LEAN, we used Direct Observation (DO) to study the process of how the units are Inspected for defects by the ICOS tool then transferred from the Tray to the carrier tape right up to being sealed into the carrier tape and packed into reels.

By using Cause and Effects Chain Analysis (CECA), we manage to identify 2 areas of focus of the project which was to improve detection capability as the current detection system in the tool was not taking into account the side effects of processing small form factors products that is far lighter from the previous generation products and this was already pushing the envelope of the tool's capability itself. Next we also had to look into how we can prevent component misplacement from happening altogether.

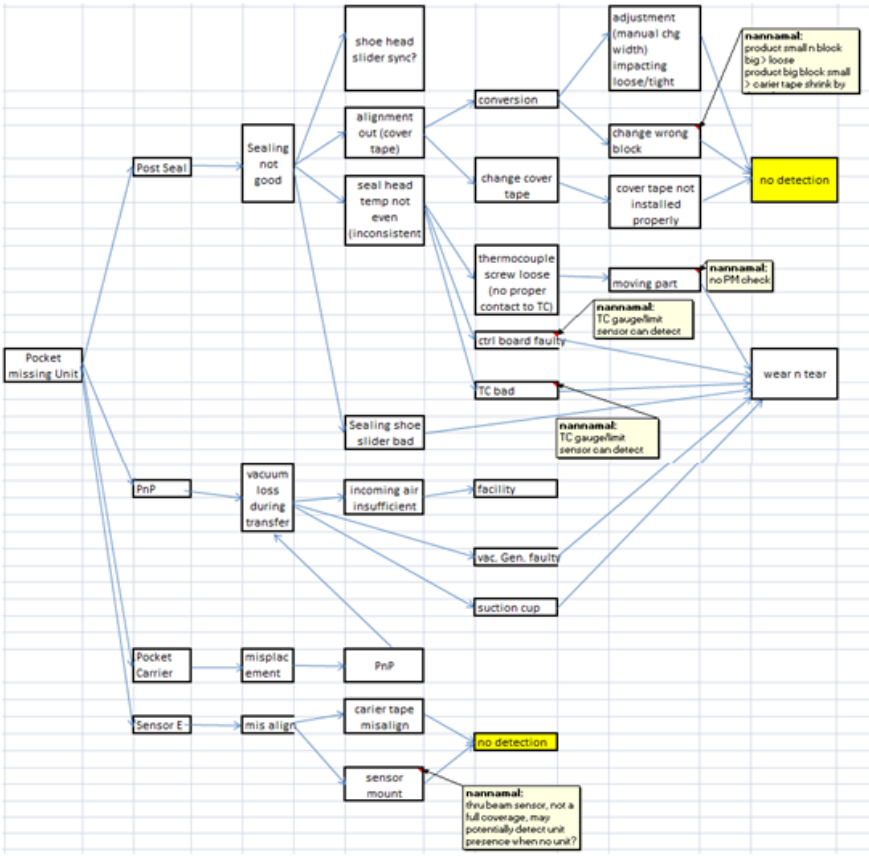


Figure 1: CECA of Missing Unit in the pocket

A series of experiments was carried to verify that we were actually looking at the right problem to solve and that our hypothesis that was done was all validated.

4.0 TRIZ

The main components of the problem area X4 are made up of the main track where the units are placed on the carrier tape from the trays (*refer to Picture 2 for area of interest*). The main track is made up from (in general) the rail that holds the carrier tape, the sensors to detect empty pocket as well units present, a moving Pick and place arm that moves the units from the tray to the carrier tape, the Seal Head mechanism and a post seal sensor.

In order to improve our system & process we came across a few contradictions that didn't allow us to do so. As the problem was component misplacement as well as missing units in the carrier tape, we came up with the following contradiction:

If a robust detection system is put in place then the measurement accuracy will improve but intermittent missing units still happens (loss of substance) as well as Productivity loss due to additional step in the process and additional cost for the purchase of the items.

Improving parameter: Measurement accuracy (#28)

Worsening Parameter: Loss of Substance (#23) & Productivity (#39)

With these parameters we mapped the information back to the contradiction matrix and found the most applicable Inventive Principle to our problem was using Inventive Principle #10: Preliminary Action.

5.0 Solution

Preliminary Action fitted our problem well as it helped solve our problem of not having a specific location for the units to be placed into the carrier tape from the tray by the pickup arm, at the same time the internal vibration that was present when the carrier tape is being moved (feed) inside the tool was also drastically minimized and finally the redesign of the detection sensors was done so that false alarm due to sensor being blocked by dust is eliminated.

Preliminary Action means we designed a sort of fixture that ensured precision on the placement of the units from the tray to the carrier tape even though the mechanism was running on motors and pneumatics that was not a fully precise tool. The step made sure that at all times the parts will always be placed at the same end location even though there is a slight drift in the placement from the pick and place arm.

As for the vibration, the design of the tool was to having many small parts at certain vital locations of where the carrier was having some sort of activities and the problem was seen to originate from the parts where the carrier tape moved freely. The solution for this was to elongate the track of the tool so that all parts of the carrier tape are taken care of and the internal vibration reduced significantly. This helps with the intermittent issue of component misplacement.

The thru beam sensors that was designed for this tool had a flaw that it didn't take into account the build up dust/particles from the process that could potentially block the receiver or transmitter of the sensors and cause false alarm. The redesign eliminated the buildup of dust and eliminated false alarm due to this issue.

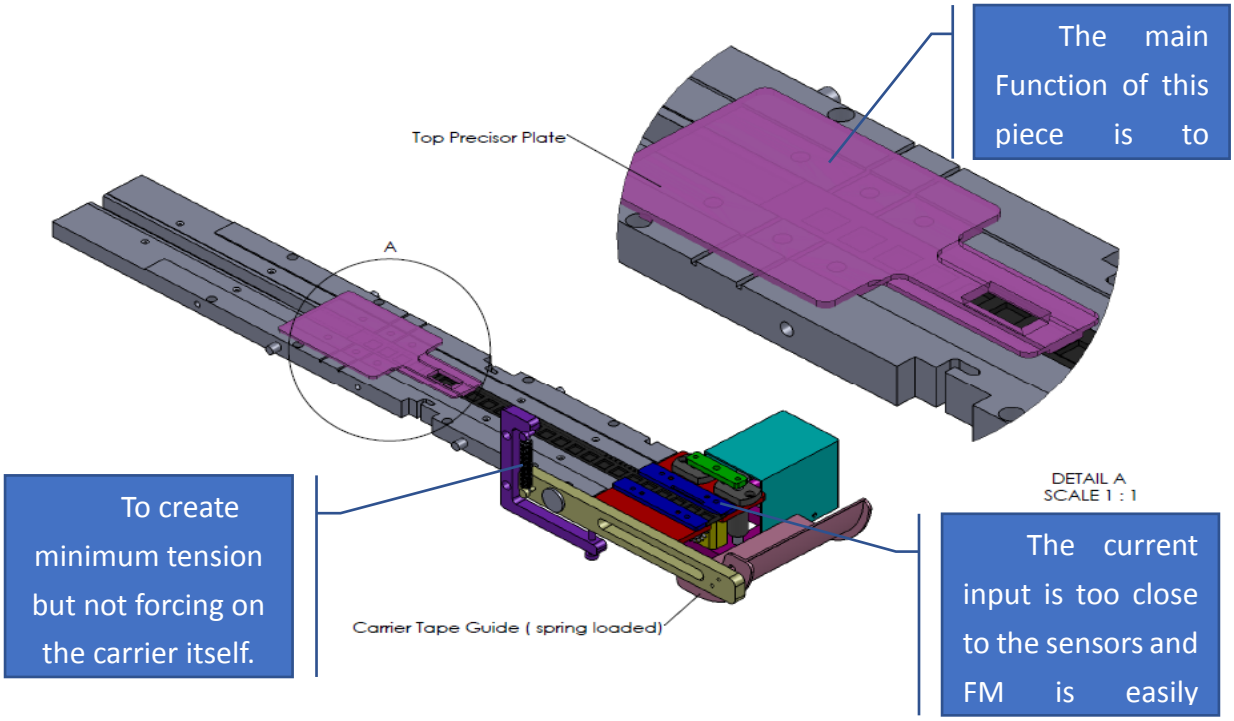


Figure 2. New Design of the X4 area

6.0 Results

This prototype redesign has been put in place in the factory on one tool and currently is under data collection mode. In its early stages we already see positive results of 0 false alarm trigger and so far we do not see any misplaced components and also any missing components. The tool handles about 50,000 units in a week.

The approximate ROI projection from the project is about USD600K within one quarter itself taking into account the number of tools and the upgrade cost as well as the number of units being manufactured.

7.0 Summary

Direct Observation in Lean is a very powerful tool as it triggers the mind to look to abnormalities as well as understand the exact problem and not rely on hearsay or hypothesis alone that may not be 100% accurate. DO also provide the observer the high level information on where the potentially problem can be or is at. TRIZ on the other hand helps with understanding the way the tool works as

the Component Model is a great way to identify the interaction of the parts and its functions and at the same time provide idea on where to focus our efforts at.

With the help to Lean and TRIZ the intermittent issue that causes us customer excursions has been thoroughly examined and we have come up with elegant solutions that is providing very positive results during the data collection stage. The issue of having component misplacement, missing component that goes undetected as well as false alarm trigger area all addressed by our approach.

8.0 Acknowledgments

Intel Penang TRIZ team comprising of Nagappan Annamalai ; Paul Devaraj, Song Chia Li, Fred Chan and Angelia Ng as well as the module owners CT Ong, Jessey Yeoh. On top of all that I would like to also thank the Department Manager, CP Ooi and the entire management of Intel PG as they were open to the new idea and provided us the opportunity to test this out.

9.0 Reference

Contradiction Matrix from http://www.triz40.com/

TRIZ 39 Parameters from http://www.triz40.com/

Paper ID: 31

Vacuum Device Mechanism for Wafer Breakage Avoidance

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Abstract

The wafer breakage problem from Polisher machines is first analyzed using function analysis and Cause-Effect-Contradiction-Chain analysis to find the root causes and contradictions. The Inventive principles, Function and patent searches, and resource tools are used to generate multiple solutions for the problem.

This project developed a Vacuum Device Mechanism for Wafer Breakage Avoidance based on TRIZ systematic methods to solve Process-Equipment problems of semiconductor Polishing Process by minimally redesign the Polisher machines. In wafer polishing machines, vacuum status has been used to hold the wafer in position while polishing. Occasionally, the vacuum status is lost due to intrusion of liquid or gas into the gap between wafer and the holding block. It is necessary to maintain the vacuum status to hold the wafer properly in position. Failure to maintain the vacuum status will cause wafer to be thrown out and be broken or damaged.

To maintain vacuum status under the situation when the wafer and the chuck is constantly rotating is difficult and energy consuming as the vacuum line must enter the centerline of rotation and leakage of gas is common due to gaps between relatively moving parts.

This invention creates simple channels inside the holding block and uses the existing resources, rotational energy, to create and maintain vacuum status without any need to use additional vacuum line and energy.

The advantages of this invention include: 1) Simple implementation; 2) effective creation and maintenance of vacuum status without using any additional energy sources by taking advantage of existing centrifugal resources; 3) Solved the problem of wafer breakage.

Keywords: Equipment improvement, TRIZ, Polisher, Vacuum Device

1. Introduction

▪1.1 Background

In depression years, it is the way to broaden sources of income and reduce expenditure for enterprise surviving. Increasing income must have a great quantity of resources invested in, but the revenues form broadening sources could not transform to profit totally. However, decreasing expenditure could be changed to profit. Cost of equipment operating has high percentage of total cost in technique industry. Furthermore, the percentage of the semiconductor industry is higher than three quarters. Therefore, to raise the utilization of equipment has a big impact on the high technique industry.

The present study investigated that the cost of material and manufacturing from co-operative semiconductor company is about 650~700 U.S. dollars/one piece, and the polishing process was half of the whole cost. Besides, polishing process was a main influence on yield and quality of wafer. In addition, it happened more than a hundred times of wafer breakage, and one piece was lost ten thousand NT dollars on average. The company hence lost more than one million NT dollars a month and more than ten million NT dollars a year. According to the results of the paper, the loss was reduced substantially.

In the research, the frequency of breakage was reduced due to redesign the parts of polishing machine. To redesign parts shipped substantially over maintenance after machines broke down and inspection before machines broke down, and solved the root problems directly. Additionally, the concept developed and integrated with TRIZ (Theory on Inventive Problem Solving) to become a systematical model for revising equipment and modifying design. It was the core contribution of the paper.

Several studies have suggested the process of maintenance issues. Jay Lee [1] developed the idea a little further. The research suggested a series of systematical innovation methodology based on the process of identifying parameters, diagnosing, preventing and improving form Jay's survey. In this study the main stress fell on shifting emphasis away from monitoring and dealing with the failure to avoiding the phenomenon radically. As mentioned above, the original open-loop conception of designing equipment became the closed-loop. As the Figure 1 indicates.

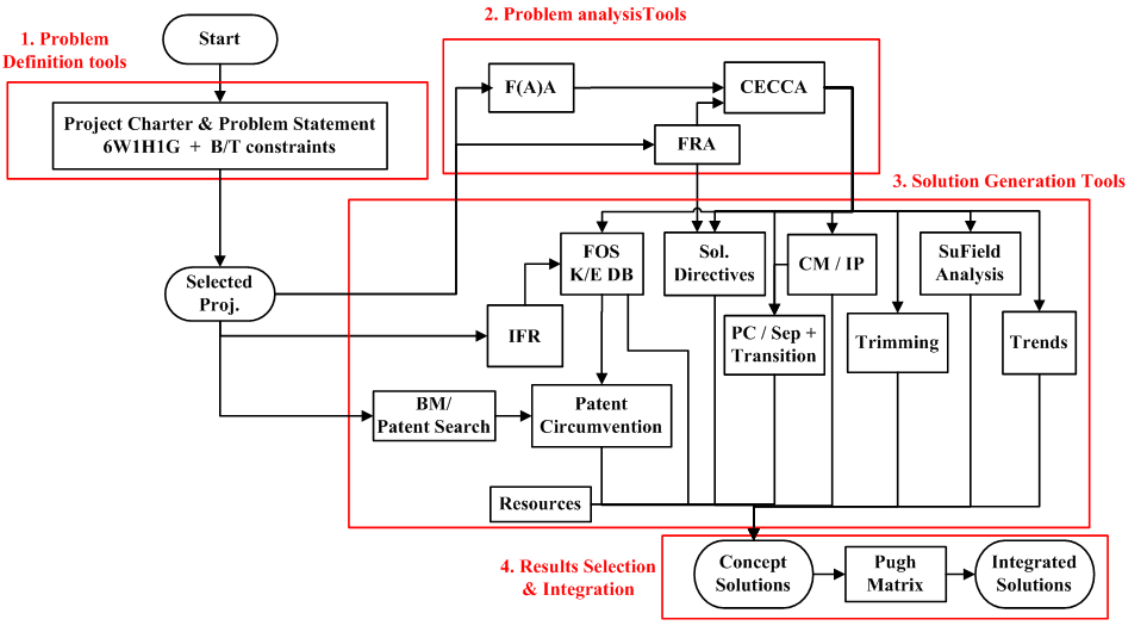

Figure 1. Solution concept map. (Resource: D. Daniel Sheu)

▪1.2 Problem Statement

The purpose of polisher is fine/rough wafer polishing. The operation character is to manufacture the necessary flatness of wafer surface (Total Thickness Variation, TTV), and strip the defects like abrasion, smudges and pit from the front-process. The side of physical equipment can be schematized as Figure 2.

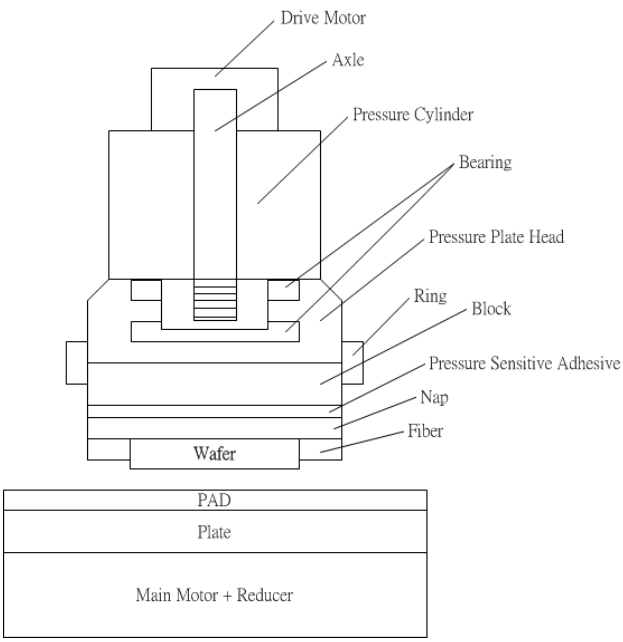

Figure 2. The side view of Polisher.

The causes of breakage problem are wafer-slipped and wafer-pulled. Wafer-slipped means there is not enough suction between template and wafer, then wafer is thrown during spin polishing. Besides, wafer-pulled means the instantaneous force exists between pad and wafer, and pulls the wafer from the template then hits other wafers.

As was mentioned above, the research raises the technique to analyze processes and solve problems. Component function analysis table has shown according to the function of components in the process as Table 1.

Table 1. Component function analysis table.

Component	Sub-component	Function	Parameter
Pressure Cylinder	Drive Motor	Provide force	Pressure, Rotational speed
	Axle		
Pressure Plate Head (PP Head)	Bearing	Stabilize force	Horizontal
	Ring	Hold block	
Block		Put template on block	Horizontal, Diameter
Template	Pressure Sensitive Adhesive(PSA)	Stick nap	Materials
	Nap	Suck wafer	Materials
	Glass Fiber	Hold wafer	Materials, Thickness
Wafer		Target	
Pad		Polish wafer	Materials, Pattern
Polish Plate		Put pad on plate	Horizontal
Main Motor + Reducer		Turn around plate	Horizontal, Rotational speed
Slurry		Polish wafer	Composition, Temperature, Flow
DI Water		Dilute slurry/cooling	Temperature, Flow

2. Methodology

This paper is composed of TRIZ theory and maintenance of equipment issue, and focus on using function analysis and Cause-Effect-Contradiction-Chain analysis. The rest of this paper is organized as follows. Function analysis is used to understand the relationship between components, and analyze useful, harmful, ineffective and excessive functions are in Section 2.2. Besides, Section 2.2 offers the research finds the conflict between operations of components further, and regards the negative function as core point, then uses Cause-Effect-Contradiction-Chain analysis to identify Technical Contradictions and Physical Contradictions. Finally the article is based on conflict analysis that using Contradiction Matrix to map Inventive Principle, and trying to solve contradictions are enclosed in Section 2.3.

▪2.1 Function Analysis

The main purpose of FA (Function Analysis) is to separate the components from the system, explores the relationship between components and identifies which component provides main function or auxiliary function. And which is target? Which are tools? Which functions are useful and which functions are harmful? These harmful, ineffective and excessive functions are called Negative Function. We could find "contradiction" from negative functions between other functions and focus on root problem quickly. Function analysis would be separated three steps: component analysis, interaction analysis and function model.

Component analysis is a hierarchical structure which develops from top to bottom, and to decompose existed components from engineering system and sub-system. First, to establish a hierarchical component structure is named for a system and to identify the main function and target from the system, then to define other components. Finally, to find the super-system existed in the full system. We could fill the components in the Table 2. as below.

Table 2. Component Analysis Table of Polisher

Engineering System: Polisher Main Function: Pad polishes Wafer

Engineering System Components	Super-system Components
Pressure Cylinder	Slurry
Pressure Plate Head(PP Head)	DI Water
Pressure Sensitive Adhesive(PSA)	
Nap	
Glass Fiber	
Wafer	
Pad	
Polish Plate	

We use function relationship matrix for finding relationships from components two by two and see Table3. To fill the "+" if there is an interaction between the components, else fill the "—" if there isn't any interaction in the interaction analysis table. Then, to remove the components which are without any interaction relationships in the system.

Function Model is the component analysis after analyzing the relationship between components within the system. Now, we also define the functions in the system. There are four functions and Basic Function (B) represents the functions to act the object, Auxiliary Function (Au) represents the functions between the components within the system, Additional Function (Ad) represents the functions between components and super-system, the foregoing are Useful Function (U). Besides, Harmful Functions are harmfulness between components in the system.

We also give the degree for these functions which are Insufficient (I), Excessive (E) and Normal (N), and fill these relationships between the components in the function model table as Table 4. Then we will illustrate the components and functions as Figure 3.

Table 3. Functional Relationship Matrix for Polisher

	Pressure Cylinder	PP Head	PSA	Nap	Fiber	Wafer	Pad	Slurry	DI water
Pressure Cylinder	X	Drive	—	—	—	—	—	—	—
PP Head	+	X	Push	—	—	—	—	—	—
PSA	—	+	X	Stick	—	—	—	—	—
Nap	—	—	+	X	Stick	Suck	—	—	—
Fiber	—	—	—	+	X	Hold	+	—	—
Wafer	—	—	—	+	+	X	+	—	—
Pad	—	—	—	—	Abrade(E)	Polish Suck(E)	X	+	—
Slurry	—	—	—	—	—	Polish	Push	X	+
DI water	—	—	—	—	—	—	—	Dilute	X

Table 4. Function Analysis Table for Polisher

Function	Object	Category	Rank	Performance Level
Pressure Cylinder				
Drive	PP Head	U	Ax	N
PP Head				
Push	PSA	U	Ax	N
PSA				
Stick	Nap	U	Ax	N
Nap				
Stick	Fiber	U	Ax	N
Suck	Wafer	U	B	I
Fiber				
Hold	Wafer	U	B	I
Pad				
Abrade	Fiber	H		
Polish	Wafer	U	B	I
Suck	Wafer	H		
Slurry				

Polish	Wafer	U	Ad	I
Push	Pad	U	Ad	N
DI Water				
Dilute	Slurry	U	Ad	N

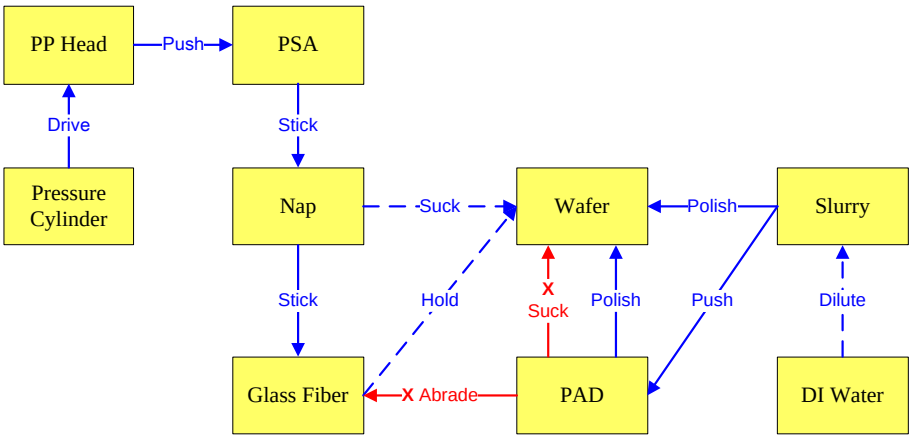

Figure 3. The FA of Polisher.

▪2.2 Cause -Effect Contradiction Chain Analysis

After finishing the function analysis, we use Cause-Effect Contradiction Chain Analysis (CECCA) to find the key disadvantage problem. According to the contradiction between components and components or components and functions when problem occurring, we would get to the bottom of the situation to find the key problem and analyze which engineering parameters to improve, then find the worse and improved parameters. We use the contradiction matrix to find the inventive principles. If key disadvantage will be solved, other negative factors will be eliminated.

The research finds that there are two reasons for wafer having slipped off the template. One is not enough force that the template holds the wafer, and the pressure plate head rotates to bring the centrifugal force to make the wafer slipped during polishing. Another is that pad sucked the wafer and took away from the template. Using CECCA and illustrating the problem as Figure 4.

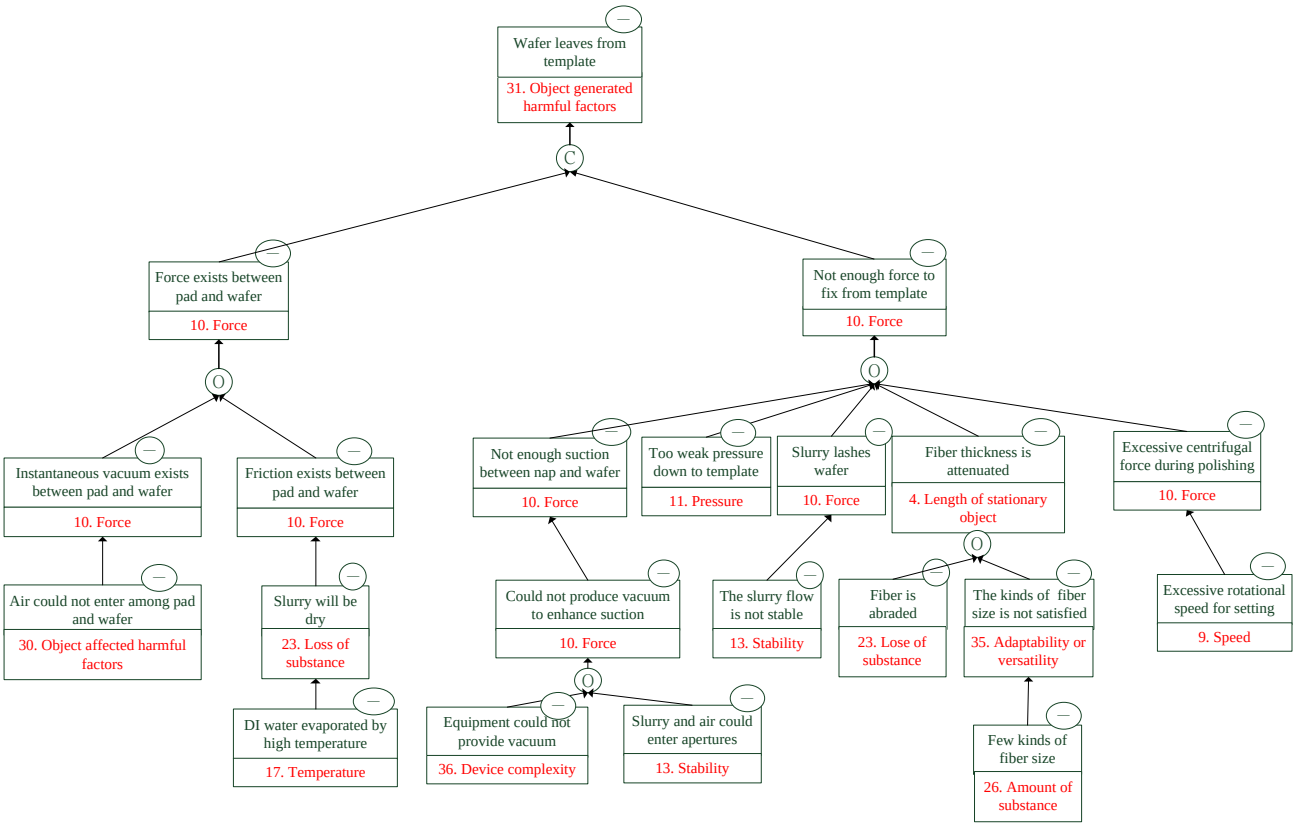

Figure 4. The Overview of CECCA diagram.

Red words in the above figure represent the engineering parameters to belong to the problem. We analyze the two reasons of wafer breakage in detail as below.

First, there is a sucking force between the wafer and pad during polishing because of the air couldn't enter the space and produce the vacuum status transitorily. The other is that the friction was exited among the wafer and pad. The temperature was going up because friction and to evaporate the water from the slurry to produce stickiness. The friction is an important force for polishing, and more friction has faster material removal rate. Therefore 「Force」 and「Productivity」are conflictive, and the part of CECCA is Figure 5.

Another reason is that the template had not enough force to hold the wafer. There are five sub-reasons; we reduce the rotation speed to avoid the wafer slipped off the template, but also reduce the material removal rate. If we add the force of pressure plate head to enhance the template to hold the wafer, and it maybe crushes the wafer. These are shown「Force」and「Productivity」have the conflict. We could add equipment like as vacuum line to produce the vacuum, but it is too expensive and complex from original, and as a result that 「Force」and「Easy of manufacture」are conflictive. Finally, in fact, to hold the wafer is the glass fiber that is fixed the skirt of the template, and there are only three sizes (three different thickness) of glass fiber to hold the wafers to fit different removal heights of wafers. Pad would also polish the glass fiber during polishing, and fewer sizes of glass fiber is

convenient to prepare, but can't to remove any kinds of removal heights. This is the conflict between 「Length of stationary object」 and 「Ease of operation」.

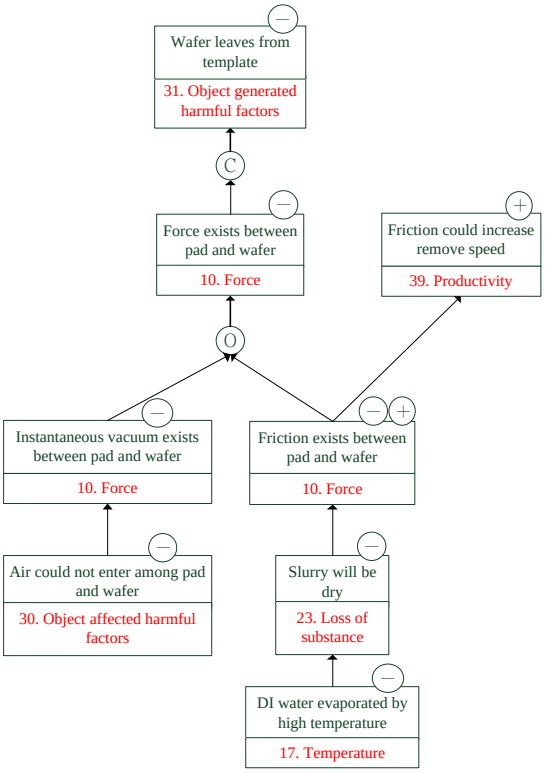

Figure 5. The pulling force of CECCA diagram.

Furthermore, the more normal force produced by the pressure plate head polishes wafer quickly, but too much normal force would cause wafer breakage. The conflict is 「Force」 and 「Productivity」. The final sub-reason is that slurry and air would enter the interface between nap and don't produce the vacuum status between them during polishing. If we re-design to add the equipment, it also has some problems as it's difficult to pass through the pressure plate head and put the vacuum line inside, and many gaps could cause non-vacuum status. Besides, rotation would make the vacuum line mixed. In order to add the equipment for vacuum is too expensive, so 「Pressure」 and 「Ease of manufacture」 are contradictions. This part is shown as Fig. 6.

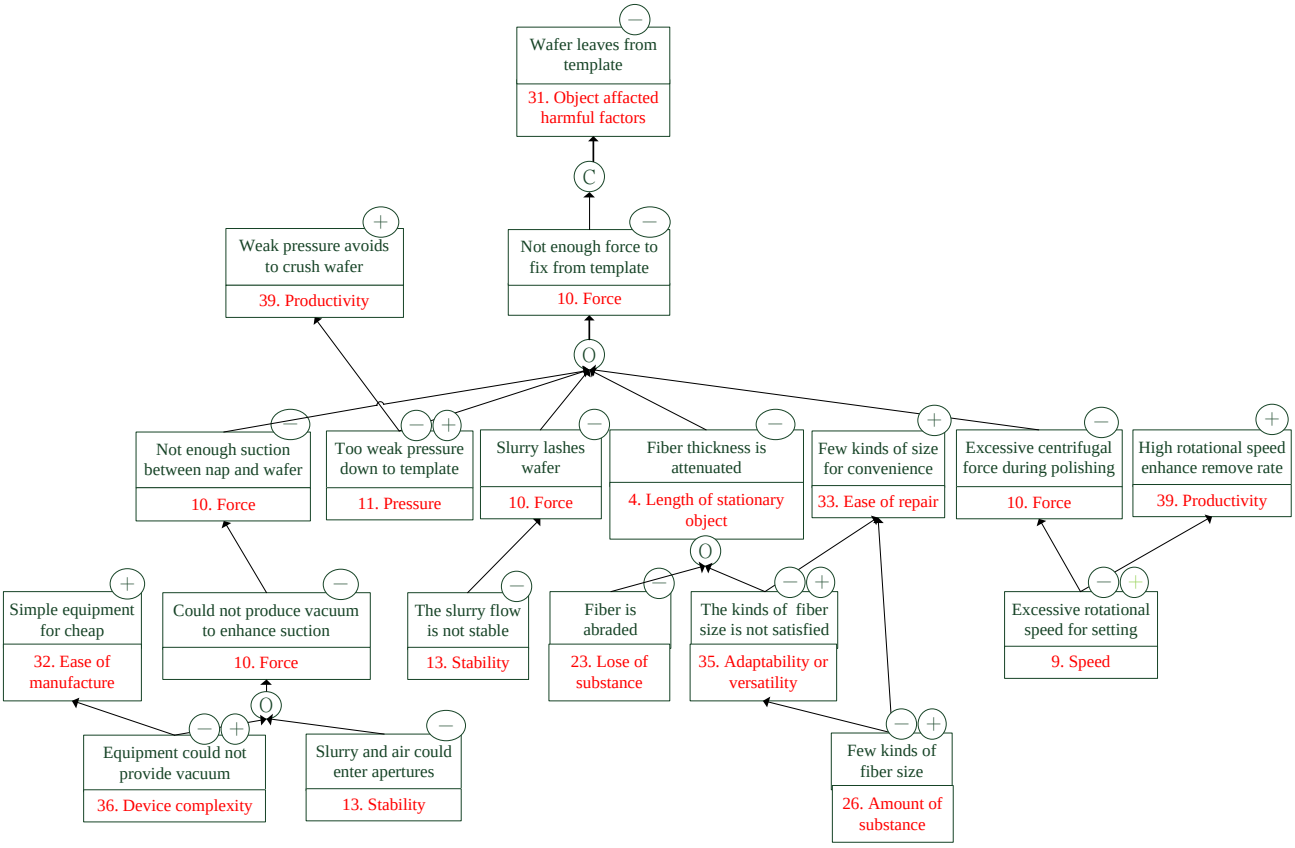

Figure 6. The centrifugal force of CECCA diagram.

▪3.3 Contradiction Matrix and Inventive Principles

Following the above conflicts and add similar contradiction parameters to make interaction. We use Matrix^{+} to find the inventive principles as Table 5 and to think about possible generic/specific solutions as Table 6.

Table 5. Wafer breakage on inventive principle selection. (Matrix^{+})

Worsen / Improve	39. Productivity	32. Ease of manufacture
10. Force	35-Parameter Changes 28-Mechanics Substitution 3-Local Quality 10-Preliminary 37-Thermal Expansion 25-Self Service 5-Merging	15-Dynamics 18-Mechanical Vibration 35-Parameter Change 6-Universality 37-Thermal Expansion 16-Partiacl or Excessive Action 10-Preliminary Action
11. Pressure	10-Preliminary Action 40-Composite Materials 25-Self Service	2-Taking out 1-Segmentation 35-Parameter Changes

	24-Intermediary 14-Spheroidality-Curvat 35-Parameter Changes 37-Thermal Expansion	17-Another Dimension 16-Partial or Excessive Action 31-Porous Materials 8-Anti Weight
Worsen / Improve	33. Ease of operation	32. Ease of manufacture
4. Length of stationary object	10-Preliminary Action 25-Self Service 26-Copying 2-Taking out 12-Equipotentality 37-Thermal Expansion	17-Another Dimension 3-Local Quality 15-Dynamics 13-The Other Way Round 4-Asymmetry 31-Porous Materials 10-Preliminary Action
35. Adaptability or versatility	15-Dynamics 24-Intermediary 3-Local Quality 4-Asymmetry 28-Mechanics Substitution 14-Spheroidality-Curvat 13-The Other Way Round 26-Copying 10-Preliminary Action	10-Preliminary Action 13-The Other Way Round 29-Pneumatics and Hydraulics 31-Porous Materials 1-Segmentation 28-Mechanics Substitution 24-Intermediary 5-Merging

Table 6. The generic/specific solutions of wafer breakage

	Generic Solution	Specific Solution
11. Pressure(+) 32. Ease of manufacture(－)	31. Porous Materials	Passing through template and block and using centrifugal force to exhaust the air or water
11. Pressure(+) 39. Productivity(－)	40. Composite Materials	Changing other materials of nap to enhance suction
35. Adaptability or versatility(+) 32. Ease of manufacture(－)	24. Intermediary	Adding sticky materials between template and wafer
4. Length of stationary object(+) 39. Productivity(－)	37. Thermal Expansion	Pre-heating the wafer to fit the glass fiber
35. Adaptability or versatility(+)	28. Mechanics Substitution	Using other way to stuck wafer to replace the nap

32. Ease of manufacture(－)		
10. Force(+) 32. Ease of manufacture(－)	35. Parameter Change	Changing the rotation speed of polishing

To summarize the possible solutions, we use the 31th inventive principle 「Porous Materials」 above Table 6 to solve the fewer vacuum between nap and wafer.

3. Results

We have many ways to add the vacuum force. The basic solution is to pass through the pressure cylinder, axle, bearing, pressure plate head, block and template, and use the air-extracting apparatus to draw out the air in order to suck the wafer. But it is not a best solution that the rotative pressure plate head would reduce the vacuum effect, hence we use 「Resource」 concept to utilize centrifugal force from rotation to draw out the slurry and water within vacuum line. The way doesn't need any outside resource and could transform "useless" resource to "useful" resource.

To base on foregoing thinking, the solution is to drill a hole in template and block and use centrifugal force during rotation to exhaust the air or slurry for producing suction to suck the wafer (It is necessary to add the one-way check valve on the outside of a hole to avoid air of water backflow and avoid wafer moving for non-vacuum status that the beginning of polishing).

We show the prototypes of the side-view and bottom-view as below. The coarse black line is the hole/ passageway for simulation. The figure 7 is the sketch. The figure 8 is a picture of reality block drilling and the sign is location for drilling.

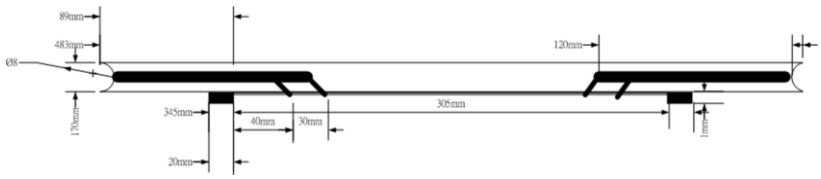

Figure 7. The sketch for drilling of block.

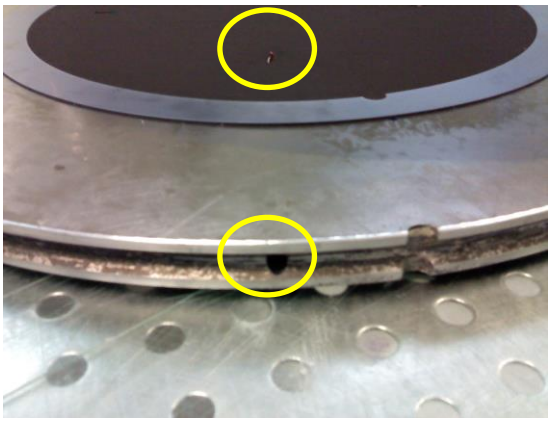

Figure 8. The picture for reality drilling .

4. Conclusions

This paper had applied for a patent for this design, and using the systematic innovation process to solve the problems completely when equipment or components were in processing and switch to other industries. The characteristic is to use the centrifugal force produced by rotation to prevent wafer breakage and do not need to increase any vacuum resource.

The case is a semiconductor company and focus on wafer reclaim. After using the design, the frequency of wafer breakage is from 30~40 times/month to less than 10 times/month and save nearly 0.13 million US dollars/year including the cost of drilling and buying check valves.

The systematic problem solving provides a quick and effective way for industries to solve manufacturing problems, and to raise the quantity and quality of the patents and would assist to circumvent patents for increasing industry competition.

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Paper ID: 33

New method for TRIZ-contradictions

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Abstract

I have developed new method to work with contradictions for technical tasks solutions.

Existing TRIZ methods proved to be effective in engineering process, however they have several flaws as well. Offered method is characterized by a completely different approach to the solve contradictions. New method allows to take engineering process to a new level as well as to fix existing flaws of the TRIZ.

The core of my method is the following:

- work with contradictions is systemized and applied in two steps;
- The first step is to identify WHAT is needed to change for finding a new solution. I suggest 10 system aspects to solve it as well as a list of systematic actions (operations) for my method;
- The second step is to identify HOW to make changes. It is proved that the task is successfully solved if systematic actions change the object in time or space.

The method I suggest is a very simple tool that allows to get the list of all possible solutions. In general engineers can work with this method using standard colledge knowledge.

In 2012 will be published a book in Russian witch will describe the method in details.

Keywords: TRIZ, contradiction, system, aspect, space, time.

My method is focused on TRIZ instruments development to work with contradictions. I offer new algorithm and method for a device improvements. The method and algorithm are based on a system approach.

The theory of inventive problem solving (TRIZ) is an efficient means of creating technical solutions. The most well-known and widely used tools of the TRIZ are methods of solving technical contradictions (TC) and the selection table (matrix) of such methods for a specific problem (the TRIZ understands a TC as a situation in which an attempt to improve one characteristic of the system leads to deterioration of some other characteristic).

Historically, the list of TC resolving method is the first TRIZ tool; it was formulated more than forty years ago.

As the TRIZ was developing, new working tools came into existence, including methods of solving physical contradictions (PC) (the TRIZ understands a PC a situation in which a problem sets opposite (mutually exclusive) requirements to the object or some part of it). Genrikh Altshuller, the author of the TRIZ, wrote (Altschuller G.S., Filkowskij G.P. (1975)), 'Introduction of the concept of physical contradictions has allowed us to overcome difficulties that appeared during analysis and caused by vague nature of technical contradictions ... There is no inventive problem unless there is a physical contradiction. ... Manipulations with the methods *(TC elimination methods - P.Sh.*) had lasted for a quarter of the century, but when the ARIZ-71 (*ARIZ – the algorithm of inventive problem solving, the most complex and powerful TRIZ tool - P.Sh*) appeared, it effectively devaluated the list and the application table of the principal methods: the ARIZ-71 envisages an in-depth analysis until the

physical contradiction is found. Usually the problem is solved at this stage, but even if it is not solved, it is better to repeat and deepen the analysis rather than to return 'closer to the surface', i.e., to technical contradictions'.

Since the inventors of the TRIZ subsequently paid less attention to the TC resolving methods, they have not been improved; therefore, they still have the disadvantages that emerged so long ago, and that look so obvious today, i.e. (Shimukovich P.N. (2009), (Shub L. (2007)):

- method selection rules have not been determined for elimination of a specific contradiction;
- the methods are not structured;
- the methods have different levels of generalization;
- the list of the methods is insufficient;
- list of the methods does not meet the current requirements.

Due to presence of the above disadvantages, the TC resolving methods have been subjected to just criticism.

Development of a new method has been oriented to creation of a TRIZ working tool that would be free from the listed disadvantages and would have high heuristic power. The following initial preconditions lay the basis for the PN-method:

- note has been taken of the TRIZ inventor's opinion regarding the need to maintain and develop the devaluated TRIZ tool: all the 40 TC resolving methods as well as the related table (matrix) were excluded from the study;
- it is suggested that any soluble creative problem be pursued up to the stage of formulating the PC (the stage at which contradictory requirements related to the same object to any part thereof are formulated) followed by subsequent resolving of this contradiction. At the same time, the PC resolving methods contained in the classical TRIZ have been subjected to critical analysis, and two methods only out of 11 have been left: resolving of spatial contradictions and resolving of temporal contradictions. The philosophic basis for such a decision is that space and time will always be the origins of any physical interactions (everything happens in time and in space). Space and time act as arguments everywhere, and can never be functions of anything, including each other. Other properties, parameters and characteristics of objects and processes usually depend on such arguments as 'space', 'time' and other arguments;
- the terms 'TP' and 'PC' have been replaced with a new term – a TRIZ-contradiction. This term is used because the TC has been removed from circulation, while the term 'PC' looks strange to the experts, since in fact there is nothing physical about it. The use of the term 'TRIZ-contradiction' immediately orients users of the PN-method to searching for an innovative solution by means of TRIZ tools on the basis of resolution in space and/or in time of contradictory requirements to an object to any part thereof;
- the processing algorithm of contradictions has a systematic basis that allows applying a new structuring scheme. Aspects of the systematic approach are used as a basis for method structuring. Since the systematic approach is an area of research methodology, which is based upon considering an object as an integral multitude of elements within aggregation of relations and links between them, a complex study of the object as a system is carried out from the standpoint of those aspects.

In accordance with the general method scheme, a fragment of reality to be created or modified within any problem is presented as the following scheme (fig. 1).

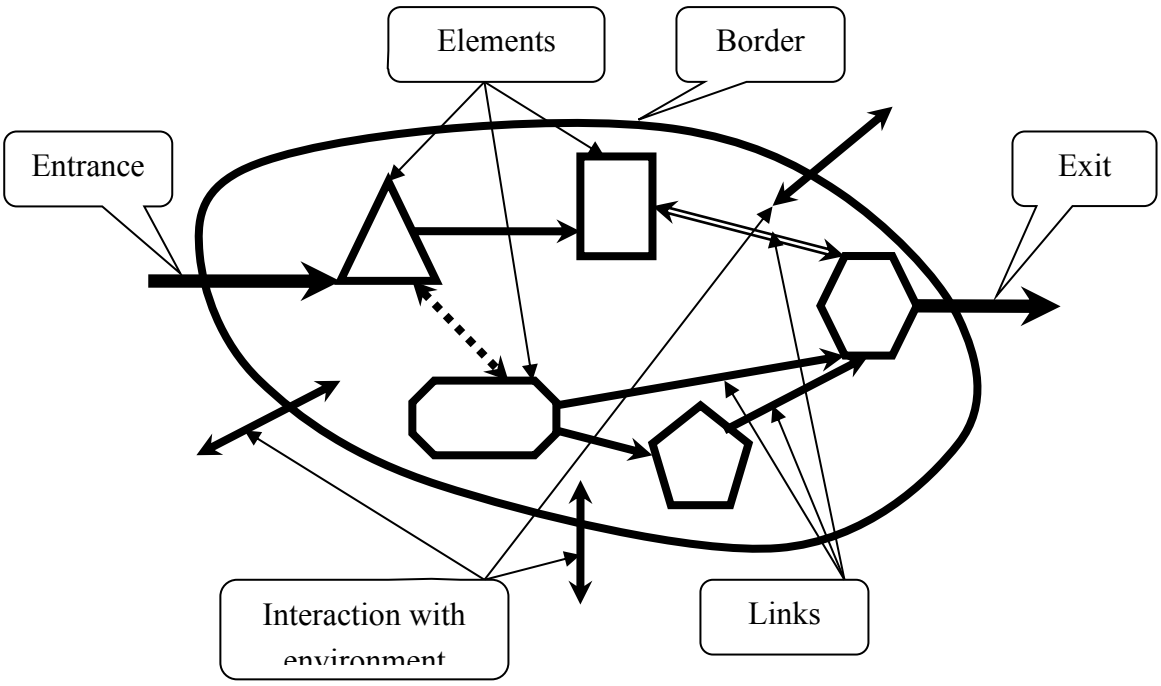

Fig. 1. Graphical presentation of the system.

The system is created for a certain specific purpose determined by its entrance and exit. The system contains various elements connected via various links. A combination of the elements and the links form the system structure. Since the system shows emergence behavior, its integral properties are not a mere sum of properties of the system elements; certain integration properties are present. In order to achieve the state of stability, the system aims at balanced use of the resources available in it. The system has certain dimensions determined by its border. Interaction between the system and the environment takes place through this border. The environment may produce certain control impacts upon the system, and the status of the system in the environment can be traced on the basis of information generated by the system. Such control impacts may also emerge inside the system. The system undergoes certain changes in time, so that it is possible to distinguish between its past, present and future.

A full idea of a system that would comply with the above description can be obtained by considering the system according to the ten aspects known in the systematic approach (fig. 2):

- target system aspect (1A);
- elemental system aspect (2A);
- structural system aspect (3A);
- functional system aspect (4A);
- resource system aspect (5A);
- integration system aspect (6A);
- communication system aspect (7A);
- historical system aspect (8A);
- control system aspect (9A);
- information system (10A).

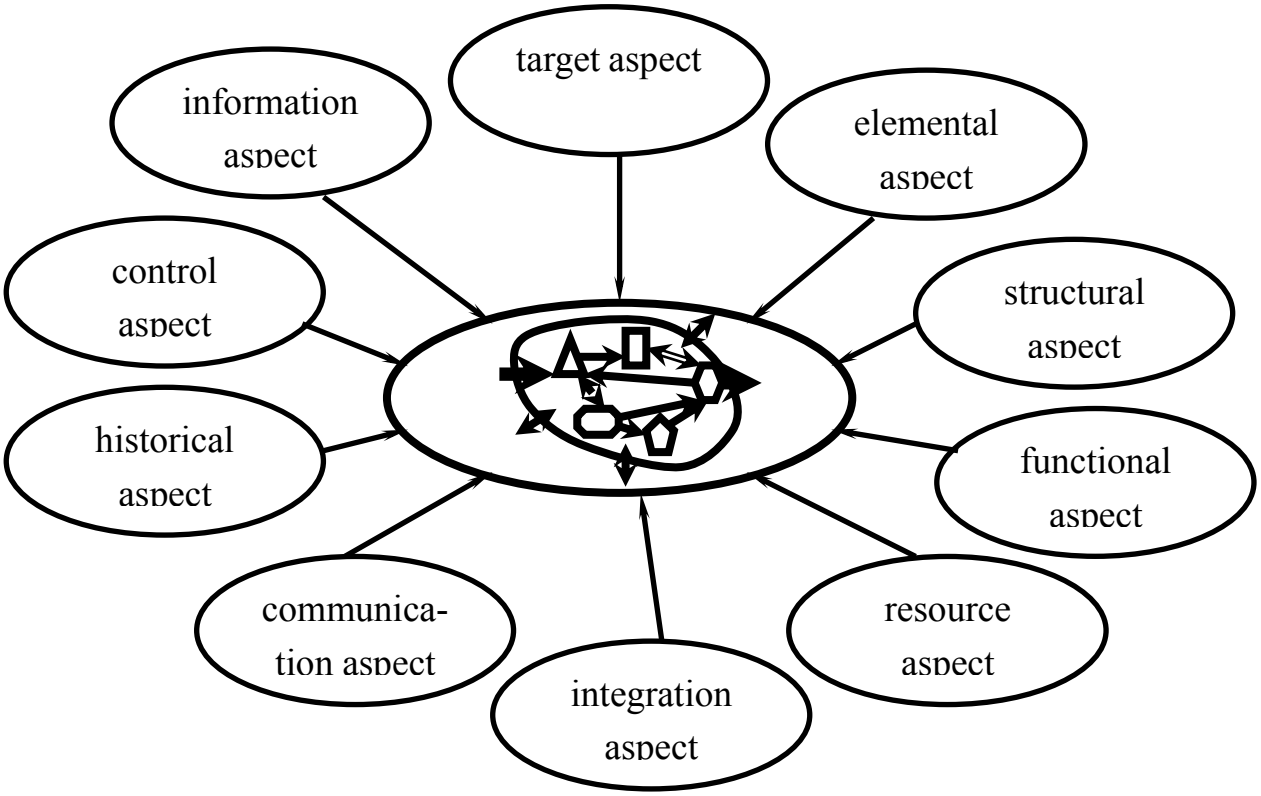

Fig. 2. System aspects.

(The digital and alphabetical indices that have been introduced above, and will be used thereafter, are intended to simplify application of the method. The use of those indices will be shown later when examples are considered).

Accordingly, any object or system containing a TRIZ-contradiction can be studied in the ten aspects within the PN-method. Based on such a study, the TRIZ-contradiction can be formulated, and then the required result can be achieved by means of resolving this contradiction in space or in time.

The list of key actions that form the essential part of the method and must be performed during its realization is shown below. An action from the below list necessary for resolving the contradictions is found via sequential search through the system aspects:

- within the target system aspect:
- change the problem specifications (C1);
- replace the object with a model (C2);
- select and formulate a new target (C3);
- within the elemental system aspect:
    - change and admit to examination new properties of the element or any part thereof (E1);
    - change parameters of the properties (dimensions, shape, weight, symmetry, homogeneity, color, temperature, etc.) (E2);
    - change position of the element (E3);
    - change the number of entrances and exits of the element (E4);
    - replace the element with a different one, with alternative properties or a different physical basis (E5);
    - represent the element as a system (E6);
- within the structural system aspect:
    - remove links between the elements (STR1);
    - add more links between the elements, including links that contain intermediate elements (STR2);
    - change the type of link, including changes of physical basis (STR3);

- break the link to insert an intermediate element (STR4);
- change parameters of the link (force, direction, etc.) (STR5);
- add elements to the system (STR6);
- remove elements from the system (STR7);
- optimize arrangement of the system elements, including the order of arrangement (STR8);
- represent an element in the form of a link (STR9);
- represent a link in the form of an element (STR10);
- convert the system structure into the hierarchic one (STR11);
- convert the system structure into the homogenous, isotropic one (STR12);
- convert the system structure into the heterogeneous, anisotropic one (STR13);
- represent the system in the form of an element (STR14);

- within the functional system aspect:
  - improve ideality of the system, optimize its functioning (F1);
  - replace a function with an alternative, opposite one (F2);
  - change the sequence of performance of the function (F3);
  - change function parameters (F4);
  - identify and use functions of the system constituents (F5);
  - use auxiliary, additional and neutral functions accompanying performance of the key function (F6);
  - convert the function from a discrete one to a continuous function (F7); conversion inversion (F8);
- within the resource system aspect:
  - use or create reserves of real or potential spatial resources (R1);
  - use or create reserves of real or potential temporal resources (R2);
  - use or create reserves of real or potential substance resources (R3);
  - use or create reserves of real or potential energy resources (R4);
  - use or create reserves of real or potential data resources (R5);
  - use or create reserves of real or potential system resources (R6);
  - use or create reserves of real or potential combined resources (R7);
  - use human resources (R8);
  - optimize consumption of resources (R9);
- within the integration system aspect:
  - obtain a system effect on the basis of object or substance integration (INT1);
  - obtain a system effect on the basis of impact integration, i.e., integration of substance, energy and data flows in various combinations (INT2);
  - obtain a system effect on the basis of splitting substance, energy and data flows (INT3);
  - obtain a system effect on the basis of resource application; on the basis of conversion of harmful resources into useful ones (INT4);
- within the communication system aspect:
  - change the type of link between the system and the environment (K1);
  - change the number of links between the system and the environment (K2);
  - change parameters of links between the system and the environment (K3);
  - change the system borders (K4);
- within the historical system aspect:
  - determine the system status on the basis of an S-curve (IST1);
  - create a forecast of linear development of the system (IST2);
- within the control system aspect:
  - create a control subsystem and include it into the feedback chain (UPR1);
  - change the status of the controlled subsystem via control variables (UPR2);

- change the purpose of the control subsystem (aim the subsystem at solving stabilization problems, performance of programs, tracing and optimization) (UPR3);
- change the control subsystem (in terms of its physical basis, feeding method, composition, internal links, inertia behavior, etc.) in order to optimize functioning of the controlled subsystem (UPR4);
- transform a control action on the basis of integration of substance, energy and data flows; conversion inversion (UPR5);
- transform a control action from a discrete one to a continuous action (UPR6); conversion inversion (UPR7);
- transform a control action from a static one to a dynamic action (UPR8); conversion inversion (UPR9);
- change the number of control impacts directed towards one controlled subsystem (UPR10);
- change the number of controlled subsystems covered by one control subsystem (UPR11);
- enhance control impact via feedback development (UPR12);

- within the information system:
  - increase the volume of inter-system information (INF1);
  - transmit external system information to modified environment (INF2);
  - change the type of information (INF3);
  - change the carrier of information (INF4);
  - change properties of information (INF5);
  - change the type of information processes (INF6);
  - change parameters of information (INF7).

The term 'resolving contradictions in space' means performance with relation to an object containing such contradiction of one or more actions from the list shown below:

- change coordination and juxtaposition of objects or their parts (1Pr);
- change size of objects or their parts (dimensions, shape, volume, cross sections) (2Pr);
- change distances between objects or their parts (3Pr);
- change angles between various directions (4Pr);
- change the number of coordinates describing the position of an object or any parts thereof (including the transition 'point – line – plane – volume) (5Pr);
- change symmetry of an object or any parts thereof (6Pr);
- change homogeneity and isotropy of an object or any parts thereof (7Pr).

The above actions must result in transformation of the object from one steady static state into another steady static state.

The term 'resolving contradictions in time' means performance with relation to an object containing such contradiction of one or more actions from the list shown below:

- change the period of time during which an object or any parts thereof stays in a certain condition (1Vr);
- change the sequence according to which an object or any parts thereof stays in a certain condition (2Vr);
- divide or combine in time the moments when certain actions are performed with relation to an object or any parts thereof (3Vr);
- change the sequence of performance of actions (4Vr).

The above actions must result in following:

- transformation of the object from one steady static state into another steady static state. Such states will be either divided or combine on the temporal axis;
- transformation of the object from the current state into a new dynamic state described by rhythm and velocity of object parameter change.

The following actions are to be taken in order to implement the method:

- analysis of a reality fragment and identification of a problem situation. The problem situation can be determined as a somewhat vague, unclear and poorly understandable impression that seems to be giving alarm signals, 'something is amiss, something is wrong'. The TRIZ also describes such a situation as an administrative contradiction;
- identification of a object that is in the center of the problem situation and must be improved to eliminate the situation;
- presentation of contradictory requirements to the object and formulation of a TRIZ contradiction;
- analysis of the identified object in terms of the known aspects of the systematic approach and creation of permissible options of actions aimed at resolving the TRIZ contradiction;
- synthesis of a new state of the object by means of the selected actions during their performance in space and/or in time; resolving of the TRIZ contradiction on the basis of such synthesis;
- selection of one preferable options out of permissible options.

The following comments shall be made to the above described algorithm.

The number of the above-listed actions is quite high, and for that reason, the method may appear to be ponderous and difficult to put into practice. But this is not so. The method has a hierarchic structure that allows achieving a relatively way to solution. Besides, thanks to the rigid structure, it is quite easy to build a compute model of the PN–method.

Implementation of the method algorithm also allows for the use of experience of many generations of inventors that is concentrated in the TC resolving methods: they (the methods) are included into the PN-method as its constituents. For example, the PN-method envisages performance of action E5 (replace an element with another one with alternative properties or a different physical basis). The list of the TC resolving methods includes method No.29 'application of pneumatic and hydraulic constructions'. It is obvious that the method E5 has a more general character and includes application of both pneumatic and hydraulic constructions and of other technical solutions with varying physical basis, including those that may be unknown at the moment, and will only emerge in the future. Selection of an alternative solution is only limited by the problem specifications, by professional knowledge of a person trying to find that solution, and by that person's aptness to creative thinking.

Similar arguments could be offered with relation to other TC resolving methods.

The following simple examples from the field of crane construction will demonstrate practicability of this method. These solutions are available already, and the PN-method helps 'find' them again.

Example 1. The boom must be long to lift loads to great heights, but it must be short so that the crane could travel conveniently: this is a well-known example of contradictions from the TRIZ textbooks. The above contradiction is resolved by creating a telescoping boom. In accordance with the PN-method, the said TRIZ-contradiction can be resolved via the actions E2+1Vr (different boom length at different periods of time). In an expanded and complete form the same conversion can be described using the actions STR6+STR3+1Pr+1Vr (fig. 3, fig. 4).

Fig. 3.

Fig. 4.

Example 2. The boom adapted for telescoping is heavy. TRIZ-contradiction: boom sections must be made of some solid material to enable telescoping, but they must not be made of solid material, since this would cause the boom weight to increase considerably. Application of the actions E2+7Pr results in obtaining the boom sections with holes located in the area that is not loaded and does not have any impact on telescoping (fig. 5). The actions STR12+6Pr+1Pr give us a boom whose telescoping part has a lattice extension (fig. 6).

Fig. 5.

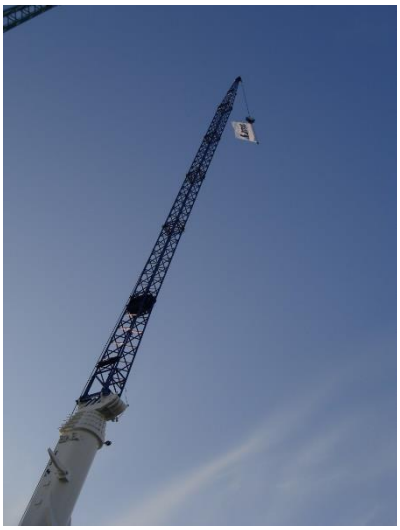

Fig. 6.

Example 3. In order to be able to lift high loads, the crane must have a high moment of stability to prevent it from tilting. One of possible solutions would be suspending heavy counterweights to the slewing unit of the crane. TRIZ-contradiction: counterweights must be used to generate the moment of stability, but they must not be used in order not to overload the crane chassis and to ensure its

controllability during traveling. Performance of the actions E3+ 3Vr brings us to the obvious solution: the counterweights are attached to the slewing unit of the crane during crane operation (fig. 7), while they are removed while the crane is traveling (fig. 8).

Fig. 7.

Fig. 8.

Conclusions:

1. The PN-method is an efficient tool for solving innovative problems. Thanks to its inherent properties, it is applicable to various problems that used to be solved by means of the aggregated TRIZ tools, i.e.: TC elimination methods, PC elimination methods and other TRIZ tools. The above data enable one to state that the PN-method can simplify application of the TRIZ.

2. Since the systematic approach by definition ensures overall consideration of processes or phenomena, this method enables one to miss no options for the necessary solution. In particular, the method offers the information aspect that is new for the TRIZ, and the control aspect is provided with an entirely new content.

3. The systems theory is a general subject in the curriculum of higher schools. Accordingly, any university graduate will be potentially prepared to perceive the suggested method of solving creative problems. We suppose that on the basis of this method, the TRIZ would also be enthusiastically accepted by those who consider themselves scholars of applied and fundamental sciences.

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Constructing FMEA, TRIZ, and AHP Methods for Innovative Product Improvement Decision Process of an Automobile Vehicle Stamping Product

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Abstract

The situation of the recent growth of technology improvement, market competition toward products has caused a short product life cycle, forcing enterprises to produce new products and services to satisfy market demand in efforts to maintain competitive advantage. Traditional product research and development processes for new products lack integrated design improvement and evaluation tools. Therefore, how to develop a product design improvement model to meet customer demand and select the optimal product improvement/corrective solution is the study background and motivation for this research.

This paper integrates three major methods, including the FMEA (Failure Mode Effective Analysis), the TRIZ, and the AHP (Analysis Hierarchy Process) as a system to build an evaluation model in the product improvement phase of the product design and development stage. This research first uses the FMEA method to predict the possible quality problem and the potential risk on the customer side. Then, we investigate the Risk Priority Number (RPN) in each production process to find the necessary corrective action. After the definition of the top major failure item in design, we use the TRIZ as the reference tool for the product improvement analysis. Finally, an expert questionnaire sets the target and sums up each criterion for the design improvement to build a hierarchy relationship between decision criteria. The AHP method is used for criterion pair comparison to come up a better design concept.

This paper uses the automobile stamping product as an illustration to provide a relevant decision-making reference for R&D personnel, and sets up an integrated model of innovative product design improvement.

Keywords: FMEA, TRIZ, AHP, Innovative Design, Automobile Vehicle Stamping.

1. Introduction

High customer expectation of product demand requires that the product have a continuous improvement plan. Occasionally, the original product design does not satisfy customer request. Therefore, the product needs a complete improvement plan of the original design. Once the initial product has been finalized in the CAD (Computer Added Design) process, the production line is scheduled with the necessary machine parameters and required facility.

This study investigates an integrated, innovative product concept and development model to design a complete and proper process that differs from the traditional method. This study uses the FMEA (Failure Mode Effective Analysis), the TRIZ (Theory of Inventive Problem Solving), and AHP (Analytic Hierarchy Process, AHP) as the corresponding procedures.

To estimate the system performance after the initial design, the FMEA is a useful tool in quality improvement, which includes three major functions: First, to identify and estimate the product/process failure risk and effectiveness; second, to conduct corrective action to terminate or reduce the reoccurrence of failure in the process/product; and third, to document the process (Carlson et al., 2001). Using the FMEA tool, the previous quality issue could be the knowledge management input and feedback to the product initial design, by which the production can decrease product difficulty and consider the feasibility of mass production with low failure.

However, introducing a new product into the market without substantial consideration is not the best policy. If the new product is not successful, all effort is wasted. Therefore, the enterprise must control the latest market trend and develop the latest production technology for greater usage of resources, and to implement a proper production plan to meet the market needs. In summary, both FMEA and innovation are basic elements to achieve customer satisfaction in a industry in order to obtain a better final result and reach maximum profit. The goals of the methodology are shown as follows:

1. Use the FMEA to investigate and find the potential risk issue in product production. Analyze and concentrate on the major failures from RPN and define the improvement solution.
2. Use the TRIZ as the method in the product improvement concept generating to provide innovation direction and insight.
3. To address customer demand and product target specification, the AHP method is used evaluate and figure out the final decision with qualitative and quantitative analysis in order to develop the final product improvement model.

2. Literature Review

This study uses the FMEA, the TRIZ, and AHP as the corresponding procedures and refers to relevant research to provide multiple applications and the theory base for this study.

2.1 FMEA (Failure Mode and Effects Analysis)

FMEA is a failure preventative method that can detect design weakness and perform a self-review of the system and machine before operation is completed. FMEA can also serve as a serial corrective action. The method first identifies and estimates the failure mode effectiveness in the production/process then identifies and terminates the re-occurrence of failure and provides a corrective action, and lastly, documents all the process needs. This method compiles all quality customer feedback into a knowledge center as feedback for the product design before the final design stage. This process can reduce cost and production difficulty (Teoh & Case, 2004).

The FMEA is based on the APOLLO plan (1960) and provides complete cooperative and certified tooling in the initial stage. Most high technology industries have recently begun to apply this method to the internal progress of a new project. Three American automobile companies have built TS-16949 certification, including the FMEA as the necessary estimate of new project progress. This certification combines the five core tool of APQP, SPC, MSA, PPAP, and FMEA. Some customers have requested high technology industries to introduce the FMEA into their production line as a system estimation process to prevent potential risk and to enrich the reliability of product quality.

2.2 Theory of Inventive Problem Solving (TRIZ)

The TRIZ is a problem solving theory with the same meaning as the Russian TIPS (Theory of Inventive Problem Solving), created by Genrich Altshuller and his group to solve the innovation problem (1946). The original TRIZ concept is the result of the investigation of more than 20 million patents and a detailed study of 40,000 innovation patents. They found a model to solve the problem in principium by summing this core principle and conducting the basics of the TRIZ.

The major concept of the TRIZ innovation is a paradigm shift, which is the basic working model of TRIZ (Mann, 2002). The procedure is described below and its concept structure is shown in Figure 1:

Step 1: Generic problem with abstract and transfer to the standard model of the TRIZ.

Step 2: Generic solution with abstract and transfer to the standard answer of the TRIZ.

Step 3: Use this TRIZ standard answer to reply to the specific question.

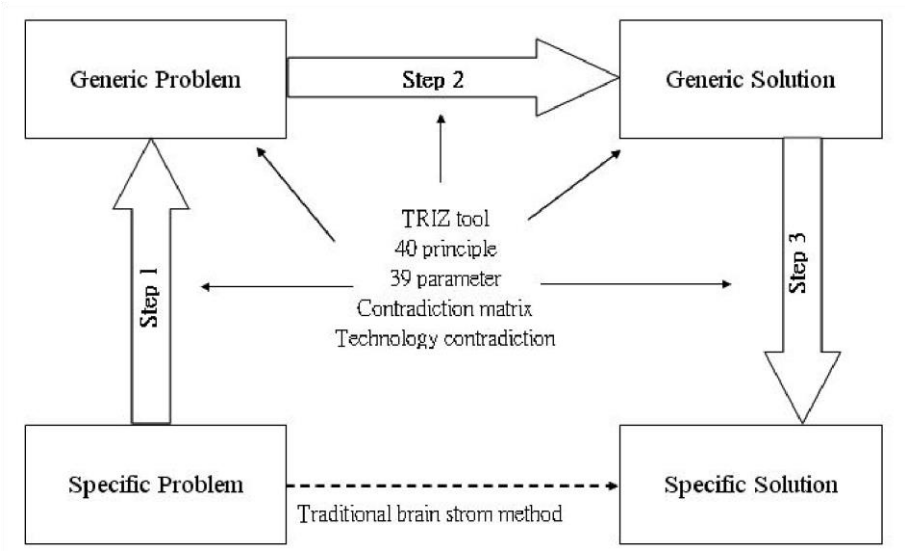

Figure 1. TRIZ concept structure.

2.3 Analytic Hierarchy Process (AHP)

The AHP, the Analytic Hierarchy Process, is a multi-principle estimate method, begun by a study in the U.S. Department of Defense Contingency Planning Problem in 1971 (Saaty, 1980).

3. Research Methodology

This study is divided into three major parts: First, the FMEA launches a detailed analysis of product quality in the requirement phase. The FMEA method then calculates the RPN value of the study target. The high RPN value is then quarantined as the corresponding corrective and improvement item. The TRIZ is conducted to extend the system. The contradiction matrix and the system analysis method are used to find the product improvement solution. After all the solution and improvement programs have been extended, the AHP is used to select the final feasible solution. The detailed flow chart is shown in Figure 2.

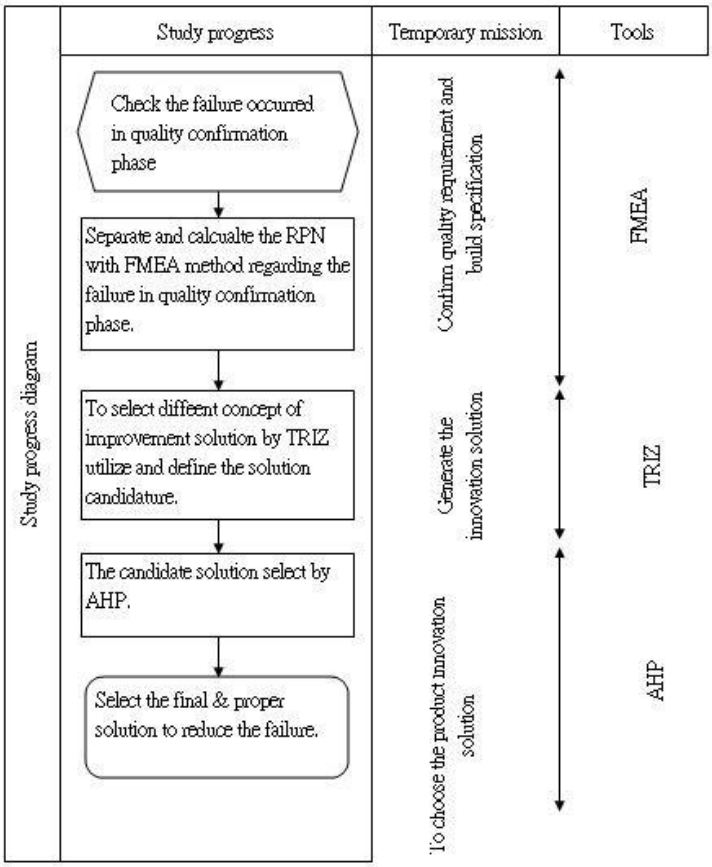

Figure 2. Research process flow.

3.1 FMEA Analysis

The FMEA serves as the past quality issue experience and feedback to the current process improvement and initial design phase. In this study, the FMEA was listed in detail and performed the initial product development phase with the cross-functional team to build the FMEA for each division. First, the product performs the functional quality test. All product processes should be in the FMEA list and can be traced to the corresponding function and their risk analysis. After building this FMEA table, the cross-functional member with all corrective action that has been implemented should be checked. After the severity/occurrence and detection data have been filled up in the FMEA list, the RPN values then can be calculated.

3.2 Generating an Innovative Improvement Solution

In this stage we use the 39 engineering parameters, 39x39 contradiction matrixes, and 40 innovation principles from TRIZ to develop an innovation improvement solution before mass production of the product.

This study applies the TRIZ concept flow shown in Figure 3 to generate product concepts. Based on the pattern transfer method to transfer the limited condition with the problem in a specific 39 engineer parameter, the transfer segregates the engineer parameter into two groups: the "feature to change" and the "undesired result." This work formats the original problem before referring to the 39x39 contradiction matrix to determine the corresponding principle code. After collecting the code, it is referred to the 40 innovation principle to consider a possible improvement method.

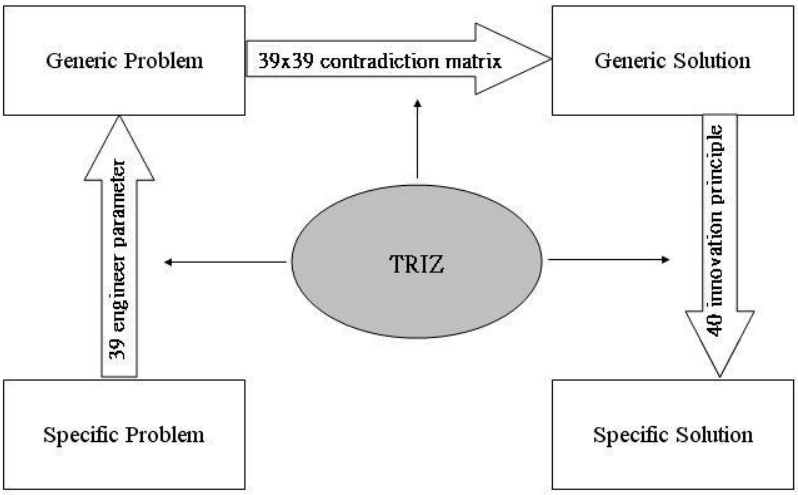

Figure 3. Concept generating flow of TRIZ.

Each column of the 39x39 contradiction concept has a maximum of four principle codes. Occasionally one innovation principle code can conduct several innovation concepts. At this time, the current study uses the concept constitute list to rearrange the concept in various contradiction situations. According to this description, 3x4x2x2=48 concepts exist. Several concepts cause confusion. This study uses the traditional ECRS method to eliminate, combine, rearrange, and simplify to manage these concepts, as detailed below:

1. Eliminate: If the innovative concept is a well-known technology, cancel this concept.
2. Combine: Combine the tiny concept as one. If the technology supports the two concepts, the concept can be combined.
3. Rearrange: If the repeat concept or non-match occurs between the concepts in the concept constitute, the concept constitute is avoided.
4. Simplify: Simplify the complex concept.

3.3 Improvement Solution AHP Structure

Based on the previous concept result, this study estimates the improvement solution and the judgment principle. Saaty suggested that the component for each layer should not exceed seven items;

otherwise, the next layer should be set up for reasonable comparison and consistency (Saaty, 1990). This study shows the relationship of components and the major structure. Figure 4 below shows the details:

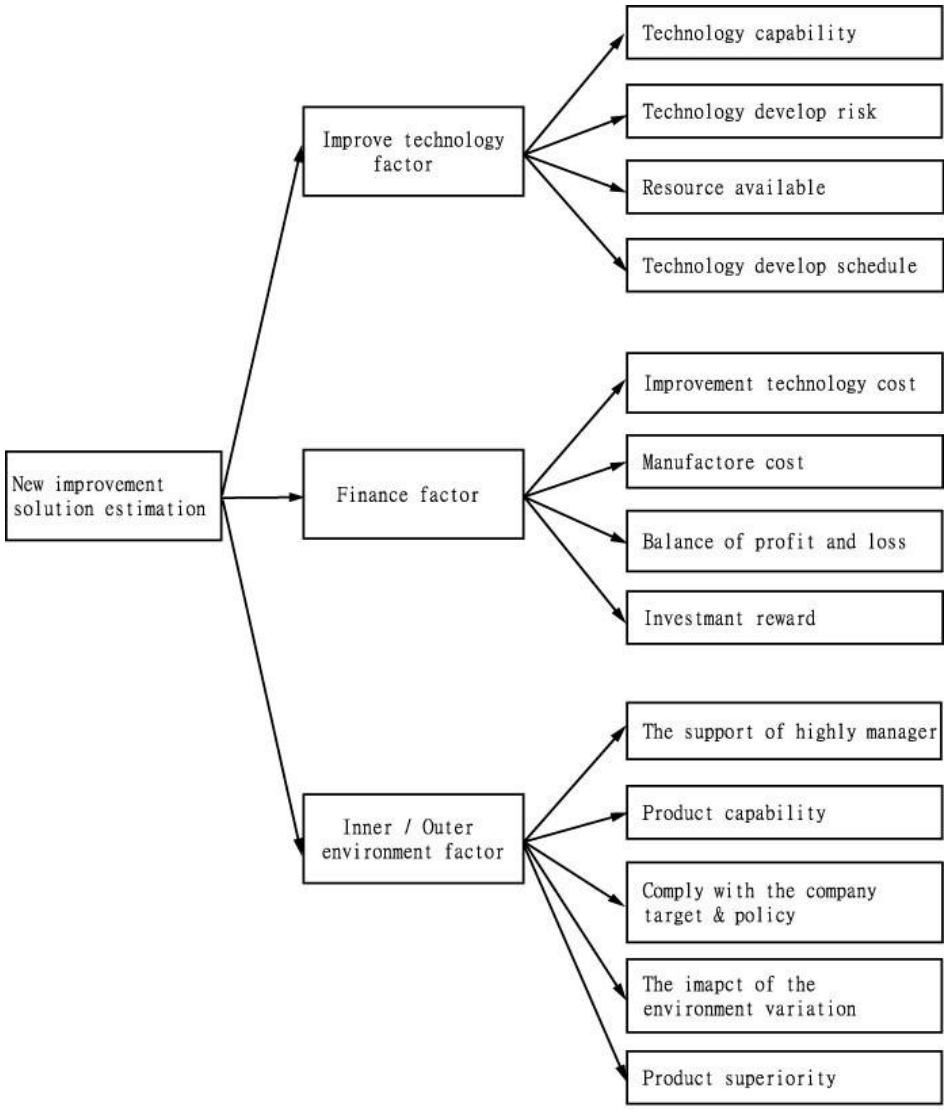

Figure 4. Improvement solution AHP structure.

From the TRIZ process and the ECRS principles, the collected concept is placed in the top layer as the beginning hierarchy of AHP structure. Each concept for the improvement solution is built as a different subsystem to extend the analysis. Every subsystem develops as a hierarchy analysis and design for the specific questionnaire for the specialist to fill in.

This study uses ExpertChoice software to calculate the pairwise comparison matrix eigenvector and uses the eigenvector to calculate the weighted eigenvalue. According to the calculation result and analysis, the total score defines the solution priority.

4. Case Study

As a result of the increased worldwide vehicle market, automobile part supplier chains have put more strength into quality innovation. Some components are not critical, whereas others are. Because every car has a head lamp on the front, the head lamp is a critical component. This study discusses the head lamp key component: the light shield.

Inside the head lamp structure is a major component to protect the bulb and mask the light with the correct reflection to obey the government prescription. The bulb mask is called the light shield. By 1980, more than 500 lumen head lamps had been used on automobiles. Head lamps strongly reflect the light and cause accidents with other cars or pedestrians. The U.S. government has concluded that extra light from the head lamp that causes third party damage will be strictly punished.

This light shield is the major function to control light reflection. Normally, the head lamp reflects light from the light bulb capsule on the multi-reflector and projects the light. However, the bulb is a common design for the vehicle. The head lamp will differ according to different car shapes. Therefore, how to control projected light with the correct optical axis and cause the correct beam pattern is a critical problem for head lamp design. The light shield is a beam pattern control component that can mask unnecessary light from the capsule and conduct the correct light on the multi-reflector to project the correct beam pattern.

In this study, the target is the light shield component that begins with the quality test in the initial process phase and certified by the quality assurance division with critical functional performance. The RPN is checked for high value to attempt and reduce the RPN value as the improvement solution. The improvement concept is extended by the TRIZ to find the proper and recommend improvement concept. These concepts are used to conduct and design the expert questionnaire. The questionnaire data is collected and calculated, and the AHP method is used to calculate the recommended solution as the final improvement solution. This is the flow for this study.

4.1 Quality Certification in FMEA

The new light shield program is from the customer design center, developed in the factory, and certified in the quality assurance examination. In the examination, the QA division found the critical issue occurred in the LEG dimension and derives from the second stamping process. After checking the FMEA value and reviewing the product phenomenon, the critical LEG dimension did not comply with the customer drawing. According to the customer assembly line request, the LEG width dimension is the necessary control item in the head lamp assembly process. The LEG width did not follow specifications, and the light shield cannot insert into the dog house on the reflector, similar to Figure 4-1 below. The non-conforming component is out of specification and the dimension is a failure

at 18 mm. If the light shield cannot be assembled on the head lamp; therefore, the major function of the head lamp has failed.

For this reason, the customer requested that the LEG dimension follow the drawing and comply with the tolerance 15 mm +0.3 /-0. The RD team and QA team also checked the 3D drawing data to detail check with the original dimension specification. The customer request is double-confirmed with the original design division and the manufacture division. The dimension details and the comparison photos are shown in Figure 5 below.

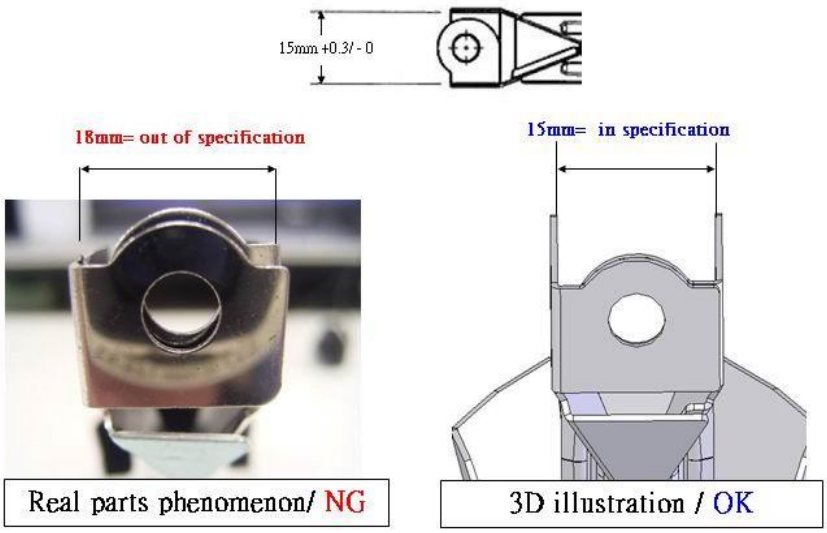

Figure 5. Part dimensions comparison.

After the QA division checks the real parts dimensions within the FMEA process. The FMEA exhibits the LEG dimension with a high RPN value and the customer requests that the RPN value should not exceed 120. However, we found the RPN value is 280, which means this type of failure needs to improve in product performance. Please refer to Table 1.

Table 1. The FMEA process table.

POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
(PROCESS FMEA)

Part No.	VxxxxX-1xxxxx4-AA	FMEA Number	Axxxx-FE
	0	Prepared by	Mr. xx, Mr. xxxx, Mr. xx, Exx, Wxxxxx
Part Name	Cxxx Fxxxx Light shield	FMEA Date	2010/12/7 (REV) 1
Process Responsibility	Production/QA/Engineering/QC/Maintenance	Rev. Date	1900/1/0
Core Team	Mr. xx, Mr. xxxx, Mr. xx, Exx, Wxxxx		

Process Function / Requirement	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s) Mechanism(s) of Failure	Occur	Current Process Controls	Detec	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	Sev	Occ	Det	RPN
2-2 Forming & lettering stamp - 2nd stamp	Improper Machine set up	Incorrect dimension	8		Incorrect or missing parameters	2	Set up correct parameters	2	32							
	Incorrect stamping method	Incorrect LEG dimension	8		Non -complete attached stamping	7	Visual check	5	280							
	Tool wron	appearance fail	6		Poor tool maintenance	2	Set up tool maintenance procedure	2	24							
	Burred on tool	Scratch	6		No clearing in tool	2	Wing blow tool and visual check	2	24							
	Dry film remove not clean	Dry film melting	6		Poor operation	2	Visual inspection	2	24							
2-9 Inspection	Dimension failure	SC failure	5	◇ SC	Cup or leg or spot welding failure	3	SC control	2	30							

According to the FMEA table and the real parts analysis, the QA division found the variation factor of the LEG dimension in the inner board and outer board did not fit together and was not robust when combined. If these two boards cannot attach completely, the LEG width dimension would be unstable and out of specification. Thus, the critical problem for improvement is to ensure that the inner and outer boards attach completely. Once these two boards can be completely combined, the LEG width dimension satisfies the customer's request. In summary, the FMEA value and the real parts analysis result provide the real root cause of this failure and the improvement direction to ensure the specified LEG width. This result can construct a concept for improvement.

4.2 TRIZ Improvement Concepts

The new light shield program has been developing in the factory and in quality assurance examination; the QA division found the critical issue occurred in the second stamping process after they performed the reliability test. According to the analysis result, the improvement concept is to ensure that the inner board and outer board can combine completely. Based on this concept, the TRIZ was used to generalize several concepts for the improvement solution idea. Before summarizing the improvement concept, there are several limitations of the LEG area from customer feedback.

1. Cannot add an additional device. If the additional device can be removed, it is not included.
2. Need to guarantee that the bottom of the board is completely flat.
3. The inner board and outer board must be completely attached.

4. The fiducial center of the screw hold must reduplicate between each other.
5. The wall of the inner board and outer board must be vertical 90 degrees.
6. The combined board thickness must be 1.2 mm. Each board thickness is 0.6 mm.

According to the customer request, before using the TRIZ, these conditions must be met and the improvement concept developed. Thus, the conceptual idea of this improvement is to control the two boards and fix the robustness to ensure the width dimension specification. A cross-functional team meeting was held to determine the improvement concept with several divisions. In this meeting, the QA division gathered to discuss the essential problem. The problem was considered at length after reviewing different opinions from different divisions.

The description of technical contradiction in system one of the parameter has been improved and the other parameter is worsening. Several parameters conflicted with each other. After discussion, they found this to be a technological contradiction and also found the improvement concept using the 39x39 contradiction matrix. The major concept of improvement is to determine the improving parameters to distinguish the worsening parameters from the matrix. In the discussion, they found the improving parameter is length of moving object and shape, and the worsening parameters are volume of moving object and area of moving object. Please refer to Figure 6 below.

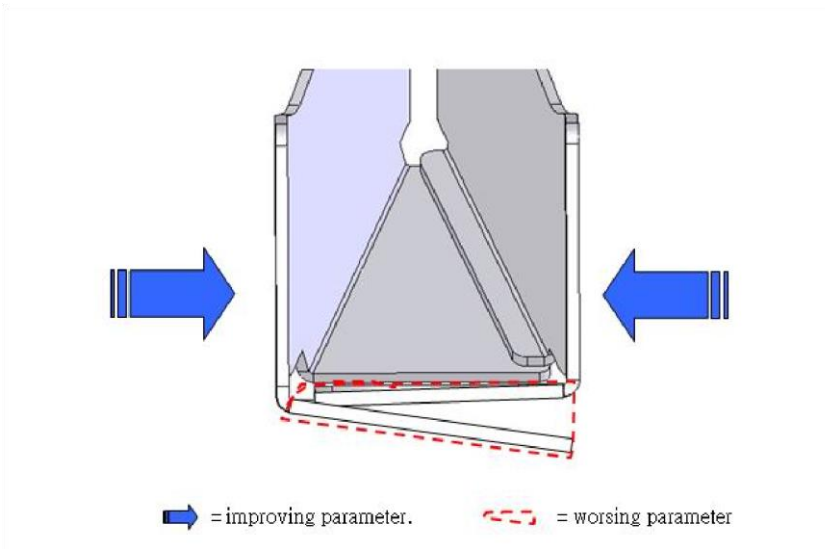

Figure 6. Analysis by problem essence.

From this illustration, the contradiction was used to find the improvement concept for this program.

According to the TRIZ contradiction matrix result and compared with the 40 inventive principles, they found eight principles to use, including Nesting (7), Transition (17), Asymmetry (4),

Transformation properties (35), Combining (5), Discarding and recovering (34), Asymmetry (4), and Prior action (10).

After collecting the concept, they used the ECRS method (Eliminate, Combine, Rearrange and Simplify) to summarize the concepts and to consider the improvement solution. From the final conclusion, they scrutinized their internal capability and resource feasibility for this improvement solution. The improvement solution was developed from the learning principle. The working principle for this improvement solution is Nesting (7), Combining (5), Prior action (10), and Discarding and recovering (34). For these available principles, they illustrated the trend chart to develop the improvement solution.

Improvement solution A:

The principle of Nesting and Combining was used to develop an improvement solution. The original concept is to design a rivet on the inner and outer board to respect the customer request limitation and also satisfy the drawing specification. Therefore, the rivet design was used to ensure completion of the requirement.

The left-hand side is the outer board and the right-hand side is the inner board. Both these boards can combine and fix robustness by the rivet design. Meanwhile, this design can satisfy customer demand. Please refer to Figure 7 below.

This is the real performance on the 3D CAD design figure. Please refer to Figure 8 below. According to this illustration, a rivet design was performed to fix the board and to ensure that the LEG dimension is within specification.

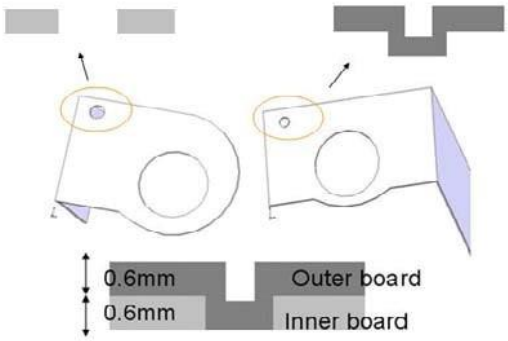

Figure 7. The rivet design.

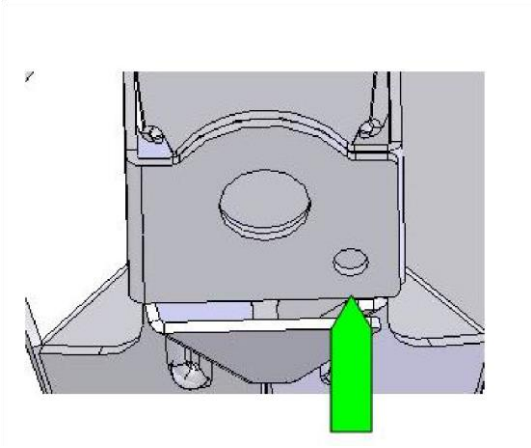

Figure 8. Improvement solution A.

Improvement solution B:

Because there are four feasible creative principles to create the improvement solution, another solution was developed to achieve the improvement requirement. Improvement solution B uses the removable component to make sure the LEG dimension is within specification and satisfies customer demands.

A removable steady rack was designed to hold the LEG dimension within specification. This rack could be removed in the assembly line. This improvement solution was developed by the creating principles 10 and 34. Please refer to Figure 9 below:

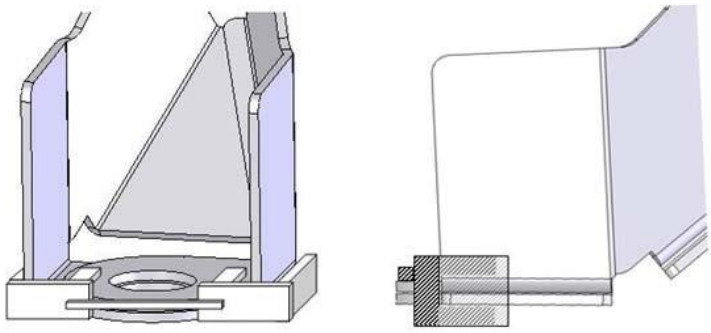

Figure 9. Improvement solution B.

4.3 Choosing the Final Improvement Solution

In the final phase, the AHP method was used to choose the final improvement solution. The result of all experts' questionnaires would fill in the AHP software, SuperDecisions, to calculate the

eigenvector and the eigenvalue. By doing so, the calculated pairwise comparison matrix can be used for selecting the final improvement solution.

AHP data analysis is mainly based on collecting the questionnaire results from 4 experts and calculating their average weight values. After the matrix consistence was confirmed, the AHP method was used to choose the final improvement solution. This means the product correction would match the company expectation and satisfy customer demands. In Table 2, the improvement solution A obviously shows a better result. In this case, the solution A was then launched and performed in the design phase and production line. The final improvement component was successfully applied to many new head lamp programs in this case.

Table 2. AHP calculation results.

No.	Evaluation Principle	Averaged Weight
1	Finance factor	0.142351
2	Improve technology factor	0.084186
3	Inner/Outer environment factor	0.106796
4	Balance of profit and loss	0.028997
5	Improve technology cost	0.053555
6	Investment reward	0.01756
7	Manufacture cost	0.042239
8	Resource available	0.017109
9	Technology capability	0.015392
10	Technology development risk	0.024342
11	Technology development schedule	0.027342
12	Improvement solution estimation	0
13	Comply with the company target & policy	0.012559
14	Product capability	0.0181
15	Product superiority	0.016063
16	Contribution to society	0.022685
17	Effect of environment variation	0.018919
18	Support of top manager	0.01847
	Improvement Solution A	1.90092
	Improvement Solution B	0.143242

5. Conclusions and Suggestions

This study integrates FMEA, the TRIZ, and AHP to establish a decision model for product improvement solution selection. Using this model, the decision of the head lamp key component product improvement solution has been logically discussed. An improper component or insufficient design frequently affects the whole production schedule for the new vehicle. The product improvement solution decision model could be used to reduce costs and improve the product.

This study combines FMEA and the TRIZ to break through the current improvement concept limitation. The improvement solution begins from the experience and professional quality control tool, FMEA, to construct an innovative concept by the TRIZ. However, TRIZ can also generate different solution ideas and potential possibilities. In the third phase of AHP calculation, we build a structure analysis hierarchy to discuss the different subjects based on the key point and find the reasonable and feasible solution for the company. The main benefits from this study are discussed and listed below.

1. Rapidly detect and find the problem and solution concept:

The failure mode effectiveness analysis is a very useful tool to troubleshoot failure and locate its position. By estimating the RPN, the problem can be evaluated and calculated. This process can reduce time and the man power waste. With professional experience from the cross-functional team member, each scope can be discussed in-depth.

2. Innovation to optimize product performance:

Innovation is the main competitive tool for an enterprise to survive in this rapidly changing business environment. Innovation theory gives enterprises the opportunity and the chance to compete and develop a useful improvement solution concept. This method is better for creating an innovation concept than trouble shooting. More innovation indicates that more products are optimized. This method shows promise of more enterprise usage in the future.

3. Structuralized and objective review:

Most previous development programs suffer a decision-making dilemma. The decision maker must occasionally consider many different scopes and cannot make objective decisions. This study distinguishes the method, defines hierarchy, and screens and categorizes the innovation concept factor. Each factor layer is defined in each principle. These principles quantify the important reference key index for the decision maker. For group estimation purposes, this type of process is also very suitable.

In order to validate our findings, the new improvement solution had been implemented and the new product is in mass production. Customer feedback indicated satisfaction with product performance. Based this study, a new process flow has been built in the company. The QA division used this method to solve many problems. They found the problem from FMEA and then distinguished the problem by using the TRIZ and using AHP to screen the best solution for the new project.

Although most of the main factors for the product improvement solution have been mentioned, some factors may not been discussed. In realty, a new product development process is usually very complex and occasionally proceeds very slowly in the initial stage. Therefore, most projects become very urgent when approaching the final stage. The designer can typically find the discrepancy

modification from the final confirmation because the original design concept was not judged with the feasible estimation and operation. Furthermore, some subjects cannot be discussed in this study because of protection of company business secrets. These include the finance structure, supplier chain relationship, and resource of the division, which draw the line of our study limitations. As in the real case study, once the limitation has been disclosed and more detail information is analyzed, this study becomes very useful to other enterprise to refer to. Future studies can extend and create multiple benefits from this model.

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Use TRIZ to construct the innovative service value chain of long-term care and medical system

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Abstract

To respond the tendency of rapid aging population and low-birth rate in Taiwan, It is an important issue for Taiwan government which should be strive to discuss and figure out the solution for how to provide a innovative service framework in order to satisfy the user requirements of Taiwan medical care system, and strengthen the service quality. The purpose of our research is to use TRIZ innovative method to construct the innovative service framework; therefore, it's possible to strengthen the service chain among cared people, care center and medical system, in order to improve the better service quality for cared people, and decrease parts of burden of related care jobs in medical system. By literature reviews and in-depth interviews to discuss the status of long-term care, estimate and analyze the existing care service mode. We also use TRIZ to develop the proprietary program interface of information system with innovative service under HL7(Health Level Seven) and the cloud structure. We are trying to build a complete, informative innovative service value chain which is combined among cared people and care center. Our research will combine care institutions and medical units to proceed case validation, and estimate efficiency of innovative service framework practically in order to be a basis for the operation of future medical care service mode.

Keyword: long-term care, community medical center, TRIZ, intelligent innovation, service value chain

1. INTRODUCTION AND BACKGROUND

It is going to be an aging society in Taiwan due to the fast growing of aging population, thus, medical treatments and effective utilization of healthcare resources has become the important issues that the government emphasizes. However, the direction of primary policy in Taiwan is predominantly based on providing basic care service by social insurance, combining national health insurance with social welfare measures, and matching the proper financial project to satisfy a demand for care requirements in aging society. Besides, there are still many defects under the policy

for long-term care from Taiwan government. For example, due to the lack of a perfect integrated project for nursing homes or retirement centers in Taiwan, the owners are not willing to pay more attention to operate their nursing homes or retirement centers, so that they are not able to respond to the actual situations.

For now, it is going to be an aging society in Taiwan, and the government gradually emphasizes the area of medical treatments. However, the direction of primary policy in Taiwan is predominantly based on providing basic care service by social insurance, combining national health insurance with social welfare measures, and matching the proper financial project to satisfy with the care requirements in aging society. But there are still many defects under the policy for long-term care from Taiwan government. For example, due to lack for a perfect integrated project for those nursing homes or retirement centers in Taiwan, those owners would not like to pay more attention for operating their nursing homes or retirement centers, so that they are not able to respond the actual situations.

For now, there is still not a perfect care system to integrate and carry out the medical system in Taiwan; each medical institution always carries out their own norms for medical treatments. For example, if those senior citizens' home, elder care and rehabilitation institutions or social welfare centers, which could use the conception of shared value from Michael E. Porter, and combine TRIZ methods in constructing a innovative system and platform to integrate and carry out the whole medical system; therefore, it will be bound to have many contributions for the medical system in Taiwan.

2. The Objective of the Research

Our research will apply TRIZ methods in constructing a innovative service value chain among cared people, care centers and medical system and build a medical and care service framework to let patients accept the diagnosis form terminal medical institutions, and then they will be forwarded to care centers, and hope to unblock those patients in terminal medical institutions, where are overcapacity, in order to provide more proper medical care service.

Due to the operation interface of care information system is too complicate to operate for users; therefore, our research will use HL7 as a framework to construct a simple and brand-new service interface to let elder people use easily, then the transmission of medical records and care information would be more convenient among cared people, care centers, medical system. To know the actual situation and choke points for medical care presently in Taiwan, and the existent mode of care

services could be discussed and analyzed to be references for constructing an innovative long-term service value chain, in order to conform to the marketing requirement.

3. Literature Review

3.1 The actual situation of long-term care system in Taiwan

According to the standard from World Health Organization, if the rate of elderly population (people who are more than 65 years old) of the country's total population is more than 7%, then the country will be identify as “aging society”. According to the Ministry of the Interior of Taiwan, the rate of elderly population was already 7.1% and became into aging society in 1993. In 2000, the rate of elderly population of the country’s total population arrives to 8.62%; according to the estimation from CEPD (Council for Economic Planning and Development) of Taiwan, the rate of elderly population will arrive 19.7% of the country’s total population. The rapid increasing of elderly population would cause the transference of population’s structures, and then more and more elders will increase more requirements for long-term care.

For now, there are many community medical service institutions, such as nursing homes or retirement centers, and so on. But due to lack of a perfect integrated project, so those owners would not like to pay more attention for operating their nursing homes or retirement centers, so that they are not able to respond the actual situations. Therefore, the long-tem care service would be based upon medical system, but lack of integrated project. Long-term service institutions consider long-term care as commercial activities, but ignore human care, so that most of people who need to be cared are all forced to accepting the diagnosis and help from large-scale medical institutions, and cause the lack of professional caregivers and poor medical quality in medical system.

3.2 The problems on the environment of long-term care in Taiwan

Due to lack of a perfect integrated project on long-term care in Taiwan, so those owners would not like to pay more attention for operating their nursing homes or retirement centers, so that they are not able to respond the actual situations. Although the National Health Insurance is a primary policy of government in Taiwan, but from the medical point of view, there are still some disadvantages for National Health Insurance. Most of charges are all born by government, so that will increase the government deficit gradually. According to literature and interviews, there are still many community medical service institutions in Taiwan that they do not have proper integrated system, lack of human power and medical equipments, including the waste of

medical resources which impute to National Health Insurance; therefore, it is so difficult to deal with those issues for the government, no matter from the policy point of view or the long-term care system.

Our research integrated and analyzed the defects for the actual situation of long-term care in Taiwan, which is included: (1) although the integration of various systems and laws was noticed, but there is still a big gap to be improved. (2) the organization orientation of long-term care center is not clear, and the employment and labour conditions of human resources is not great. (3) The new item of service is hard to promote and there is still a dilemma to wait to solve. (4) the budget estimation on long-term care service is not accurate , and the efficiency on the application and issuance of funds also need to improve.

3.3 FUJITSU Long-term support system

Tele-care support system is the linked networks among cared people and care institutions as shown in **Figure 1**. It is also a total support system to proceed tele- health management and tele-care by images, sounds, and Vital information. This system is from FUJITSU in Japan. Japan is the country, whose aging of population is the fastest in the world, but providing a perfect care insurance system. According to this support system, every single elder is able to benefit by the service care institutions provide, if they have emergency suddenly, the support system will immediately contact with care institutions. Therefore, elder health situation will be improved, and decrease the expenditure of medical charge apparently.

(1) Social welfare institutions: constructing the connection between social welfare institutions and cared people. Not only proceed regular home visiting, but also use video phone to go forward care consulting service.

(2) Hospitals, Clinics: constructing the connection between hospitals and cared people. Doctors are able to know well about the health situation of cared people directly, it will be helpful for recovery observation and medicating management.

(3) Health institutions / Service providers: transmit Vital data (blood pressure, pulse, body temperature, etc.) to health institutions to proceed the daily health management.

(4) Fire bureaus: connecting with Fire bureaus to provide emergency announce service.

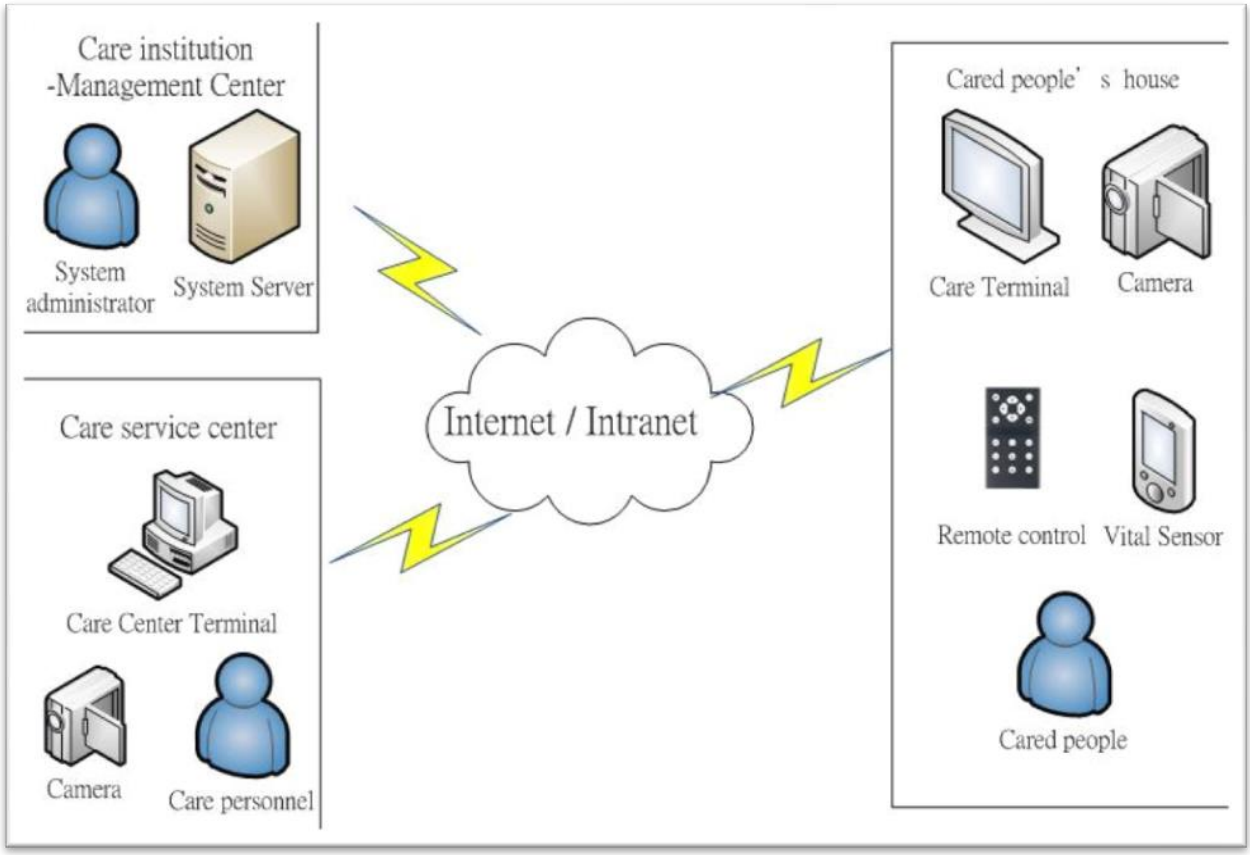

Figure 1. Long-term support system

3.4 FUJITSU Nursing System

Nurse Helper is based upon nursing operating procedures, and reach a greatly improvement in nursing assessment, nursing interventions schedule, nursing records, vital signs records, care activities schedule, nursing summary and so on; the nursing system is able to wildly decrease nursing staffs' duplicate record works, and screen data in multidimensional ways, in order to help nursing staffs to know well about patients' actual situations, and widely improve the operating efficiency.

FUJITSU nursing system is designed on the basis of EMR（Electronic Medical Record）of FUJITSU, Japan. After over 10 years of marketing trial, the market share rate of this system is No.1 in Japan, so this FUJITSU nursing system is definitely a system which is complete and proper for nursing operating procedures. For the reason of specific of nursing activities, FUJITSU nursing system, Nurse Helper is provided with some specifics, such as "flexible system design","doctor's advice and nursing interventions schedule", "simplified input operation", and so on. Then, we hope that the working efficiency of nursing staffs would be improved by leading in this care system as shown in **Figure 2**.

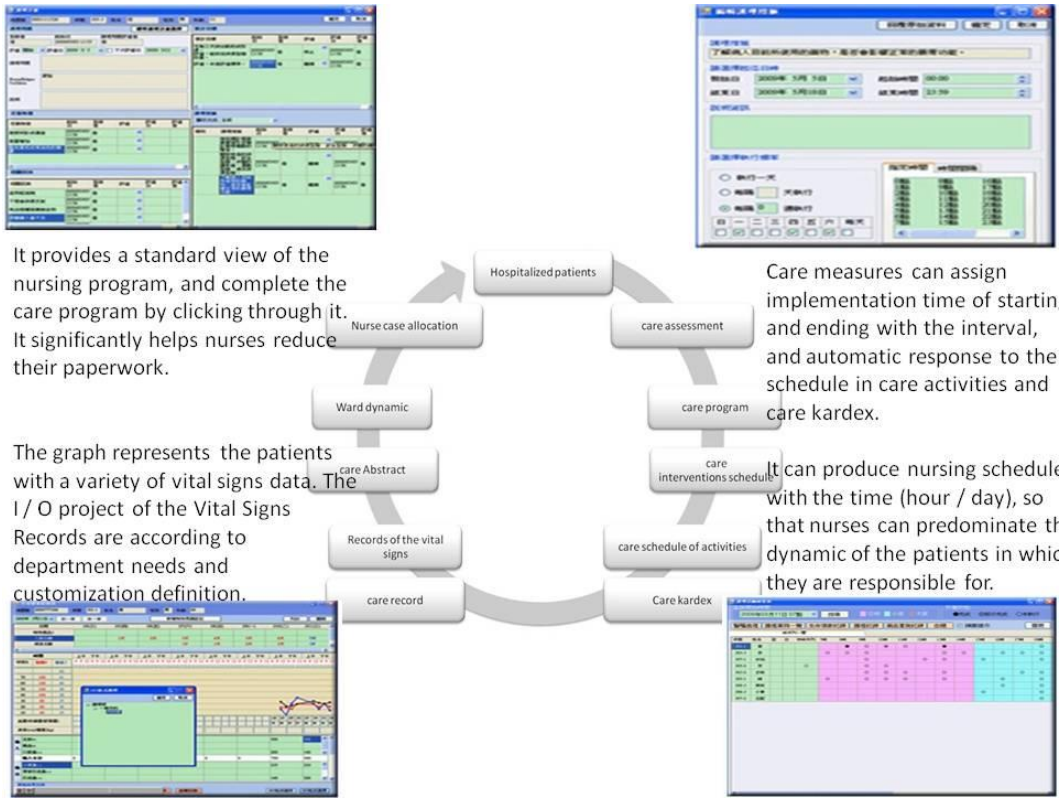

Figure 2. The care system

3.5 Intelligent Innovation

From innovative thought, “Intelligent Innovation” is based on various tools of TRIZ to evolve the possible processive ways of products into“VOP: Voice of the Product”. From the thought of intellectual property rights, “Voice of the Law” will be evolved by tools, such as patent analysis. From the thought of market, “Voice of the Customer” will be evolved form existent products by tools, such as Kano Model. According to the analysis of variance in actual situation from the three of the above, we are able to figure out “innovation holes”, “patent holes ”, and “demand and supply holes”. The concept map of intelligent innovation was summarized in **Figure 3**. The three holes will use value configurations to share innovative function into various products of market compartment. The target of intelligent innovation is to look for: (1) application of new commercial skills, (2) new commercial mode, (3) new service products, (4) new marketing mode.

The magic square of TRIZ tools is a pretty good one of intelligent innovation tools. The magic square would depend a problem environmental analysis system, which is constructed by factors of time(now, past, future), and factors of space(super-system, system, and subsystem) on segmenting problem environments particularly, and using various views, such as value point

of view, patent point of view, demand and supply point of view, etc. to do the most detailed analysis at each part of the magic square, and use other proper tools (ex: use Kano Model on service quality) to proceed intelligent innovation.

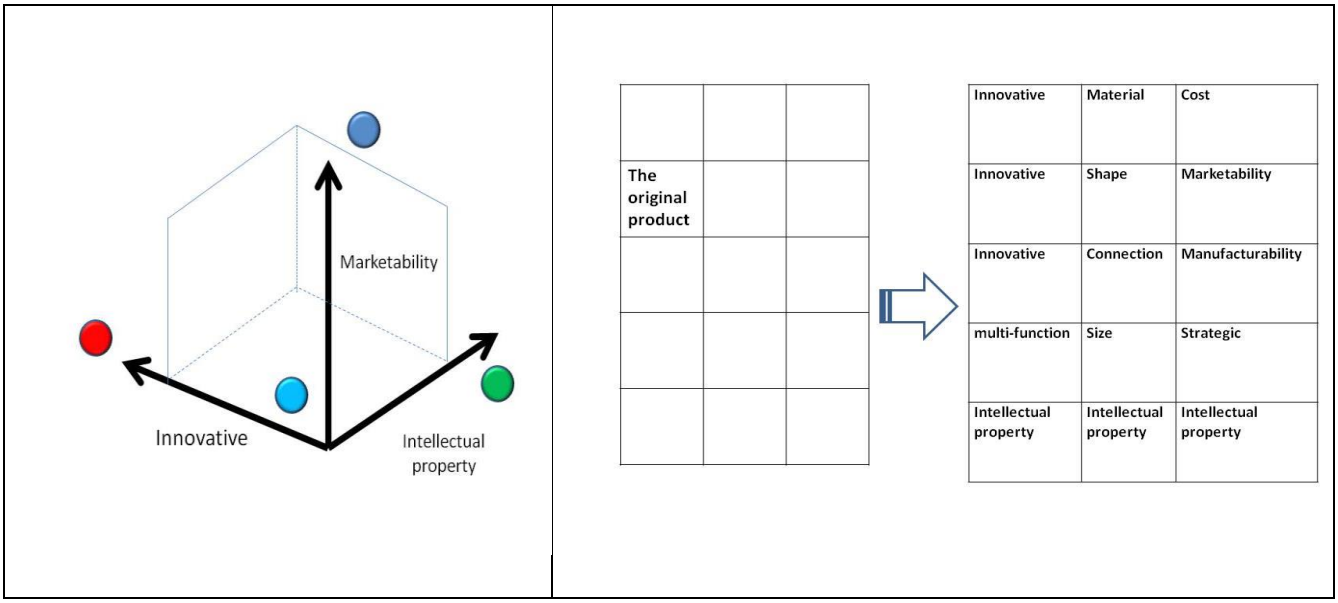

Figure 3. The concept map of intelligent innovation

4. Methodologies

TRIZ emphasizes that innovation is able to accord to systemic methods, but it is not necessary to have a particular steps and procedures, or refer to success cases to find out answers of questions for our targets. Therefore, our research used TRIZ on the innovation for the service value chain of long-term care service, and our approaches to develop information services and innovative service chain were summarized in **Figure 4.**

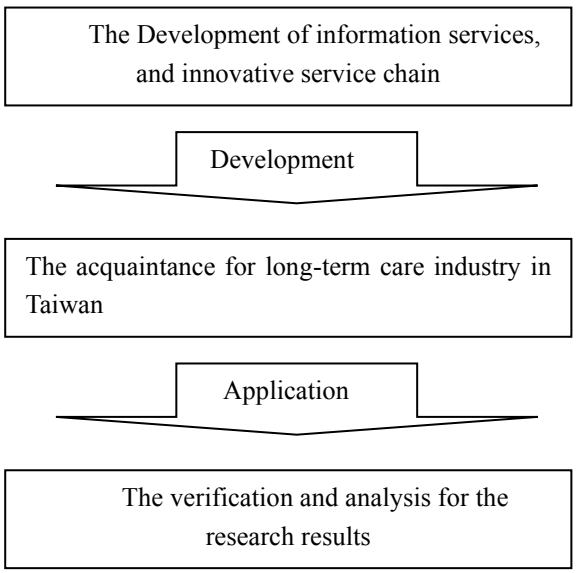

Figure 4. Our approaches to develop information services and innovative service chain

4.1 The Development of Long-term Care Information System with TRIZ

This development of the system will be under the framework of HL7 to develop the platform interface of innovative service (**Figure 5**), and then related care institutions and medical units will do the verification for innovative service execution and combine with TRIZ; then, the result of verification will provide a practical and feasible suggestion for this innovative service chain, and estimate the feasibility of this innovative service.

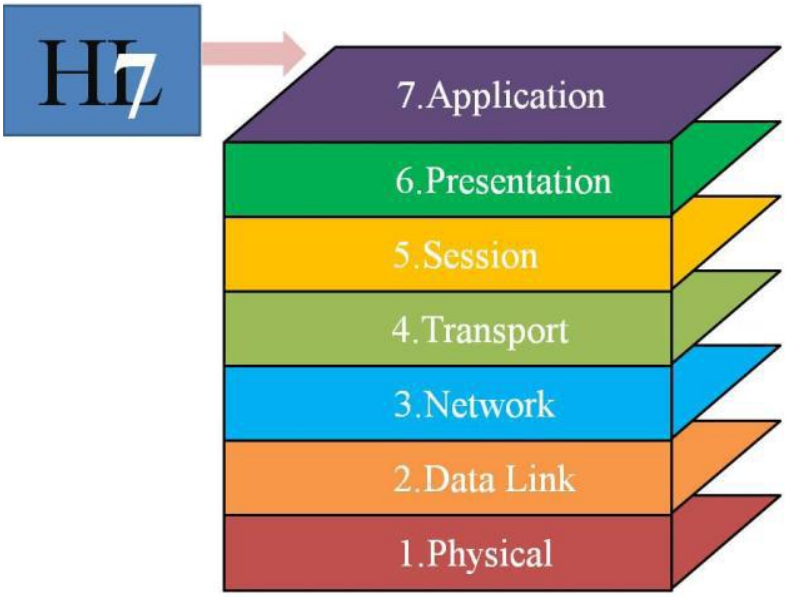

Figure 5. HL7 structure

Moreover, our research will build a Cloud service platform by innovative long-term care service mechanism, and take related care institutions and medical units for example to proceed actual verification. The globalized medical industry is tend to notice the same key points with the regional united development that how to make it possible that regional information could be transmitted among different medical institutions smoothly, and the utilization rate of information and integrated analytical applications will be increased and strengthened, in order to improve service quality, and try to control the cost of medical treatment that insurance institutions might not have been able to carry on, so this tendency will be definitely a important developing trend and perspective of application for global medical industry.

4.2 Innovative Service Value Chain

Our research will predict to construct a cloud medical system of shared value by innovative long-term care service mechanism (**Figure 6**). Michael E. Porter refers to three key ways to achieve the concept of shared value: 1. reconstructing products and markets; 2.

redefining the productivity of value chain; 3. improving the development of regional clusters. Therefore, our research use this three key ways to be a basis to build the cloud medical service system and create shared value under the framework of HL7; moreover, take related care institutions and medical units for example to proceed actual verification.

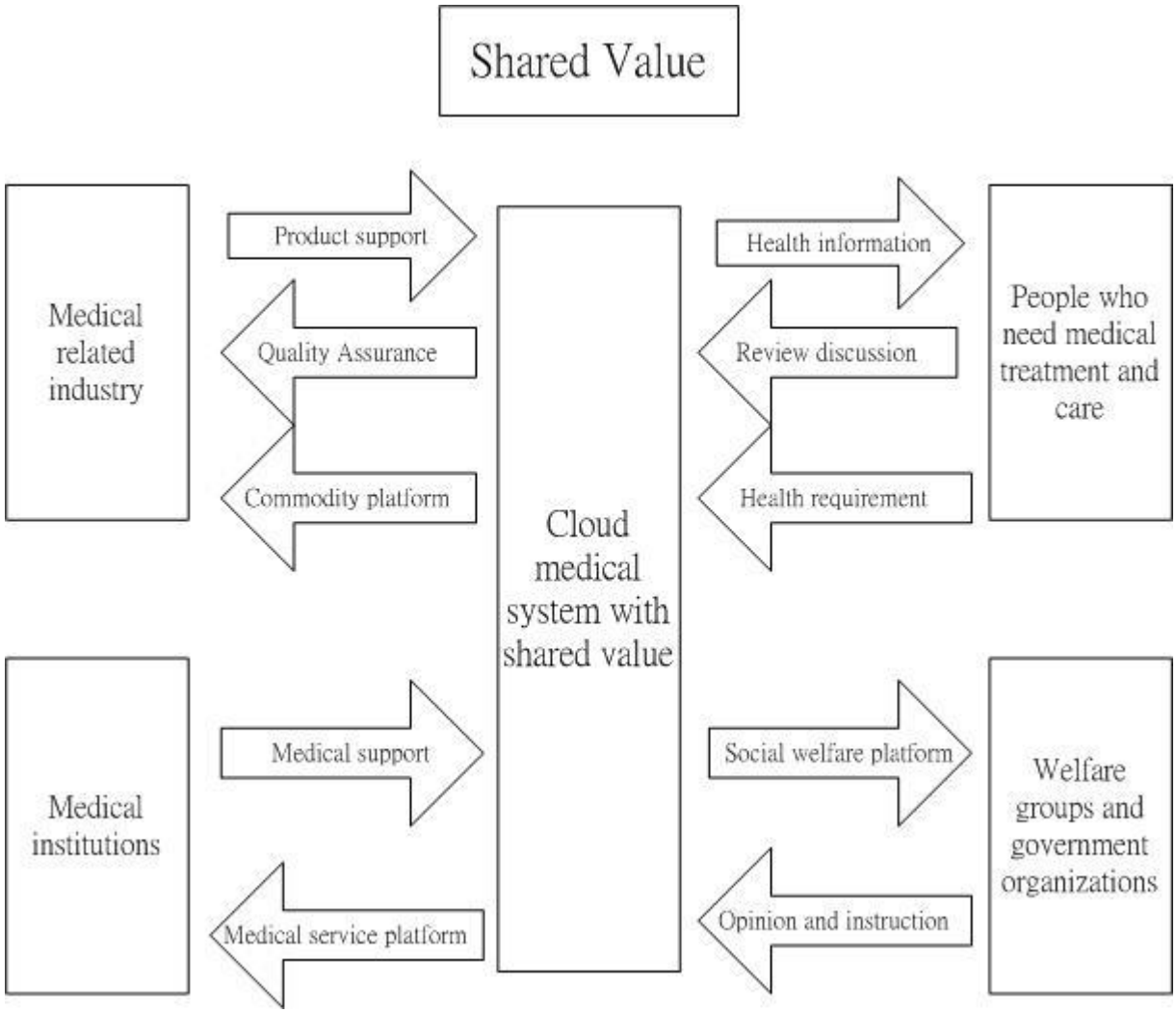

Figure 6. The cloud medical service system with shared value.

According to the problems for long-term care actual situation in Taiwan, we could use the magic square of TRIZ methods (**Figure 7**) to figure out a possible direction of solution for "organizational structure", "manpower issues", "Service supply", "financial resource lack", and use contradiction matrix to look for a proper inventive principles, in order to construct an innovative service value chain.

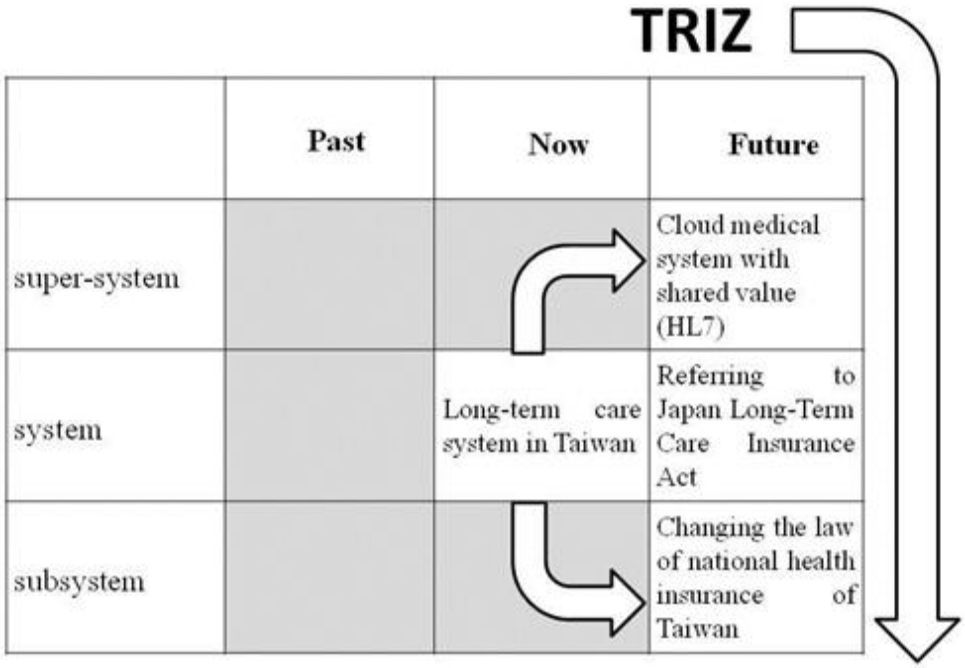

Figure 7. Build up the TRIZ magic square.

4.3 Managerial implications

According to comparison and analysis among HL7 of Taiwan, FUJITSU nursing system and telecare support system of Taiwan, we find out they are able to let medical treatments and long-term care system connect with each other, and integrate a new medical platform. Nursing system is able to help manager to manage information easily, and possess“flexible system design” , “doctor's advice and nursing interventions schedule”, “simplified input operation”, and so on. Telecare support system is able to proceed self health management, health consultation, care service, and so on by web conference. If we could integrate those systems, it would be bound to create more added value and contributions for medical treatments and long-term care system of Taiwan. Therefore, there are three feasible managing targets in our research:

(1) Improving the new system development of existent long-term care information system.

(2) Constructing and improving the innovative service chain among cared people, care centers, and medical system.

(3) Improving the usage efficiency of the resources of national health insurance.

4.4 Conclusion

Constructing a innovative system and platform by TRIZ is able to integrate medical system and framework efficiently, and apply TRIZ in using new way to construct the system instead of traditional conception, in order to make it possible that the medical system of Taiwan is able to have a better development, and efficiently integrate elder care and rehabilitation institutions, senior citizens' home, nursing home, and so on; therefore, it would not only decrease the waste of medical resources, but also have a great insurance for patients' rights and interests, including service quality; the flexible system framework is able to benefit doctors and nursing staffs to deal with emergency or emergency patients, etc., those are all the advantage of system constructing, and make the development of medical system more proper and complete.

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Inner Psychological Preparation in Systematic Innovation

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Abstract

The purpose of this paper is to focus on inner psychological preparation in systematic innovation. Although there are many tools for breaking free of psychological inertia, methodology and the process of how such paradigm shift is pertained in TRIZ and systematic innovation are unclear. Furthermore, TRIZ and other tools focus on solving physical contradictions of matter (material). This paper gleans information from current research in mindfulness and the long-time practice of meditation to give insight on how paradigm shifts are met when encountering mental contradictions. Meditation trains the mind to let go of attachments and detach preconceived notions, bias, thoughts, self-ego, etc. Mindfulness facilitates awareness of the present state. By analyzing mindfulness and the practice of meditation, this paper proposes that systematic innovation should incorporate inner psychological preparation into the system and develop ways to obtain conscious awareness and attention in the systematic innovation. Understanding how to break free of inner psychological inertia when encountering mental conflicts and enhancing mental preparation prior to using systematic tools is crucial in the development of a creative mind. Both the internal (the mind) and the external (TRIZ and systematic tools) state should synergize to increase the level of creativity.

Keywords: meditation, mindfulness, paradigm shift, psychological inertia

1. Introduction

TRIZ and other systematic thinking tools are created to solve contradictions and produce creative or systematic innovations. The role of these tools is often used to overcome psychological inertia and preconceived notions. In order to attain a breakthrough, the mind needs to break free of psychological inertia. Although there are many tools for breaking free of psychological inertia, methodology and the process of how such paradigm shift is pertained in TRIZ and systematic innovation are unclear. Furthermore, TRIZ and other tools focus on solving physical contradictions of matter (material) and not inner psychological contradictions. What happens when a person encounters mental contradictions? Mindfulness research and the long-time practice of meditation give insight on how paradigm shifts occur when encountering mental contradictions/conflicts.

2. Psychological inertia

Psychological inertia (a.k.a. mental inertia) takes on various forms, whether it is preconceived notions, habitual thinking, assumptions, bias, self-ego, etc. It is considered a roadblock in the innovation process. Kowalick (1998) defines *psychological inertia* as “an indisposition to change” or "stuckness due to human programming”. Mike (2011) states it as “individual construct of reality”, where “continual practices, prejudices, experience and beliefs you contain within your brain.” Mann (2004) describes psychological inertia as “hole-digging”, where we dig holes deeper and deeper, and we get stuck our holes in systematic innovation.

Cameron (2010) listed eight causes of psychological inertia (p.3):

- Having a fixed vision (or model) of the solution or root cause.
- False assumptions (trusting the data).
- Language that is a strong carrier of psychological inertia. Specific terminology carries psychological inertia.
- Experience, expertise and reliance upon previous results.
- Limited knowledge, hidden resources or mechanisms.
- Inflexibility (model worship; trying to prove a specific theory, stubbornness).
- Using the same strategy. Keep thinking the same way and you will continue to get the same result.
- Rushing to a solution – incomplete thinking.

TRIZ and other innovation methodologies have many different ways of overcoming our psychological inertia and gaining valuable insights, such as brainstorming, mind maps, de Bono’s six thinking hats and lateral thinking, TRIZ procedures—Ideal Final Results, Functional Goal Setting, Physical Contradiction Statement, etc. However, they all focus on solving physical contradictions of matter (material) and not inner psychological/mental contradictions.

3. Thought Process and Mental Inertia

When a thought is formed, neurons in our brains start to fire or light up. They may fire or light up simultaneously, in coordination with a group, or in association with other groups of neurons. In 1949, Hebb proposed a theory that is often stated as "*Cells that fire together, wire together*." (cited in Wikipedia, Carla Shatz, Stanford University). Hebb’s theory indicated that “cells that are repeatedly active at the same time will tend to become 'associated', so that activity in one facilitates activity in the other." (cited in Wikipedia, Hebb 1949, p. 70). If this action or activity is repeated numerous times, it generates a strong link or association and creates memories. The more a memory is triggered, the stronger the link or association of the neurons. During this process, knowledge can be stored in our memories. The more we want to memorized a piece of knowledge, the more we repetitively activate the neurons.

However, thoughts that created psychological inertia, such as preconceived notions, habitual thinking, assumptions, bias, self-ego, etc. can also be formed with our stored knowledge or memories. Therefore, when a memory or thought is triggered, our psychological inertia mode is also triggered. Mental conflict or contradictions emerge as this happens. Take Mann's "hole-digging" for example, we want to get out of the hole we dug, but cannot due to our mental inertia of digging and digging. In conclusion, when our neurons fire off, it also triggers our psychological inertia, creating mental conflicts or contradictions, especially when a thought, memory, or knowledge is activated.

4. Inner Psychological Preparation in Systematic Innovation

To be able to overcome or break free from psychological inertia, inner psychological (mental) contradictions or conflicts needs to be eliminated, reduced or avoided. In other words, in order to disengage from psychological (mental) inertia, the link or association between neurons of the psychological inertia must be weakened. If strengthening a link or association between neurons is to activate or fire off (light up) neurons, then weakening it is not to activate it. Hence, to weaken a thought means not think of it often and to let go of the thought the minute it arises. For example, how can you stop water ripples? The best thing to do is to do nothing and let it settle or die out, because anything you do will make the water ripple even more.

Mental training can exercise the mind to let go of psychological inertia, or weaken the link or association between neurons. Therefore, inner psychological preparation is needed to break away from thoughts that created psychological inertia, such as preconceived notions, habitual thinking, assumptions, bias, self-ego, etc. Matchett (2009) listed some preparatory strategies (p.14-15):

- Become quietly centered.
- Take conscious control of your mind and body.
- Let your mind surrender all desire and pretence to take command.
- Let go of everything that is stress inducing, all fears and anxieties.
- Let go of all pre-concepts and expectations of goal, process, resources, and structure.
- Let go of all thoughts, anticipation, knowledge, memories and habits.
- Let go of everything that inflates your ego—get yourself completely out of the way.
- Let go of everything other than a "will to meaning"
- Perfect your nothingness, but become totally alert and available.
- Permit the present moment to be your total world. Totally open to unexplored possibilities—like a newly born baby, exceedingly vulnerable, yet unconcerned.

The strategies listed above are similar to mindfulness training and meditation practices. Therefore, going to the source of long-time practice and training of mindfulness thinking and meditation can give insight on how mental conflicts or contradictions are eliminated and understand methods to break free of psychological inertia.

▪3.1 Mindfulness Training

Mindfulness research is often used as a practice in psychotherapies for stress management, relieving anxiety and stress, or depression among patients and athletes. However, recently, mindfulness is also used in education, teaching students to become focused, attentive, aware, and alert. Mindfulness facilitates awareness of the present state as it happens. By being aware, we can disentangle from our habitual responses. It focuses on how things as they truly are, instead of interpretations or preconceived ideas. It is a reference point for "noticing aspects of our lives that we may have missed" (Fronsdal, 2001). Therefore, when we encounter problems or situations, we can clearly see the problem at hand to the point where we might have overlooked things and resolve it without judgment, resistant, or clinging on to anything.

The initial step in mindfulness is training of "noticing". Therefore, the first step in being aware of psychological inertia is to understand or notice our thoughts and acknowledge them, but not to react to them. Hence, to see things clearly as they really are is to understand what your thoughts are the moment they arise. Here are two applicable exercises in training the mind to notice our thoughts and gaps.

Steps in Noticing Thoughts (Schoeberlein, 2009, p.106):

1. Breathe normally, paying attention to the feeling of the breath as it fills your lungs and then flows up and back out the way it came.
2. Notice when a thought arises.
3. Acknowledge the thought, perhaps by saying "thinking" silently in your mind.
4. Switch your attention from that thought in particular, back to watching for thoughts in general.
5. Continue to watching and acknowledging your thoughts until your session ends.
6. Be patient, gentle, and kind with yourself.

Steps in Noticing Gaps (Schoeberlein, 2009, p.107):

1. Breathe normally, paying attention to the feeling of the breath as it fills your lungs and then flows up and back out the way it came.
2. Notice when a thought arises.
3. Acknowledge the thought, perhaps by saying "thinking" silently in your mind.
4. Switch your attention back to watching for thoughts in general.
5. Notice whether there is any space between switching your attention from inwardly a thought or saying "thinking" to watch for the thought, and then let the space go without labeling it.
6. Continue watching thoughts and gaps until your session ends.
7. Be patient, gentle, and kind with yourself.

▪3.2 Meditation Exercises

Mindfulness and meditation are two side of the same story, letting go of attachments to become attentive, alert, and aware of the present state as is, without any judgment, resistant, or clinging on to anything. Part of mindfulness training is set at meditation. Current studies on meditation are commonly used for patients on easing their pain and unpleasantness. However, meditation can also exercise the mind to let go of self-ego, self-centered thoughts, habits, bias, etc. The mind then becomes decentralized, deautomatized, and detached (Shapiro et al, 2006). Although meditation facilitates the mind to disentangle perceptions, thoughts, feelings, judgments, and biases, letting go of attachments doesn't mean to train the mind to become mindlessness. Instead, it is the opposite; it promotes the mind to become mindfulness, "seeing clearly of the present". By not being attached to any thought, the mind can become fully aware of the whole situation at present. Therefore, during mindfulness training, in the practice of "noticing" or the practice of being aware of our thoughts, once a thought arises, learn to let it go and leave out the "self" and other attachments or "clinging".

Fronsdal (2001) listed four kinds of clinging that Buddha enumerated: (1) clinging to spiritual practice, (2) clinging or grasping to our views, including all opinions, stories, or judgments that we hold on to, (3) clinging or grasping to a sense of self, and (4) clinging or grasping to sensual pleasure. Understanding we have such clinging can facilitate our understanding in why we have psychological inertia. For example, over the years of working or studying in our own field of expertise, our knowledge and our concepts build only in a certain area. If we become successful in solving problems in a certain way, we maintain the same pattern, doing things habitually, or even thinking habitually. We do so because we cling on to the fact: "I was the one coming up with the solution; it was correct, so I will keep doing it", "I was successful", or "I am the expert in solving such a problem." We cling on to our views, our sense of self, and our pleasure of success. These are the cause of our mental conflicts, causing pain, suffering or frustration. It even causes us to think habitually in a certain way, psychological inertia. Therefore, meditation can eliminate the desire to cling on to things.

Zen is the oldest form of meditation in Buddhism. Another form is shikantaza, a Japanese term for zazen introduced by Rujing (Wikipedia). In Zen, there is vipassanā bhavanā or vipaśyanā (觀禪) and samattha bhāvanā or śamatha (止禪). Vipassanā (Pāli), or vipaśyanā, literally meaning "clear seeing" (Fronsdal, 2001). It is an ancient and central form of Buddhist meditation, introduced by Gautama Buddha and commonly referred to Westerns as "insight meditation", which means "insight into the true nature of reality" (Wikipedia). Samatha (Pāli), or shamatha, is also a form of Buddhist meditation focusing on concentration practices (Wikipedia). It is designed to cultivate "attention", stability, and being calm. In other words, it trains in calming the mind and becoming concentrated. Silent illumination Chan (mozhao chan 默照禪) is the integrated practice of Samatha and Vipassanā, called yuganaddha (union), meaning practicing with both a calm mind and insight observation (Wikipedia).

▪3.3 The Perfect State of Mentality

In TRIZ, the Ideal Final Result is a "perfect" state. The "perfect state" in mental activity is being attentive and aware of everything of the present state as it happens, but letting go of all attachments, including self (I, me, mine thoughts). In the words expressed in the movie *Peaceful Warrior*, "There is never nothing going on. Take out the trash, Dan. The trash is anything that keeping you from the only thing that matters, this moment, here, now." Our minds are clogged up with trash (our self-ego, beliefs, attitudes, etc.). When we clear the trash out of our minds, we can think clearly and become aware, alert, and attentive of what is happening in our surroundings. This is crucial in seeing the picture as a whole and not fragments, so when we encounter problems or conflicts, we can clearly see the situation and resolve the issue by pinpointing the problem.

To achieve this "perfect" state of mentality, there are three paradigm shifts of mental activity: (1) illusion (妄相), (2) voidness/emptiness (空相), and (3) reality/ the real aspect (實相). Through meditation, it goes through three S-curves as shown in Figure 1. Since the goal is to see reality in real aspect, without any judgments or bias, the first step is to understand our false beliefs or illusions of how we see the world. Then, understanding the voidness or emptiness of how the world really is, meaning nothing really matters, so our emotions won't get in the way of our thoughts and clogging our minds with faulty perceptions and misjudgments. Finally, through understanding illusions or unreality and voidness or emptiness, we can see the real world in real aspect, without any emotions, judgments or bias (meaning no attachments).

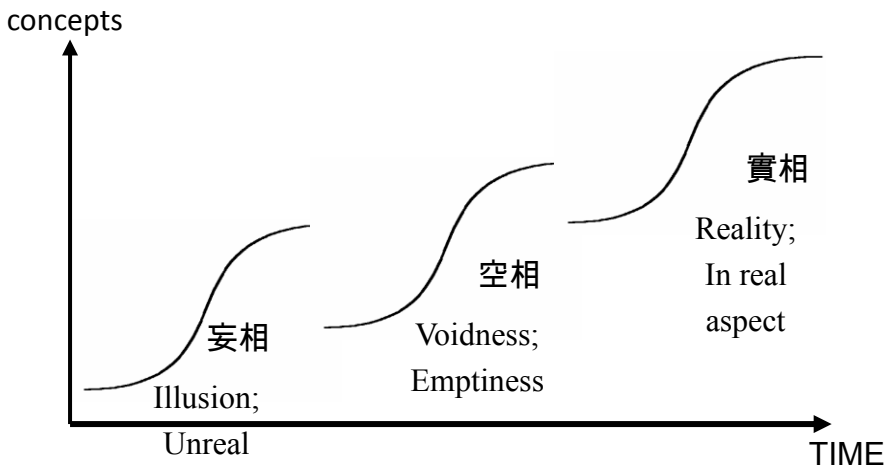

Figure 1. Towards A Perfect State of Mind

5. Mental Contradictions and TRIZ

In the psychological preparation process in systematic innovation, it is essential to understand how to break free of inner psychological inertia in encountering mental conflicts or contradictions. In TRIZ, there are four basic method of eliminating contradictions or conflicts (Mann, 2004):

1. Separation in Space

2. Separation in Time
3. Separation on Condition
4. Separation by Transition to an Alternative System

These methods can be applied to eliminating psychological inertia as well.

There is a chapter in ***Vimalakīrti Nirdeśa Sūtra*** on non-duality. It describes how to overcome conflict of two and obtain non-duality. The mental conflict reaches non-duality through transition, and paradigm shifts occur when the transition is reached. Here are two examples of non-duality from ***Vimalakīrti Nirdeśa Sūtra*** in understanding transition to alternative systems:

Example 1: 善宿菩薩曰：「是動，是念為二，不動則無念，無念則無分別，通達此者，是為入不二法門。」 The bodhisattva Bhadrajyotis declared, " 'Distraction' and 'attention' are two. When there is no distraction, there will be no attention, no mentation, and no mental intensity. Thus, the absence of mental intensity is the entrance into non-duality." (see Figure 2)

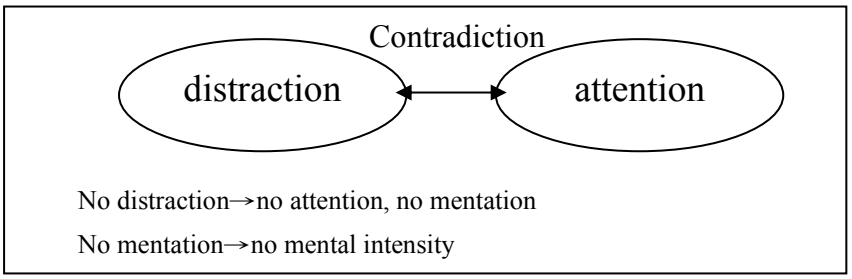

Figure 2. Transition to Inverse System (Counterbalance).

Example 2. 淨解菩薩曰：「有為，無為為二，若離衣竊數，則心如虛空，以清淨慧無所障礙者，為入不二法門。」The bodhisattva Suddhadhimukti declared, "To say, 'This is happiness' and 'That is misery' is dualism. One who is free of all calculations, through the extreme purity of gnosis - his mind is aloof, like empty space; and thus he enters into non-duality." (see Figure 3)

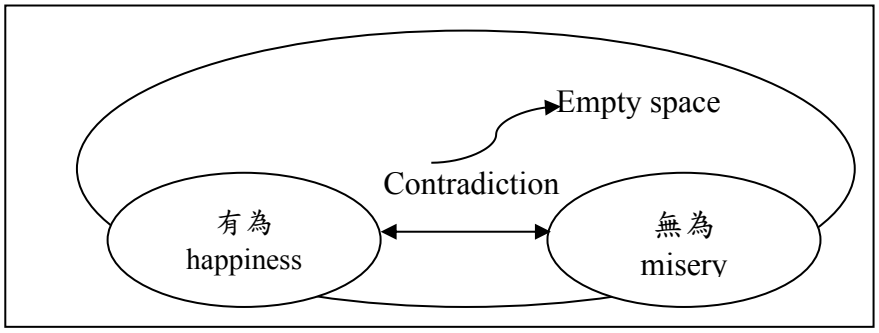

Figure 3. Transition to Super System.

6. Discussion and Conclusion

When neurons fire off, it also triggers psychological inertia, creating mental conflicts or contradictions, especially when a thought, memory, or knowledge is activated. Hence, to be able to overcome or break free from psychological inertia, inner psychological (mental) contradictions or conflicts needs to be eliminated, reduced or avoided by disengaging or weakening the link or association between neurons. Meditation trains the mind to let go of attachments and disengage preconceived notions, bias, thoughts, self-ego, etc. Mindfulness facilitates awareness and attention of the present state in reality. The perfect state of mental activity is being attentive, focused, alert, and aware of everything of the present state as it happens, but let go of all attachments, including self (I, me, mine thoughts).

In the book, *Journeys of Nothing in the Land of Everything* (Matchett, 1975), it advocates that we should become nothing and remain merely a point (also known as "cipher" in this book) and nothing more. It notes that it's essential to "forget yourself," because a point "doesn't pretend to be clever" or "has its own will". It also states not to put too much effort at forgetting nor attempt to remember, because staying alert or not "falling asleep" is the only requirement of a point. Then "all the cares" ("the burden of knowledge, of values, ideas, ideals, preferences, attitudes, beliefs, and skills") laid upon you will disappear. Therefore, the gateway to eliminating psychological inertia is to let go of any substantial values, ideas, ideals, preference, attitudes, beliefs, and skills by weakening its neural links.

In the book *A Theory of Everything* (Wilber, 2001), it states that everything is connect, both the interior states (consciousness) and exterior states (material). However, over the years, science has focused on the development of material state, and religions focused on the inner psychological or conscious state. Both areas have developed advanced levels of ideas, knowledge and wisdom. Nonetheless, both the internal state, inner psychological world, and external state, outer material world, should integrate together for our society to be holistic. Therefore, both the internal, the mind, and the external, TRIZ and systematic tools, state should synergize to increase the level of creativity. In conclusion, understanding how to break free of inner psychological inertia when encountering mental conflicts/contradictions and conducting mindfulness training and meditation exercises prior to using systematic tools are both crucial in the development of a creative mind.

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Paper ID: 42

Three New Patterns of Technical Systems Evolution

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Abstract

Classical TRIZ proves that technical systems evolve in predictable patterns which is so called the patterns of technical systems evolution, Since 1970s, Genrich Altshuller and his colleagues has discovered eight evolution patterns and then classified them into three groups, which are called: statics (trends 1-3), kinematics (4-6a) and dynamics (7,8).

After attentively observing and studying the history of a series great scientists and inventors in the human being, and nearly over ten years concrete practice on TRIZ, CAI and SI, the author has revealed another three new patterns of technical systems evolution and detailed described how they works in this article. The first law is called the trend of Pyramids, the second is called the trend of Cannikin Law and the third is called the trend of Bionics.

It is well known that the patterns of technical systems evolution or trends are used as a forecasting tool and for failure analysis for the development and evolution of technical system. The Author has discussed in this article that the three new patterns could be used not only as a

forecasting tool or failure analysis in the development and evolution of technical system, but also it could be used as a innovation opportunity identification tools. The author has taken some real examples to show how to use these new patterns.

***Keywords**:* Bionics, Patterns of Technical Systems Evolution, Pyramids, Cannikin Law, Trend, Innovation

1. Introduction

In the beginning of 1970s, Genrich Altshuller and his colleagues has discovered eight evolution patterns They are:1.Completeness of parts of the system;2.Energy conductivity of a system;3.Harmonizing the rhythm of the system parts;4.Increasing ideality;5.Uneven development of the system parts;6.Transition to a super-system; 6a.Dynamization;7.Transition from macro- to micro-level;8.Increasing the s-field development.

For the easy of using, Genrich Altshuller has classed these laws into three groups:

statics (trends 1-3), kinematics (4-6a) and dynamics (7,8).

As it is well known, these laws or patterns are very helpful when engineers predict the most likely improvements for a developed product. But people have to think: if we got more patterns, we will be getting more powerful in solving innovation problems.

2. Another three new patterns of technical systems evolution

After attentively observing and studying the history of a series great scientists and inventors in the past and nearly over ten years concrete practice on TRIZ,CAI and SI, the author has revealed another three new patterns of technical systems evolution. Here Share with you all.

The first law is called the trend of Pyramids. It means that the technical applications are relying on the scientific effects progress, the scientific effects appears after the progress of mathematics, the mathematics, scientific effects and the technical applications is construct as a Pyramids, and the trend is 1.mathematics, 2. scientific effects, 3. technical applications. Details please see Fig-1, the trend of the evaluation is shows in the right side arrow.

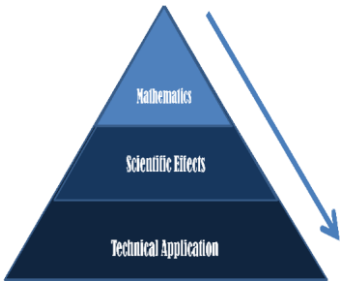

Fig-1 Trend of Pyramids

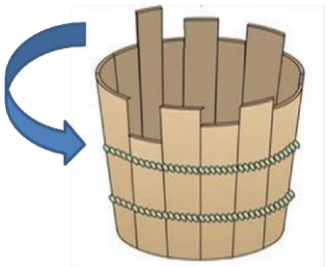

Fig-2 Trend of Cannikin Law

The second trend is called the trend of Cannikin Law. As we all known that the Cannikin Law described a highest level of a Cannikin can fulfill with water is depending on the shortest board of the cannikin, but here I use this management laws to describe that a technology is introduce into one sector and to another one in turn, the first sector could be called a central industry, while the another sector could be called the side industry. Take the steam engine for an example, In the 18 century, when steam engine was been invented, first, it was be used as the power in mining industry (central industry), then the steam engine was be used in textile industry, then shipping industry, and then auto industry (side industries), etc. The technology trend from the central sector to side sector could be called the Cannikin Law trend, like the cannikin board from longer one to shorter. While, we should

understand that the central sector differs in different countries and in the different Times, sometimes, the central industry is depending on the country's program. (See Fig-2 for details).

The third trend could be called the trend of Bionics, it means when inventors push the innovation work by Bionics way, they usually follow these three stages in their works: the first stage, copy the shape of some animals, insects or plants in nature; the second stage, simulating the functions of some animals, insects or plants in nature; and the third stage, the whole copying, that is simulating from functions to shape of some animals, insects or plants in nature. These three stages or steps described a trend, that is Shape->functions->shape plus functions.We call it as the trend of Bionics. Fig-3 has shown the details.

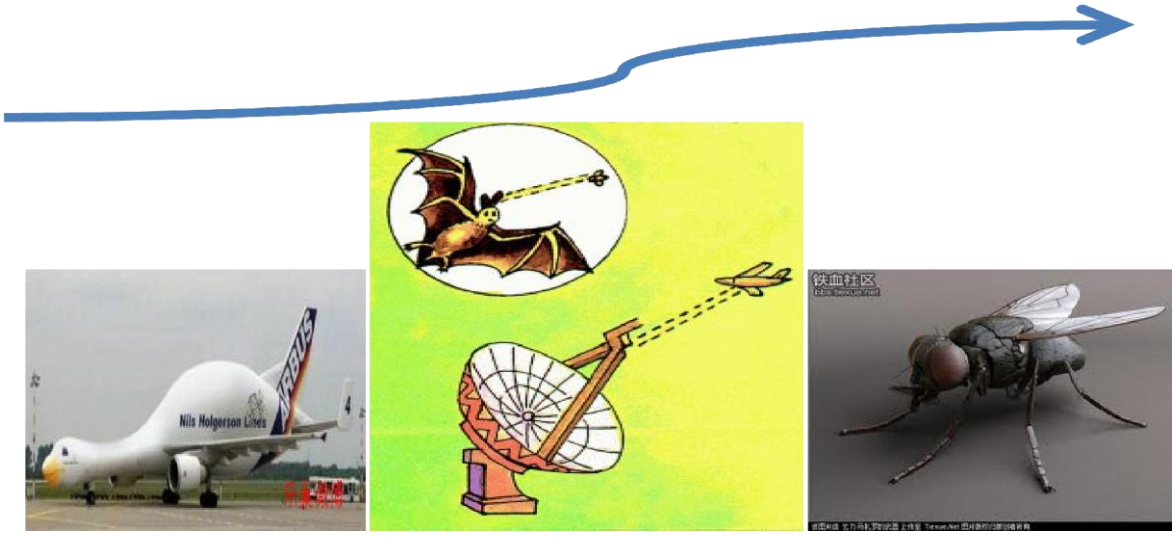

Fig-3 Trend of Bionics

3 Application of the new trends

It is well known that the patterns of technical systems evolution or trends are usually used as a forecasting tool or for failure analysis for the development and evolution of technical system. While the Author think thees three new trends could used not only for forecasting tool or for failure analysis in the development and evolution of technical system but also could be used as a innovation opportunity identificating tools.

For example, if we have known that there are some new scientific effects has been discovered by scientist, we could use, at the first time, this scientific effect in all kind of industries to find out their new application for renewing the existing inventions. And if we learnt that a central industry has achieved gratifying successes by means of some kind of technology applications, we could take some side industries as our next goal of invention. While when we have known that some copying invention of nature has been done, we can take the function copying or whole copying (Shape plus Functions) as our next steps for the further innovation. This method described that these three new

trends or patterns could be used not only as a forecasting tool, but also as innovation opportunity identification tools in the practice innovation jobs.

We have another example for these new trends application, When we have got a paten busting project which need to overcome the noise of a microwave oven. At the first, We have surveyed the whole scientific effects library and found out an scientific effect, this effect says that the ferrimagnetic materials have a temperature which called curie temperature, once the ferromagnetic materials meet this temperature, they will lost their magnetic property. And we also learnt that some people has used this effect to solve a problem in large projector, here we can defined the large projector industry as a central sector, while the microwave oven industry could be taken as the side industry, so we can use the same effect to fix the noise of a microwave oven and finished the patent busting.

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Paper ID: 45

Application of a TRIZ-based Systematic Method for Health Care Management with IT technology

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Abstract

The theory of inventive problem solving (TRIZ) has widely adopted in diverse disciplines as an effective systematic innovation method and it has revealed its promising development. In this paper, we applied a TRIZ-based systematic method to analyze the problem existing in daily life for the disabled or the elders. The process of method to analyze the problem includes TRIZ tools such as problem hierarchy diagram, 9-windows, ideal final result (IFR), function attribute analysis (FAA). We found some feasible solutions based IT technology solution and evaluate their effects. A case study was demonstrated to illustrate the process of the proposed method. The method proposed in this paper might provide a reference for related applications on healthcare management.

Keywords: TRIZ, Healthcare management, function attribute analysis (FAA)

1. Introduction

The theory of inventive problem solving (TRIZ) has widely adopted in diverse disciplines as an effective systematic innovation method and it has revealed its promising development. However, most of the illustrated examples for TRIZ in literature are engineering-oriented and the learners need to have the related specific domain knowledge.(R. Fulbright,2004) This phenomenon results in some barriers for novices. TRIZ owns useful tools such as 40 inventive principles, the matrix of contradictions, laws of technical system evolution, substance-field analysis, and ARIZ (algorithm of inventive problems solving). In this paper, we focused on developing a TRIZ-based systematic method and its application for health care management with IT technology. A case study including an integrated application with mechanical, electrical and information techniques was also used to illustrate the application of the method.

2. Literature Review

TRIZ has been developed over six decades and attracted a great deal of interest in industry and education. It can provide a systematic approach to analyze problems where innovation is needed and to provide strategies and methods to solve the problem. Recently, considering the specific situations and scenario in different disciplines, many scholars have proposed some new contradiction matrices in their researches. TRIZ can be seen as a collection of tools, a complete method, or a philosophy. (D. Mann,2004) It consists of many tools such as 40 inventive principles and the matrix of contradictions, laws of technical system evolution, substance-field analysis, ARIZ (algorithm of inventive problems solving). TRIZ can also be a practical auxiliary tool for product development, there have been many research papers that integrate TRIZ and others effective design or decision-making techniques such as AHP (H.T. Chang & J.L. Chen,2004), QFD (S. Li, Y. Ma, G. Yang, & Y. Li,2009) , Kano (L.S. Chen, C.C. Hsu, & P.C. Chang,2008), Sheu (D.D. Sheu,2007) illustrated an overview of the classical TRIZ (Theory of Inventive Problem Solving) body of knowledge with a TRIZ Knowledge Map and Problem Solving Model. He classified two ways of using TRIZ tools: by "contents" of generic solutions and by following specific problem analyzing/solving "processes. As TRIZ is a powerful tool, it has been applied on many disciplines to systematically solve problem. For engineering application, Fresner et al.(2010) developed a generic approach for option identification by using elements of the so-called TRIZ method for cleaner production projects. Recently, there are also many applications of TRIZ for safety improvement (K.V.,2008) and eco-design (H.T. Chang & J.L. Chen,2004) (E. Jones & D. Harrison,2000) as these issues exist contradictions accompanying opportunities.

3. Research Method

The process in the proposed method in this paper is shown in Figure. 1. The process has five stages including problem direction, problem definition and tool selection, solution generation and evaluation, concept embodying, goal-inspiring. For the first stage, problem direction decision, it is very important that the team members' interests and expertise need to align the problem direction from life experience and requirement. The problem definition and tool selection stage includes a more detailed analysis with various TRIZ tools such as Ideal Final Result (IFR), 9 windows of resources and constraints, problem explorer, Function Attribute Analysis(FAA), and S-curve. After finishing the problem definition, one can select the more suitable tools to generate several solutions. The third stage, solution generation and evaluation, can use some TRIZ problem-solving tools such as technical contradictions/physical contradiction along with 40 inventive principles, substance filed analysis along with standard solutions. In order to let student assimilate the innovation concept, we propose the fourth stage, concept embodying, used to train student's capability transforming concept to real prototype with hands-on practices. At the final stage, goal inspiring, teacher can guide students to participate competition or assist them to apply patents with related resources. This paper also suggests that goal inspiring process can simultaneously be discussed in the first stage so that students will have more strong motivation to finish the project.

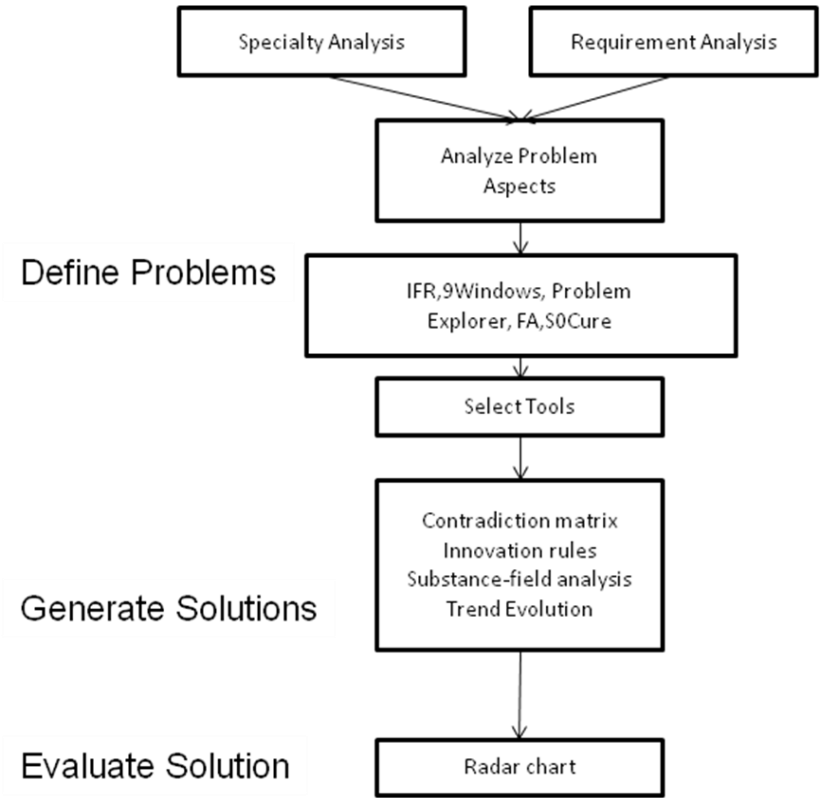

Figure 1. Process of TRIZ-based systematic innovation method

4. Case Study

In this section, an example implemented by a topic research project finished by a team including four undergraduates and four teachers was demonstrated for illustrating the proposed method in previous section. Besides, problem hierarchy analysis and benefits analysis for the stakeholders were shown in Figure. 2 and Figure. 3. Finally, the project direction was decided to develop an individual drying racks with automatic shrink and stretch functions. In order to avoid the tedious description, this paper only shows some snapshots or related information. Figure. 4 shows the function attribute analysis for a traditional system. From the diagram of the FAA analysis, one will analyze harmful/insufficient/ excessive/missing/effective functions between components of the product so that he can focus on the key-points of the problem. Table 1 shows the adopted inventive principles in the example and the feasible implementation methods in the case study. The work in the project includes an integrated application with mechanical, electrical and information techniques. As the interest and expertise of the team member has analyzed in stage 1, every student responsibly and happily did his own job based on his interest and expertise along with the goal of competition participation and patent application.

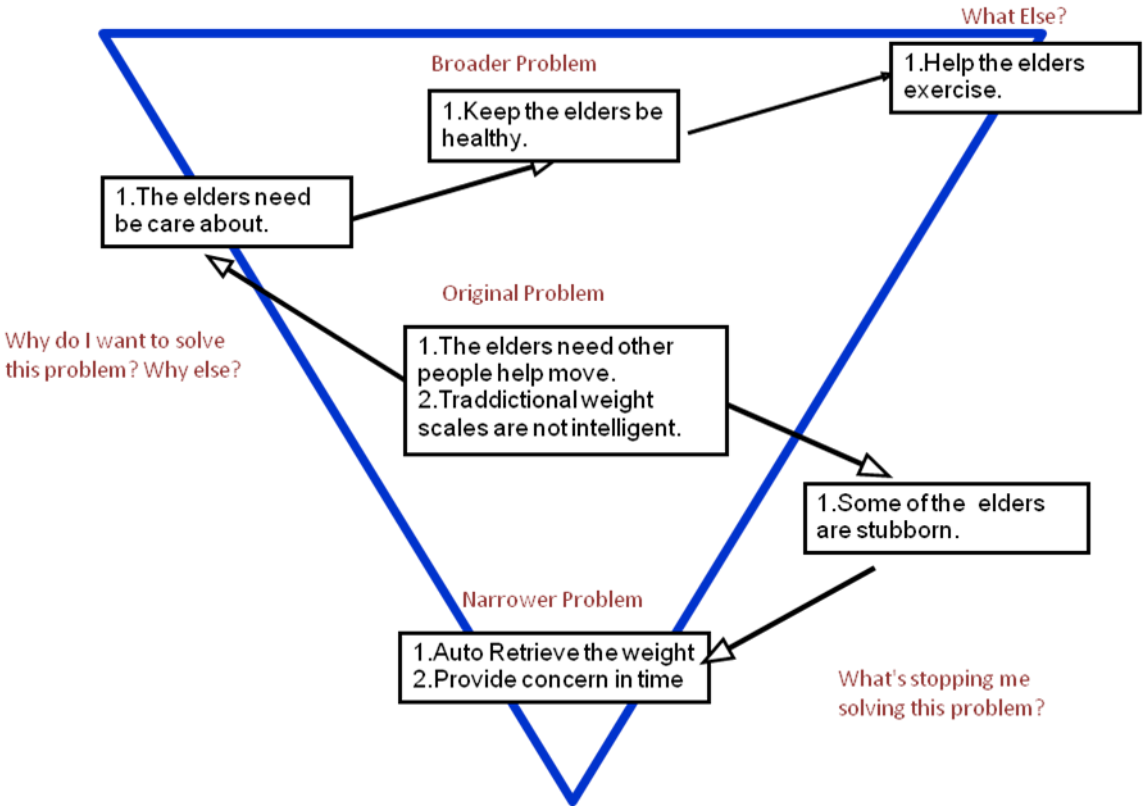

Figure 2. Diagram of problem hierarchy analysis

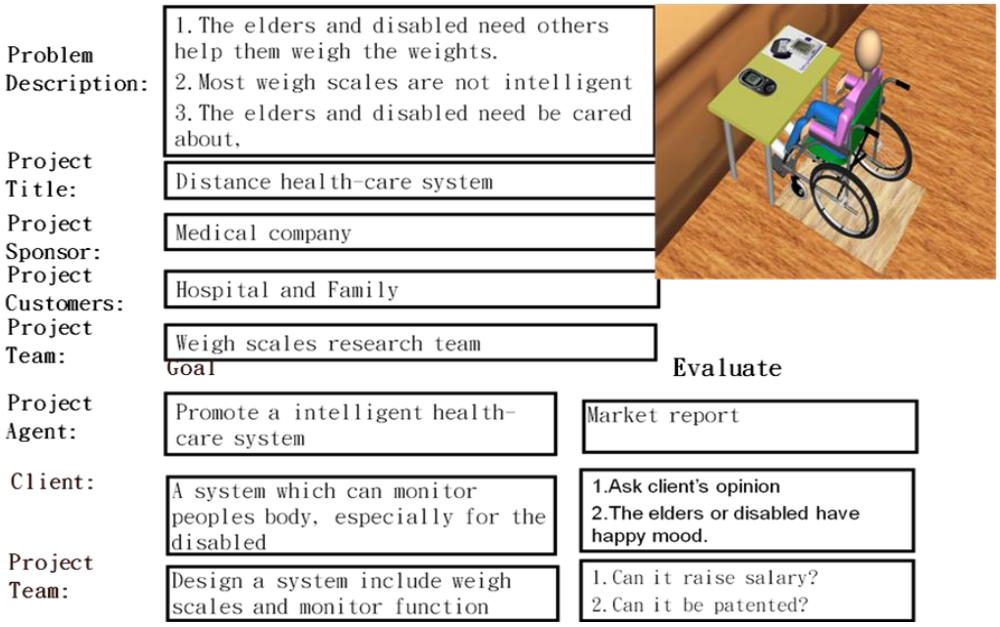

Figure 3. Benefits analysis for the stakeholder in the project

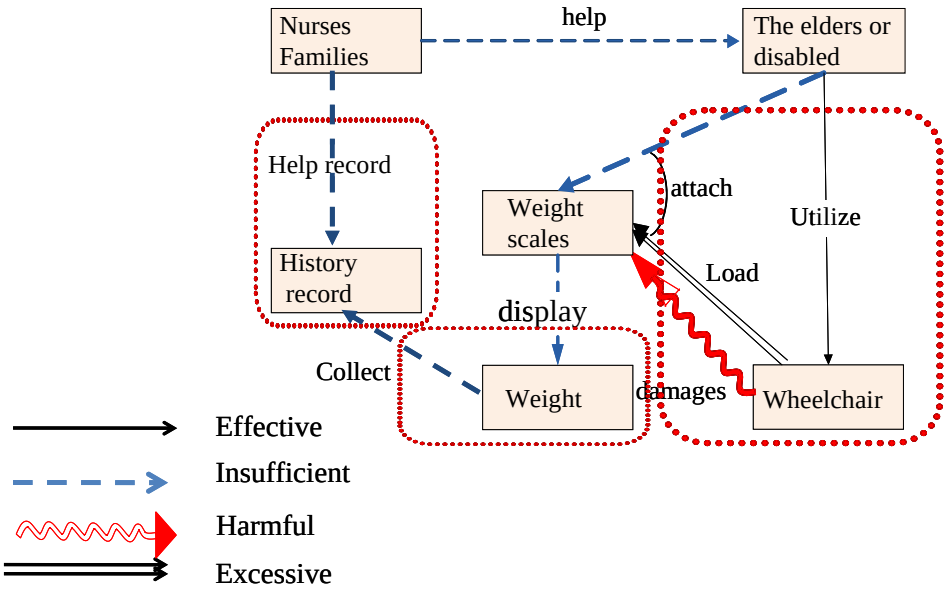

Figure 4. Diagram of function attribute analysis for traditional system

Table 1 The adopted inventive principles in the example

No. of IP	Sub-item of IP	Implementation Method in the cast study
5. Merging	a. Combine in space homogeneous objects or objects destined for contiguous operations	Combine weigh scales, RFID, computer, network, databases and hospital.
6. University	a. Make a part of object perform multiple functions; eliminate the need for other parts	With functions of monitor and auto retrieve data
11 .Beforehand Cushioning	a. Prepare emergency means beforehand to compensate for the relatively low reliability of an object	If the data crosses the predefined threshold, the alarm system will be triggered.
17.Another Dimension	b. User a multi-story arrangement of objects instead of a single-story arrangement	Embedded the weigh scales underground, so it saves spaces.
23.Feedback	a. Introduce feedback (referring back, cross-checking) to improve a process or action.	The system feed the data to doctors, families.
25. Self service	a Make an object serve itself by performing auxiliary helpful functions	The system measures weigh automatically, and provide alarm functions.

5. Conclusions

In this paper, we focused on engineering innovative education and developed a TRIZ-based systematic method applied to for health care management with IT technology based on their life experience and capability. A case study including an integrated application with mechanical, electrical and information techniques was also illustrated for the method and process. The authors

expect this research could provide a reference for engineering innovation education and the method proposed in this paper is general in form to be applied for the other disciplines.

Acknowledgement

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The Application of the TRIZ 40 Inventive Principles to the Wind Energy Education in Elementary School

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Abstract

This research introduced the TRIZ 40 Inventive Principles to the elementary school students for the design of the wind turbine. Through the presentation of online 3D animations, the students could benefit from the digital multimedia learning materials for its intuitive convenience and off-site accessibility. The objective of this research was to make students aware of proper energy and TRIZ concepts so that they could develop constructive energy conservation awareness in their early age. It is expected that students would become more involved in future energy initiatives by establishing proper values via the design activity.

Keywords: TRIZ 40 inventive Principles, elementary school, wind energy training.

1. Introduction

The advent of digital revolution age makes the half-time of knowledge rapidly shortened; the production of knowledge is no longer an arithmetic progression but a geometric progression to increase. The instant evolution and update of knowledge is sweeping the whole world. The miracle of Apple developed by Steve Job's creativity is concrete evidence. Creativity achieves the technology generation in the present century, leading human beings into an unexpected world. Members in the global village undoubtedly realize that future belongs to those who use digital information as weapons. All countries aggressively involve fast-changing digital resources into teaching and learning resources. This has been a mainstream trend in the junior and elementary school (U.S Department of Education, 2010).

As a member of the global village, the Ministry of Education (MOE) in Taiwan views technology education as an important issue and include it in the Grade 1-9 Curriculum. Technology education is formally extended into elementary school. MOE has recruited elites in society and been devoted to organizing resources (e.g. Learning Six Fields Websites) so that students could learn

technology by doing it. Until 2007, the construction of the Internet has been popular in all classes of junior and elementary schools in fifteen cities and counties and the update of computer hardware is up to 90 %. Accordingly, it shows the determination that MOE in Taiwan focuses on computerizing education. It is the primary challenges for education practitioners concerning how to integrate information technology into teaching design, approach, and content so as to make education reach its full potential. The role of teachers has been transformed from the past knowledge authority to the current facilitators who inspire students' autonomous learning. It is expected that students in the future could better use technology to solve problems and become achievers full of creativity in life.

The contemporary students were born in a technology-laden age, belonging to "Digital Natives." Their models of receiving messages, thinking logics, and learning are different from their "Digital Immigrants" teachers. When it comes to the efficacy of instruction, it is a critical point if the teachers broaden their views for trans-boundary learning and concentrate on the transformation of educational contexts (Prensky, 2001). Therefore, the shift of teaching patterns, the development of information technology integrated teaching models, and the elimination of the gap between the "Digital Immigrants" and "Digital Natives" to benefit the both generations as well as to create a new situation have been the goals that all countries strive toward. Thus, the present study aimed to apply TRIZ Principles to the teaching activities, facilitating elementary school students to develop creativity thinking and to construct wind turbines.

2. Proposed approach

2.1 TRIZ 40 Inventive Principle

The TRIZ Principles were proposed by Genrich Altshuller, a Soviet scientist, in 1950s. The full name is "Theory of Inventive Problem Solving." He developed 40 Principles from 1956 to 1971, which are (1) Segmentation, (2) Extraction, (3) Local Quality, (4) Asymmetry, (5) Combining, (6) Universality, (7) Nested, (8) Counterweight, (9) Prior Counteraction, (10) Prior Action, (11) Beforehand cushioning, (12) Equipotentiality, (13) Inversion, (14) Spheroidality, (15) Dynamics, (16) Partial or excessive actions, (17) Another dimension, (18) Mechanical vibration, (19) Periodic action, (20) Continuity of useful action, (21) Skipping, (22) Convert Harm into Benefit, (23) Feedback, (24) Intermediary (Mediator), (25) Self-service, (26) Copying, (27) Dispose, (28) Mechanics substitution, (29) Pneumatics and hydraulics, (30) Flexible shells and thin films, (31) Porous Materials, (32) Color changes, (33) Homogeneity, (34) Discarding and recovering, (35) Transformation of Properties, (36) Phase Transition, (37) Thermal expansion, (38) Accelerated Oxidation, (39) Inert Environment, (40) Composite Material （Altshuller，1999）. These 40 Principles are usually associated with Contradiction Matrix. However, the participants in the present study were elementary school students, so the major research purpose was to investigate the difference if they would gain the knowledge of the principles before the instruction and after the instruction.

2.2 Electronic Schoolbag Teaching

The electric schoolbag, which allows learners to immerse themselves in the process of learning by doing and to increase their learning motivation, becomes an advantageous learning tool (Kirriemuir & McFarlane, 2004；Sweetser & Wyeth, 2005). Players can have a sense of achievement from the continuous challenges provided by digital games, which elicit their "inner motivation" of the participation in the digital games (McGrenere, 1996). The players constantly renovate their learning experiences through the multi-sensory and problem-solving learning provided by digital games learning, actively test their learning hypotheses, and acquire concepts and knowledge through continuous reflection. The study combined the electric schoolbag and 3D animation to elicit students' learning motivation and to concentrate on the learning of the TRIZ 40 Principles.

3. Case study

Using ASUS EeePad as an electric schoolbag, the study designed an instruction course whose content was relevant to the TRIZ 40 Principles. By means of a game-based course of the electric schoolbag, it activated students' experience of flow and created a development context of creativity. To introduce the TRIZ 40 Principles via easily understandable 3D animations, it satisfied the elementary school students' learning desire driven by their curiosity, cultivated their association abilities, and finally helped them accomplish a creative activity of designing wind turbines.

As far as the experimental design is concerned, the teachers whose classes attended in the study must participate in a seven-hour introductory course provided by the Society of Systematic Innovation in Taiwan so that they could have accurate understanding of TRIZ. In terms of the 3D animations of the TRIZ 40 Principles, the producers were 40 pre-service teachers, who took professional education courses, like Foundation of Education, Introduction to Learning Technology, and Child Psychology. They transformed the TRIZ 40 Principles that were used in industrial fields into simple 3D animations that meet elementary schoolers' comprehension. They used Autodesk 3DsMax to produce animations and Unity3d android device to convert the animations into Android APP that could be used in Android tablet PCs (Figure 1).

Figure 1. The production process of app teaching material

To examine if the students learned the TRIZ 40 Principles, a program was used to design a learning worksheet. After playing every four animations, the program would randomly select one of the animations to ask the students which Inventive Principle it applied to. There were ten quizzes to

help the students memorize the principles. After the completion of questions about the TRIZ 40 Principles, the students would have a total test. The program would present a multiple-choice pattern with four items and play the animations for the students so that they could answer which Inventive Principles was displayed by the animations. By means of the test, the students' learning achievement about each Inventive Principle could be understood. Afterwards, the students were required to apply the TRIZ 40 Principles to design a wind turbine. The design procedure used in this study includes the following steps (Figure 2):

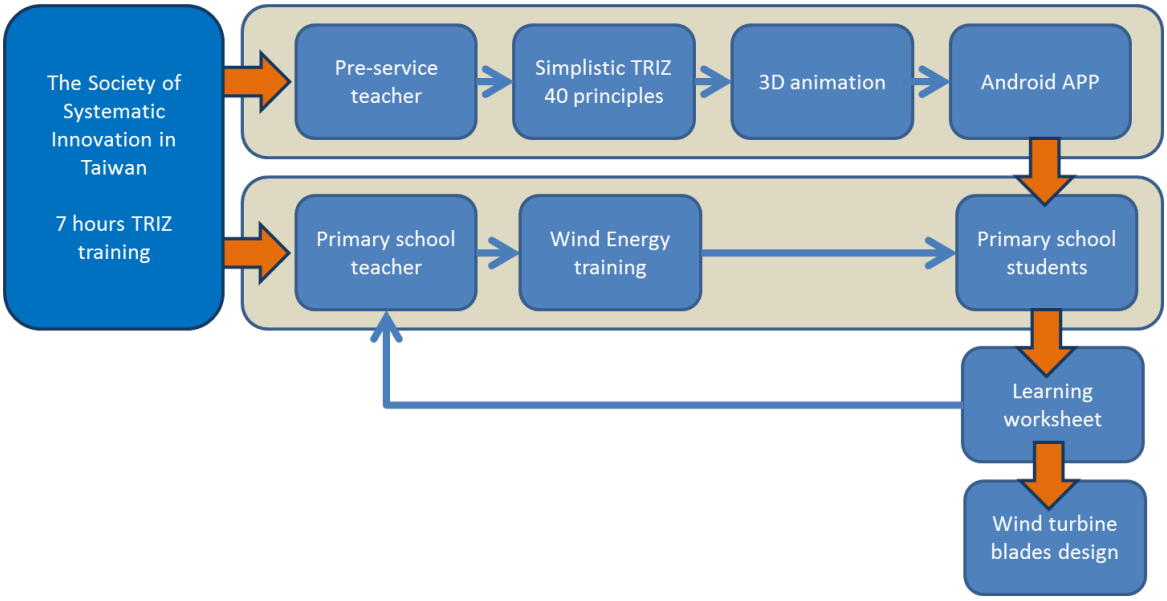

Figure 2. The overview of this research

4. Conclusion

The integration of the electric schoolbag into instruction has been evidenced in a range of research literature that it could effectively promote learning motivation and interests. By taking advantage of the features of the electric schoolbag, the present study popularized it to elementary schools in Taiwan (see Figure 3) and helped elementary school students develop creative thinking and problem-solving ability. The preliminary findings revealed that the three principles most frequently used by a class of 30 low-grade students to design wind turbines were (5) Combining, (32) Color changes, and (6) Universality. In contrast, (20) Continuity of useful action, (16) Partial or excessive actions, and (18) Mechanical vibration were the three principles with highest error rate in the participants' learning worksheet. It might result from the reason that the low-grade students do not have any science and technology class. Thus, they might not understand the phenomenon, such as resonance, atmospheric pressure, and so on. However, generally speaking, the participants' average rate of accuracy in memory of the TRIZ 40 Principles was 81%, showing that the 3D animations could indeed effectively enhance students' memory. The results also confirmed the Cone of Experience proposed by Dale (1946) that, compared to the static pictures (e.g. texts), animated

pictures could better facilitate memory. In the future studies, we plan to conduct more large-scale popularization of the electric schoolbag and 3D animations so that more elementary schoolers could benefit from the theory of TRIZ.

Figure 3. The elementary school students design their wind turbine blades with an electronic schoolbag

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Paper ID: 47

Application of neuro-linguistic programming for a communication system for people with weak hearing

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Abstract

People with weak hearing often have trouble communicating because they do not wear hearing aid and in order to address this issue this study applies NLP's Walt Disney strategy, which includes several key elements of NLP, such as collecting information, defining a problem, reframing the problem, setting up a goal, searching for resources, and the TOTE (Test, Operate, Test, Exit) procedure. The study also proposes using a Bluetooth communication set to help people with weak hearing to communicate.

Keywords: NLP (neuro-linguistic programming), TOTE, weak-hearing

1. Introduction

There are many approaches to achieving innovation, such as six thinking hats, brainstorming, Mandala thinking, the KJ method, 6W thinking. and so on. Figure 1 shows the stages of the innovation process, which starts at defining the problem, then moves on to divergent thinking, then to convergent thinking, and finally to finding a solution and taking action. Divergent innovation process can lead to mass ideas and convergent can filter these mass ideas. Although many skills can help people have clearer thinking and better evaluate their ideas, there is skill such as NLP which can enhance people's motivation and lead to them to achieve better performance, as shown in Figure 2.

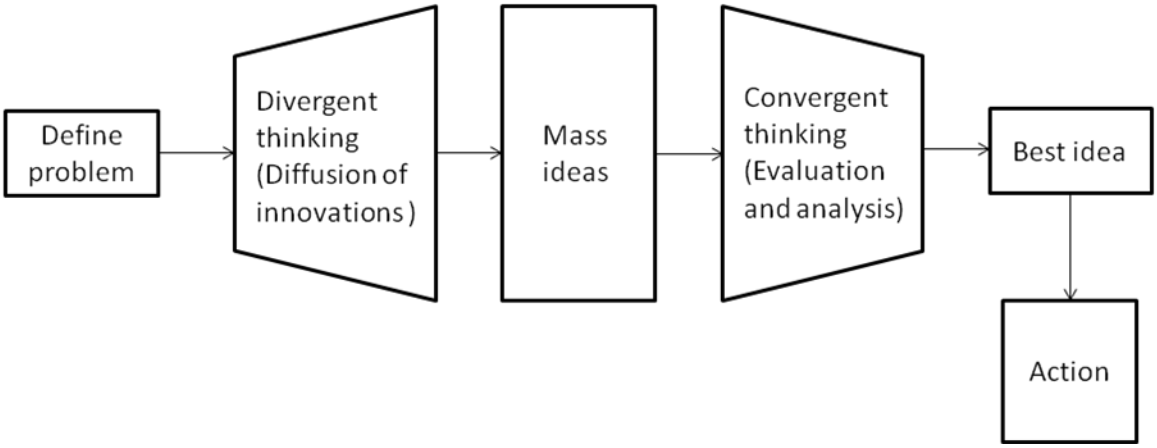

Figure 1. The process of innovation

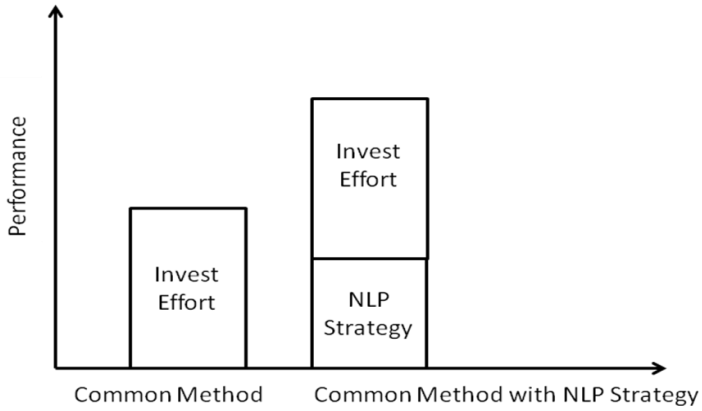

Figure 2 NLP can increase performance

2. NLP

NLP is an approach to communication, personal development, and psychotherapy that was first developed in the 1970s by John Grinder and Richard Bandler, based on the work of Virginia Satir, Fritz Perls and Milton Erickson (Bandler, Richard & John Grinder, 1975).

NLP help people set up their goals by state. The state that we experience now is called the present state, and whatever we want to achieve is called the desired state. Figure 3 shows that there is gap between the present state and the desired one in the NLP model, with problems preventing progress to the latter, although resources can be used to overcome these.

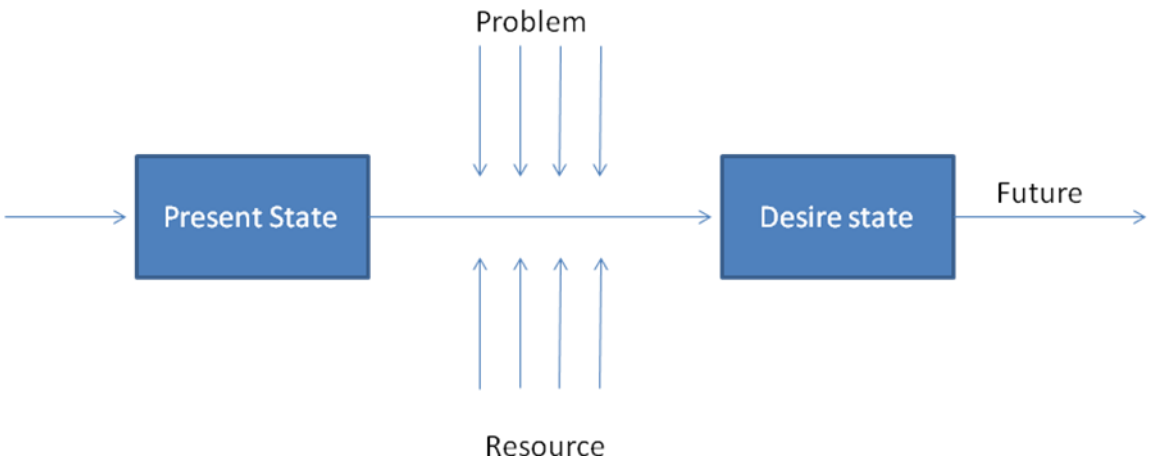

Figure 3 Application of resources to the present state can lead to the desired state

The TOTE Decision model was proposed by George A. Miller, Eugene Galanter and Karl H. Pribram (1986), with the name standing for Test,Operate, Test, and Exit, a process that can help people make better decisions. The four stages are as follows:

1. Test to know what you want achieve and determine the measure you will use to know when you have succeeded.
2. Operate in a flexible way to accomplish the goal.
3. Test to check if you have achieved the goal. Continue the loop from Test to Test until you have achieved you goal.
4. Exit to another goal.

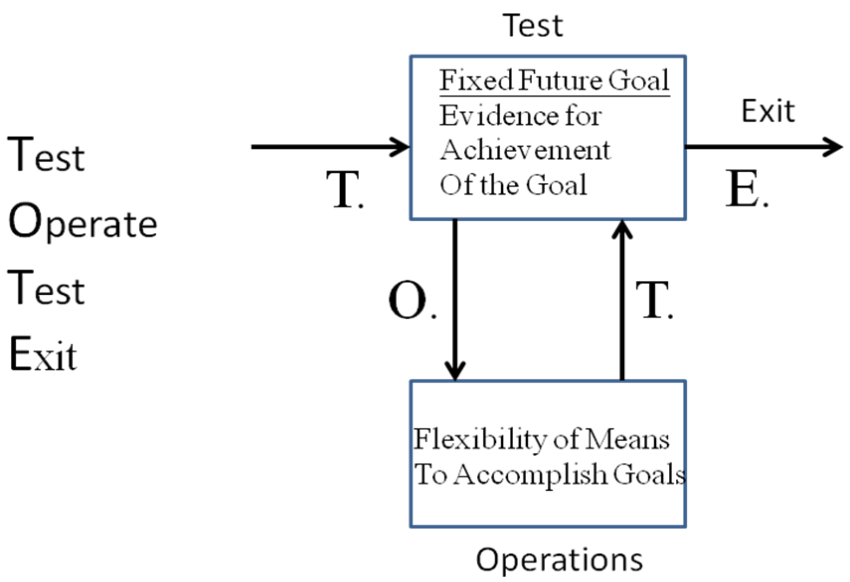

Figure 4 TOTE

NLP can help people to better utilize resources. The key terms used in NLP are introduced below.

Resources: These are all the means that can be brought to bear to achieve an outcome. Resources include physiology, possessions, thoughts, strategies, events, people, possessions, and states. According to NLP's presuppositions, people already have all the resources they need, and their mental resources include their past experiences, those of others, and also their imagination.

Resourceful state: The total neurological and physiological experience when a person feels resourceful (David, 2007).

Strategy: A set of explicit mental and behavioral steps used to achieve a specific outcome, such as decision, motivation, learning, and specific skills. NLP also presupposed that if anyone can do something, then anyone else can learn how to do it. Therefore, people can learn how to do everything others have done by imitating what others do, and NLP offers the ways to achieve this.

3. Walt Disney Strategy

NLP aims to change a person's perspective to obtain specific results. By changing one's perspective, it is possible to reframe one's thoughts. This paper illustrates how to use the so-called Walt Disney strategy to create a technology to help people with poor hearing to communicate.

Walt Disney was one of the most creative thinkers of the twentieth century, and Robert Dilts (1995) developed the Walt Disney strategy based on the work of this visionary business leader, which is now one of the most important NLP strategies. The process of Walt Disney strategy is also an innovation process, including defining problem, divergent thinking, convergent thinking, and action.

The Walt Disney strategy had three clear stages for taking an idea through the characters of a dreamer, realist, and critic. When an inventor is adopting one of these different roles, they can perceive an idea from variety of perspectives. And this approach based on TOTE includes loops of Test, Operate, and Test, is also.

3.1 Roles

(1) Dreamer

The dreamer has the role of a creator, and is free from of real-world limitations. When the person is adopting this role, they can use their imagination to think about the problem they

are dealing with. A dreamer's ideas may be impractical, and absurd, and the key point is that they should not feel limited in exploring an issue.

(2) Realist

A realist takes the output from the dreamer and then evaluates it using real-world principles, seeing what is actually possible using the available resources.

(3) Critic

A critic then checks the details of the plans that a realist produces, improving ideas by making them more practical and well-developed.

Table 1 shows the unique characteristics of each role.

Table 1 Characteristics of a Dreamer, Realist, and Critic

	Dreamer	**Realist**	**Critic**
Characteristic	Imaging freely. without constraints.	Practical. Support resource	Find disadvantages. Improve them.
Physical gestures	Look upward. Relax.	Look straight. Lean forward.	Look downward.
Thinking patterns	What do you want? Is there any other choice?	How can I do? Who can do it?	What could hinder the work?

3.2 Procedures

First, a person marks three blocks on the floor into dreamer, realist, and critic, as shown in Figure 5.

Step 1: The person searches his past creative experience and keeps experiencing the feeling once more. They can then enters the dreamer area, relax, and experiences this creative feeling. After he has been experiencing the creative feeling for about two minutes, a person leaves the dreamer area.

Step 2: The person searches their past pragmatic experiences, and then enters the realist area. After he has been experiencing the past pragmatic experiences for about two minutes,

the person leaves this area.

Step 3: The person searches their past experiences of providing constructive criticism. If it is difficult to do this, then they can use their imagination and enter the critic area.

Step 4: After experiencing these three feelings, the person can anchor them in the three areas, and start to develop solutions to the problem. The person then enters the dreamer area and works to find solutions using creative thinking, without worrying about real-world limitation. When a solution is obtained, the person then leaves this area.

Step 5: The person enters the realist area, and then considers how to implement the solution from the previous step using the available resources. The person can pretend they are ready to do the job, and thus carry out the solution.

Step 6: Once again, the person enters the critic area, with the aim of finding weaknesses in the plan from the previous step. With constructive thinking, the person can consider whether anything important has been ignored, with a focus on the desired outcome. Here, the person must also take a natural and detached view of their ideas, and then leave the critic area.

Step 7: At this point, a person should have several practical solutions. If these are satisfactory, the process ends. If not, it starts to go back to step 2 again.

Figure 5 Dreamer, Realist and Critic areas on the floor

4. Case Study

Problem definition: many people with poor hearing are reluctant to wearing hearing aids as they are ugly, noisy, and inconvenient. However, without a hearing aid, such people face communication problems.

At first, the person defines the problem, with the goal of figuring out communication

patterns that people with weak hearing can accept. The person marks three areas on the floor as dreamer, realist, and critic, and enters into the resource states of each role.

In the dreamer stage, the person comes up with several solutions, and these are examined in the realist stage. Finally, as a critic, the person identifies weaknesses in the solutions and works to overcome these, and can do this by pretending to be a person with poor hearing.

After the whole process, the person evaluates these solutions and decides which ones are useful. In this case, the solution is a Bluetooth microphone and small earpiece. The dreamer suggests some convenient ways to collect the sound of a speaker's voice. The realist then implements the idea with the microphone and earphone. The critic, adopting the perspective of a user, requests that the product should be quiet and beautiful, and the Bluetooth microphone and earpiece can meet these requirements. Some of the disadvantages of the technology are reframed to advantages during this process. While a Bluetooth microphone's transmission range is very short, it is enough in practice for this use. Figure 6 shows this process, and Figure 7 shows the communication pattern.

Figure 6 Applying the Walt Disney strategy to an innovation search process

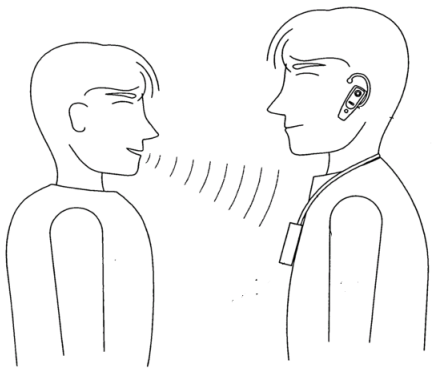

Figure 7. The communication pattern

5. Conclusion

The results of innovation searches are not always high quality ones, because innovation is an uncertain process, but NLP can improve this. This research applied NLP's Walt Disney strategy to an innovation process and achieved good results, a Bluetooth microphone and earpiece to help the hard of hearing. NLP can help people to view problems from various different perspectives, and thus improve their performance. With regards to inventors, the resource state can help achieve good outcomes, and thus during the creative process they should aim to keep themselves in this state.

ACKNOWLEDGMENTS - This work was supported by the National Science Council of Republic of China under grant NSC 100-2221-E-029 -016.

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Paper ID: 49

Innovative Design on Armrests of a Toilet Stool

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Abstract

The function of traditional armrests of a toilet stool is simply limited to help raising bodies of the users such as the disabled and the elders after using. There is not any other usage on the armrests apart from raising body. This study develops some mechanism designs of toilet armrests for the disabled and the elders to improve the function of present simple toilet armrests. The functions include: two sets of four-bar linkages to lift the toilet lid and seat, two arm trainers built in the armrests for arm training, two hand grip trainers built in the armrests for hand grip training. With all of the improved functions of toilet armrests, the toilet stools are more convenient to use for the disabled and elders. It also provides more exercising equipments to improve the health of the disabled and elders. In this paper, a SCAMPER-based systematic method has been applied to create equipments on traditional simple toilet armrests to promote its additional value. The process of this method includes requirement analysis, confirmation of problem direction, problem definition, selection of SCAMPER tools, generation of solutions, and evaluation of solutions.

Keywords: Toilet armrest, disabled, four-bar linkage, arm trainer, hand grip trainer.

1. Introduction

Armrests are general installed at both sides of a toilet stool to help the elders or the disabled people to raise their bodies after using the toilet as shown in figure 1. This kind of armrest has no other function besides supporting. It can be added some other functions to help the elders and the disabled persons to solve some problems.

The most common problem that is faced while using a toilet stool is to lift up the toilet lid and set down the toilet seat by hands. It could cause diseases because the problem of sanitation. Although there are already some auto devices for handling the toilet lid and seat, they are normally expensive due to the electronic devices and thus cannot be popular.

On the other hand, the elders usually do not exercise enough, if some simple hand and arm exercising appliances are installed on the armrests, the elders can have some soft gripping exercises and arm stretching exercises. It will promote the health of the elders.

Figure 1. Traditional armrests of a toilet stool.

2. Objectives

This research proposed some new designs on armrests of a toilet stool with three functions as follows:

1. A manpower saving mechanism formed by a four-bar linkage to lift up the toilet lid or the seat. It helps to solve the sanitation problem of a toilet stool.
2. Two sets of arm-training pulling rods are designed and installed beneath the armrests, those can help increase the elders' arm strength.
3. Two hand-gripping appliances are installed at the ends of the arm-training pulling rods

The features of armrests of a toilet stool stated above will enhance the functions of ordinary armrests.

3. Research Method

3.1 Systematic innovation process

This research enhances the functions of armrests of a toilet stool by systematic innovation process. First of all in the analysis of requirements, the armrests of a toilet stool are normally used to help the users to stand up after using. The armrests will play better roles and will be more popular if they are equipped with more functions. Therefore the problem is defined as "Improve functions of armrests of a toilet stool." Then the SCAMPER method, with 7 actions, is applied to generate more ideas related to improving functions. Finally the results of actions

are analyzed and evaluated to obtain feasible solutions. The flowchart of systematic innovation process is shown in Figure2.

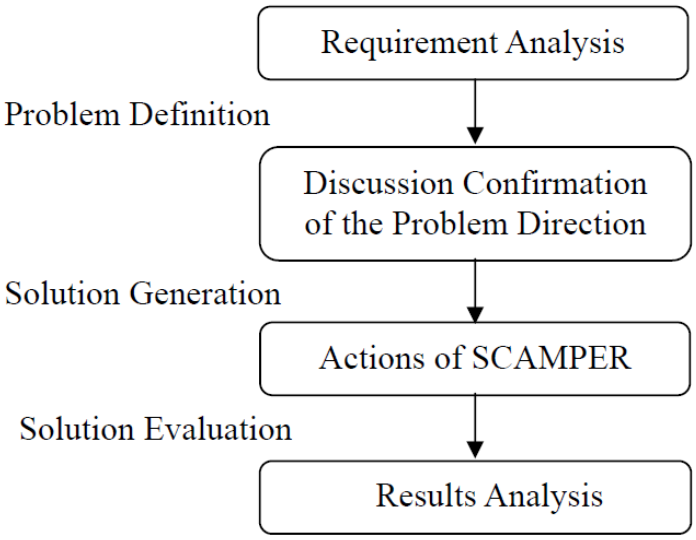

Figure2. Flowchart of systematic innovation process

3.2 Problem Hierarchy Analysis

The Problem Hierarchy Analysis is applied to analyze the problem when the systematic innovation process is confirmed. Firstly the original problem is defined as "Improve functions of armrests of a toilet stool," then functions are added to armrests. The action of "Add functions of hand-grabbing and arm-training" is taken to narrow the problem. The action of "Help users in many ways" is taken to broad the problem including "Improve sanitation of a toilet stool"、"Add flushing function" and "Lift the toilet lid and the seat" etc. Problem Hierarchy Analysis is shown in Figure3.

3.3 Actions of SCAMPER

SCAMPER is a tool to create more ideas systematically by applying 7 actions to create ideas. When the actions of SCAMPER are taken in detail, more than 10 ideas are created for armrests. They can be applied to improve functions of armrests of a toilet stool, as is stated to be the original problem in the problem hierarchy analysis figure3.

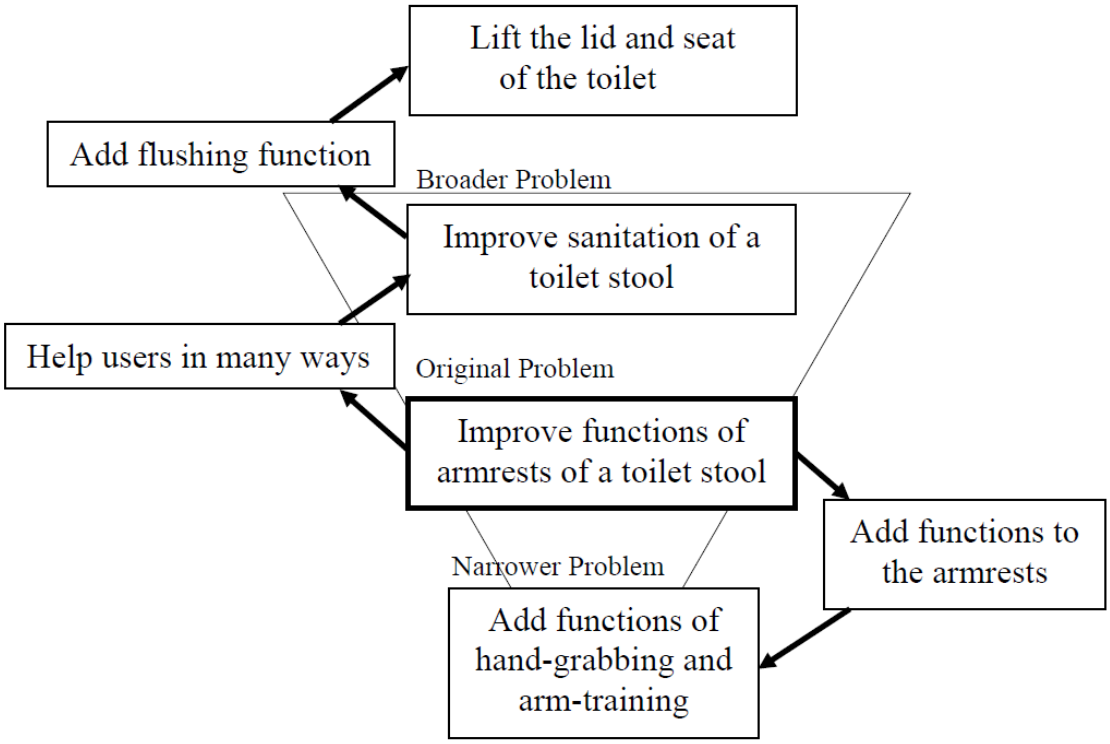

Figure3. Problem hierarchy analysis.

Table1. Actions of SCAMPER to create ideas for armrests.

No.	Actions	Ideas
1	Substitute	a. Substitute the armrests with tables. b. Substitute the armrests with high platforms.
2	Combine	a. Combine the armrests with arm trainers. b. Combine the armrests with hand grip trainers. c. Combine the armrests with hand massager by vibration.
3	Adapt	a. Adapt the armrests as the fix points for mechanisms to lift the toilet lid and seat. b. Adapt the armrests as the fix points for mechanisms to flushing function.
4	Modify/Magnify	a. Modify the height of armrests by moving up and down. Modify the b. surface of armrests to be rough enough for easier grabbing. c. Transmit heat to warm the armrests for the elders in winter.
5	Put to other uses	a. The armrests can hang bags, umbrellas, sticks, etc. by adding some hangers on the horizontal bar.
6	Eliminate	a. Remove some material by changing the shape of armrests ⊓ into shape of ┬.
7	Reverse/Rearrange	No application.

3.4 Results Analysis

Ideas are generated by S.C.A.M.P.E respectively after SCAMPER actions are taken. For example, the arm trainers can stretch the elders' arm and that promotes health when the armrests are combined with arm trainers. Hand-grip trainers can train the grabbing power of a palm and warm up the elders' hands when the armrests are combined with hand-grip trainers. A four-bar linkage can be installed to lift the lid and the seat of the stool when the armrests are adapted as the fix points for mechanisms. These three ideas are evaluated to be excellence and will be further studied for the detail mechanical design. The evaluations of ideas created by SCAMPER are listed in table 2.

Table2. Evaluations of ideas created by SCAMPER.

No.	Ideas	Evaluations	Explains
1	Substitute the armrests with tables.	Fair	A table is not easy to grab unless an arm is install in/on the table.
2	Substitute the armrests with high platforms.	Fair	A platform is not easy to grab unless an arm is install in/on the platform.
3	Combine the armrests with arm trainers.	Excellence	Arm trainers can stretch the elders' arm and that promotes health.
4	Combine the armrests with hand-grip trainers.	Excellence	Hand-grip trainers can warm up the elders' hands and that promotes health.
5	Combine the armrests with hand massager by vibration.	Good	Hand massager can also warm up the elders' hands and that promotes health.
6	Adapt the armrests as the fix points for mechanisms to lift the toilet lid and seat.	Excellence	A four-bar linkage can be installed to lift the lid and seat of the stool.
7	Adapt the armrests as the fix points for mechanisms to flushing function.	Fair	It may be feasible but will raise the cost of the system.
8	Modify the height of armrests by moving up and down.	Fair	Adjustable height of armrests will fit all users' convenience but will raise the cost of the system.
9	Modify the surface of armrests to be rough enough for easier grabbing.	Good	It will protect from slipping when grabbing the armrest.
10	Transmit heat to warm the armrests for the elders in winter.	Fair	It will raise the cost of the system.
11	The armrests can hang bags, umbrellas, sticks, etc. by adding some hangers on the horizontal bar.	Good	It enhances functions of armrests and is feasible.
12	Remove some material by changing the shape of armrests ┌┐ into shape of ┬.	Good	It will reduce the cost of the system but the fix surfaces of the armrests and the ground should be strong enough to ensure the safety.

4. Research Results

4.1 Four-Bar Mechanism for Lid and Seat

As some ideas are obtained by applying SCAMPER method on the armrests of toilet stool, detail designs are next to be worked on the ideas that are evaluated as excellence. As shown in Figure4, lid-lifting or seat-lifting mechanism is designed by a set of four-bar linkage to transmit the movement of lifting lid or lifting seat. In Figure5, when the arm of the four-bar linkage is pushed forward, link2 and link3 will transmit the movement to lift up the lid or the seat of the toilet stool. When the arm of the four-bar linkage is pushed backward, the lid or the seat of the toilet stool will be set down.

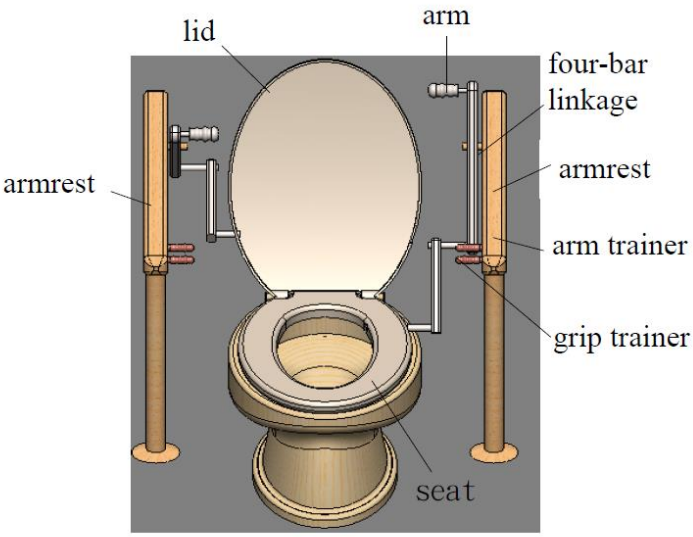

Figure4. Four-bar linkage on the armrests.

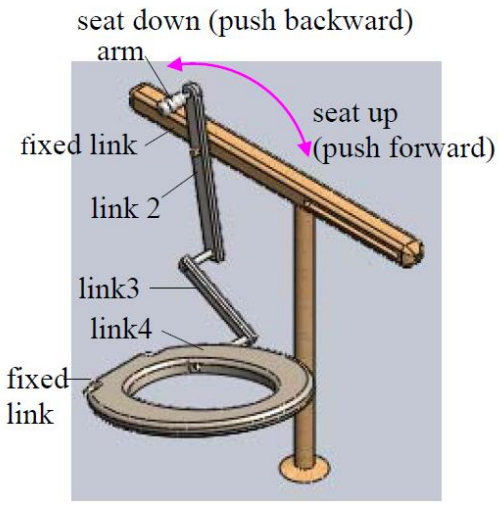

Figure5. The seat is set for use by four-bar linkage.

4.2 Arm Trainers and Hand Grip Trainers

As shown in Figure6, when the handle is pushed forward, the spring inside the armrest will be stretched and that will train the arm strength. The motions of back and forth will be repeated according to personal condition. In Figure7, when the handles are gripped by palm and fingers, the spring will be compressed and that will train the gripping strength. 圖 As long as push the handle forward to stretch the spring inside the armrest. To train the arm strength. The motions of continuous gripping will be repeated also according to personal condition.

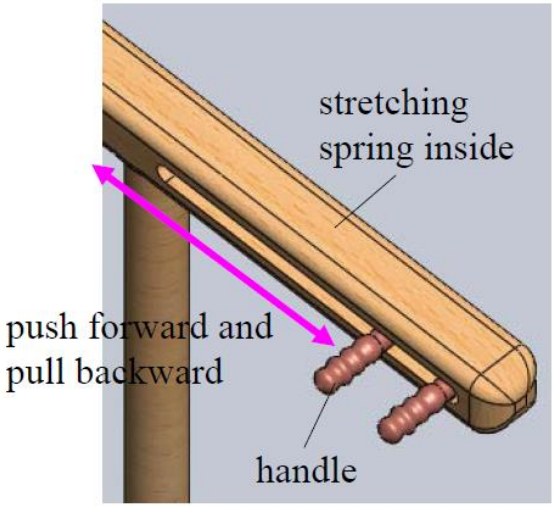

Figure6. Arm Trainers on the Armrest.

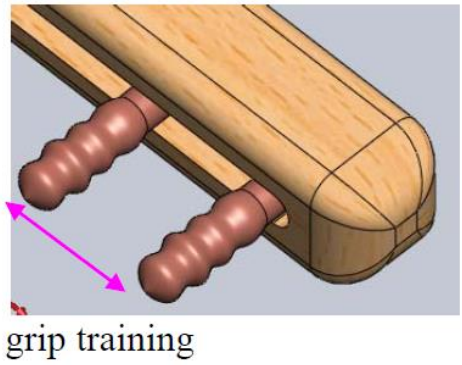

Figure7. Hand Grip Trainers on the Armrest.

4.3 Mockup Manufacturing

Figure.8 shows the manufactured mockup of the innovative design armrests of toilet stool based on the ideas created by SCAMPER actions. There includes two sets of four-bar linkages, two arm trainers and two grip trainers. All of the new designs meet the expected goals. The mockup was made in a smaller scale than the ordinary one for easy shipping and demonstration. In real use this mockup can be enlarged by the real scale.

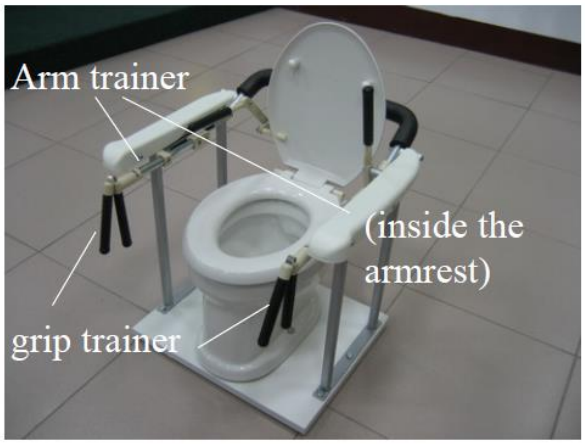

Figure8. Arm Trainers and Grip Trainers on the Armrests of a Toilet Stool.

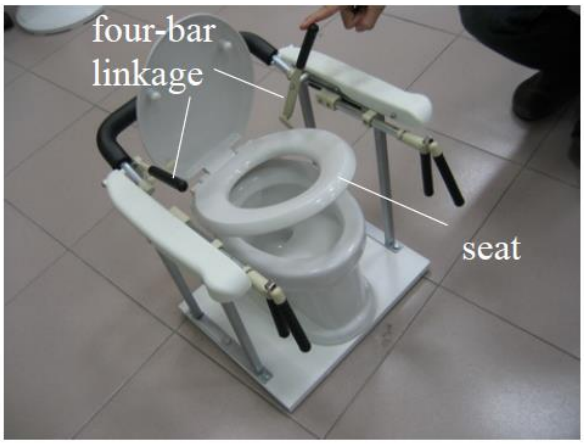

Figure9. Four-Bar Linkages on the Armrests.

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Paper ID: 52

How to teach TRIZ when time is limited: the "spiral" teaching technology

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Abstract

The report describes the approach to the teaching of technologies of revealing and solving inventive problems according to which students are first explained the operations procedure described by the algorithm of improving problem situations (AIPS) and study the minimal necessary set of methods and tools.

Already after the first day, thus trained students can effectively work on problems and at the following training levels they consistently deepen their understanding of the peculiarities of dealing with a problem situation and inventive problem; master additional tools and methods; improve their skills of using the algorithm.

This approach makes it possible to organize a systematic multi-level training of company's specialists. In addition, introducing a single standard algorithm of work on problems changes the company's inventive work into a well-organized process.

Keywords: problem-solving algorithm, spiral teaching technology, TRIZ learning.

1. Contradiction

What is the peculiar feature of studying TRIZ in the current situation? It consists in the radical decrease of time people are ready to spend on training. In principle, it concerns approaches to learning no matter what. Specialists of companies want to obtain a required amount of knowledge within minimal time. In addition, a purely theoretical knowledge is not strongly called for, there is a need for immediate practical results.

For the period of its existence, TRIZ has accumulated a huge knowledge body. It includes theoretical propositions as well as a number of tools and a rich database. Trainees should learn to understand the TRIZ-methodology foundation. It is necessary to explain them the working mechanisms of TRIZ tools and to give them practical skills of using these tools. It is necessary to teach them using the database and, first of all, using it all for obtaining a result – inventive problem solving.

It is impossible to teach TRIZ within one day. Even a two- or three-day workshop (such workshops are considered long enough) will be sufficient for giving only a portion of valuable information. Thus, we have the following contradiction:

- learning TRIZ to the extent sufficient for practical use requires much time,

- but companies interested in TRIZ training courses want to obtain the same result within minimal time.

2. Resolving

This contradiction can be solved by one of system transitions: providing a required state of some part of a component leaving the rest of the components in the initial state.

We can consider a specialist to be trained as a component to be changed. Let the entire specialist be in his usual state and only his part responsible for inventive problem solving undergoes changes.

The company's specialist is a grown person having knowledge and experience. The only difficulty is that he has been trained based on the classical traditions of education aimed not at creation and invention, but at exploitation, engineering, organization and other problems united under the common slogan of optimization. It is good for everyday work. However, when facing an unresolvable situation, such a specialist can found himself at a loss, not because he has no knowledge –he does have it – but just because he lacks understanding of how to apply his knowledge to a new, nontrivial problem.

The spiral TRIZ-teaching technology is aimed at the maximal use of the specialist's knowledge and experience and simply helps to target them – to organize them for solving an inventive problem. This is the essence of resolving the above-mentioned contradiction. We do not teach specialists to think in a new manner, in a TRIZ manner, but simply give them a key to their own knowledge.

The spiral technology is the elaboration of *the network TRIZ-teaching technology* proposed by N. Khomenko [1, 2]. The network technology was also developed in response to the necessity of shortening the training time. The common feature for both technologies is also practice-oriented approach.

The basic difference is as follows. In the spiral technology, the entire training process is geared to a single algorithm and trainees should pass through all of its steps while solving each problem. No such central algorithm is present in the network technology. Training problems are selected in such a manner as to lay an emphasis on one or another TRIZ tool. This distinction can be also explained in the following way. In the spiral technology, we start with explaining the structure, demonstrating the relations between the problem-solving actions, whereas in the network technology the comprehension of these relations proceeds gradually.

The essence of the spiral teaching technology can be expressed in the following way: the first thing to do is to explain a trainee *what and why should be done* for solving a problem and them to show *how it can be done.*

The core of the spiral teaching technology is a single problem-solving algorithm. This algorithm has several levels of complexity: from the simplest and generalized which can be explained within an hour and immediately applied practically to the most detailed one the explanation of which requires writing of a whole book [3]. The algorithm was named the Algorithm of Improving Problem Situations, AIPS.

The complexity buildup in the training process is gradual and uniform. The first "round" is dedicated to the explanation of the sense of actions according to the most generalized algorithm version. Then the larger actions are segmented into small steps, the algorithm becomes more and more detailed. In the next "round", one TRIZ-tool is offered for performing each step. Then it is shown that one and the same action can be performed by different tools. Also, the flexibility of the algorithm and the possibility of adjusting it to the solver's individual preferences are demonstrated. Each case of algorithm-based problem solving leads to refining the skills of TRIZ tool application. At each run, basic theoretical propositions and their relations with each other and with the tools are explained. Trainees not only master practical skills but also start understanding the TRIZ philosophy.

As a result, even if training was very short, trainees have no gaps in their bundle of TRIZ knowledge: they have the required minimum of information on each significant theoretical proposition and each effective tool. Moreover, in-room training is followed by self-education and all newly-obtained knowledge finds their place in the preset structure.

Different complexity levels of the algorithm are presented in the graphical schemes which are visually successive with respect to each other.

▪2.1 The first complexity level of the algorithm

At the very beginning, students are explained that the disadvantage-eliminating work is divided into three stages (Figure 1). The first, analytical stage is dedicated to the investigation of an initial problem situation for identifying its core – a conflict. Then a technical problem about the conflict-eliminating way is formulated. The second, stage deals with problem solving. This is done by performing the following actions. Using one of the transformation tools of TRIZ (here we usually enumerate these tools without going into detail) or just using engineering experience, for example, by finding an analogous solution. This provides some idea about the technical system transformation. To realize the transformations, we need some resource. To find this resource, first it is necessary to describe in maximum details requirements imposed on it. While looking for a resource, it is important to be guided by IFR – Ideal Final Result. After finding the resource, it is necessary to formulate a solution – the description of changes in the initial technical system. At the third stage, it is necessary to make sure that the proposed changes eliminate the conflict.

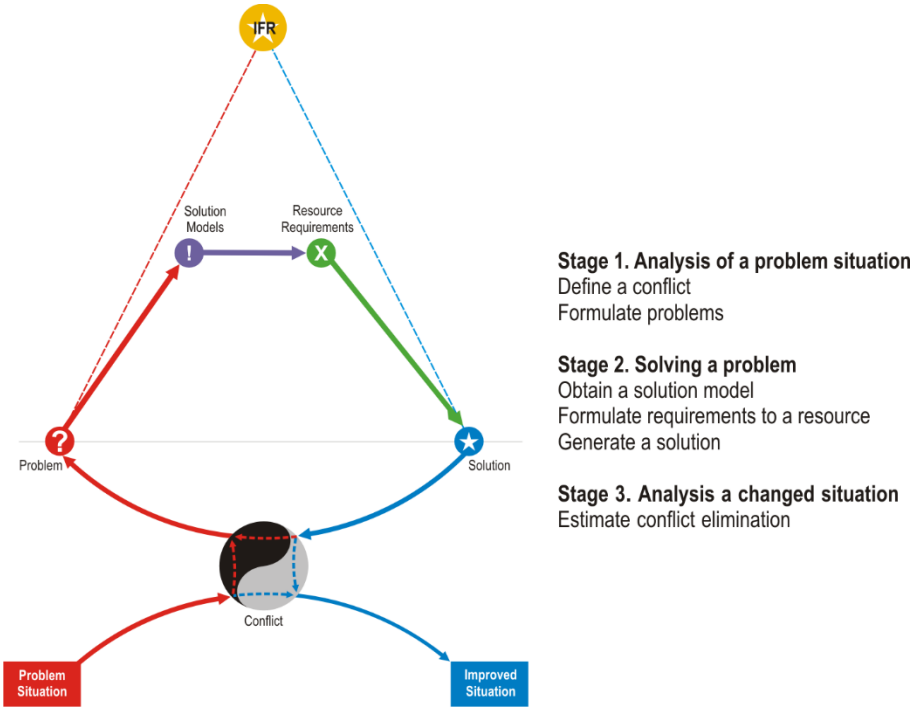


Figure 1. The first complexity level of the algorithm.

▪2.2 The second complexity level of the algorithm

A single passage from a problem to a solution does not often give a good result. In addition, TRIZ tools are many and the question is which of them to choose.

An analogy can be drawn with shooting. It is very difficult to hit a target with the first shot, so adjustment fire is used: they make several adjustment shots, determine errors and introduce corrections. Similarly, it is better to solve a problem using this “adjustment” method. First, it is necessary to obtain a solution by any method, even if this method is costly and requires use of an expensive and complicated equipment. Then you can aim at an ideal solution. To this end, ideality requirements are made more and more stringent in the course of generating new solutions.

Each “shot” is the application of one or another TRIZ-tool (the application order is specified by the algorithm). To use a tool, it is necessary to build different problem models, deriving necessary information from the initial problem statement.

After passing all the four solving iterations, the solver obtains a set of preliminary solutions. Then he selects one or combines several of them to build a final solution (Figure 2).

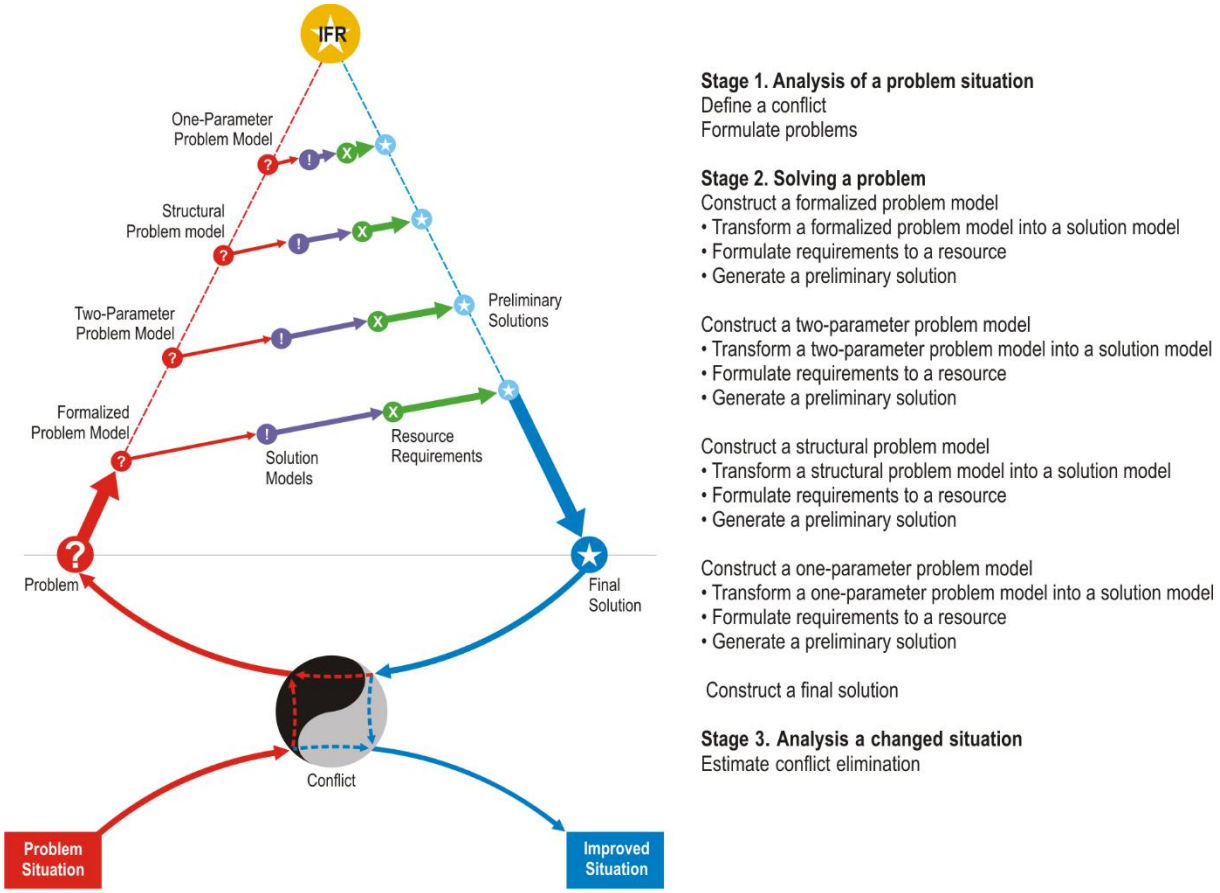


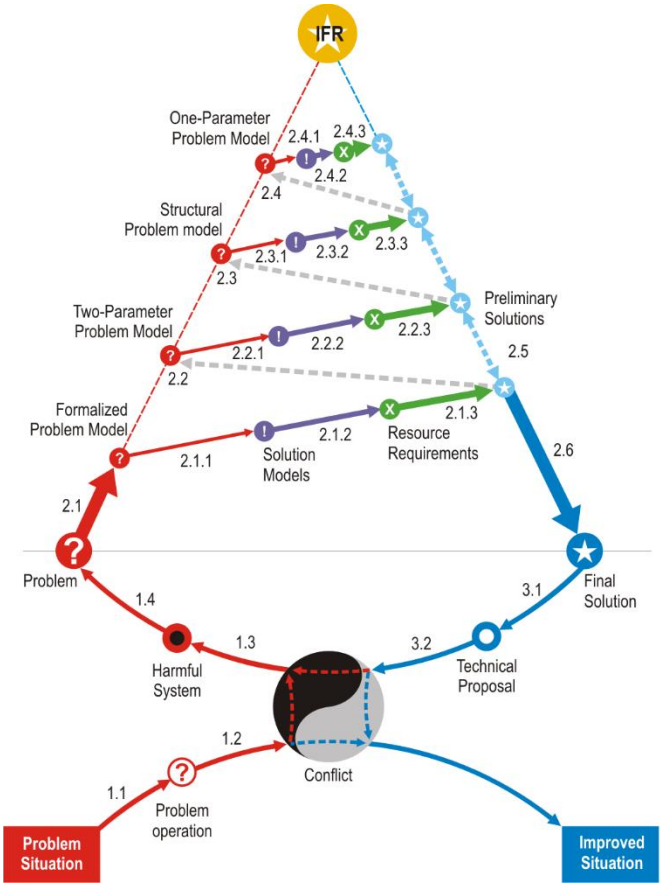
Figure 2. The second complexity level of the algorithm.

▪2.3 The third complexity level of the algorithm

The actions at the first analytical stage of the algorithm are complicated enough. At this level, the actions are specificated more thoroughly: it is shown that revealing a conflict requires determining the problem-causing operation of a production process and technical problem formulation starts after investigating the conflict causes (Figure 3). Each of these steps is in turn divided into sub-steps (Figure 4).

The second stage of the algorithm also needs specification. Iterations of work on a problem cannot be independent of each other. Each new preliminary solution clarifies the problem core. Moreover, the problem can alter: instead of the initial statement, there can appear a new goal – finding a technical method of realizing the solution obtained at the previous iteration. The dashed lines on the scheme show these additional relations (Figure 3).

At the third stage, an intermediate step is also introduced: making a technical proposal.



Stage 1. Analysis of a problem situation
Step 1.1. Revealing a problem operation
Step 1.2. Define a conflict
Step 1.3. Investigate conflict causes
Step 1.4. Formulate problems

Stage 2. Solving a problem
Step 2.1. Construct a formalized problem model
Step 2.1.1. Transform a formalized problem model into a solution model
Step 2.1.2. Formulate requirements to a resource
Step 2.1.3. Generate a preliminary solution

Step 2.2. Construct a two-parameter problem model
Step 2.2.1. Transform a two-parameter problem model into a solution model
Step 2.2.2. Formulate requirements to a resource
Step 2.2.3. Generate a preliminary solution

Step 2.3. Construct a structural problem model
Step 2.3.1. Transform a structural problem model into a solution model
Step 2.3.2. Formulate requirements to a resource
Step 2.3.3. Generate a preliminary solution

Step 2.4. Construct a one-parameter problem model
Step 2.4.1. Transform a one-parameter problem model into a solution model
Step 2.4.2. Formulate requirements to a resource
Step 2.4.3. Generate a preliminary solution

Step 2.5. Generate alternative preliminary solutions
Step 2.6. Construct a final solution

Stage 3. Analysis a changed situation
Step 3.1. Compose a technical proposal
Step 3.2. Estimate conflict elimination

Figure 3. The third complexity level of the algorithm.

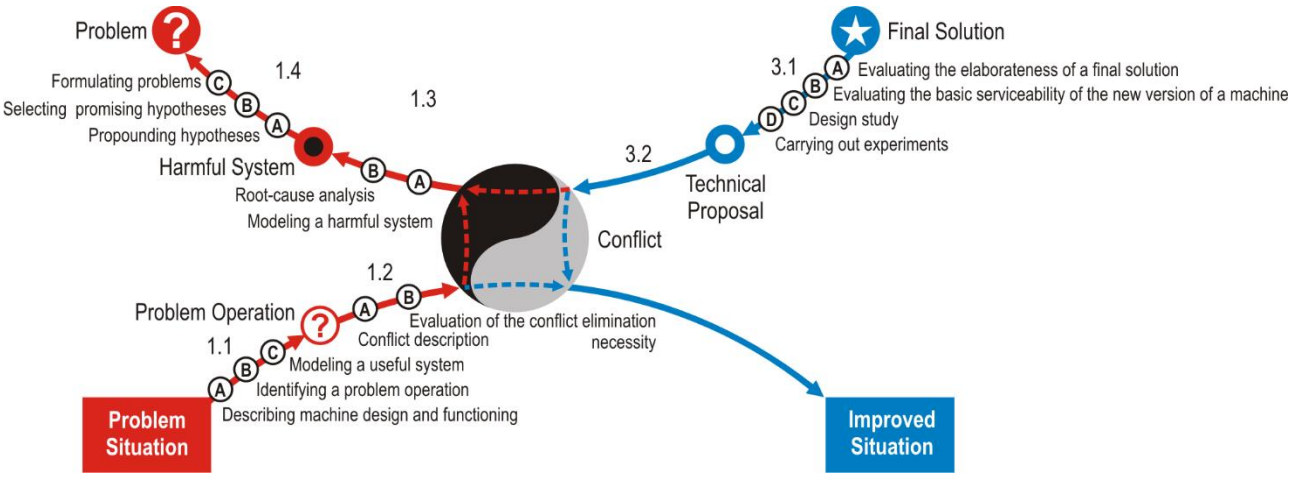


Figure 4. Sub-steps of the first stage steps.

▪2.4 The algorithm plus tools and methods

To understand what tool and method should be used at a given stage, trainees can use the scheme shown in Figure 5. The set of tools in the scheme depends on the training program.

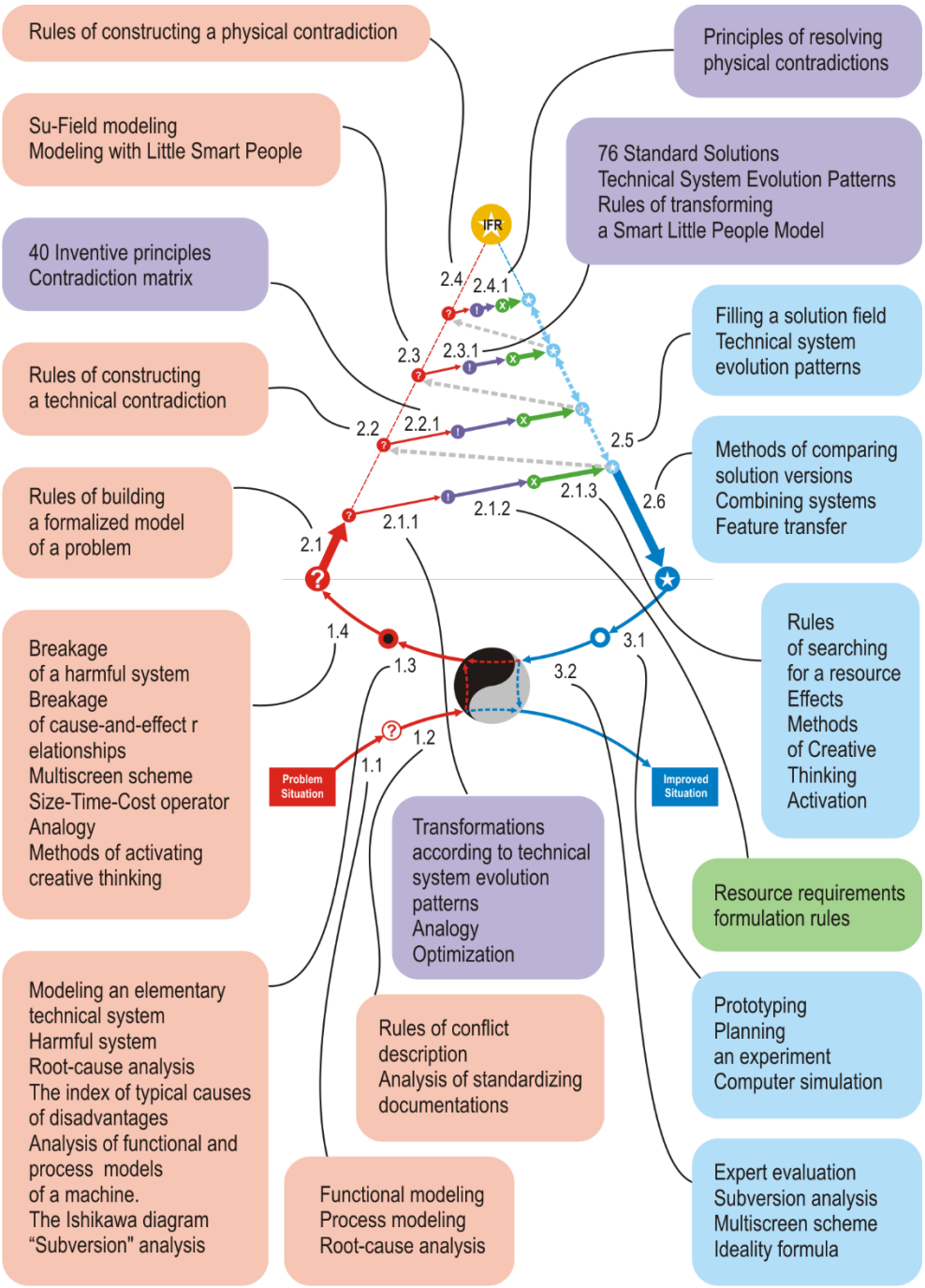


Figure 5. The algorithm plus tools and methods.

▪2.5 Further study during practical work

Having such an algorithm at their disposal, trainees do not stop learning after leaving the classroom. When they solve their practical problems, each application of the algorithm results in better understanding of the action sense and the tool and method application skills become automatic.

To make this "life-long learning" even more effective, we have started proposing our trainees to solve problems by using our Solving Mill software product based on the above-described algorithm.

The spiral is an endless curve. Similarly, knowledge and skill perfection are infinite. The main thing is showing a trainee the right direction, the rest depends on himself.

▪Conclusion

1. The main contradiction in teaching TRIZ is in that learning TRIZ requires much time and company specialists do not have much time.

2. Correct use of resources – initial knowledge and skills of a specialist – allows organizing effective teaching of TRIZ within a short period of time.

3. The spiral teaching technology gives a specialist only the most necessary information for redirecting his efforts toward inventive problem solving.

4. The problem-solving algorithm expansion principle is demonstrated – from the generalized to the expanded AIPS-2012.

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Paper ID: 53

Solving Algorithm for Solving Software

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Target Invention

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Abstract

The report describes the development of a problem-solving algorithm which can be used both as a methodological support to an inventor and a solver and as a basis for solving software packages.

Why is it difficult to transform existent TRIZ algorithms into a software form? What are the requirements for the effective solving algorithm? What are the main principles of the solving algorithm and software package development?

The algorithm development and its following adaptation for the software served as an indicator of the weak points in TRIZ methodology practical application. Some parts of a problem solving process were difficult to formalize and algorithmize because of the insufficient methodical elaboration. How can the weak points be improved?

Keywords: methodical support of inventor, problem-solving algorithm, TRIZ-based software.

1. The need for the algorithm and software for solvers of specific production problems

There are many TRIZ-based software products available, yet solvers always want something else, something better. Existing software undoubtedly helps solvers and satisfies many of their needs, but these products can still be improved for meeting the solver's most urgent demand – mere solving of real production problems.

Why does it happen? We think that one of the main reasons is the imperfection of the problem-solving algorithms underlying these software products.

Most TRIZ-based software products are modular in structure. One module represents one TRIZ-tool. It is natural because separate TRIZ tools are easily translated into a software language. What can be easier than programming the contradiction matrix? Only programming such tools as the multi-screen scheme and size-time-cost operator. The system of standards are also comparatively easy to algorithmize [1], though this job will be more labor-intensive.

Each of such modules performs its specific tasks perfectly, covering one or another stage of the work on a problem. It turns out that a large algorithm of work on a problem is essentially reduced to several small algorithms of work with separate tools. It would have been acceptable if there had been observed an obvious consistency between the work results in different modules. Unfortunately, the modules generally have a very conventional relation with each other. Each module is designed as self-contained.

The point is that dealing with a problem requires a consistent application of various TRIZ tools. To ensure adequate work, a solver needs an algorithm for the entire problem-solving process. Such an algorithm should specify when and wherefore each of the tools should be used. That is, separate TRIZ tools (and, accordingly, software modules) should be integrated into a single logic structure.

At first sight, such a structure is represented by ARIZ 85B. Yet the attempts to build software by carefully following the ARIZ logic are blocked by a number of its peculiar features, such as:

- By no means all the classical TRIZ tools found their niche in ARIZ 85B, not to mention new, effective tools which appeared after the creation of the classical ARIZ 1985 version.

- There is a violation of logic in ARIZ. In particular, step 4 violates the logic sequence of actions; the definitions of a physical contradiction and an operational zone are contradictive; the bond between the repeated uses of the system of standards is weak. Find more detailed information about these and other problems with the ARIZ logic in publications [2, 3].

- The levels of detail of the steps are very different. Some aspects of the solving process are well-elaborated while others are given in the form of general recommendations.

- The language and methodological approaches of ARIZ are very unusual. Only an advanced TRIZ-solver can deal with ARIZ, which is expressly stipulated in the introduction to this algorithm [4]. It means that an ordinary user will not be able to use ARIZ software effectively and adjustment of the software to such a user will entail a considerable alteration of the algorithm.

There is one more important disadvantage of ARIZ which does not affect its conversion into a software form but restricts it usefulness for the problem-solving process. It refers to the absence of the problem situation analysis for identifying a specific problem. It is expected that problems have been formulated by the moment the work with ARIZ starts. However, the identification and formulation of problems are a huge portion of work which also requires a methodical support to a solver. However, ARIZ 85B does not offer this support.

In addition to ARIZ 85B, there are also more recent algorithms which support a solving process (both converted into a software form and used off-line). Without dwelling on the analysis of these algorithms, it is worth mentioning the characteristic feature of many of them: they are largely designed for work at high abstraction levels. These algorithms are very useful for strategic problem solving, but are of little use for non-global, up-to-the-minute problems of an ordinary engineer.

Let us consider an example. Perhaps, it is a little bit exaggerated but it can serve as a good illustration to this situation.

There is a problem relating to the carriage of iron products by sea. Iron partially corrodes during carriage. High abstraction level algorithms recommend fighting the cause but not the effect. As a result, the following types of solutions can be obtained: carrying iron only by land or, even better, by air. No land transport? Too expensive by air? OK. Make a step back from IFR. It is necessary to avid any contact of iron with saline moisture. Let us carry iron not in ship's holds but suspended high above the deck. An excellent solution. Economists can calculate profit, designers can make calculations for creating a new design which will prevent the ship from turning over due to the cardinal change of the center of gravity, shipbuilders can prepare slips...

The question is what an engineer responsible for the preservation of the iron should do right now. Not in the three years when a ship of a new design is launched. Iron is corroding right now and the company is loosing profit right now.

Thus, ordinary production engineers have there own needs which are not fully satisfied. We felt it necessary to set sights on the creation of an algorithm and software for solving vital production problems.

2. Problem-solving software algorithm development

What requirements are imposed on an algorithm suitable for problem-solving TRIZ-based software product? Such an algorithm should:

- be specialized, tailored especially for solving disadvantage-removing problems. Indeed, an effective and detailed algorithm cannot be universal (for instance, cannot be equally suitable for disadvantage-removing problems and for prognostic problems). [5]

- provide methodical support to the entire problem-solving process: from a problem situation to the complete removal of a disadvantage.

- be fully logic, without any inaccuracies, ambiguities and contradictions.

- have an equal level of detail at all its steps.

- be, to extent possible, simple without loosing the solving properties, i.e., have an optimal level of complexity.

Such an algorithm called AIPS, The Algorithm of Improving Problem Situations (Figure 1) was developed and repeatedly tested in production projects [6]. Then a problem-solving software product was worked out on its basis (it was given the name of Solving Mill).

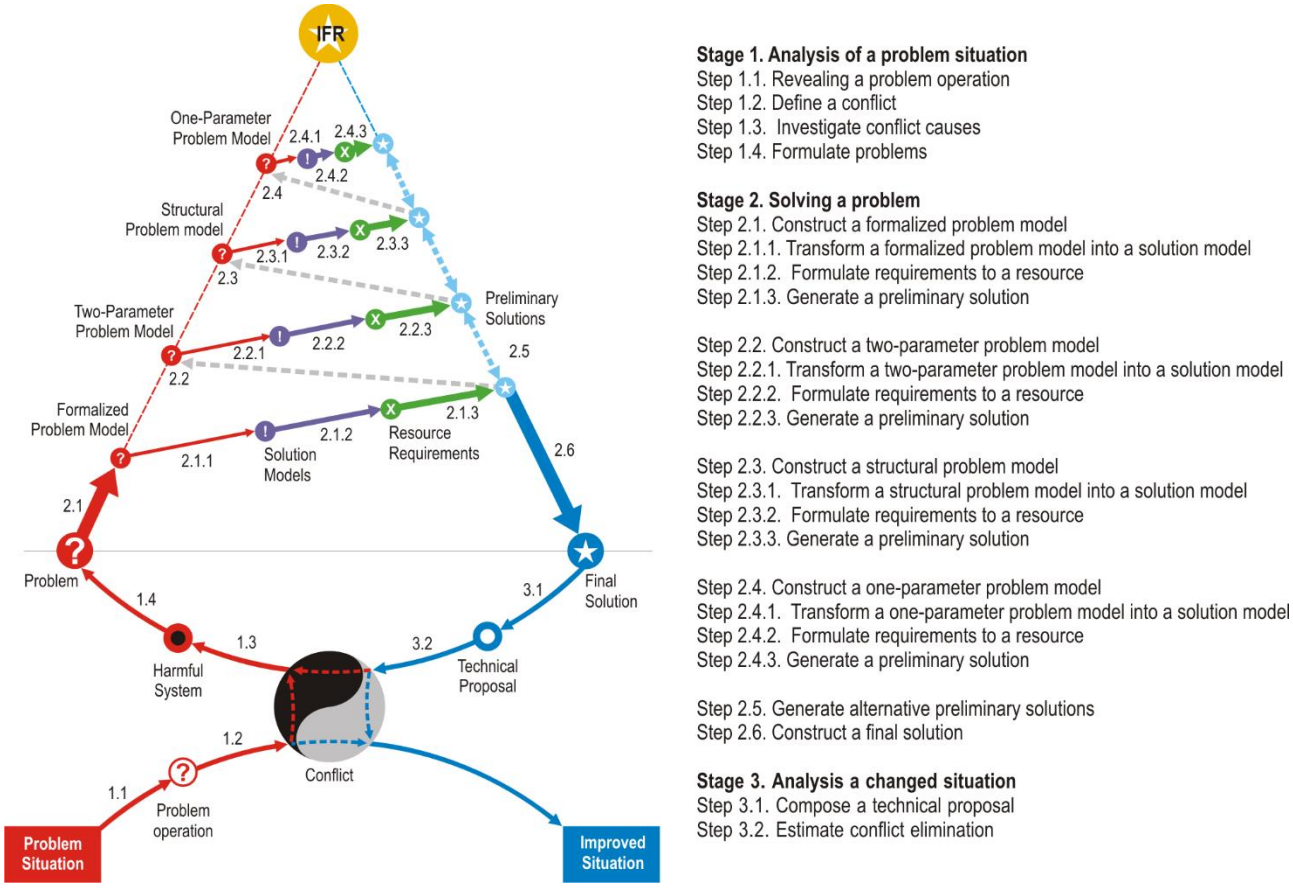

Figure 1. The Algorithm of Improving Problem Situations (AIPS, version 2012) and its graphical scheme.

We built the algorithm on the basis of the entire methodical body of TRIZ, including individual tools, ARIZ and theoretical propositions.

The elaboration of an algorithm for a software product has one peculiar feature: it reveals all the disadvantages of the methods underlying the algorithm. Both well-formalized methods and propositions expressed in a free form coexist in TRIZ. However, software requires an extremely distinct logic and any ambiguity and hidden contradictions becomes obvious. For this reason, tales should be turned into technologies.

Let us dwell on two “bottlenecks” of the problem-solving process based on the TRIZ method. They required a thorough study. The first bottleneck is identification of a specific technical problem in a problem situation. The second one is obtaining a specific technical solution suitable for real production circumstances.

▪2.1 Identification of a technical problem in a problem situation

Correct formulation of a technical problem is a key moment of a problem-solving process. In ARIZ 85B, this important moment is completely absent. It is assumed that we start ARIZ-based work

after formulating a problem. The classical TRIZ does not provide any distinct tools for identifying and formulating a problem. Naturally, this important moment could not be disregarded by TRIZ experts.

A.M. Pinyaev [7] proposes to pass to an inventive problem through the functional analysis of an inventive situation and causal analysis of undesirable effects and identification of the key ones.

In the ARIZ version of the Kishinev TRIZ school (ARIZ-SMVA-91) [8], it is also proposed to formulate problems by means of functional analysis of an inventive situation and identification of harmful functions to be removed.

GEN3 methods propose a still wider angle of vision of a situation [9] so as to select a promising technical system for improvement and not waste time and efforts on a system of a little promise.

All these methods perfectly suit the large-scale improvement of technical systems and design of new ones. All disadvantages are revealed and a technical problem is formulated with respect to each of them.

But an ordinary production engineer does not often deal with strategic situations. They generally need to remove some specific disadvantage relating to an already existing and operating technical system. They must deal with tactical problem situations to be resolved here and now using available resource.

The algorithm AEPC (by G. Ivanov and A. Bystritsky) most fully responds to the aspirations of our engineer, probably, because its developers have a multi-year experience in production activities. According to AEPC, it is necessary to analyze resources directly connected with an “undesirable element” causing an “undesirable event”. Then, using the IFR formulation, it is necessary to formulate problems about the possibility to apply the chosen resources [10]. Note that there is no question of dissipating the solver’s attention due to multiple disadvantages. The solver only deals with one specific disadvantage.

Our approach is close to that of Ivanov and Bystritsky – we also propose searching in several directions for ways of removing a disadvantage by formulating a bunch of problems. The distinction is in the problem–identification method itself, because an auxiliary step is used. It is the formulation of a hypothesis about conflict-eliminating ways.

After studying the machine relating to a problem situation, revealing conflicting components and investigating the conflict causes, a solver has enough information for outlining the conflict-eliminating ways.

A hypothesis is a supposition of what the conflict-eliminating conditions are like. That is, what should be done to eliminate a conflict.

However, the realization of the proposals can be hindered by various restrictions or the realization itself can cause the appearance of new disadvantages. Also the technical way of realizing the proposals may not be known. Thus, a specific technical problem is becoming obvious: how to achieve a goal bypassing the restrictions, avoiding the appearance of new disadvantages, etc. The problem has a formulation – how to do what is proposed in the hypothesis.

If no new disadvantages and restrictions occur and the technical implementation method is obvious, the hypothesis automatically turns into a solution.

What benefit do hypotheses provide?

- They allow viewing the entire field of possible solutions and prevent missing important search directions.
- Due to the full picture, it is easy to select promising work lines.
- A hypothesis can contain a suitable solution and additional labor input becomes unnecessary.

While searching for a tool used for making hypotheses, it became clear that many tools used in TRIZ for different purposes may be adapted to hypothesizing.

The simplest ones are the size-time-cost operator and multiscreen scheme. They allow a broad view of a situation and swing the mental inertia. The “harmful system” [11] and root-cause analysis are more targeted tools. Various methods of destroying a revealed disadvantage-causing harmful system are an excellent source of hypotheses. Similarly, one can try to break a cause-and-effect relation of negative events which lead to the appearance of a disadvantage. One more tool is improvement of the useful system components.

Each of these tools is easy to formalize. The tool use guide can be formulated in the form of a simple mini-algorithm composed of several steps. And, not surprisingly, such an algorithm can be implemented by program means.

The procedure in the software is as follows (Figures 2, 3, 4). The user formulates hypotheses based on his engineering experience or using one of five operators. Already at the hypothesis suggesting stage, the user can perform initial selection so as not to transform knowingly dead-end solving lines into formulated problems.

Then the user points out, if necessary, what prevents the hypothesis realization and formulates a technical problem. It only remains to determine the problem solving procedure: to select the most promising problems leaving the rest of them as a reserve.

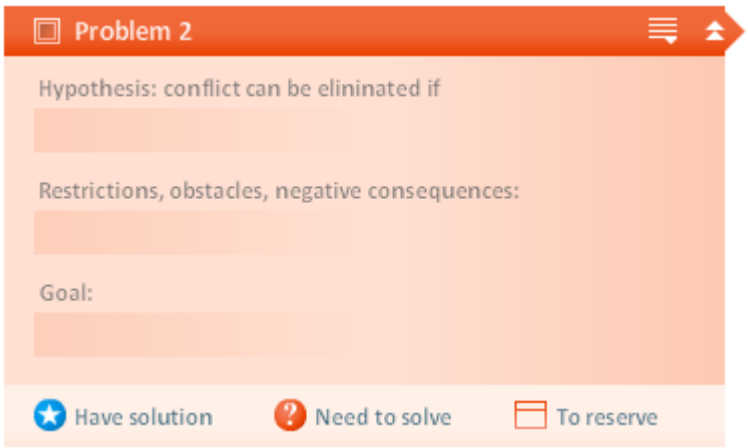

Figure 2. The template of problem formulation.

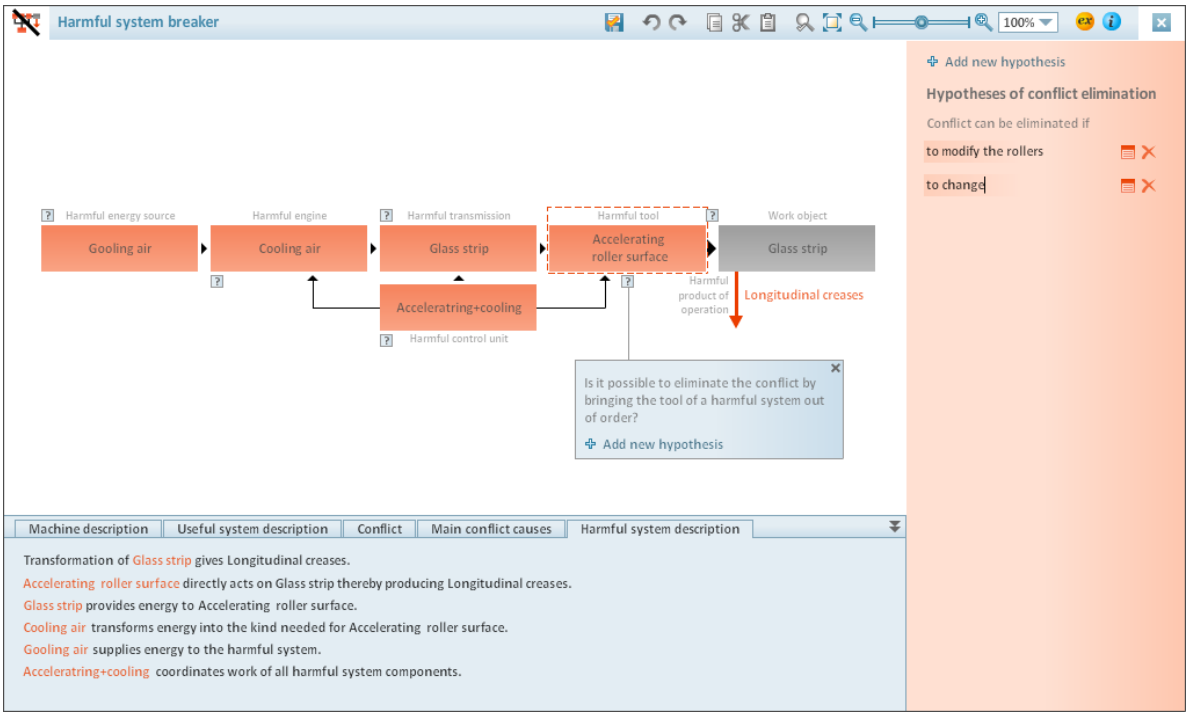

Figure 3. The operator for hypothesizing by destroying a harmful system.

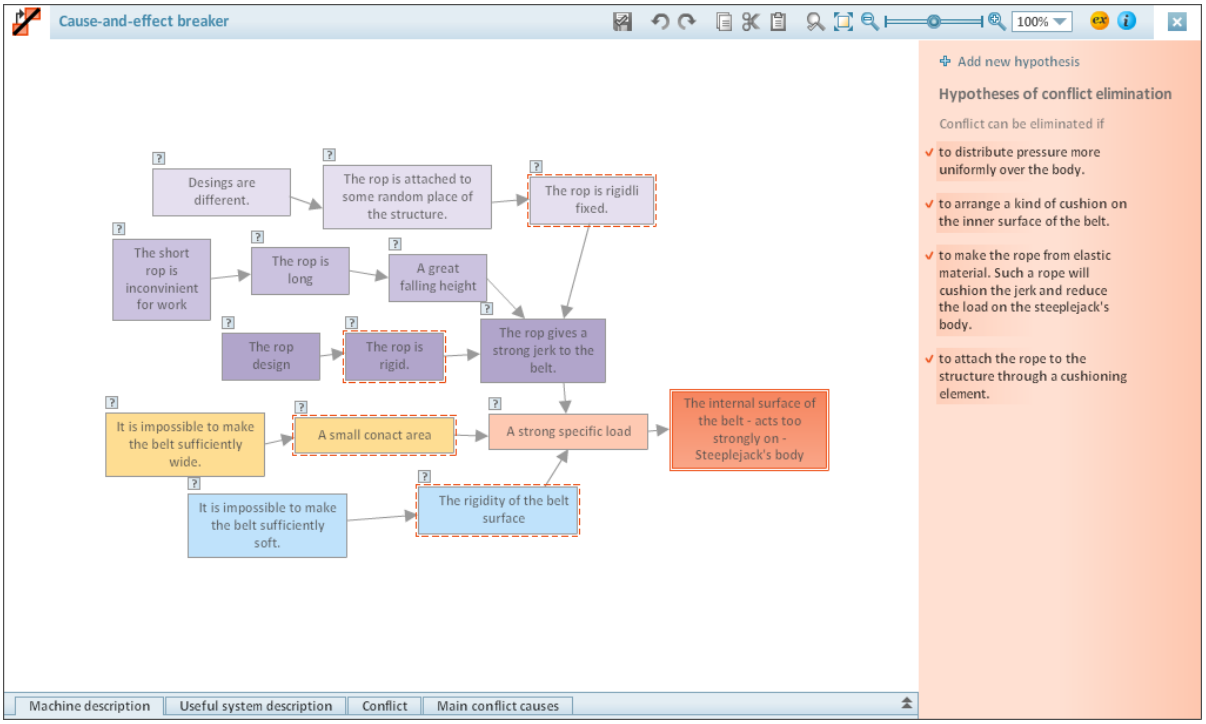

Figure 4. The operator for hypothesizing by breaking cause-and-effect relations.

▪2.2 Transition from a conceptual solution to a technical solution

TRIZ offers many tools for obtaining a conceptual solution to the problem: inventive principles, system of standards, smart little people modeling, evolution patterns, resources, golden fish method, size-time- cost operator, etc. Here the key word is conceptual solution. Unfortunately TRIZ tools can only stimulate the solver to use some idea, give a useful prompt, but the solver should cover the rest of the way towards a specific technical solution by himself.

All algorithms we know are built according to the following method: “use <tool>, write down the idea”. The gap between the application of a tool and an idea, i.e., a technical solution, is too big. We though it necessary to fill the gap (remember about one of the requirements imposed on a problem-solving algorithm - uniform detailing).

We managed to do it by building a chain of actions:

- using a transformation TRIZ tool (obtaining a solution model, i.e., a general idea);
- formulating resource requirements which will enable the embodiment of this idea in a real technical device;
- analyzing the available resources for the compliance with the requirements;
- adapting the suitable resource for the use in the given technical device.

The first stage is well-elaborated in TRIZ and is easy to formalize. Above, we have already mentioned that TRIZ tools were converted into the software by many developers.

As to the requirements imposed on a resource, the situation is somewhat more complicated. The set of these requirements may be extremely diverse. The simplest variant is allowing the solver to write down these requirements in any form. In this case, however, we will be unable to effectively use the list of requirements for searching for a resource.

We tried to structure the requirements. What is a list of requirements for a resource? It is the resource description, a kind of verbal "portrait". Let us draw an analogy with making a photofit. There is a number of significant attributes that can be used for classification – face shape, forehead size, distance between eyes, etc. Although resources for inventive problem solving are much more diverse than human faces and anything may turn out to be a suitable resource: a substance, a field, or a device. Nevertheless, it is possible to identify a series of attributes which have very many chances to belong to vast classes of resources. For example, for substance resources, they are size, number, material properties, chemical properties, surface properties, etc.

While checking the attribute description of a resource at workshops and in practical work, it became clear that it is more useful to divide a description into two parts and describe the attributes of an action required for conflict eliminating and the and the resource (performer of action) itself separately (Figure 5). Action attributes are action type (for instance, heat, hit, brake, separate), intensity, permanency/periodicity, acted area size, etc.

Attributes of action	Hide empties ▲ Show brief ▲
Action type	
Presence / Absence	
Intensity	
Uniformity / Structure	
Place in system	
Acted area size	
Acted area shape	
Motion	
Start and finish	
Permanency / Periodicity	
Restrictions	
Custom attributes	

Attributes of resource	Hide empties ▲ Show brief ▲
Performer type	
Presence / Absence	
Size	
Quantity	
Shape	
Surface properties	
Internal structure properties	
Material properties	
Chemical properties	
Motion	
Restrictions	
Custom attributes	

Figure 5. The template of requirements to a resource.

Here more and more detailed structuring of requirements is expected so that not the solver, but the software itself can search for a suitable resource. This is in our plans. Meanwhile we use the list of requirements composed by a user, assist him with searching for a required resource. The program automatically generates a series of questions, the answers to which help to determine the degree of conformity of the resource under analysis with the. the requirements (Figure 6).

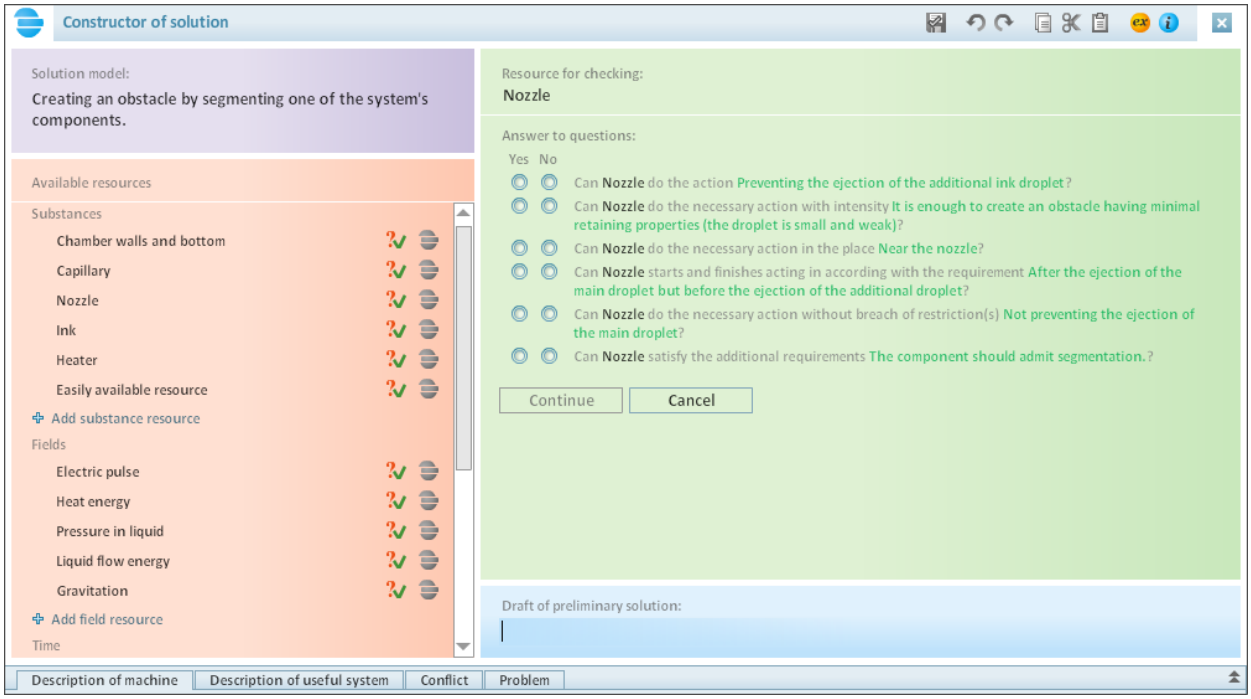

Figure 6. The operator for solution constructing.

If the resource is suitable, the program proposes a draft solution for the user to specify and refine, that is, to formulate a technical solution as such.

This last step is much more difficult to formalize, because every device is unique and generalization (and formalization inevitably leads to generalization) turns us back to the initial situation of "general idea". That is why at this step the software only helps the user by giving methodical recommendations. Yet it would be very useful to provide software support for adapting the selected resource to specific technical conditions. This is the challenge we are going to respond to in one of the next versions of the Solving Mill software.

▪Conclusion

1. There is a series of problem-solving algorithms and software product. They do not fully satisfy the needs of production engineers.

2. The needs of production engineers can be satisfied by a specialized algorithm designed for solving disadvantage-removing problems. The algorithm should be fully logic, uniformly detailed and simple if possible.

3. While developing this algorithm, there were created new methodical tools, in particular, the method of obtaining technicals problems by creating hypotheses relating to conflict-eliminating ways, tools for transition from a conceptual solution to a technical solution, a template for describing a required resource by means of attributes.

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Organization of teachers' innovation activities on the basis of the Theory of Inventive Problem Solving (TRIZ)

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Abstract

The rapid development of modern society requires a cardinal change in all education system components. Accordingly, the requirements imposed on the teachers' work conditions, educational process and its outcomes also undergo changes. Currently, management of teachers' innovation activities and support of innovations in the field of education are live issues all over the world. The Theory of Inventive Problem Solving (TRIZ) and the General System of Powerful Thinking (OTSM) are taking a special significance in the innovative processes occurring in the field of education. On the one hand, they should become a basic component of the education content because they provide domain-free tools required for managing the education process based on the revealing and solving of problems from various fields of knowledge by students themselves. On the other hand, TRIZ and OTSM offer teachers effective tools for solving problems in the field of education, that is, for creating innovations.

This article is dedicated to the problems of organizing teachers' innovation activities on the basis of the Theory of Inventive Problem Solving (TRIZ).

The article is concerned with the analysis and selection of a theoretical foundation necessary for the development of a model of innovation activities in education: psychological theories of activities, typologies of innovations in the education theory and classification of inventive solutions in TRIZ, TRIZ laws of system evolution in the context of pedagogical systems. There were revealed key contradictions in the management of teachers' innovation activities and conceptual solution alternatives. They were used as a basis for the development

of the principles of organizing the innovation activities of teachers. The principles are represented by four groups:

1. Principles of pedagogic definition of objectives in an innovation process;
2. Principles of updating the teacher's activities content in the course of innovation realization;
3. Principles of organizing teacher's activities in an innovation process;
4. Principles of resource renewal of teacher's innovation activities (program and methodical aspect).

Based on the conducted research, the typology of innovation problems which fall within the competence of a teacher was proposed and the scheme of arranging pilot areas was developed for wide introduction of pedagogical OTSM-TRIZ tools into the education process. The results presented in the article make it possible to control the process of creating and introducing innovations in the sphere of pedagogical activities.

Keywords: innovations, innovations in Education, TRIZ, OTSM

1. Introduction

The reorganization of the educational system in response to the socio-economic changes occurring in society at the world and at the Russian level manifested itself in new problems to be solved for ensuring the educational system functioning stability. The problems of organizing the teachers' work conditions, determining new requirements imposed on the pedagogic process realization and its outcome effectiveness are now becoming ever more urgent. Solving these problems determines the necessity of organizing the following working areas in the educational system:

1. Continuous coordination of institutional and non-institutional education, which determines:

   – the demand for continuing self-education, creation of new technologies, exploiting of new resources within the shortest periods of time, development of the unique potential of each student;

   – the necessity of developing the skills of handling non-typical problems, behaving in non-standard situations, modeling with non-standard situations in practice, an ability to employ new learning tools (Khomenko N., Murashkovska I., 2011).
2. The realization of the education functions by means of virtual models, which causes the necessity of fast creation and continuous development of the virtual component of the educational environment for distance learning and e-learning.
3. Provision of the communicative-information controllability of the educational environment: the necessity of controlling information sources (from dictionaries and encyclopedias to

direct Internet-contacts with experts in a given field of activities), increasing the requirements for communicative skills (communication in different languages, taking into account different types of mentality, etc.).

4. Organization of productive exchange of experience between generations, which implies considering the effectiveness of assimilating the new living environment by children as against people of the older generation.

Thus, setting of new goals imposes new demands on the education system as well as on the search for new solutions, i.e. innovations.

The notion of "innovation" is used in education for describing categories: process, system, activities and their components. Innovations perform the functions of apprehension and application of new ideas, theories, concepts, approaches, principles of education organization.

Innovations became widely used in various components of the teaching process – teaching, upbringing, management, continuing education of staff. They are used in the organization of lessons, methods of content presentation and conveyance, and result evaluation methods. Initiatives based on the use of new upbringing tools, developmental educational technologies, planning and problem diagnosis methods, etc. also belong to innovations (Khutorskoi A.V., 2008).

The goals of this work include the analysis of key contradictions in the innovative activities of a teacher; models for describing innovative problems; determination of competences a teacher should possess to implement the teaching process under innovative conditions; principles of teaching staff training on the basis of revealed contradictions.

2. Research

To determine the teacher's functions according to the modern qualification requirements for the organization of a pedagogical process, it is necessary to consider the notion of "innovative activities". Generally, "innovation", "innovation process" and “innovative activities" are not differentiated into independent notions, which emphasizes their interrelation. Gouzeev V.V. determines education activities as a set of processes of control, management, transformations and changes where the first three processes are subjective while the fourth one is objective. The activities result in a text, broadly defined as some object of culture. Accordingly, the following roles are identified: a subject of management - a manager, a subject of control – an expert, a subject of transformations – an operator. The external control of this process is performed by the carrier of the triad "needs - motives - goals" - a supervisor (or a customer) (Gouzeev V.V., 2011).

In addition, to determine the teacher's function in innovative activities, it is necessary to take into account that the teaching process may be both individual and group. As a consequence, the system level of the teacher's control activities change: expertise suggests both the activity control and the obtained product control: the activities take place in the continuously developing and renovated educational environments.

Accordingly, we think that the following functions reflect the innovation characteristic of the teacher's activities in the modern teaching process: 1) an expert in a certain field of knowledge: mathematics, physics, literature, etc. (checks problem solving in a given area, adequate use of corresponding notions, rules, laws); 2) a teaching process organizer (manages the interaction of students with each other and with other process participants, in particular, organizes project, research activities); a tutor who supports the individual progress of a student within the educational field; 4) a teaching aids specialist responsible for the assimilation in the continuously changing educational environment.

Let us use a system approach to the analysis of the relevance and domination of problems in the modern innovation process. To this end, using the revealed functions, we will determine innovation problems to be solved by teachers at a given stage of the education system evolution. The system evolution will be characterized by the S-shape curve law (Fig. 1). The values on one coordinate axis indicate the system lifetime, the values on the other axis denote the summary performance indicators. Three system evolution stages have been determined and the stages are described based on the law which underlies TRIZ research (G. Altshuller, 1997).

The first stage is the occurrence of a new system. The reasons are: 1) the appearance of new functions which cannot be realized within the existing system leads to the necessity of creating a new system; 2) new resources create a potential for the effective function realization by new tools. The analysis of topical educational problems leads to a conclusion about the simultaneous functioning of both variants: on the one hand, the traditional system of education forms specific complexes of knowledge and skills, but does not teach people to get oriented in new problems, that is, does not perform the new function. On the other hand, the appearance, for example, of computer training environments which allow modeling objects and processes previously inaccessible for visual learning, also requires introduction of significant changes into the educational system, i.e. new tools for the education function realization appear.

The peculiar feature of system development at the first stage is low effectiveness; sometimes, the first attempt to introduce a system shows that the system is inoperable (the world's first airplane did not get off the ground; the second attempt resulted in a three-minute flight). At the same time, the advantage of the "newborn" system is that it works for achieving a new goal using new resources and can provide a fundamentally new quality of goal realization. Creating such a system is generally connected with solving high-level creative problems.

The second system development stage is characterized by an abrupt increase in the system effectiveness. At that time, there appear a large number of inventions which are not great, yet significant enough to increase the system performance. For example, such systems as social computer networks are currently passing through this stage. They work effectively and experience rapid growth.

The second lifecycle phase of a system is characterized by the appearance of a large number of problems which cannot be solved through system modernization. At this stage, the system, on the one hand, still functions effectively and, on the other hand, the number of its development resources decreases notably. A great many of inventions of a low novelty level are being created. They, however, do not influence the system overall effectiveness. In additions, the system function becomes less topical because more and more alternative systems appear, and the system does not satisfy the changed requirements. This is exactly the stage at which the school education system remained for a long time in many countries of the world, which is proved by general system problems such as decrease of schoolchildren motivation for learning (according to the British scientists who held an opinion poll among their European, American and Russian colleagues, 40% of high school students and 50% middle-school pupils are not motivated for learning)[1].

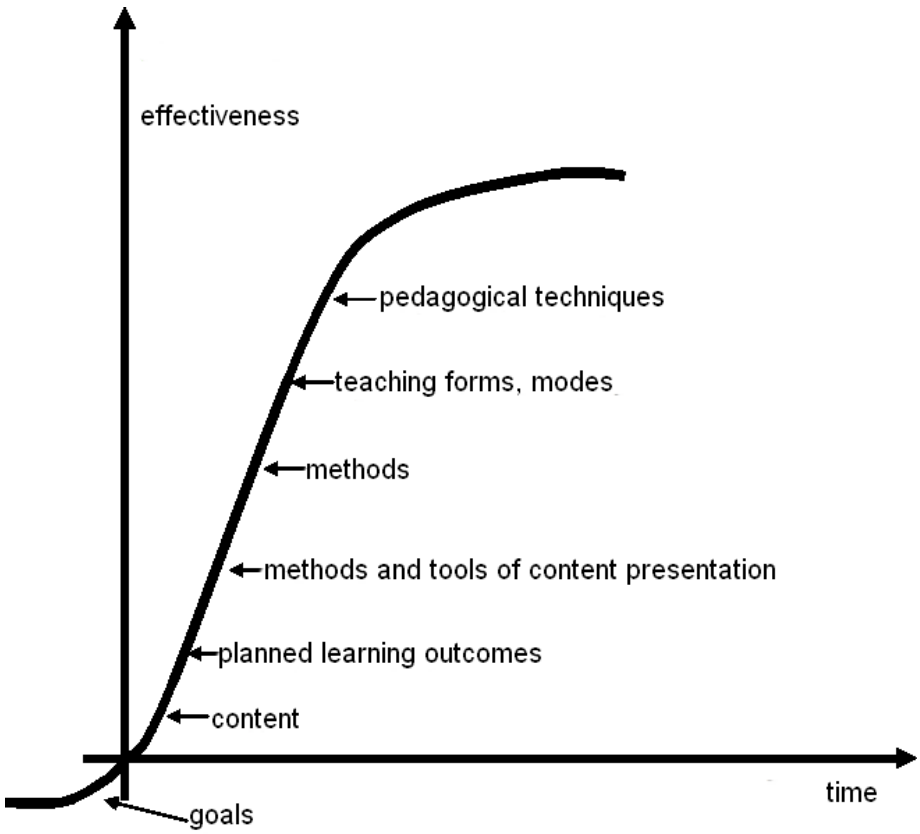

Fig. 1. Innovations in the evolving educations system

As stated above, the creation of a system becomes topical when the necessity arises to define new goals and solve problems of content selection and presentation forms. In so doing, the provision of minimal operability of a system is achieved by presenting the content in some implementable and verifiable form (planned learning outcomes) and the most acceptable training methods and forms are selected from among the already elaborated ones. Then (at the next system development stage), new methods and tools of education content presentation are developed. And, finally, at the third system "perfection" stage, new solutions are moved into the field of pedagogical techniques for improving teaching forms and methods.

In the course of the pedagogic system development, it is necessary to distribute the responsibility for creating innovations and methods of evaluating the innovation effectiveness during the experimental activities among scientific consultants and developers, administration, educational supervisors and teachers. In our opinion, the teacher should introduce innovative solutions into the teaching process within the frame of their functionality. The teacher's sphere of innovative activities depends on their role. The expert’s role suggests using innovation solutions in the field of the education content. The sphere of the teaching process organizers and tutors is the assimilation of innovations relating, in the first instance, to the content presentation methods and teaching models (methods, forms, modes). Being a specialist in teaching tools, a teacher assimilates innovations available in this sphere. Anyhow his major task is the *introduction* of innovation practices. In this process, however, a teacher has to deal both with typical and non-typical problems.

We will show the problem occurrence process by using the “Hill” model (N.N. Khomenko) which is one of the basic models of the Algorithm of Inventive Problem Solving (G.S. Altshuller). In our case, it helps to determine the teacher's role in an innovation process and to correlate it with real needs for innovation realization in the teaching process.

A problem always occurs in a specific situation. To obtain a solution, first it is necessary to move the problem to a higher level of abstraction, taking into account which features of this situation are essential. For example, with respect to some pupils the problem “a pupil cannot write a summary" means a problem of inability to structure a text and present it in an easy-to-remember form while for other ones it is a problem of poor vocabulary. Still other pupils find it difficult to concentrate attention while writing a summary. At present, all the three problems have technological solutions applicable to a large-scale innovation practice. If an abstract problem model has an abstract solution model, first of all it is necessary to check the possibility of solving it by standard methods.

At the next step, it is necessary to transfer from an abstract model to a specific solution, for example, by teaching a pupil to identify and fix the text structure on the basis of Mind-mapping method. If the applied method is effective, it can be stated that the problem is typical

and the use of the innovative practice is effective. If no result is achieved, there occurs a contradiction which needs to be solved.

For example, it is necessary to teach a child to structure material, but drawing and writing trouble him and he cannot arrange text on a sheet of paper, his motivation for this kind of work is low. There arises a problem which can also be solved depending on specific resources of the child or group. It can be solved by using preprepared materials (words, drawings, pointers) for constructing a map, or the pupil can be included in a group, to communicate with his/her classmates in a specific way or the text structure can be presented by means of other mediators (for example, some objects) or it can be solved by passing to a fundamentally new solution. A teacher often faces such situations in the innovation practice.

Thus, the use of innovations by a teacher is motion from the specific to the abstract and from the abstract to the specific. The practical experience analysis shows that the larger the innovation scale, the higher the system rank of the innovation occurrence. Accordingly, the higher the abstraction level, the more difficult the transition from a specific situation of a teaching process to its abstract model and from the abstract solution to its specific implementation, the more non-standard situations and non-typical problems can arise on this way.

Also, solving the main problem is accompanied by the occurrence of a great number of additional problems, including the contradiction-containing problems. And, accordingly, when identifying problems of a higher complexity which cannot be solved by standard methods, it is necessary to have the skills of using tools for dealing with non-standard problems.

Thus, to introduce innovations, a teacher should be able to apply typical solutions described at the highest level of abstraction. This, in turn, implies the ability to handle models which reflect the teaching process realities based on the laws which govern this process (cybernetic, psychological, sociological, information, etc.) as well as to form non-typical solutions by entering the domain of new facts, laws and work methods.

This means that there is an independent function – work on a problem - that provides a link between the teacher’s work and the innovativeness of this work. As shown above, this function is characteristic of all spheres of teacher's activities.

The ratio of typical and non-typical problem solutions in the innovative activities of a teacher depends on various factors: the novelty level of an innovation being introduced, the level of readiness of the environment and collective, material and technical as well as teaching provision, the priority of the process of functioning or development in the innovation implementation, etc. At the same time, the implementation effectiveness of most innovations is determined by the teacher's qualification and preparedness for problem solving. Let us

formulate the contradictions the solution of which determines the level of teacher's preparedness for implementing innovations in a teaching process.

Contradiction 1. The teaching process should be stable in order to provide solid, predictable results. This means that teachers should tend to deal with problems they can solve by themselves. In a current situation, a teacher can solve typical problems formulated at the same system level as the one required by the solution. The lower the abstraction level, the shorter the way from a situation to a model and the greater the number of typical solutions represented in the teacher's experience, the more predictable the result is.

However, obtaining of innovation results having a high degree of novelty requires a high generalization level and solving of non-typical problems. Consequently*, it is necessary to combine the teaching process stability and its innovativeness.*

Contradiction 2. The necessity for innovative solutions may be determined by external and internal needs of the education system functioning and development. In this connection, teachers should realize and improve the new teaching process built on the recent innovative solutions while they themselves were trained in the traditional way and have neither motivation nor knowledge nor experience for realizing such a process.

It should be noted that this contradiction cannot be reduced to the absence of necessary knowledge and skills (these can be obtained within the frame of a traditional process of advanced training). The objectively substantiated absence of experience and the value system which would allow the formation of adequate and integral images of a new pedagogical process and its result is becoming an essential feature.

Contradiction 3. The change rate of the system of advanced training should be ahead of society and the system of education. Basically, the priority development of some parts is the system evolution regularity. However, the current teachers' training and advanced training system lags behind the education system development. Further, taking into account the education development trends and general laws of system evolution, the system of education can undergo very serious changes in the long view, to the extent of disappearance and blurring of the teacher's role in its present form.

The completely developed skill of learning allows a person to independently control their own development rate in the educational environment and select as their teachers those people who are experts in their problems of interest. We therefore think that one more key contradiction within the framework of which it would be expedient to develop education systems can be

formulated in the following way: *advanced training of teachers should be continuous, but a special system for performing this process will reduce the work effectiveness.*

Contradiction 4. The teaching process combines the work of specialists of different qualification whose activities are organized in specific ways. While managing this process, it is necessary to control both general pedagogic aspects and specific aspects, including the activities content.

The introduction of innovative changes into a teaching process has different degrees of influence on these components. Accordingly, innovative solutions teachers propose for implementation should be universal with respect to the content of activities so as to solve the key contradiction of the education system, thereby providing its development, and they should be extremely specific so that a teacher could use them in their work.

Contradiction 5. The teacher organizes the process aimed at the assimilation of social environment which is assimilated more effectively by children. According to M. Mead's classification, we are dealing today with a prefigurative culture, when the younger generation has experience which is inaccessible to the older generation[1]. Accordingly, to organize a purposeful pedagogic interaction and to expertise the children's activities, the teacher should master the applied tools and technologies at a higher level, which does not corresponds to their real possibilities and needs.

The directions of solving these key contradictions under current conditions determine the principles regulating the support of the teachers' innovative activities.

Based on the revealed contradictions, we have determined features for ranking and systematizing the principles of teaching staff training and advanced training while organizing an innovation process: the functioning and development stability of a teaching process; continuing improvement of the teacher's innovative competence; managing the tools for problem solving; effective assimilation of the new; specification of universal solutions in the teaching activities ; we have also identified uncontrolled aspects of a teaching process as a pedagogic system having an additional innovative characteristic. As a result, the following system of principles has been formulated.

1. The principles of pedagogical goal setting in an innovation process (definition of objectives and planning of outcomes). For example, the principle of problem saturation which is realized through the identification and solving of pedagogical problems of different levels.
2. The principles of refreshment of the teacher's activities content while realizing innovations. In particular, it is necessary to mention the principle of continuing content refreshment which determines the need for a system of continuing in-house education of teachers.

3. The principles of organizing the teacher's activities in an innovation process. For example, the principle of role flexibility means that a teacher lives through the experience of a pupil, teacher, supervisor by performing their roles.
4. The principles of resource renewal of the teacher's innovative activities (program and methodical aspect). One of them – the education environment priority principle – consists in the creation of a continuously evolving environment which would provide conditions for assimilating new contents and new technologies by all the teaching process participants.

3. Resume

Based on the undertaken study, the typology of innovative problems which are within the competence of a teacher is proposed and a scheme of organizing pilot areas for a large-scale introduction of pedagogical OTSM-TRIZ tools into a teaching process. The outcomes presented in the article make it possible to manage the process of creation and implementation of innovations in the sphere of pedagogical activities.

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Research on the Suction-tape Feeding Technology Maturity of Printing Press Based on TRIZ

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Abstract

TRIZ is a theory and method to solve innovation problem. In this paper, the patents of the suction-tape feeding technology of printing press in the world were analyzed. To find the basic patent, core patents and epitaxial patents, we used the way of the patents excluding analysis. Then, the patents were graded in five levels. The suction-tape feeding technology maturity of printing press were predicted with the TMMS software which can predict the technology maturity of product based on patent analysis and the results were analyzed with the TRIZ conflict resolving theories, which could find innovative solutions. This method can make enterprises forecast the technical development of the product fast and accurately and realize the technical innovation of product. It would provide an important guideline for making strategic decision and trading technology.

Keywords: Suction-tape feeding technology, Technology maturity of product, Patent analysis, Conflict

1. Introduction

Famous press manufacturers, such as Roland, Heidelberg and Mitsubishi, are successively using the suction-tape feeding technology in the press, which have used the suction-tape feeding technology in the printing press successively. Chinese enterprises mostly take use of foreign technology to improve their product quality, they do not make breakthroughs in innovating the suction-tape feeding technology. Therefore, there is practically a significant meaning to formulate the new product development strategy and shorten the gap among the enterprises by analyzing the suction-tape feeding technology and the maturity.

2. Classification, analysis and excluding ways of patents

Any one technology patents could be divided into basic, core and epitaxial patents. They could be determined by the citation numbers and the citation relations among patents. The patent is founded on the basis of the cited patents, if it cites number of other patents. Its technology is a improvement one, and already a maturity technology. The patent with the core value is the basis of the subsequent patents, if it is cited by number of other patents. Core patents generally could change the efficiency, perfect the function or cure the symptom, so that they can reduce the cost and increase profits. The technologies of epitaxial patents are often used in the other fields. The study found that, if a patent is cited 5 or more times, Kodak's experts classify it into a higher level. The relationship shows in figure 1 between the importance and index number.

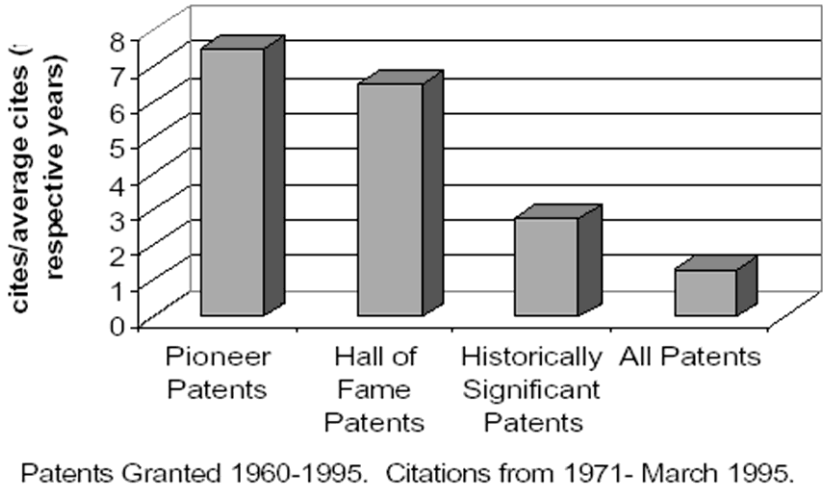

Fig. 1 Very high citation indices found for selected patents

3. Forecasting techniques and systems of maturity based on patent analysis

Norman's study pointed out that the product which meet the average demand of the customer on the product efficiency represent the technology maturity. In May 1966, Professor Vernon of Harvard University first proposed the theory of the life cycle, which is divided into introduction, growth, maturity and decline. The maturity of the product technology could be predicted by S-curve, or on the basis of analyzing the patents directly. Altshuller's mode was the study of the relationship among Efficiency, Level of Inventions, Number of Inventions and Profit to predict the maturity. Darrell Mann's model determined the maturity by the investigating two special patents, which are the patents of reducing cost and symptom curing, in the distribution of the S- curve. Aurigin's model mainly studied the relationship between the number of citations that is related to the maturity and the value of patent citation counts and the

maturity of the product technology. On the basis of integrating the research fruits of Altshuller and Darrell Mann, Professor Zhang Huan-gao developed the technology maturity of product prediction software (TMMS).

The system of TMMS selected the number of patents (PN), level of patent (PL) and the number of symptom curing patents (SCP) as the indicators of the prediction model, which shows in fig 2, and refined the life cycle into pre-1st stage(pre-infancy), post-1st stage(post-infancy), pre-2nd stage (pre-growing), pre-2ndstage (post-growing), pre-3rd stage(pre-maturity), post-3rd stage(post-maturity) and 4th stage (recession).

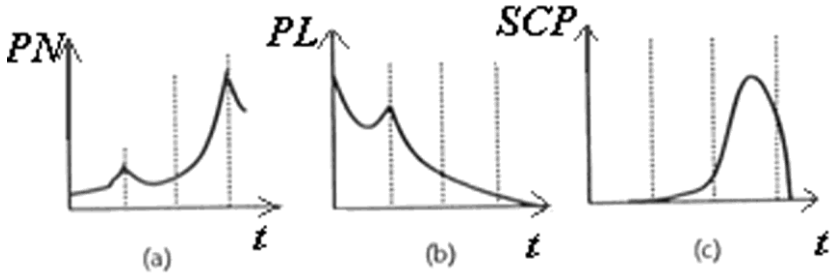

Fig.2 Curve of patent characteristic

Technology Maturity forecast of products is classified eight parts, which are searching patent data, filtering patent data, classifying and grading patent, patent summary statistics, generating the graph, forecasting the technology maturity, evaluating the prediction results，solving technical problems .

3.1 Maturity of suction-tape feeding technology of printing press

The suction-tape feeding technology of sheet-fed press is a new way of feeding. Feed table generally could be classified as ordinary type and suction-tape type. Suction-tape feeding equipment uses the negative pressure of the suction room to generate friction between the paper and suction tape, so the equipment could complete the transmission of the paper on the feed board, as figure 3 shows. The feed board leaves out the parts of the pressuring roller, so the structure has been simplified. This design improves the product efficiency. The study focuses on the structure-innovation of suction-tape feeding table.

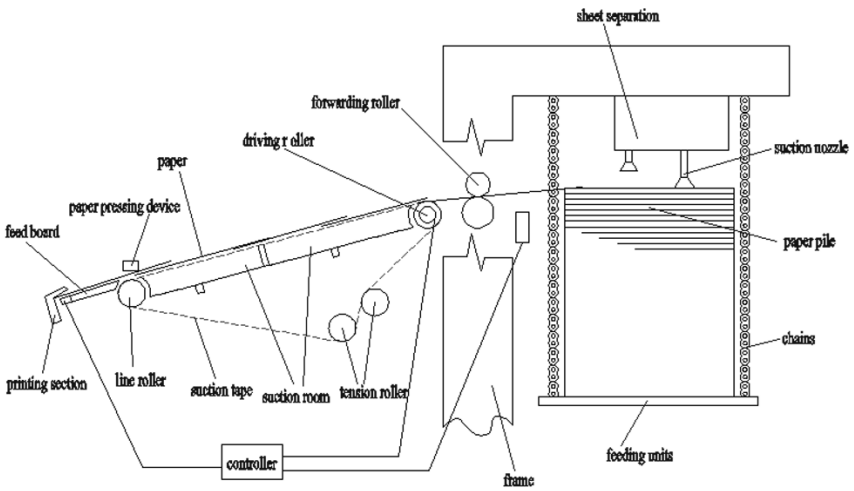

Fig.3 Sketch of Suction-tape feeding equipment

3.2 Maturity prediction of suction-tape feeding technology of printing press

In the analysis the patents of suction-tape feeding technology of printing press, we search the related patents of suction-tape feeding technology nearly 50 years, which are based on the patent database, which includes the US Patent and Trademark Office (USPTO), the European Patent Office (EPO), the Japan Patent Office (JPO) and State Intellectual Property Office of the P. R.C(SIPO). We use the key word 'suction-tape feeding technology of printing press' or 'vacuum paper feeding technology' have searched 468 patent primary data, containing 389 utility models and 79 inventions. Then, we filter and classify the patents which we have got, by two key technologies that have mentioned in above. In the further, we get the final data--213 patents by the way of excluding analysis.

The basic data is summarized, which is filtered the patents of suction-tape feeding technology. The results are shown in table 1. Then, we input the data to the system of TMMS, which is fitting the result by cubic curve. The results are shown in figure 4.

Tab.1 Summary of patent information of suction-tape feeding technology

Time	PN	APL	SCP	Time	PN	APL	SCP
1962-1972	2	2.15	0	1996	19	1.98	4
1976	4	2.00	0	1998	21	2.00	5
1980	6	1.90	2	2000	30	1.80	7
1984	8	1.95	13	2004	38	1.46	14
1988	13	1.97	6	2008	45	1.10	32
1992	15	1.93	5	2012	44	1.05	32

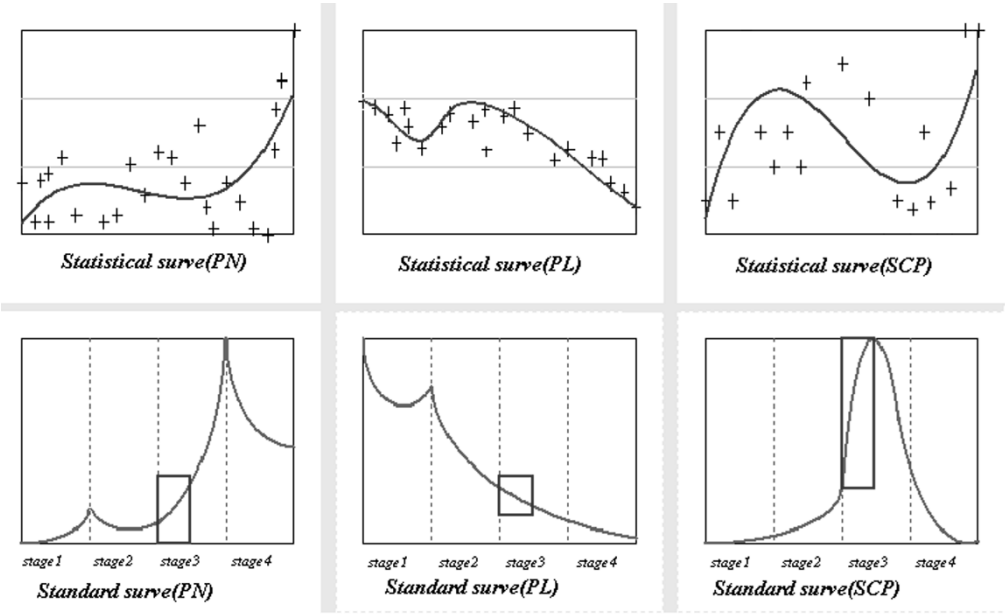

Fig.4 Map of mapping technology maturity of suction-tape feeding

3.3 Result of Maturity prediction

The result shows that, the efficiency of the product close to the limit, which is supported by the suction-tape feeding technology, the competition is fierce among the enterprises, the inventions are rapidly increasing, but the level of inventions is declining, the profit close to the maximum , and the product technology is in the early maturity (pre-3rd stage) .

The suction-tape feeding technology in the press have been developing many years, the product has the limited efficiency, maximum profit and a downward trend. The pace of product development begins to slow down and the product cost is nearly the least. Therefore, the prediction results are credible that these two key technologies of suction-tape feeding of the press are in the early maturity. The results could help the enterprises find the gap, improve their own technology targetedly, look for the innovation, and provide the information for the next strategy of the enterprises.

3.4 Technical conflicts and resolution

In the TRIZ (Theory of Invention Problem Solving) theory, the sign of the product innovation is to solve the design conflicts and arise from the new competitive solution. G.S.Altshuller classified conflicts into three categories, management conflict, physical conflict and technical conflicts. Technical conflict often appears in the machine design. Technical conflict always involves two basic parameters A and B, B becomes worse when A is improved. Through years of research, analysis and comparison, Altshuller put forward conflict matrix,

which established correspondence between the 39 engineering parameters and 40 inventive principles. It could solve the problem of selecting the inventive principles in design.

As the air is the working medium in the suction-tape feeding technology, and the air could be compressed. The adsorption force of paper would be change, when the external conditions change. The feed board leaves out the parts of the pressuring rollers, the structure has been simplified. But the pull of paper changes in the process, and it often appears the paper skew condition. These could affect the feeder rate of the overall print. So the conflicts can be certain, the improved parameters are stability (13) and reliability (27), deterioration parameter is the complexity of the system (36). Searching the contradiction matrix, the corresponding principles can be found, the part of the conflict matrix shows in the table 2.

Tap.2 Contradiction matrix

Improved parameters		Deterioration parameters		
		35	36	37
		Adaptability, versatility	Complexity of the system	Complexity of control and measurement
13	Stability	35,30,34,2	2,35,22,26	35,22,39,23
14	Strength	15,3,32	2,13,25,28	27,3,15,40
……	……	……	……	……
26	Amount of substance	15,3,29	3,13,27,10	3,27,29,18
27	Reliability	13,35,8,24	13,35,1	27,40,28

By searching the matrix, the corresponding innovation principles are as follows: Segmentation (1), Separation (2), Do it in Reverse (13), Convert harm into benefit (22), Copying (26) and Parameter changes (35). Using the above principles could get a range of innovative solutions.

Scheme 1: using the Segmentation, the entire input cardboard is divides into two parts. Adjust the size of the two gas chamber volume, which can adjust the speed of two feeding tape to eliminate of the paper skew condition.

Scheme 2: the principle of Do it in Reverse. In order to eliminate of the paper skew condition, it is added to the mechanical differential in advance.

Scheme 3: using the principle of Parameter changes, the material of feed tape changes nylon fiber. And the holes of feed board are long round ones, the holes of feed tape are circular ones. Assume the radius of feed board hole is R, center distance is a, the radius of feed tape is r, the vertical distance of the feed tape hole center and the feed board hole center is D. Due to

limited paper format, the result is only list. After designed, the result is R = 8mm, a = 59mm, r = 8mm, D = 0.5mm.

4. Summary

On the basis of analysis-ing the technology characteristics and patent applications of the suction feeding, we predict the key technology maturity of the suction-tape feeding of printing press, the results were analyzed with the TRIZ conflict resolving theories, which could find innovative solutions. This method can make enterprises forecast the technical development of the product fast and accurately and realize the technical innovation of product. It would provide an important guideline for making strategic decision and trading technology.

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Model for the application of TRIZ in the product design process

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Abstract
Current research in design process indicates that the decisive point in the act of designing resides in the stage at which inventive ideas are implemented, and that without such ideas, there is no thriving future for the new products. It is for this reason that the Theory of Inventive Problem Solving (TRIZ) encompasses great potential for applying to improvement of the NPD process.
To this purpose, in this essay the possibility of using new problem solving methods in design sections has been selected and the algorithm of problem solving (TRIZ) for such an aim will be studied and at the end the results of this research and presented model can be used by all the organization that intend to use innovation problem solving algorithm for current problems in improvement design product t or new product design.
Keywords: Creative, Engineering design, TRIZ, Product, model

1- INTRODUCTION

If we will have a definition of new product development, this is answer: New product development (NPD) is a complex system of activities that produces the information-derived from market needs-required to bring new products to manufacture.
Most successful companies view NPD as crucial. It is the arena in which the feasibility of the organization itself is determined. Managers and researchers agree that while it's important to manufacture products and services that gain consumer acceptance, it's even better if those products and services create greater satisfaction through innovation.
As product development cycles continue to shrink, companies must continually retool and improve their NPD processes. Various computer-aided design tools and methodologies are used to increase design effectiveness and productivity, but unless these tools and methods are integrated, their efficiency and effectiveness are limited
In this article, we tried that all the steps be similar to a model for TRIZ method which has been used in the Pilot company. In the following first we present the primary explanation, then the executive steps of the model will be mentioned and some of them will be explained.

2- What is TRIZ?

"TIPS" is the acronym for "Theory of Inventive Problem Solving," and "TRIZ" is the acronym for the same phrase in Russian. Altshuller (1984a, 1984b, 1996) had the main objective of finding alternatives to traditional creative problem solving methods, that were based on trial and error. Altshuller approached technical creativity by its main evidences: patents. He tried to figure out the underlying process by which good solutions were found, no matter what type of technology was used. By doing so he found regularities that constituted the foundation of a knowledge base and various methods for solving technical problems. Later, these methods were developed into what Altshuller named TRIZ – Theory of Inventive Problem Solving.
Modern TRIZ is a wealth of methods for finding and solving problems, a knowledge base, trends and laws. Main TRIZ researchers argue that the field is still in its infancy. TRIZ still has methodology status and has yet to be further developed to achieve theory, and possibly science status. The TRIZ methodology is relatively new to western countries, but interest in it is growing fast.
The three primary findings of this research are as follows:
Problems and solutions were repeated across industries and sciences Patterns of technical evolution were repeated across industries and sciences.
Innovations used scientific effects outside the field where they were developed.
In the application of TRIZ all three of these findings are applied to create and to improve products, services, and systems.

In recent years numerous researchers have begun to analyze worldwide patents in all fields and to update the TRIZ tools.
TRIZ has been recognized as a concept generation process that can develop clever solutions to problems by using the condensed knowledge of thousands of past inventors. It provides steps that allow design teams to avoid the "psychological inertia" that tends to draw them to common, comfortable solutions when better, non-traditional ones may exist.

With reference to Figure 1, a design team using TRIZ converts their specific design problem to a general TRIZ design problem. The latter is based on the analysis and classification of a very large number of problems in diverse engineering fields. The general TRIZ design problem points to corresponding general TRIZ design solutions from which the design team can derive solutions for their specific design problem. The power of TRIZ, therefore, is its inherent ability to bring solutions from diverse and seemingly unrelated fields to bear on a particular design problem, yielding breakthrough solutions.

3- Application of TRIZ for designer

In the mid-1990s Ford Motor Company engineers were confounded by a design problem with a new model of the Ford Escort: Incorporation of an airbag into the steering wheel column resulted in unacceptable levels of steering wheel vibration during engine idle, that would certainly hurt sales and increase warranty costs. After unsuccessfully trying to come up with solutions through traditional brainstorming techniques amongst the design team members – for example the team tried adding a lead block to the steering column without success - management hired a TRIZ (pronounced 'trees') consultant to assist. Working with the design team, they were able to relatively quickly come up with a solution. By attaching the airbag to the steering column with flexible connectors, they were able to use the airbag itself as a damper, significantly reducing the vibrations without increasing the weight (and cost) of the steering column.
In 2000, the imaging and printing group at Hewlett-Packard had a very short time to introduce their next line of printers, including the Deskjet 990C. With very little testing time, they needed to predict how the printer's output mechanism could fail during use, and make appropriate design changes to mitigate against those failure modes. The design team turned to a TRIZ-based software tool, Invention Machine's TechOptimizer that resulted in several design changes being implemented in the final design. The Deskjet 990C printer was one of HP's besting selling printers in 2001.
The traditional approach to creativity (using methods such as brainstorming, lateral thinking, etc.) calls upon the designer to look inward for inspiration. This can be a daunting task. TRIZ, on other hand, invites the designer to use a ready pool of knowledge for inspiration. It does not discount the use of these traditional approaches. On the contrary, TRIZ ensures that design teams use these traditional methods in a systematic directed manner by carrying out intelligent idea generation in areas where other people have solved a similar general design problem.

4. USE OF TRIZ IN MECHANICAL SYSTEMS DESIGN

The systematic approach to engineering design proposed by Pahl & Beitz (1988) is a well proven methodology, valid for component design as well as complex systems design. TRIZ includes some very useful elements that are not included in the traditional systematic approach to mechanical systems design. Altough TRIZ is based on knowledge from all technical areas; its scope is narrow, directed to specific problems. How could TRIZ be effectively used in systematic design?
According to León-Rovira & Aguayo (1998), TRIZ concepts of ideality, contradiction and resources should be used along the whole design process. TRIZ problem solving methods can be used for removing contradictions every time these are found.
Terninko (1998) and Domb (1998) suggest combining TRIZ, QFD and Robust Design. QFD should be used to identify conflicts between requirements (house of quality roof), that could be resolved with TRIZ. Robust design should be used to find optimum levels of technical parameters.
Savransky (1998b) suggests using TRIZ methods in the upfront of the development process, for obtaining innovative concepts. Traditional engineering methods should then be used for further concept development. According to Savransky (1998b), the same procedure could be used to redesign products.
Malmquist et al. (1996) suggest unifying TRIZ and the systematic approach. The systematic approach should be used as a framework with TRIZ elements included in some points. Linde & Hill (1993) have proposed WOIS - Widerspruchsorientierte Innovations-strategies or Contradiction-Oriented Innovation Strategy. This is a methodology for complex product development, based on German systematic design

methodologies and TRIZ. In their book, Linde & Hill present many case studies, proving that their approach works properly.
The authors are presently working on a descriptive model of systematic product planning and conceptual design based on the systematic approach by Pahl & Beitz (1988), TRIZ, and other creative problem solving methods. There are two central ideas to be implemented in this model:

- to enhance reuse of design knowledge available in catalogs of conceptual solutions, patent funds, and other sources;
- when development of solutions is needed, to prompt the engineering design team to use the most appropriate method for each type of problem. Use of effective but difficult problem solving methods like those of TRIZ is proposed only after trying to solve problems with simpler methods like brainstorming (Osborn, 1953).

5-The give model for problem solving in design process of product

This model is a combination of problem solving steps by MECHANICAL SYSTEMS DESIGN, and innovative problem solving.

Considering the existence problems in understanding a utility of Innovative problem solving, this method does not used by organizations, therefore, in this model much efforts has been made to use TRIZ tools which has move efficiency in problem solving. These tools and methods are:

- Formulating a problem
- Contradiction table

The methods which usually have been used are for problem solving with less complicity. Due to this, most of the given solutions for the problems are in innovative levels of one or two. The new method besides of having ability to solve the above problems in case of facing a serious contradiction, by using collected information (data) in ISQ (which is complementary for other tools) and problem formulate tools and at the end the contraction table in the interim of recognizing the existence contradiction, take action to idealize for problem solving. After that the engineers and experts can use these ideas and effectively try to find solution for the problems.
Another advantage of the given model is it's executively. Considering that in the all economic organizations profit is a main element and goal and undeniable, the benefit and executively of the given model also have great importance. So, most of the model parts, discussing about executively such as time table, studying the results, and standardization
Due to the above mentioned points, briefly, the given model is a combination of Innovation situation Recognition questionnaire and a model which most of the companies are using as executive model.
After completing the questionnaire, IF the problem does not solved yet, according to the formulating tools. The problem will be formulated and the contradictions will be recognized and at the end the contradictions by the Altshuller's 39 parameters will be simulated, and according to the contradiction table the problem will be idealized. This idealization has important rule in problem solving.
In continue we refer to the titles of this model and then explain some of the parts:

A- *Problem Recognition*
1- Subject selection
2- Understanding the real situation, selection and determination the goals.
2-1- Collecting information regarding the system which you want to improve and its environment
2-1-1- System's name
2-1-2- Primary useful output of the systems
2-1-3- present structure and the desired system.
2-1-4- Quality of the system's output
2-1-5- System's environment
2-2- The available resources
3- Planning for activities
4- Standards for selecting solution's ideas
5- Cause analysis
5-1- The factor which caused the problem
5-2- the history of the coming to existence and expansion of the problem
6- Studying the system's changes.
6-1- Studying the changes (except the limitation of the system)
6-2- The existence limitation for system's changes
7- Background of experienced solutions on the problem.

7-1- The effects of the problem solving in the past
7-2- The systems with similar problems
8- Specifying the solution and performing
9- Studying the results.

B- Formulating the problem
10- Formulating the problem.
11- Drawing the Graph of the problem.
12- Changing the graph to the text.
13- Distraction the problem's figures.
14- Specifying the solution and performing.
15- Studying the results.

C- Searching the previous resolved problems (using the 3a engineering parameters)
16- Using the contradiction table.

D- Using the previous resolved problems (using the 40 inventive disciplines.)
17-Studying the disciplines
18-Specfying the solution and performing
19-Studying the results

E- Other points
20- Classification of the solution from importance aspect.
21- Standardization

Now we can explain some parts which in the other sources, considering the essays subject, do not have enough information.

-Selecting the subject
The design groups by using different tools and methods can recognize and select the different problems. Some of the available methods for recognition are:

- The given proposals by different sections of the organization.
- Request and criticism of customers.
- Current problems

By utilizing these methods and tools, it is possible to recognize, select and finally analyze and solve the problems, and the potential problems in the designing, manufacturing and so on.

- **Planning (Programming) for activities**
In this phase the necessary process action for the determined action and the time table of the activities will be provided.

- **Performing solutions**
After studying the collected information we try to determine the solution and performing it.

If above studies does not lead to the recognition and performance solution, we should utilize the other TRIZ techniques and tools for solving the problem. In this regard we can use the problem formulating, technical and physical contradictions and ideal design.

-Classification of the solutions from importance aspect
With the attention to presented idea and the expenses, possibility and effectiveness indicators, the ideas will be classified, and determine the priority.

-Standardization
For observance of the performed systems there may be necessity of man power and equipments.
In this phase we will study the related resources and activities of the system maintenance.

6-Conclusion
- As we saw TRIZ creativity methodology as aided instrument, has an important rule in improvement of production.

- Considering the given method TRIZ methodology will present a general structure for design process problem solving.

- TRIZ methodology by using the related methods and techniques such as ISQ and problem formulating presents effective solutions for system's problem.

-TRIZ creativity methodology has an important role in the problem solving of production quality improvement which could not be solved by current methods and TRIZ will lead the minds of inventors to the new and special areas.

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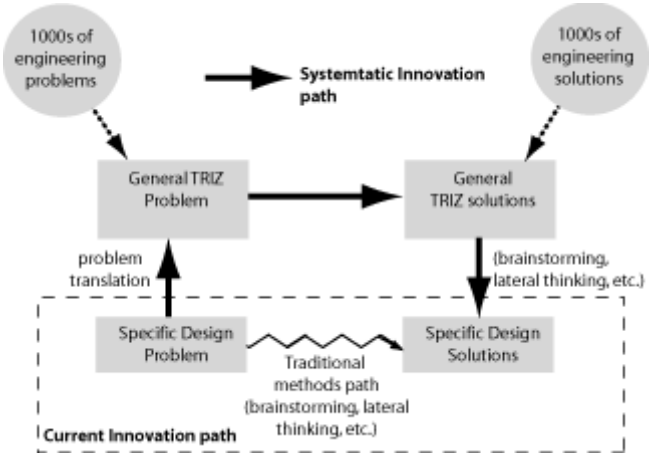

Figure 1: Systematic Innovation with TRIZ

Paper ID: 62

INDUSTRIAL CLUSTER ANALYSIS FOR ICT-BASED CREATIVE INDUSTRIES BY INNOVATIVE THINKING AND SYSTEM DYNAMICS

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Abstract

Applications of systematic innovative process on industrial cluster design is critical to contemporary industry development. This research has focused on investigating the development of an Information and Communication Technology (ICT) creative industry cluster using innovative thinking and system dynamics. By learning about the factors and effects affecting the cluster size, effective policies can be applied to develop the industrial cluster and increase the competitiveness. The factors are determined through literature analysis of previous study about cluster size and an observation of Taiwan creative ICT industry. The proposed model using innovative thinking and system dynamics has justified the behavior and the effect of each factor.

Keywords: industry cluster, ICT industry, system dynamics, innovative thinking.

1. Introduction

The concept of creative industries emerged in the late of 1990s, primarily as a policy and academic discourse. A detail classification definition of creative industries was enlightened by UNCTAD (2008), which was grouped into heritage, arts, media, and functional creations. After the 2008 global financial crisis and the subsequent economic downturn, creative industries sectors have been showing its potential and actual contribution to the economy by taking the lead on innovation (Pratt, 2009). The way creative industries affect economy's innovation has been observed by a survey of more than 2,000 creative industry enterprises (MÜller, Rammer, & TrÜby, 2009). It showed that creative industries are innovative sectors in the economy in two ways; they support innovation in a variety of other sector, and they are important users of new technology innovation

from particular information & communication technology (ICT) technology. This research focuses on creative industries which use ICT as their main support to affect their performance, so called ICT based creative industry. The creative industries that have been growing in key Western cities are recently emerging as a significant presence in Singapore, Hongkong, Seoul, Taipei and several Asian cities.

Cluster industry has become extremely popular as a strategy to develop an industry to improve regional even national competitiveness. Cluster is different from other forms of cooperation and network, because elements / actors involved in a cluster are linked in a value network instead of simple supply chains. The cluster concept focuses not only in linkage of producing products and services, but also emphasizes in developing competitive advantage from sharing knowledge and producing high innovation. Cluster policy has been applied in many types of industry and regions. Studies on creative industries and those on clusters have intensified both the characteristics of creative industries cluster (Cooke & Lazzeretti, 2008) and the place it tends to cluster. The exploration of the reasons why cluster is chosen as a strategy to develop creative industry also has been done. The most relevant implication is clustering forms of creative industries depending on local resources, agglomeration forces (structure of the industry/scale, localization economies, and urbanization economies), and the characteristics of individual countries (Lazzeretti, Boix, & Capone, 2009).

Taiwan is chosen as a role model in this study for its high annual growth (22%) in creative industry with design, software, movie-making, electronic games, and publishing supplying much of the momentum. In addition, it is one of the highest growing industries among countries in East Asia. The most important characteristic of this ICT based creative industry in Taiwan which differentiates it from other countries is the industry background mostly are Small Medium Enterprises (SME) base. The ICT based creative industry in this research focuses on digital concept and application. The aim of this research is to identify how to develop ICT creative industry applying cluster industry as strategy, by using digital games as the case study. In detail, the study investigates what and how factors affect the cluster size. The factors are determined through literature analysis and from benchmark to Taiwan creative industry.

2. Taiwan's ICT Based Creative Industry

As the knowledge and information integrated society come to arrive, ICT based creative industry is regarded as a novel knowledge-integrated industry geared up with hi-tech industry and creative idea. This has been noticeable in areas such as software, publishing, design, music, video movie making and electronic games, where the links to ICT-based hardware are strongest and changing consumption patterns. This is mainly due to the advancement in infrastructure of information system and the development of internet. In the Asia-Pacific region, the creative industries have been an important element in the development of the mature economies of countries such as Japan and the Republic of Korea and, to a lesser extent, in the fast-growing economies such

as Malaysia. Many city authorities in China, Japan, Korea, Taiwan and Singapore have formulated economic investment policies based on creativity and creative enterprise as a strategy for economic growth and competitive advantage (UNCTAD, 2008).

Cunningham (2003) studied the characteristics of ICT based Creative Industry in some countries in Asia. For example, Korea is a country that has built its economy on very strong corporative linkages between government and big businesses. It is not surprising that its approach to creative industries has seen major investment in big infrastructure. In Hong Kong, this broad sector approach uses the UK template established. The focus down on a specific set of strengths: advertising, design, publishing, conventional entertainment (analogue film and television), and digital entertainment. Singapore's investment in information and communications technology has brought it to a very pre-eminent position in the region, if not in the world, with education as the crucial delivery vehicle.

In Taiwan, the ICT based creative industry is characterized by small and medium sized base. The key strengths derive from the strong digital technology infrastructure especially for gaming and animation. In order to effectively guide the expansion of ICT based creative industry, Taiwan Ministry of Economic Affairs (MOEA) combined all possible resources and strength to form a team: "Digital Content Industry Progressive Office" (DCIPO). DCIPO works with the academics and industries to build a suitable environment for investment and legislation. In this way, Taiwan's industries could attract more international investment and cooperation. Taiwan's domestic industries have already built up a great foundation to complete the system for economic assistance on industries development, strengthen core technologies and product development, train industries innovation and creation talents, and assist industries in leveling up their international marketing strength. Taiwan's government support the industries by offering rent & tax preferential, research and development assistance, low interest loan, and training preferential policies. High support from government has shown from regulations; related to production cost: standard land rental cost and labor cost, taxation regulation, investment incentives & administrative support (Cheng, 2010). The government also invests in improving ICT based creative industries by combining strength and knowledge from government, society, and industries. Impetus organizations are formed to collaborate with industries and academia to perform continuous innovation. The government gives full assistance to the ICT based creative industries to be more competitive and attract foreign investment into Taiwan market.

3. Modeling

This research has focused on investigating the development of an Information and Communication Technology (ICT) creative industry cluster using innovative thinking and system dynamics. The model is used to determine the factors affecting the cluster size. It must be able to describe the relationship among factors and show how it affects the cluster size. The factors were generated from the interaction among the actors involved in the cluster. Choi et al. (2010) defines

government, university, R&D center, creative industry, and other related fields as the actors in the cluster. Government has role as facilitator and booster to increase growth of industry. University and R&D centre are sources for knowledge and technology. University and other education institution are also sources of labor and skills. The involvement of other related fields is used to access other resources and to have lower costs.

The literature study and industry observation determine factors which affect the cluster size. The factors include the size and nature of markets, interaction with universities and R&D centre as sources of knowledge and technology, government support, and the manpower availability. As mentioned by Porter (1990), the increase of firm competitiveness within the cluster exerting an attraction for new firms and resulting in a gradual accumulation the firms of human resources, facilities and other resources in the cluster. This shows the two side relationship between the factors and the cluster size. The relationship and feedback effect of the cluster size and those factors are drawn in the causal loop diagram (see Figure 1). In general, this causal loop diagram consists of 3 main causal loops: output product value, number of employees, and number of firms. The causal loop diagram also shows the government role in supporting the system.

4. Experiments

The model was developed and run using Vensim®. Most computer simulation applications using system dynamics models rely on Vensim®, in which the mechanisms of system dynamics can be handled by a user-friendly interface. The simulation used data from the 2002-2010, which the sources are varied and mostly from the Taiwan government publication (i.e., MOEA , DCIPO , ITRI , and DGBAS).

The model should generate behavior typical of the past as a base from which to anticipate the future. The time horizon is set to 100 years, starting from 2002 to 2102 with nine years historical data. This time span will lead to desired behavior to provide the information which can be used to produce a set of policy recommendations that are internally and mutually consistent. If the fundamental nature of the present system is carefully examined, most essential dynamic mechanisms for the next several decades should be detectable.

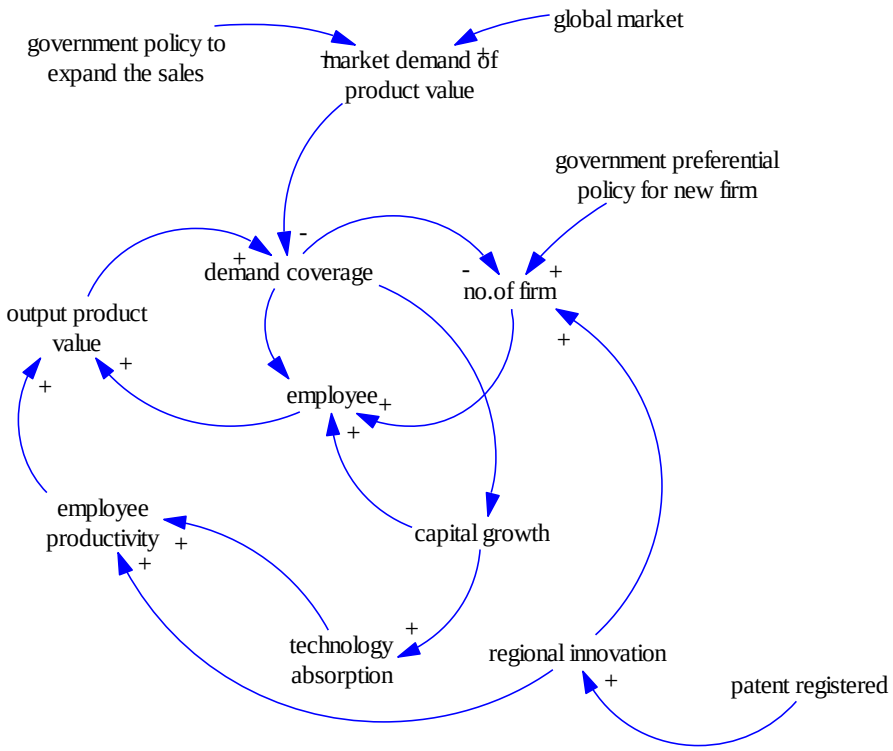

Figure 1. Causal Loop Diagram of Involved Factors in Cluster Size

Figure 2 shows the global market, which is assessed from the historical data and utilized to generate the other output data. The global market is set to grow for 20 years as an assumption of products type lifespan. The comparison between output product value and market demand value generate demand coverage. Demand coverage value, government incentive, and regional innovation become attractiveness points for firms to join in the cluster.

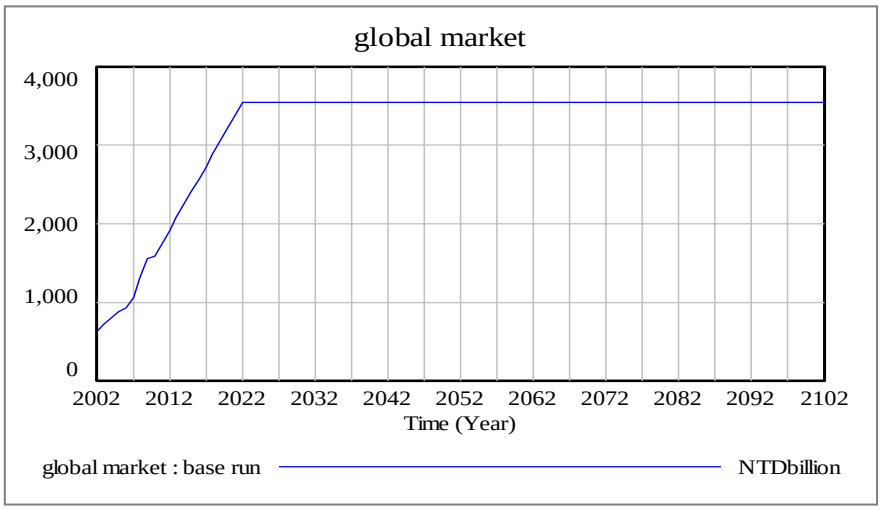

Figure 2 Global Market

Figure 3 demonstrates simulation result of number of firms, number of employees, and output product value. The growth of number of firms is shown by Figure 3(a). The growth can be divided

into three types of average growth. The first is positive average growth during 2002 – 2013, which is equal to 7% per year. Second, the zero average growth (0% per year) occurred in 2014 – 2022 and 2028 - 2037. The third is the negative average growths which are equal to -3% per year in 2023 – 2027 and -2% in 2038 – 2066. The result is according to the relationship of market opportunities, incentive, innovation, and the effect of multi variable in the model by using look-up function. However, the growth of number of firms is mostly affected by the increasing market opportunities. Figure 3(b) represents the simulation result of number of employees. It can be divided into five parts of average growth. The five parts in sequence are 7% per year in 2002 – 2022, 0% per year in 2023 – 2028, -3% per year in 2029 – 2035, 0% per year in 2036 – 2041, and -1% per year in 2042 – 2066. The growth of number of employees mostly is in line with the growth of number of firms. It is also affected by market opportunities through its relation with capital growth. The simulation result of output product value can be seen in Figure 3(c). The behavior of output product value is different from number of firms and number of employees. It only consists of two types of average growth which are 9% and 0% in 2002 – 2034 and 2035 – 2066, respectively. The output product value is affected by number of employees and employee productivity. Employee productivity has a very significant contribution to the output product value. It explains the consistency output product value even when the number of employee is decreasing. In addition, it also represents the characteristic of creative industry which not categorized as mass production that depends on number of employee, but to its employee's creativity supported by technological absorption.

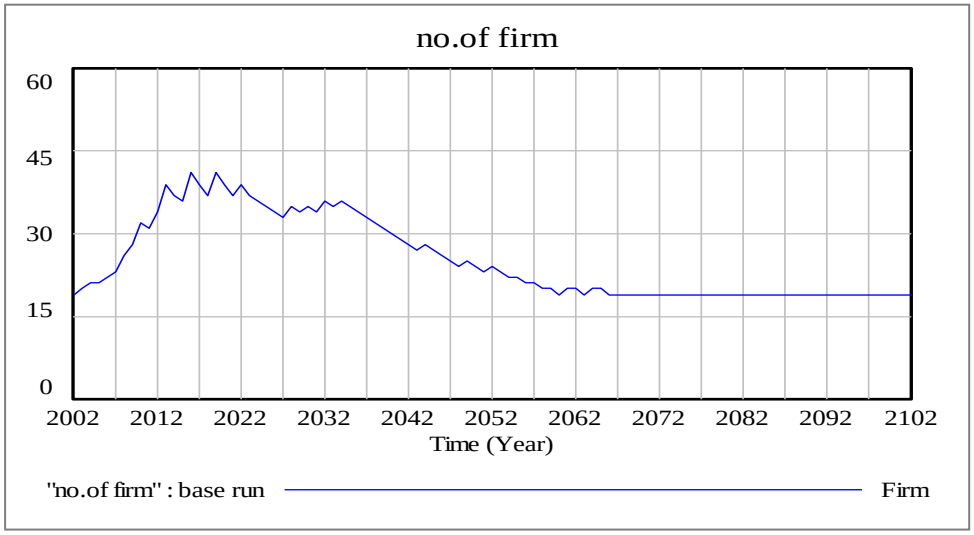

Figure 3 (a) No. of Employees

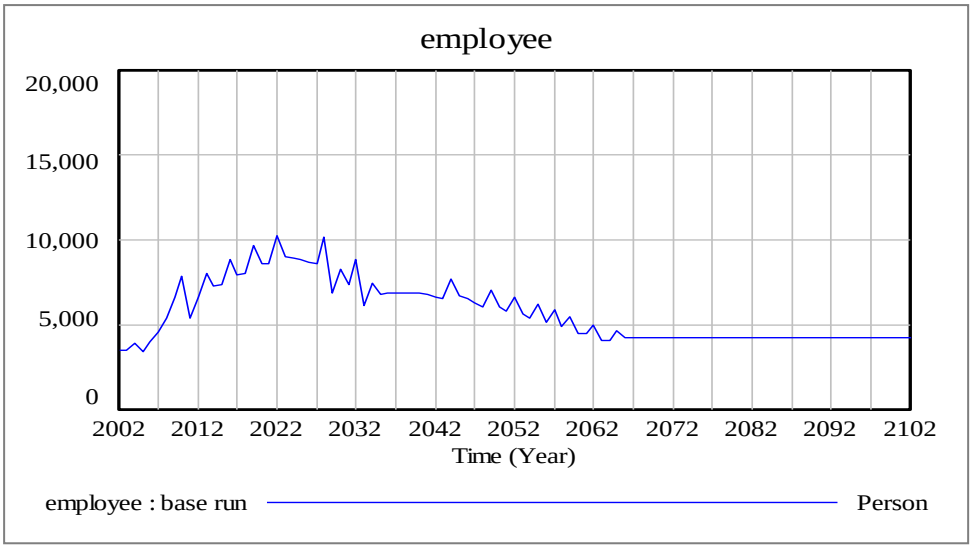

Figure 3 (b) No. of Employees

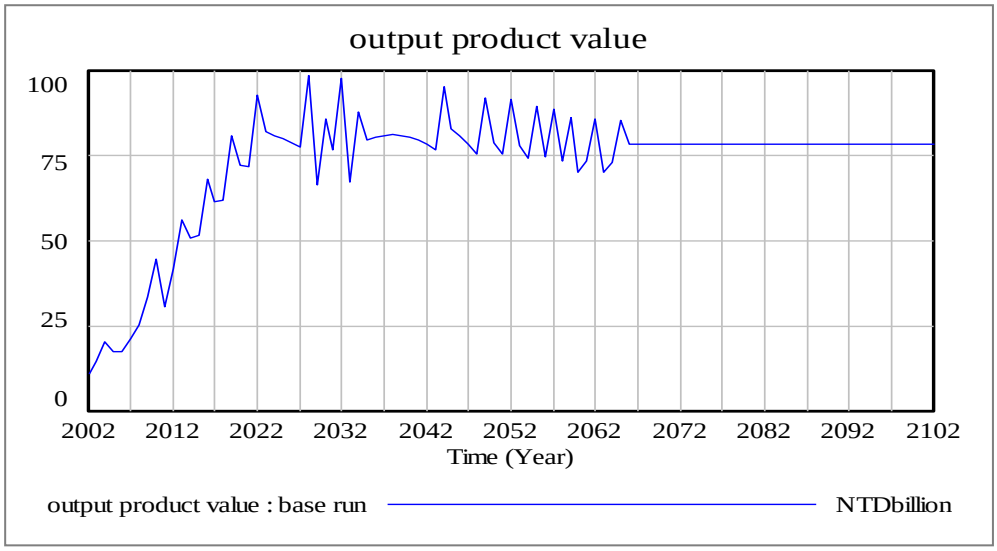

Figure 3 (c) Output Product Value

5. Conclusion

Applications of systematic innovative process on industrial cluster design has been critical to contemporary industry development. This study has focused on investigating the development of an ICT creative industry cluster using innovative thinking and system dynamics. By learning about the factors and effects affecting the cluster size, effective policies can be applied to develop the industrial cluster and increase the competitiveness. The factors are determined through literature analysis of previous study about cluster size and an observation of Taiwan creative ICT industry. The proposed model using innovative thinking and system dynamics has justified the behavior and the effect of each factor.

This research has presented a model for forecast and analysis the development of a cluster size. The model provides important factors that affecting cluster size especially for ICT based creative industry. Demand, innovation, and government support (e.g., giving incentive for new company) are the direct factors to increase cluster attractiveness.

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Integration between Cause-effect Chain Analysis and Root Contradiction Analysis and Its Application

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Abstract

This research develops a cause-effect and contradiction chain analysis (CECCA) for contradiction identification and problem solving, which integrates the cause-effect chain analysis and root contradiction analysis in order to quickly identify the key functional disadvantages and the underlying contradictory parameters simultaneously. Then inventive principles, separation/transition principles, and generic solution are used to solve the contradictions. The proposed CECCA also identifies contradiction families and provides a quantitative method that can used to evaluate the prioritization of contradictions. A new "Combine" relation in addition to the existing AND and OR relations is introduced as an operator in the analysis. In addition, a problem solving procedure with three paths, function attribute analysis, function relationship analysis, and the CECCA, is identified for contradiction identification and problem solving. Moreover, this study identifies the accumulative effect of contradictions and disadvantages quantitatively, which could solve the problem according to their significance. Finally, this study uses the case of the blade deformation problem of wind turbine as an example to illustrate the methodology proposed.

Keywords: Cause-Effect Chain Analysis, Root Contradiction Analysis, TRIZ.

1. Introduction

Most products of today usually have a very complicated system in their design process, and it is not easy to find a root cause of a problem in the process without using a suitable method. However, from the literature, we know that TRIZ (Theory of Inventive Problem Solving) (Altshuller, 1988) can solve problems in engineering systems from identifying disadvantages or contradictions.

The current reality tree (CRT) in Theory of Constraints (TOC) is a method used to search for the core problem. The first step is to list all the undesired effects of the current system, then to construct the cause-effect relationships among the undesired effects in order to derive the core problem (Goldratt, 1994). Domb and Dettmer (1999) considered if the traditional TRIZ can combine some technique from TOC, such as CRT, then TRIZ becomes more powerful. Mann and Stratton (2000) used this idea to solve the problems and conflicts in the areas of both engineering and management. In the

following, some techniques in the TRIZ, such as cause-effect chain analysis, root contradiction analysis, and root conflict analysis will be discussed.

Cause-effect chain analysis (CECA) (Ikovenko, 2009) in the TRIZ is used to identify the key disadvantages of the analyzed engineering system. This can be accomplished by building cause-effect chains of disadvantages that link the target disadvantage to its fundamentals causes or key disadvantages.

Root contradiction analysis (RCA) was proposed by Mann (2002), which is to find the root contradiction of a system. The user can start to ask "what am I trying to improve?" then ask "why" from the answer of the above question. Answer the "why question" and at the same time to consider "what gets worse/what's stopping me?" and "what gets better/what's helping me?" By asking at least 5 times of "why" to create 5 answers with parameters, then the user can find the contradiction point from parameters. The advantage of this method is to help users close to the root of problem by improving its parameters.

Root conflict analysis (RCA+) was developed by Souchkov (2005). It represents all causal chains of causes and effects that contribute to a problem, and then identify conflicts that can further be resolved with TRIZ. The starting point of the RCA+ is a general negative effect. It might be a very general expression, like "machine crushes". However, the next step is to ask a question such as "What causes the effect to occur?" to find what causes the machine to crush. The answer has to either identify exactly what object with its feature or identify some physical parameter with an object, like "temperature" and its relative value, which is responsible for producing the negative effect. This makes considerable difference with classical RCA.

If we compare the above three methods in details, we can find their advantages and disadvantages. The CECA have a relationship among all disadvantages and can trace from a target disadvantage to find its key disadvantage(s), but there are no corresponding parameters identified with disadvantage; hence, we cannot find the contradiction. The RCA can identify the root contradiction and its parameters; but it has no linkage between cause-effects. The RCA+ can find the contradiction of a problem and the disadvantages have a relationship; but it does not point out its corresponding parameters. Based on the above discussion, it provides a motivation to this study to develop a cause-effect and contradiction chain analysis (CECCA), which integrates the cause-effect chain analysis and root contradiction analysis in order to quickly identify the key functional disadvantages and the underlying contradictory parameters simultaneously.

The remainder of this paper is organized as follows. Section 2 discusses a problem solving procedure through contradiction analysis; section 3 is the core of this study which is to explore the cause-effect and contradiction chain analysis; section 4 gives an example for the illustration of using the analysis; and the last section gives a conclusion.

2. Problem Solving Procedure through Contradiction Analysis

This study proposes a problem solving procedure through contradiction analysis as shown in Figure 1. In the beginning, we describe the problem and its limitations using the method of 6W1H1G to ask questions, which include (1) What is problem (sore point)? (2) When was it happen? (3) Where was it found? (4) Why did it happen? (5) Who were involved in the problem? (6) How was it happen? (7) What do we do? (8) Project objectives.

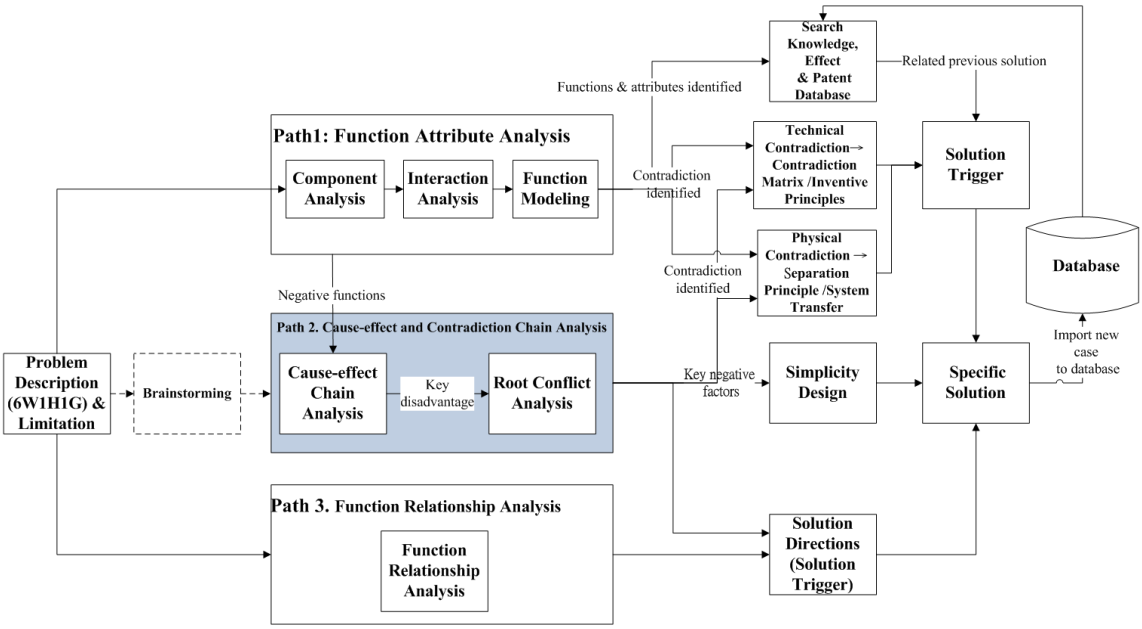

Figure 1. Problem solving procedure through contradiction analysis.

After we have defined the problem environment and its solution limitations, we have three possible pathes: (1) Function Attribute Analysis (FAA) (2) Cause-effect and Contradiction Chain Analysis and (3) Function Relationship Analysis (FRA).

▪2.1 Path of function attribute analysis

The FAA consists of three steps: component analysis, interaction analysis, and function modeling. In the FAA, if some component generates a useful function and a harmful function at the same time, then we have an engineering contradiction.

The engineering contradiction can use the contradiction matrix and inventive principles (Mann et al., 2003; CREAX, 2005) to obtain the generic solution, which will trigger ideas to find a specific solution. If the contradiction is a physical contradiction, then we can solve it by separating, satisfying, or bypassing contradictory demands. There are four methods of separation: separation in space, time, relation, and system level. In addition, searching knowledge, effect, and patent database, we can obtain the generic solution from previous recognized cases. Moreover, simplicity design by trimming certain

components and redistributing their useful functions among the remaining system or super-system components can find a specific solution with minimal cost.

▪2.2 Path of cause-effect and contradiction chain analysis

The CECCA combines CECA and RCA. After the FAA, when a negative function is found, we can use the CECA to find the key disadvantages. On each disadvantage, it can be formed a cell with the key problem parameter. If there is more than one parameter in the cell, then we need to break down into sub-cells. Assign the parameter of each cell into either improving or worsening parameter. The parameter of the target sore point is assigned to be improving. Any improving parameter and worsening parameter can form a contradiction pair, and then we can use the contradiction matrix and inventive principles and other methods to solve the problem as describe in section 2.1. It is better that the contradiction pair is chosen as close to the root braches as possible.

▪2.3 Path of Function relationship analysis

The function in the function relationship analysis (Terninko et al. 1998) can be either the function of a component or anything (event, activity, etc.) the user wanted to achieve, which can be useful, harmful or contradiction. The user can use a cause and effect graph to represent the function relationship. After a function relationship graph is completed, we can generate a serial of solution directions that will help the user think how to solve the problem. For the following example: when function A can generate useful function B and harmful function C at the same time, then function A is the contradiction point. On the solution directions, we will try to keep function B to be useful, avoid function C to be harmful, and allow function A not to be contradictory. The Innovation WorkBench software can perform function relationship analysis (Ideation International, 2005).

3. Cause-effect and Contradiction Chain Analysis

The cause-effect and contradiction chain analysis developed in this study integrates the cause-effect chain analysis and root contradiction analysis in order to quickly identify the key functional disadvantages, cause-effect relationship, root contradiction, and contradiction group. The process of the CECCA is shown in Figure 2.

At step 2, the disadvantages relationship of the cause-effect chain in the CECCA can be divided into AND (denoted as A), OR (O), Combine (C), and straight cause (no symbol). Step 6 is looking for contradiction group. All contradictions with their factors in a single chain belong to the same group. Contradictions with their factors coming from more than one chain and having AND or Combine relationship belong to the same group too. If the key disadvantages or root contradictions of a group are removed, then all contradictions in the group are solved together.

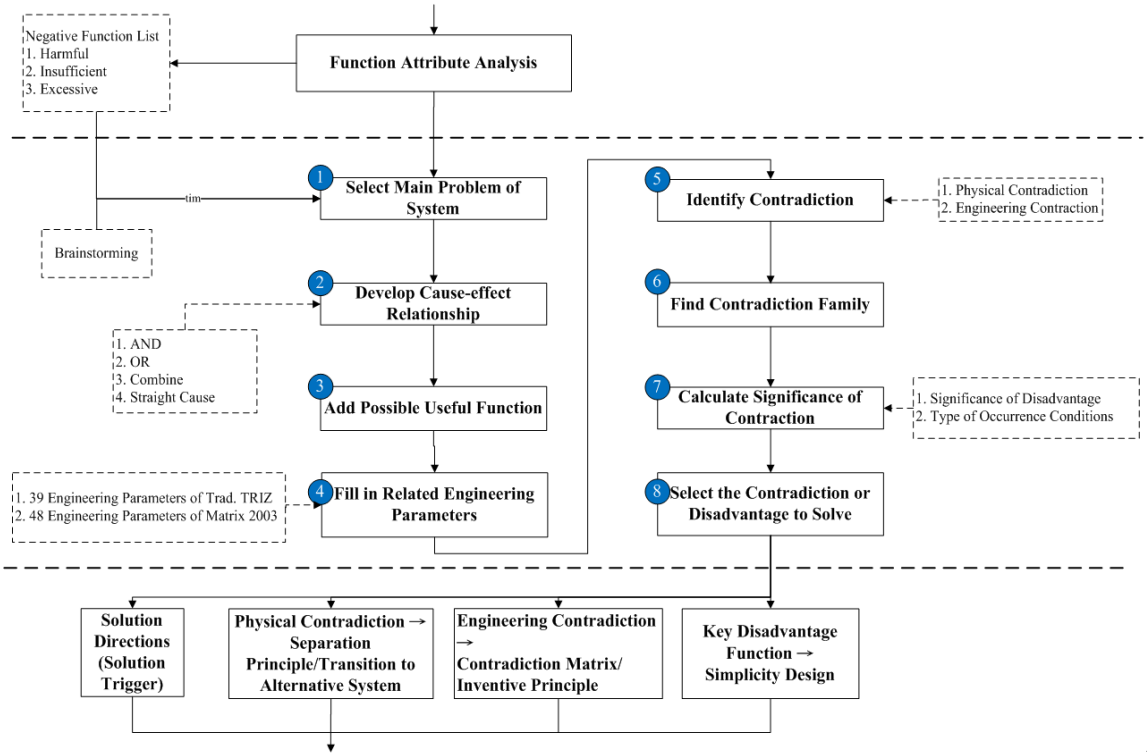

Figure 2. Process of cause-effect and contradiction chain analysis.

At step 7, we need to calculate the significance of each contradiction and disadvantage in order to solve them in sequence. The effect of both contradiction ($C_{(j)}$) and disadvantage ($D_{(i)}$) has a range of *1,2,3,4, and 5*. The higher value of $C_{(j)}$ or $D_{(i)}$ indicates more significant effect that need to take care immediately. In the cause-effect and contradiction chain, we have four operators, OR, AND, Combine, and Straight Cause, as stated at step 2, and a conceptual example is shown in Figure 3 to illustrate how disadvantages and conflicts work with various operators in the CECCA. When we calculate accumulative effect after each operator, we will follow the following rules:

(1) Operator OR (O) – a disadvantage or contradiction can be triggered when any one of two or several disadvantages or contradictions come to the OR operator. Adjustable coefficient $\alpha_{(i)}=1$ for disadvantage $D_{(i)}$ and $\beta_{(j)}=1$ for contradiction $C_{(j)}$.

(2) Operator AND (A) – a disadvantage or contradiction can be triggered when all disadvantages or contradictions that are recognized come to operator AND. Adjustable coefficient $\alpha_{(i)}=1/n$ for disadvantage $D_{(i)}$ with operator AND triggered by number of disadvantages and contradictions in total number n and $\beta_{(j)}=1/m$ for contradiction $C_{(j)}$ with operator AND triggered by number of disadvantages and contradictions in total number m.

(3) Operator Combine (C) – a disadvantage or contradiction will be triggered when all disadvantages or contradictions that are recognized come to operator Combine. Effect of each disadvantage or contradiction on the triggered disadvantage or contradiction can be determined by the adjustable coefficient. Adjustable coefficient $\alpha_{(i)}=\gamma/n$ for disadvantage $D_{(i)}$ with operator Combine triggered by number of disadvantages and contradictions in total

number n and $\beta_{(j)}=\gamma/m$ for contradiction $C_{(j)}$ with operator Combine triggered by number of disadvantages and contradictions in total number m. Contribution of operator Combine is between operators AND and OR, where $1 \le \gamma \le n$ or $1 \le \gamma \le m$.

(4) Operator Straight Cause – One disadvantage or contradiction is triggered by its upstream disadvantage or contradiction. Adjustable coefficient $\alpha_{(i)}=1$ for disadvantage $D_{(i)}$ and $\beta_{(j)}=1$ for contradiction $C_{(j)}$.

Figure 3 shows how each operator works in the CECCA. Target disadvantage is at the most upper level and from which we can trace the key disadvantage at the lowest level. The key

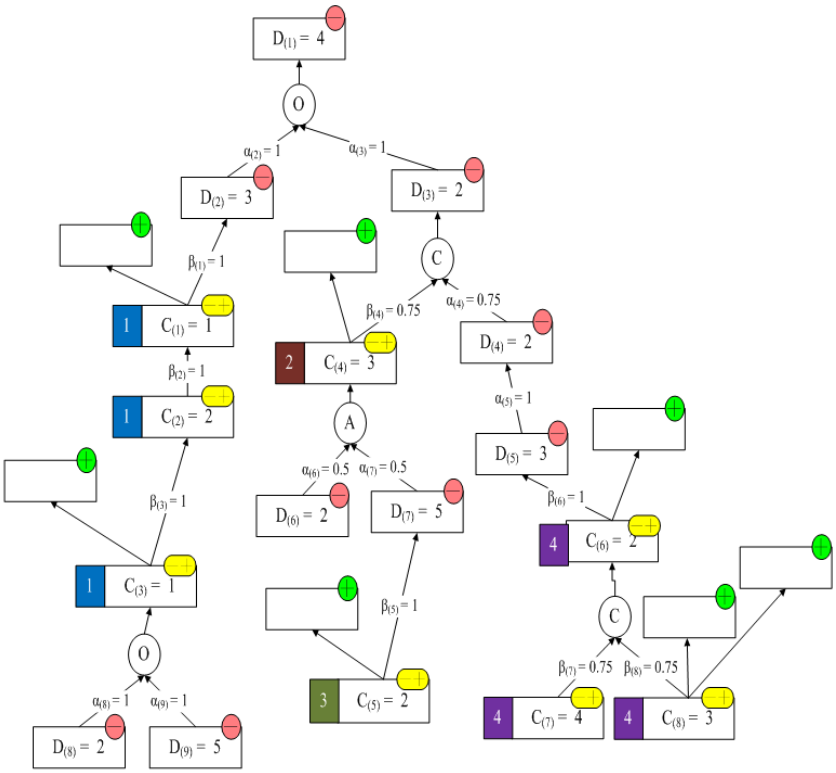

Figure 3. Disadvantages and conflicts work with various operators in the CECCA

disadvantage has most significant effect to the target disadvantage. The accumulative effect of disadvantage *i* ($AD_{(i)}$) can be calculated as the following equation:

$$AD_{(i)} = \sum_i \alpha_{(i)}[D_{(i)}] \in SD + \sum_j \beta_{(j)}[C_{(j)}] \in SC \tag{1}$$

where SD is the set all disadvantages from target disadvantage to disadvantage *i*, SC is the set all contradictions from target disadvantage to disadvantage *i*. Similarly, the accumulative effect of contradiction *j* ($AC_{(j)}$) can be calculated as follows:

$$AC_{(j)} = \sum_i \alpha_{(i)}[D_{(i)}] \in SD + \sum_j \beta_{(j)}[C_{(j)}] \in SC \tag{2}$$

Tables 1 and 2 show the effect and accumulative effect of contradictions and disadvantages described in Figure 3, respectively. Contradiction group is also identified in Table 1. Disadvantage 1 is the target disadvantage and either Disadvantage 8 or 9 is the key disadvantage. Contradictions 5, 7, and 8 located at the bottom of chain are root contradictions. Contradictions 1, 2, and 3 having straight cause relationship belong to the same group. Contradictions 6, 7, and 8 having Combine relationship belong to the same group. Accumulative effect of Contradiction 4 can be calculated from Equation (2): $AC_{(4)} = C_{(4)} * \beta_{(4)} + D_{(3)} + D_{(1)} = 8.25$. Accumulative effect of Disadvantage 9 can be calculated from Equation (1): $AD_{(9)} = D_{(9)} * \alpha_{(9)} + C_{(3)} * \beta_{(3)} + C_{(2)} * \beta_{(2)} + + C_{(1)} * \beta_{(1)} + D_{(2)} * \alpha_{(2)} + D_{(1)} = 16$. Based on the value of accumulative effect of disadvantages and contradictions, we can identify the significance of each disadvantage and contradiction for the sequence of problem solving.

Table 1. Accumulative effect of various contradictions.

Contradiction	Effect of $C_{(j)}$	Accumulative Effect $AC_{(j)}$	Contradiction Group
1	1	8	**1**
2	2	10	1
3	1	11	1
4	3	8.25	2
5	2	12.75	3
6	2	12.5	4
7	4	15.5	4
8	3	14.75	4

Table 2. Accumulative effect of various Disadvantages.

Disadvantage	Effect of $D_{(i)}$	Accumulative Effect $AD_{(i)}$
1	4	4
2	3	7
3	2	6
4	2	7.5
5	3	10.5
6	2	9.25
7	5	10.75
8	2	13
9	5	16

4. Case Illustration

A case used to illustrate the problem solving procedure and cause-effect and contradiction chain analysis proposed in this study is a damage problem in the blade of turbine of wind power generator as shown in Figure 4. The turbine converts wind power into mechanical energy that hence drives generator to generate electricity. In order to generate more electricity, most turbines are installed in the windy area, such as see shore. However, when the weather is in high winds, the blades of wind turbine will rotate too fast, which will result in the blades to be deformed if there are sand and rain-drops coming with the wind to hit the blades.

Figure 4. Case of wind turbine (Mann, 2002)

This case can be described in Table 3. Based on the problem description in Table 3, we can develop a function analysis as shown in Figure 5.

Table 3. Problem description with the method of 6W1H1G.

1. What problem?	The blade speed of wind turbine is too fast, when the weather is windy. Meanwhile, the sand and raindrops in the wind hit the blades, it causes the deformation of blades. Damaged blades will affect the efficiency of power generation, which results in the replacement of the damaged blades on a regular basis; hence in turn it will increase operational cost.
2. What?	
3. When was it happen?	
4. Where is it found?	
5. Why?	
6. Who?	
7. How was it happen?	
8. Goal of the project	To improve wind turbine blade deformation problem

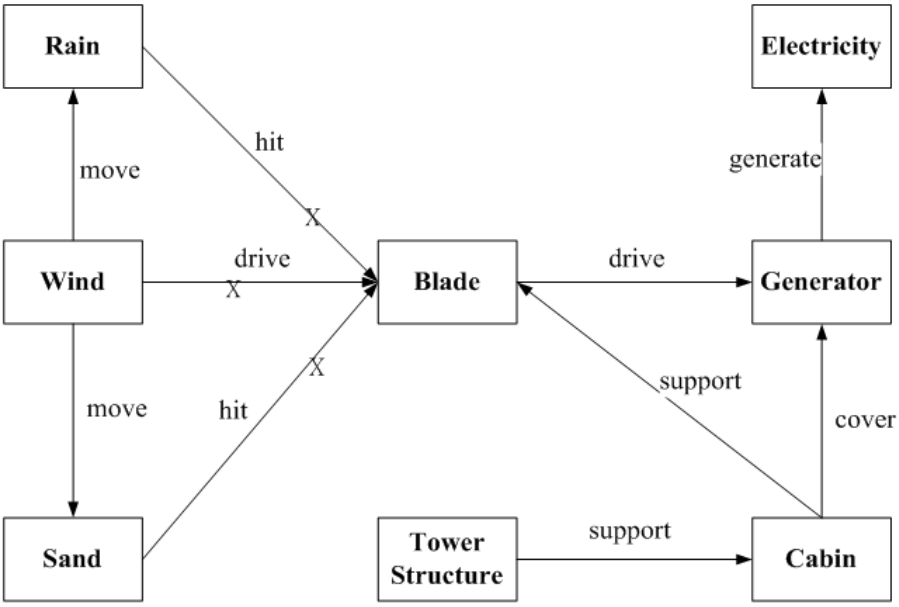

Figure 5. Function analysis for wind turbine case.

With regard to the blade deformation problem, the cause-effect and contradiction chain analysis (path 2 in Figure 1) can be used for a deeper analysis as shown in Figure 6. According to the effect of each contradiction and disadvantage with various operators, the accumulative effects of contradictions and disadvantages are shown in Tables 4 and 5, respectively. Combining the results shown in Tables 4 and 5, we can find the most significant accumulative effect among contradictions and disadvantages as shown in Figure 7, which should be taken care first. In the case of wind turbine deformation problem, Contradiction 5 has the most significant accumulative effect and we need to handle it first. Because its improving parameter (feature) is "Strength", and its worsening parameter is "Weight of Stationary Object", the inventive principles will be Composite materials (40), Porous materials (31), etc. as shown in Table 6 based on Matrix 2003 contradiction matrix. Then we can go through the list of inventive principles for looking for solutions and starting from the first list first. The first suggestion in the inventive principles is "Composite materials", and then we can check the suitable database or website. There are many suggestions for composite materials that can consider strength and weight at the same time, such as fibre-reinforced plastic (FRP) or carbon fibre materials (Griffin and Ashwill, 2003).

5. Conclusions

This research has developed a cause-effect and contradiction chain analysis (CECCA) for contradiction identification and problem solving, which integrated the cause-effect chain analysis and root contradiction analysis. The proposed CECCA could identify the contradiction families and provided a quantitative method that could use to evaluate the prioritization of contradictions. A new "Combine" relation in addition to the existing AND and OR relations was introduced as an operator in the analysis. A problem solving procedure with three paths, function attribute analysis, function relationship analysis, and the CECCA, was identified for contradiction identification and problem

solving, which provided more powerful tools for problem solving in the TRIZ family. This study used the case of the blade deformation problem of wind turbine as an example to illustrate the problem solving procedure with the CECCA, and it was proved that the proposed procedure and analysis could identify the accumulative effect of contradictions and disadvantages quantitatively, which could help us solve the problem according to their significance.

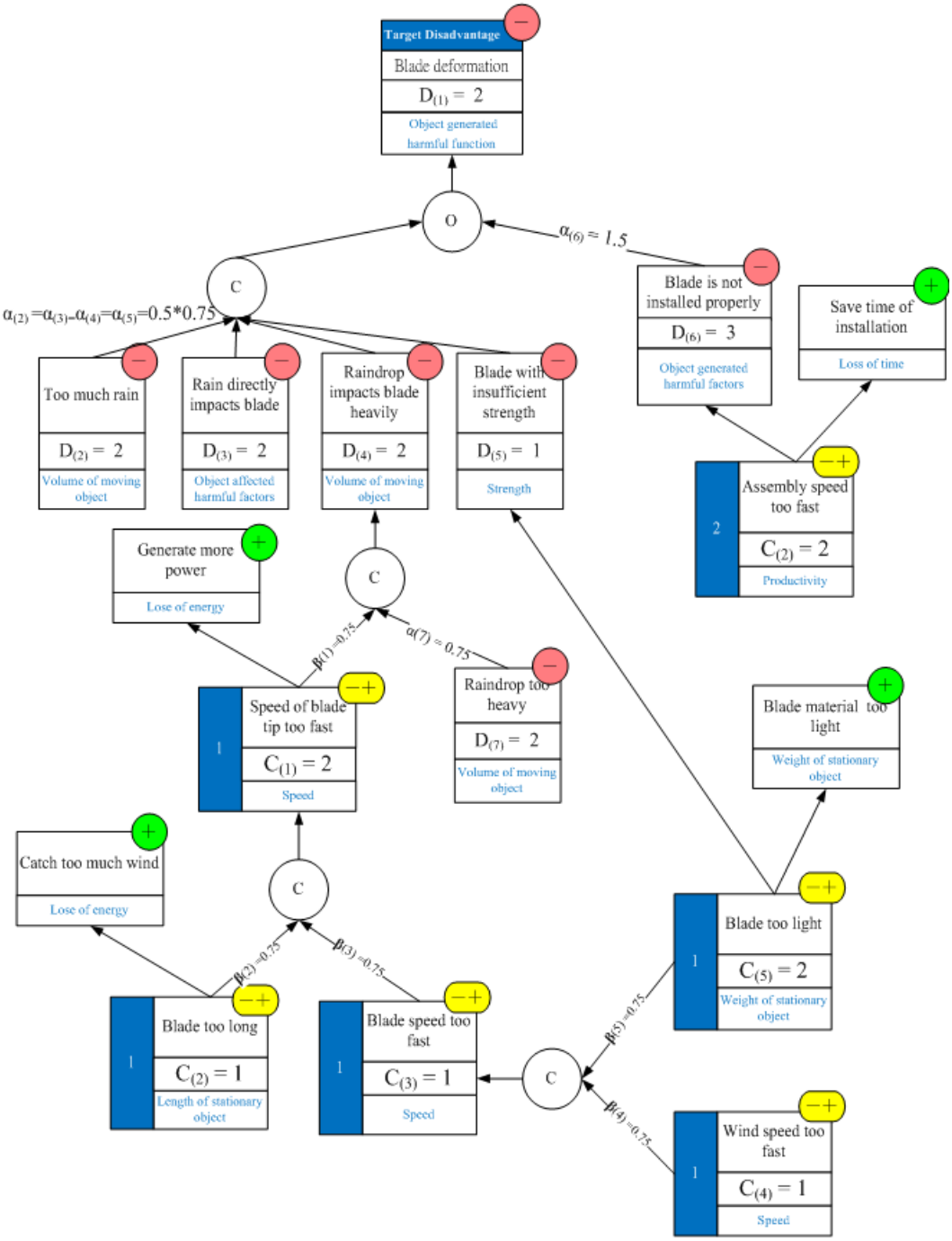

Figure 6. Cause-effect and contradiction chain analysis for wind turbine case.

Table 4. Accumulative effect of various contradictions for wind turbine case.

Contradiction	Effect of $C_{(j)}$	Accumulative Effect $AC_{(j)}$	Contradiction Group
1	2	4.25	1
2	1	5	1
3	1	5	1
* 4	1	5.75	1
* 5	1	6.75	1
* 6	2	4.5	2

Table 5. Accumulative effect of various Disadvantages for wind turbine case.

Disadvantage	Effect of $D_{(i)}$	Accumulative Effect $AD_{(i)}$
1	2	2
2	2	2.75
3	2	2.75
4	2	2.75
5	1	2.75
6	3	3.5
7	2	3.5

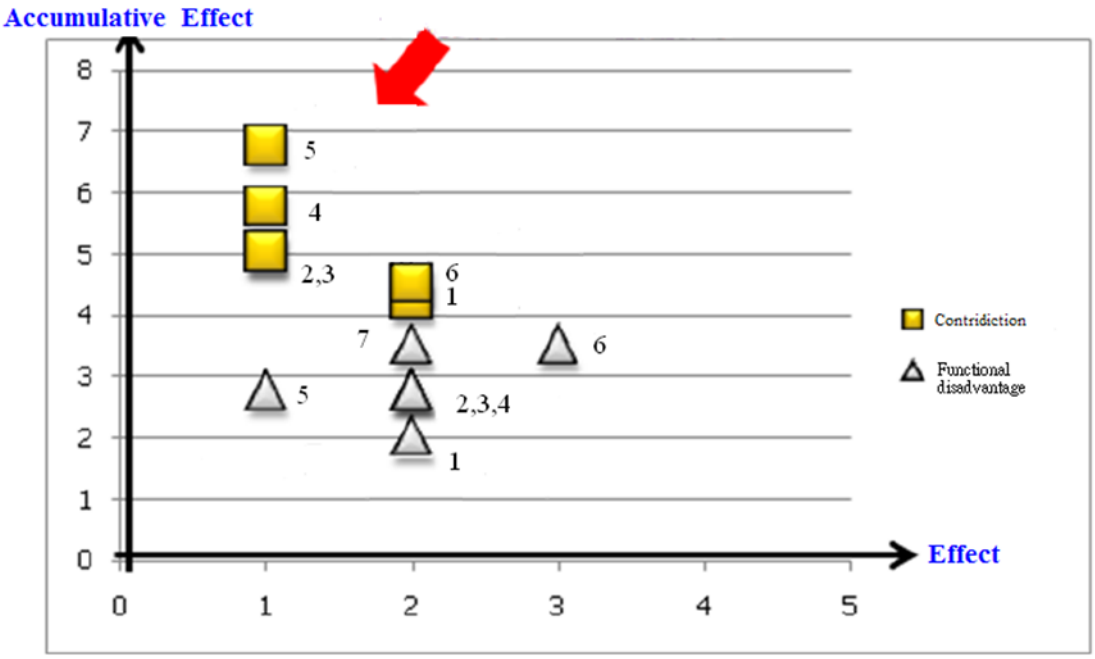

Figure 7. Scatter diagram of contradictions and disadvantages for wind turbine case.

Table 6. Inventive principles from contradiction matrix for wind turbine case.

Contradiction	Improving Parameter	Worsening Parameter	Inventive Principles
*5	Strength	Weight of stationary object	40. Composite Materials 31. Porous Materials 2. Taking Out/Separation 1. Segmentation 17. Another Dimension 26. Copying 35. Parameter Changes 3. Local Quality

Acknowledgments

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Systematic New Product Ideation: IDEATRIZ Methodology and IDEATRIZ Innovation Software

Marco Aurélio de Carvalho, Rodolfo Krul Tessari and Jônathas Gobbi Benazi Grillo

Abstract

IDEATRIZ is a methodology based on heuristics for new product ideation. The heuristics are derived from TRIZ, Value Analysis, Disruptive Innovation and the General Theory of Innovation. IDEATRIZ has four main stages: definition of the target product for innovation, generation of new ideas, resolution of contradictions and evaluation of ideas. IDEATRIZ was tested and the results were promising. However, its process is complex in comparison with the most used new product ideation technique, brainstorming. And complexity naturally hinders adoption. Therefore, a project aimed at developing IDEATRIZ-based software began, with a focus on improving the usability of the methodology. In this presentation, we describe IDEATRIZ and the current stage of development of IDEATRIZ software.

Keywords: Ideation, IDEATRIZ, TRIZ, New Products, Innovation, Computer Aided Innovation (CAI).

Introduction

Product innovation is an essential factor for a company to succeed against market competition. According to Cooper [1], the leadership status is strongly correlated to innovative firms. However, most of the new products launched on the market tend to fail, as demonstrate Christensen and Raynor [2]. There are many reasons for this to happen, but one of the main ones is the quality of new product ideation.

Ideally, only successful new product ideas should be generated. Therefore, resources would only be spent in developing products with high chances of market success. However, the generation of new ideas is usually performed through empirical methods that seek to solve problems through trial and error or successive approximations. These methods enable the generation of a large number of ideas, but only a small part of those can be considered truly creative, defined as both unique and useful [3].

Thus, the problem falls back to the issue concerning on how to save money and time in the innovation process by just having new product ideas with great sales potential. De Carvalho [4] sought to provide an answer to this question, after studying existing approaches and techniques for new product ideation. The solution was a systematic methodology, IDEATRIZ, designed to lead to valuable new product ideas.

IDEATRIZ methodology was tested and the results were promising. However, its systematic process demonstrated to be complex in comparison to the widespread ideation technique of brainstorming. Since complexity may hinder adoption, a project aimed at developing software based on the methodology began, focusing on the improvement of its usability.

In this paper, we describe briefly the main roots underneath IDEATRIZ methodology and present the IDEATRIZ Innovation® software.

IDEATRIZ Methodology

Based on a mixture of existing approaches and techniques for new product ideation, IDEATRIZ was built over four main pillars. The first and central one is the value concept [5], as a means to take customer needs into account; the second is the voice of the product strategy [6], an effective way to gather knowledge about the market and add it to the ideation process with a minimum of formally researched information; the third is a way to consider that innovation can also be achieved through low-end and new market disruptions, the concept of disruptive innovation [7]; and, finally, TRIZ [8] and its derivative GTI (General Theory of Innovation) [9] complete the foundation of IDEATRIZ methodology, thanks to their high potential for creating breakthrough solutions.

IDEATRIZ methodology core structure has four main stages, illustrated in Figure 1.

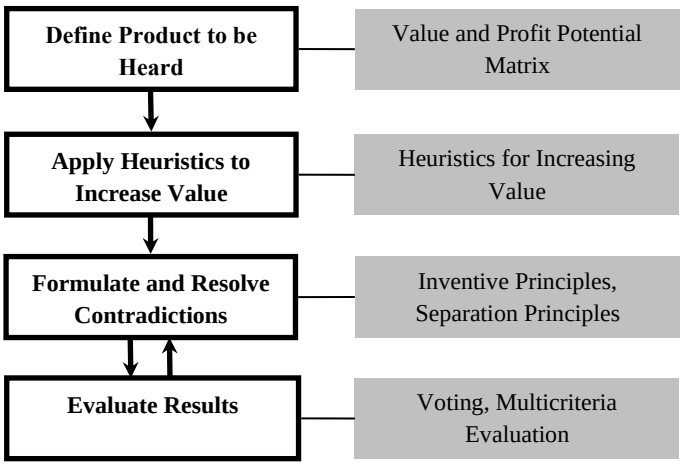

Figure 1. IDEATRIZ New Product Ideation Methodology Stages and Tools.

IDEATRIZ starts with the definition of the focus product for ideation, i.e. the product to be heard. Based on the concept proposed by Goldenberg & Mazursky [6], which admits that the market knowledge is consolidated into a company's own goods, the focus product for ideation is chosen from a range of products currently available on the market. The identification of the product to be heard can then be performed directly by the company's need (in case of low sales level, for example), or obtained by positioning its products along the axes of the Value and Potential Profit Matrix, proposed by De Carvalho [4], in order to subsidize this decision.

The next stage of the methodology is the ideation process itself, where the increase of value is achieved by applying the 51 heuristics of IDEATRIZ. Such heuristics are divided in two groups with different objectives: the first group is made of 20 heuristics, aimed at the increase of functions; the other one is composed by 31 heuristics that seek to decrease the number of connections of the product under analysis.

IDEATRIZ heuristics were derived from TRIZ heuristic methods, especially from Inventive Principles and Separation Principles [8], and other systematic methods, such as the 121 Heuristics [10]. Some examples of IDEATRIZ heuristics for increase of value are:

- "Combine system with anti-system", which consists of combining a base system that performs a particular function with another system responsible for

undo or reverse the action of the base system. A typical example is the pencil-eraser;

- "Integrate with other systems", that proposes to add to the base system the structure or function of other similar or correlated systems, just like happened with smartphones, result of the convergence of cell phones and computers.

Another example, now of heuristics for decrease of connections, is the heuristic "Eliminating the need for an object", which proposes the deletion of parts of the system without its main function undergoes changes. Practical examples include wireless devices widely applied to informatics.

At this point, ideas generated often present obvious disadvantages. Thus, the next stage of the methodology involves the formulation and resolution of technical and/or physical contradictions through the use of Inventive and/or Separation Principles. Here TRIZ is strongly applied, allowing the generation of even more original ideas.

The fourth and last stage involves assessment of ideas and decision of which ones to implement, which is done through an evaluation matrix. At this step, each idea is evaluated separately, enabling the development of new product concepts through the union of the best ideas of each section or part of the target product.

IDEATRIZ was tested during its development in training events and was validated in a number of real situations [11], attaining promising results. The simulations done in training environments did not involve the whole process, being focused only on the ideation step. In real applications, however, all stages of the methodology were applied [12].

IDEATRIZ proved to be useful, but its methodology is essentially more complex than the most widespread Idea Generation Technique, brainstorming. Therefore, we started the development of IDEATRIZ-based software, focusing on improving the usability of the methodology.

IDEATRIZ Innovation® Software

IDEATRIZ Innovation software, under development process, is a Computer-Aided Innovation (CAI) tool that has the intention to consolidate and disseminate IDEATRIZ methodology. We expect it to lead users to an easier way of new product ideation and design.

During the software structure formulation process, we chose to use the Visual Basic programming language, especially because of its object-oriented structure and graphical interface of "Windows Form Application", being intended for Windows operational systems. Besides, it also fulfilled our needs of having a free and high level programming language.

As discussed earlier, IDEATRIZ methodology is divided in four dependent stages. Therefore, the software logical structure development was built on a sequential manner for data input. In the first stage, information about the company and its products are entered by the user to enable the identification of the focus product for ideation.

The software makes a list with the company's products and positions them along the Value and Potential Profit Matrix, that may be used to decide which product is most recommended for innovation. The matrix is dynamic, allowing the user to manually position each previously selected product in different quarters, as well as enable their positioning through auxiliary tools that correlates data of sales profit and market research.

Sequentially, the ideation step for increase of value allows users to make use of the 51 ideation heuristics in three different directions: use only heuristics for the increase of functions, only for reduction of connections, or both increase of functions and reduction of connections.

After this decision, users are taken to the screen where they can initiate the ideation process. On this screen, all heuristics are displayed in subsequent panels, with text boxes that allow users to generate ideas without having to worry about storing them. In addition, each heuristic also has a help button that provides a succinct definition of each heuristic, along with some illustrated examples of its application.

For each generated idea, users can also use TRIZ Inventive Principles and Separation Principles to solve any technical and/or physical contradictions that may have arisen due to the application of heuristics. At this stage, we are studying the creation of a list of synonyms that will allow users to select the engineering parameters involved in the raised contradiction by indirect ways, facilitating the application of those TRIZ methods mentioned above. In addition, we seek a practical way to consolidate the use of the Contradiction Matrix automatically, requiring a minimum set of data input by users.

The current version of the software has already a mechanism that redirects users to the appropriate principles for each possible contradiction, which analyses if the conflict involves the same or different engineering parameters. If equal ones are selected, users are taken directly to the Separation Principles, or directed to a group of four to six Inventive Principles, in cases of technical contradictions.

Throughout the ideation section, the separation of ideas is done simultaneously with their creation. The software has a field related to the system's sector to which the idea belongs, where users must only select the part that most fits each case. It is possible to perform such separation for up to 20 different areas, allowing the generation of a greater range of final product concepts at later stages.

After the idea generation process, the software returns to IDEATRIZ Innovation main screen (shown in Figure 2), where the main stages of the methodology are presented in different tabs. In each of them, there are buttons that allow users to edit the content presented, add or remove images of the target product of innovation, and get help. In the "Ideation" tab, users can access ideas generated by them, divided according to each heuristic. They can also generate ideas for heuristics that have not been used before, as well as resolve any contradictions that may have arisen.

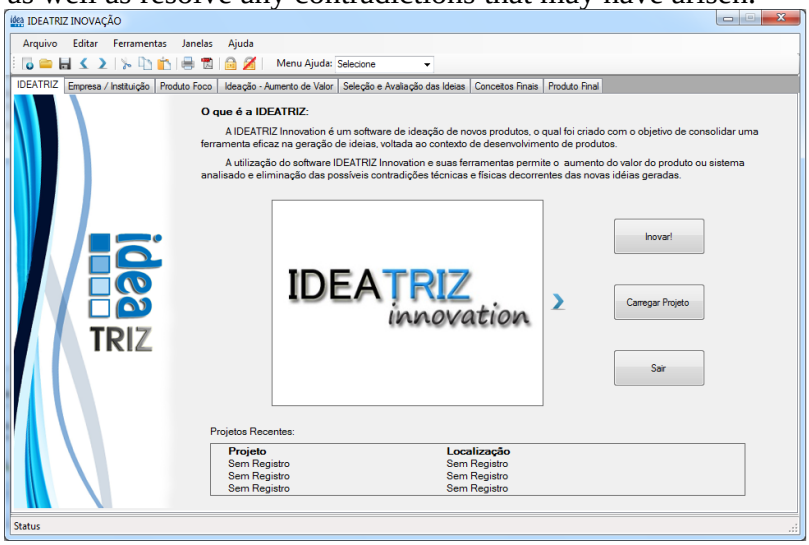

Figure 2. IDEATRIZ Innovation main screen.

In the Selection and Evaluation tab, generated ideas are presented in lists, organized according to the system's sector or part to which they belong. By selecting each idea individually, users can evaluate them according to multiple criteria, predetermined by IDEATRIZ methodology [12]. The evaluation is performed by assigning values to each criterion, which vary in a range from very bad to very good. Thus, it is possible to choose the five best ideas (those ones with the most originality and innovative potential) for each existing sector, allowing them to be a viable option for some final product.

In the final stage of the ideation section, the Final Concept tab, users can create new product concepts manually, or they can use the software's tool for self-selection, which allows the creation of new product concepts in an automated way (according to the total score obtained by each idea in the previous step). Furthermore, it is possible to add sketches for each selected ideas, so that final product concepts can already start to present an initial contour or physical shape.

Finally, users can view up to five final product concepts and add representative schemes for each of them on the "Final Product" tab. This step ends the application of IDEATRIZ methodology, but there are some buttons that provide additional tools for creating a report (generated in PDF format), containing the details of each step taken, and printing it.

In addition, along the use of the software it is possible to save the ideation project, allowing users to open it later on and continue it from the same step, as well as protect the project, preventing unauthorized access to the project information. There is also a help menu bar, which provides help on any program function or methodology topic.

Conclusion

IDEATRIZ methodology clearly boosts the new product ideation process by inducing users directly to the crucial points of the product subjected to ideation, focusing efforts on the increase of functions and reduction of connections. With the development of IDEATRIZ Innovation software, we believe it will become possible to optimize even more the process, thanks to the automation of secondary actions, such as the storage and organization of ideas, which required significant manual work previously.

In the software, the simplification of IDEATRIZ methodology becomes evident through the organization of data entry in sequential steps in a "wizard" format. By this, users enter data sequentially, advancing to the following steps through the "Next" button. This makes the data acquisition dynamic, preventing users' fatigue.

Within the contradictions resolution stage, when comparing the manual application of the Contradiction Matrix (as it was done in case studies) with the automated process provided by the software, there was a huge gain of time and minimization of errors due to the improper view of the improved and worsened parameters cross. Besides, the software previously checks the contradiction type to be solved (either physical or technical), and indicates the Principles to be used according to the circumstances.

The presentation of each ideation stage in different tabs on the main screen also allows users to have an overview of the process, as go back to review and edit previous

steps. During ideation, we aimed at optimizing the selection process, which is already done simultaneously with the generation of ideas, through the association of each idea to the section to which it belongs. By this, the software subtly connects the ideation with the generation of final concepts.

The documentation of ideas can be generated in electronic or printable format, which constitutes an advance to the methodology and also permits a better organization of the project along its steps, making its use easier.

Although some processes still need to be implemented and bugs to be fixed, we believe the software has already achieved a positive result by allowing users to focus their efforts on the core function of the whole process: the generation of creative ideas.

Acknowledgements

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Innovative Design of Customized Fashion Handbags

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Abstract

Regardless of the times or backgrounds, nearly every woman who leaves her home has a handbag with her. Handbags are always indispensable, important, and intimate items for women, and handbags not only need to be practical, but are also features of fashion and functional beauty. However, due to the influence of the global recession, past fashion trends of "LOGO craze" have gradually declined. Now, smart consumers are willing to pay for "good products". Thus, only quality products with unique appearances, excellent manufacturing quality, and intricate handiwork can demonstrate uniqueness and beauty of personality, in turn, attract consumers and gain their favor. Thus, this study first uses market surveys to understand the needs and expectations of consumers regarding customized handmade handbags, and then uses "TRIZ systematic innovation" to distinguish consumer market opportunities and seek resolutions to related problems. After following design procedures to design image drafts for innovation in the design styles, the materials are tested and calibrated to ensure that materials are well-made and conform to functional needs. Handmade test is conducted manufacturing and model modification to make the product intricate and perfect. Finally, customized handmade handbags are created to satisfy personalized needs, in hopes of creating new business opportunities for the creative design industry.

Keywords: TRIZ, systematic innovation, customization, handmade made-to-order handbags, innovative design

1. Introduction

(1) Research Motives

Women love beauty, and when they buy handbags, the first priority is usually for aesthetics, and the second priority is practical use. A beautiful and practical bag can categorize the items in the bag, is convenient to use, and adds unique style to the users. Psychologically, it can satisfy personal style, self-accomplishment, and demonstrate one's economic abilities. Thus, regardless of the times or backgrounds, nearly every woman who leaves her home has a handbag with her. Handbags are always indispensable, important, and intimate items for women. They not only need to be practical, but are also features of fashion and functional beauty. However, due to the influence of the global recession, past fashion trends of "LOGO craze" have gradually declined. Now, smart consumers are willing to pay for "good product." Thus, only quality products with unique appearances, excellent manufacturing quality, and intricate handiwork can demonstrate uniqueness and beauty of personality, in turn, attract consumers and gain their preference.

(2) Research Purposes

Based on the above research motives, this study attempts to explore the feasibility and development of customized handmade handbags, analyze the difficult problems encountered in customization of handbags and resolutions, apply procedures and models of innovative design in customized handmade handbags in order to create unique products with market value. Thus, this study first uses market surveys to understand the needs and expectations of consumers regarding customized handmade handbags, and then uses "TRIZ systematic innovation" to distinguish consumer market opportunities and seek resolutions to related problems. After following design procedures to design image drafts for innovation in the design styles, the materials are tested and calibrated to ensure that materials are well-made and conform to functional needs. Handmade test is conducted manufacturing and model modification to make the product intricate and perfect. Finally, customized handmade handbags are created to satisfy personalized needs, in hopes of creating new business opportunities for the creative design industry.

2. Literature Review and Research Questions

(1) The characteristics of fashionable handmade customized handbags

Each customized bag is given a symbolic meaning, with new trendy elements in the new styles, new ideas, and new materials, creating a sense of quality and novelty with new beginnings.

There is emphasis on the psychological feelings of the users, and innovative change is used to attract consumer attention. For instance, LV sells legends and stories, inspiring consumers the precious feelings for uniqueness.

In terms of consumption market channels, handbags have many different types and levels: there are luxury goods stores, exclusive counters, creative markets, online auctions, and street vendors, with over a hundred different brands attempting to fight over market share. Why can handmade handbags hold their positions in the consumer market with prices near the average unit prices of luxury brands? Why are consumers willing to spend money to order a customized handbag? It is because customized bags are selling a kind of tradition, a kind of craft, a kind of culture, and a kind of perseverance. When traditional craft and culture are no longer being insisted upon, the focus on mass production in assembly lines have caused traditional handbag production speeds to be unable to keep up with the massive sales or control over quality. Then, what remains is a brand without culture, and meanwhile, they lose the unique meaning to be fought over by people.

Why are people willing to wait for the one year for the manufacturing of customized bags? This is because customization emphasizes the value of handmade manufacturing. For instance, the French brand Hermes, known for handmade artisan quality, has a classic Kelly Bag. Its manufacturing requires at least 13 hours, and the inside is required to be labeled with the artisan's name. If customers require maintenance for the bag in the future, the same artisan can be responsible. This produces a unique exclusive value and sense of belonging. Designers of handmade customized bags can use different material styles, materials, and textiles that consumers can ask to match together, turning them into exclusive handbags, used to realize the dream of owning unique styles; or with the good handiwork and craft of old masters, who carefully make the buttons and seams carefully. The artisan feels like he is completing an artwork from selecting the style to matching the colors. It is a guarantee of outstanding character, insisting on handmade quality, the essence of which will be transferred to the consumer bit by bit, so that every detail is forever imprinted on his heart forever.

(2) Current conditions of fashionable handmade production (customized) handbag market

The origins of the term "fashionable handmade and customization" can be traced back to Paris in the 18th Century. According to Ku (2004), after the French Revolution in the 18th century, at the time the rise of the bourgeoisie and middle class led to the liberalization of clothing and accessories, and high-end customized clothing came on the scene. Later, in the mid-19th century, stores that sell high-end customized clothing or other brands of handmade customized luxury products gradually came into being in France, Italy, and England. Early on, in Taiwan, so-called "customization" services refer to the "current apparel" in the fashion field. For men's Chinese-style suits, western-style suits, or women's western-style cuts and qipao, these were all mainstays of the customized handmade apparel market. In recent years, the influence of globalization has led to the gradual rise of Taiwanese designer brands. Chen (2008) mentioned that Taiwanese designers not only have their own brands, but also provide for customization services. For instance, well-known designers such as Go-ji Lin, Gou-chiang Fang, Dai-lee Pun, Ji-min Chen, Shu-chi Huang, Yi-liang Pan, and Ching-chu Wun are all world-class. Shiatzy Design Director, Wang Chen Tsai-Hsia, also frequently designs dress gowns for Taiwanese businessmen and socialites. In fact, in terms of market demand, these brands all have professional teams behind them, and also design and produce handbags, shoes, leather products, and accessories.

Regarding the professional issues of production management, along with the changes in economic forms, scholars in Taiwan have found that product manufacturing or service procedures of mass customization can provide for low quantities and many types of products or service through flexible manufacturing processes. It seems that this is a key in resolving the problem of product diversity and competitive advantage. According to Wu (2007), product diversity and mass customization can both have positive influences on competitive advantage, while product diversity will make activities internal to the organization more complex. Conversely, mass customization would help in simplifying activities within organizations.

With the advent of the 21st century and under the influence of globalization, Taiwan also found the attraction of fashion irresistible. Fashion is no longer a symbol of power for the royalty, but can be the symbol of fashionable matters during a period of time. The February issue of ARCH Glamour Style Magazine (2008), the article Spatial Fashion Code defined fashion as "the popularity of something over a period of time." Lin and Chen (2009) suggested that fashion is not only popular culture, but is also a

life attitude, since the changes in lifestyles result in the endless changes of the lifecycles of consumption markets. Therefore, the above perspectives show that everyone can have fashion, it does not have to be extremely extravagant, but must be trendy at the time or have personal style features. Based on this position, handmade customized products or items are a part of the fashion industry. Facing customer groups with different demands, there are different marketing strategies and channels. The next section will focus on the research subject, "handbags," to summarize the brands of cases that accept orders for customization and organize the strengths and weaknesses of the marketing channels.

Table 1 Analysis of marketing channels and brand cases that accept orders for customized handbags

Marketing channel	Brand or case		Strength	Weakness
Luxury brand stores or exclusive counter brands	Foreign brands	Louis Vuitton	International brands have careful customization services. Other than product assurances, customization procedures are clear, and the prices are cheaper than the limited edition bags.	Consumers can only make certain types of changes. After the orders are made, they must be sent back to the original factory overseas, so the turnaround time is longer.
		Hermes		
		Cartier		
		Roger Vivier		
	Taiwan	Amopola customized handbag series	Can use lower prices to design handbags with a sense of quality and style	Lower name recognition, fewer exclusive counters, limited service ability.
		Caltan design		
Online marketing	Catwork: photo bag customization MINAS: photo bag customization Mimi tailors: production of canvas bag orders kitty.dog: production of canvas bag orders Happy workshop: production of canvas bag orders SewZakka Handmade: production of canvas bag orders		Uses yahoo, open-air auctions, and other online shops as marketing platform, save on costs of products and store costs; looking for consumer groups who love creativity and individualism; handbag designs are generally cute and stylish.	Businesses would set a few styles and specifications to be chosen by consumers, less uniqueness. Consumers cannot directly see the materials and the production processes, and there is a lower sense of trust; further, the method of material selection is more likely to produce errors.
Micro-workshops	Private textile mosaic classrooms, print and dye workshops, or leather sculpture workshops can accept customized orders.		The consumer can communicate with the designer face-to-face, and can go to the site to choose the materials and styles, view the production process, or even learn and experienc	Storefront or workshop addresses are generally in communities or margins of city center, with limited promotional ability, insufficient human resources, and less standard

		e the process.	prices.
Creative markets	Creative markets or holiday markets have vendors who focus on handmade textiles, leather sculpture, weaving, and techniques with other materials; consumers can communicate with the vendor, creating different handbag styles according to personal preference.	Save capital and human resource costs, service scope can expand all over Taiwan, and is one of the easiest ways for entrepreneur to earn name recognition.	Impossible to complete the sale of the ordered customized bag, less post-sale service for consumers; the prices cannot be set too high, which may result in uncertainty in terms of materials or quality.

Source: compiled by this study

(3) Analysis of consumer emotional needs

Smart consumers in the new age are inclined toward considering: how to satisfy their wants, placing the focus on innovative unique products and services, preferring products and services with authenticity. They are independent and individualistic, and they are willing to participate in the consumption process and have knowledge relating to consumption. They would ask vendors to tell them simply: what can this product give me? How is this product special? Is the price reasonable? Are the functions suitable? What kinds of guarantees can you give me?

Consumption behaviors originate from need, and the source of these needs can be divided into two types: (1) personal intrinsic factors, including lacks or dissatisfaction in terms of personal clothing, food, residence, transportation, education, or entertainment, or personal expectations for change and novelty; (2) external factors, including marketing stimulations or imitation and learning in social life. These different intrinsic and external factors would cause individuals to have the demand for consumption, eliciting consumption to satisfy related demands (Jian, 2008).

Social change have given consumers in the new age greater purchasing power and consumption knowledge, giving them more diverse products to choose from. Consumers search among different products, but now they want more, and hope that the products they buy can increase their own value, or demonstrate their own style and tastes, while helping them resolve pressures of daily life. Smart shoppers have sufficient self-perception ability to understand which products can care for their own internal emotional needs (Michael J. Silverstein, Neil Fiske, John Butman, Chen (trans.) (2004)). New consumer emotional demands are analyzed as follows:

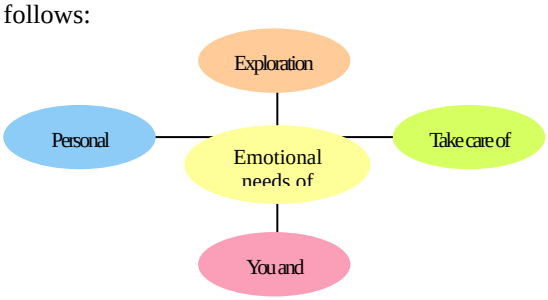


Figure 1 Types of consumer emotional needs
Source: Created by this study after consulting Michael J.Silverstein, Neil Fiske, John Butman, Chen (trans.) (2004)

In the product development process of many popular fashion industries, they should pay more attention to the value perceived by the consumers of the brand, and create irreplaceable new luxury items. Products or services that appeal to emotion can better move people, and this phenomenon is more salient for fashion products. This is because consumers do not really “need” this product, but rather they believe that it is “worth” having; therefore, products themselves must emphasize expression of cultural content, sense of quality, and unique characteristics, to use creativity, channels, and consumer connections to enhance product value (Lin and Chen, 2009). Another issue to appreciate is that the fashion products that have successful sales and have made most money are ones that have focused on emotional needs. For many consumers, consumption relating to food, clothing, residence, transportation, education, and entertainment would all encounter the four emotional needs. Customized products demonstrate that buying a customized handmade handbag can accentuate one’s own characteristics and tastes (personal styles), can be used to reward oneself after hard work (take care of oneself), can express the attraction of outstanding value in socializing (you and me together), participate in the design and creative process, learn more about products and

experience the fun of creativity (exploration and learning).

(4) Apply TRIZ creativity concepts into creative design

（a）TRIZ systematic innovation theory and meaning

The book by Stan Kaplan (trans by Jiang) (2008) points out that: TRIZ is the acronym of Russian Teoriya Resheniya Izobreatatelskikh Zadatch, which means "the theory of inventive problem solving," and was invented in 1946 by Genrich Altshuller. Genrich Altshuller (trans by Hsiao) (2008) pointed out that TRIZ theory was found after 200,000 patent analyses, picking out 40,000 that have more innovative patents to explore their resolutions and application methods, in attempt to find basic principles and forms. Thus, TRIZ is unlike using brainstorming to produce new concepts or creativity, avoiding blind spots or lack of systematic character produced by participant member breadth of knowledge. TRIZ stresses that invention or innovation can follow certain procedures and steps, rather than just random ideas or disconnected brain stimulation (Lin, 2009).

Song (2009) suggested that systematic innovation-TRIZ is the most important tool for the cultivation of creativity and innovation. According to the perspective provided by Hong (2004), it can be found that, the proposition of TRIZ theory is because the phenomena or process of product development produced physical contradictions or technical contradictions and other problems. The matrix system is used to point out the problems, and find the solutions to form the TRIZ systematic innovation theory that can resolve older problems and invent new inventive methods (see Figure 2). Gao (2005) indicated that TRIZ includes four primary methods and tools, which are (1) 39 contradiction matrices and 40 innovative problem-solving principles; (2) materials, context analysis, and 76 standard solutions; (3) science and technical achievements database; (4) ARIZ.

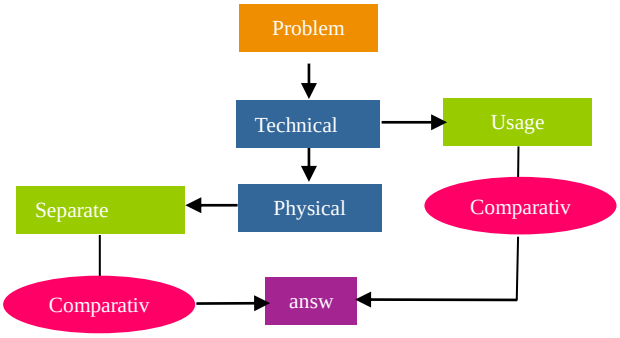


Figure 2 Procedures for using TRIZ to resolve contradictions

Source: Drawn by this study after referring to Hong (2004)

（b）Applying TRIZ innovation concept into creative design

Today, when personal needs have received more attention, in order to satisfy user needs, regardless of food, clothing, residence, and transport, manufacturers have promoted personalized services to keep or attract more consumers. For e-mail, auction websites, online audiovisual websites, instant messaging software, and search engines to personal online photograph albums and blogs, it is easy to find personalized services. Actually, top-level consumers are not concerned with price but a service value and respect, for instance: (1) use the highest-quality tools and materials; (2) specialized services; (3) listen to the decisions and requirements of customers; (4) make one's own designs longstanding and even become a classic. It is not only necessary to satisfy customer needs, but also necessary to cover aesthetics, appearance, and practicality, because the top-level customers want these things. Of course, the services must be very detailed as well; in turn this would leave deep impressions on the customers. Since society is approaching an M shape, this study argues that handmade customized handbags are feasible alternatives, and the market would have these demands as well. Thus, this study hopes to design a TRIZ systematic innovation-based design procedure for customized handbags that is convenient and practical, and can be used to find a developmental path for the demand for customization in Taiwan.

3. Research Method and Design Procedures

(1) Research Method

This study first conducts literature review to explore the characteristics of customized handbags, and carry out analysis of the Taiwanese market in the handmade customization orders in the fashion industry, as well as analysis of customer emotional needs, TRIZ systematic innovation theory application on innovative design. Then, using customer questionnaire analysis and interviews with store owners, this study collects consumer opinions and perceptions for customized handbags, and explores the problems that stores seek to improve upon in the process of producing or marketing customized handbags. After integrated data analysis, this study summarizes customer demands for handbag customization as well as current issues and contradictions faced by business owners, and uses concepts in TRIZ systematic innovation theory to construct the procedures for designing

customized handbags. After the material is analyzed and tested, actual production of customized handbags is carried out to complete developmental design. Finally, this study proposes conclusions and related suggestions.

(2) Research and Design Procedures

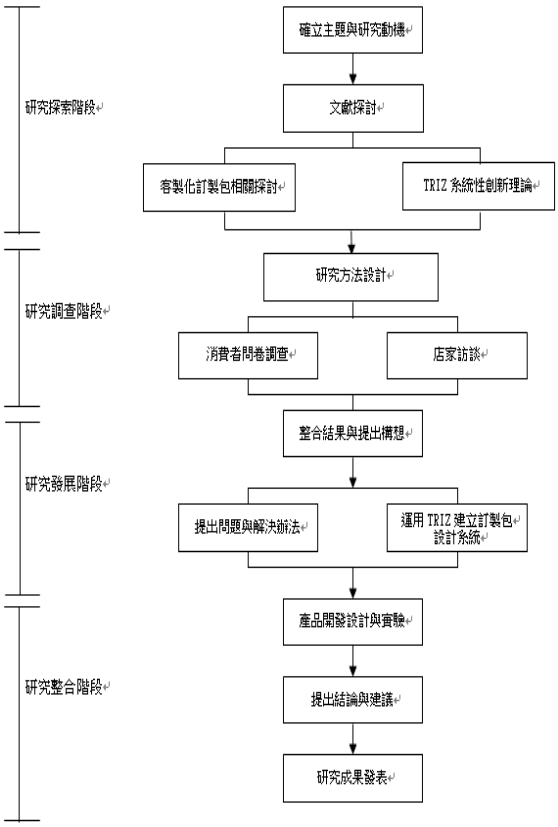


Figure 3 Research procedures

(Source: compiled by this study)
Research exploration stage
Ascertain topic and research motivation
Literature review
Exploration of customized handbags
TRIZ systematic innovation theory
Research investigation stage
Research method design
Consumer questionnaire survey
Interview with store owners
Research development stage
Integrate results and propose concepts
Propose problems and solutions
Use TRIZ to establish design system for customized handbags
Research integration stage
Product development design and experiment
Propose conclusions and suggestions
Publication of research results

4. Research Result Analysis

(1) Results of consumer questionnaire survey

Considering that handbags cover a wide range in terms of materials and forms. For instance, in terms of handbag form, there are clutch, large backpack, small backpack, small purse, coin purse, and party handbag. In terms of material, there are genuine leather materials, nylon materials, woven materials, bead materials, and wool materials. There are major differences in the customer groups, so this study focuses on the handbag market in Taiwan. Questionnaire survey was conducted on individuals who currently intend or do not intend to purchase customized handbags. The area of research included seven cities and counties in Taipei, namely Taoyuan, Taichung, Changhua, Tainan, Kaohsiung, and Pingtung. A total of 600 questionnaires were released, and 600 valid questionnaires were retrieved, with 200 each in the central-north, central, and south.

(a) Handbag functionality analysis: the top consideration is convenient mobility, followed by practicality

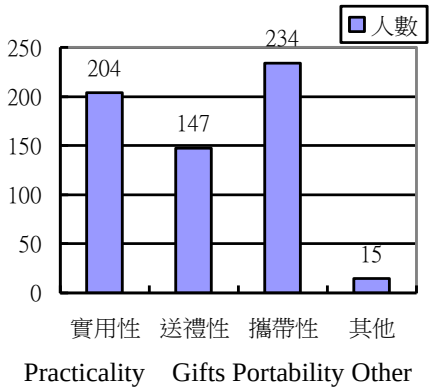
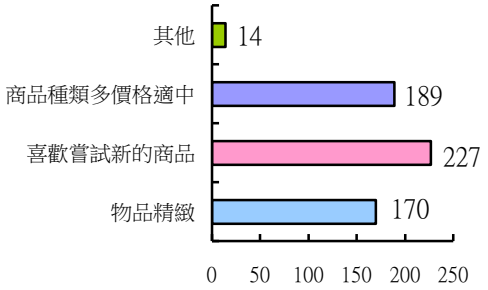


Figure 4 Survey of handbag functionality

(b) Analysis of consumption reasons

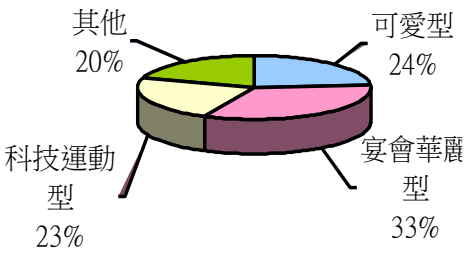


Other
Many types of products and suitable prices
Likes to try out new products
Intricate items

Figure 5 Analysis and survey of consumption reasons

(c) Analysis of handbag categories and types: the questionnaire surveys show that if consumers want to purchase customized

handbags, as many as 33% of the subjects in Taipei and central Taiwan prefer more glamorous or banquet-style handbags

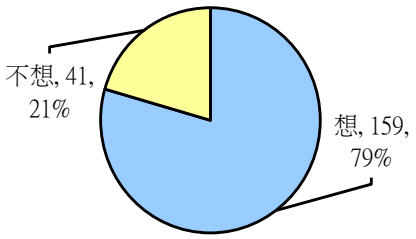


Other Cute type
Technology or sport type Party and glamorous type

Figure 6 Survey of the forms and styles of handbags preferred by consumers

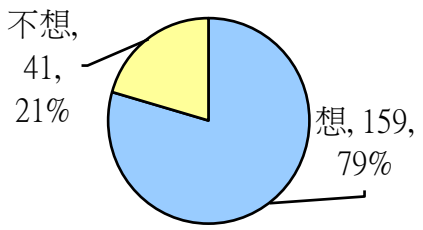
(d) Hope to have a handbag customized for oneself

Customization analysis shows that as many as 80% of the consumers are willing to accept customized handbags. This finding shows that the feasibility of customized handbags is a business opportunity and a trend for future shopping by consumers.



Do not want Want

Figure 7 Statistical chart for northern Taiwan: want to have a customized handbag

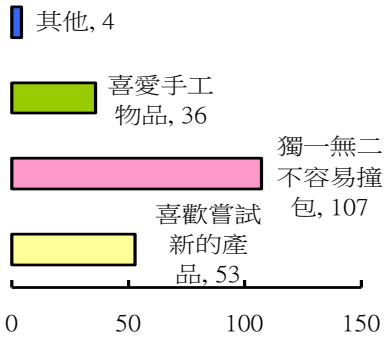


Do not want Want

Figure 8 Statistical chart for central Taiwan: want to have a customized handbag

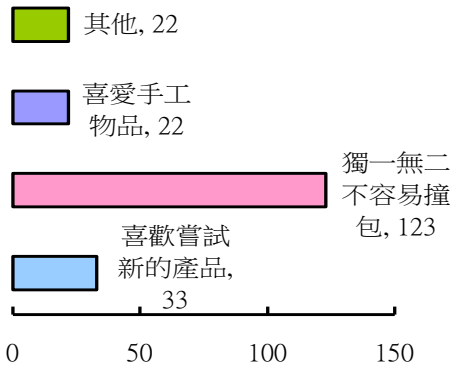
(e) Analysis of greatest reason for willingness to order customized handbags

Statistics for the 600 questionnaires in northern, central, and southern Taiwan



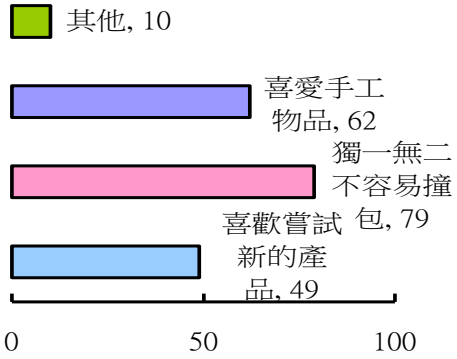
Other
Likes handmade items
Unique and not likely to encounter the same handbag
Likes to try out new products

Figure 9 Statistical chart for northern Taiwan: how to attract you into buying a customized handbag



Likes handmade items
Unique and not likely to encounter the same handbag
Likes to try out new products

Figure 10 Statistical chart for central Taiwan: how to attract you into buying a customized handbag



Other Likes handmade items
Unique and not likely to encounter the same handbag

Likes to try out new products

Figure 11 statistical chart for southern Taiwan: how to attract you into buying a customized handbag

As high as 52% of consumers who order customized handbags are willing to accept customized handbags because they are unique and unlikely to be in the presence of the same bag.

(2) Contradictions and innovative problem-solving principles in customization procedures for handmade customized handbags

This study uses the 39 contradiction matrices and 40 innovative problem-solving principles according to TRIZ theory in attempt to discover the problem contradiction parameters for the development process of customized handbags, and find the items that are suitable from 40 innovative problem-solving principles.

Table 2 Contradiction matrix analysis of customized handbags

Contradiction parameter	Prevent deterioration / Feature for improvement	Shape (12)	Durability of moving parts (15)	Waste of materials (23)	Waste of time (25)	Precision of manufacturing (29)	manufacturability(32)	convenience of usage (33)	maintainability (34)
1	Shape (12) *Formal design*	+		35, 29, 3, 5	14, 10, 34, 17	32, 30, 40	1, 32, 17, 28	32, 15, 26	2, 13, 1
2	Durability of moving parts (15) *Durability*	14, 26, 28, 25	+	28, 27, 3, 18	20, 10, 28, 18	3, 27,, 16, 40	27, 1, 4	12, 27	29, 10, 27
3	Waste of materials (23) *Testing of materials*	29, 35, 3, 5	28, 27, 3, 18	+	15, 18, 35, 10	35, 10, 24, 31	15, 34, 33	32, 28, 2, 24	
4	Waste of time (25) *Production process*	4, 10, 34, 17	20, 10, 28, 18	35, 18, 10, 39	+	24, 26, 28, 18	35, 28, 34, 4	4, 28, 10, 34	32, 1, 10
5	Precision of production (29) *Communication gap*	32, 30, 40	3, 27, 40	35, 31, 10, 24	32, 26, 28, 18	+		1, 32, 35, 23	25, 10
6	manufacturability(32) *ease of production*	1, 28, 13, 27	27, 1, 4	15, 34, 33	35, 28, 34, 4		+	2, 5, 13, 16	35, 1, 11, 9
7	convenience of usage (33) *Usage needs*	15, 34, 29, 28	29, 3, 8, 25	28, 32, 2, 24	4, 28, 10, 34	1, 32, 35, 23	2, 5, 12	+	12, 26, 1, 32
8	Maintainability (34) *Post-sale service*	1, 13, 2, 4	11, 29, 28, 27	2, 35, 34, 27	32, 1, 10, 25	25, 10	1, 35, 11, 10	1, 12, 26, 15	+

Source of data: compiled by this study after referring to the TRIZ contradiction matrix

(3) TRIZ innovative procedures for designing customized handbags

TRIZ theory is generally used in scientific inventions. Even application in the design field is generally for highly industrial or technical product designs; thus, this study first extracts the meaning of TRIZ theory and refers to some of what can be applied to innovative problem-solving principles. This study finds that for handmade customized innovative product design, 39 contradiction matrix and 40 innovative problem-solving principles in TRIZ theory are more suitably applied. However, the customized creative design procedures are not completely in conformity with the 39 contradiction parameters and 40 innovative problem-solving principles in TRIZ theory. Research finds that in terms of design semantics, procedures, and conceptualization in the customized creative products: the four steps of "designer and consumer communication", "material selection and production techniques", "design and production procedure", and "marketing strategy" are parts that need more systematic confirmation to benefit selection by micro-corporations or brand. Thus, after the summarization and analysis, the TRIZ systematic innovation procedures for designing customized handbags are planned as follows:

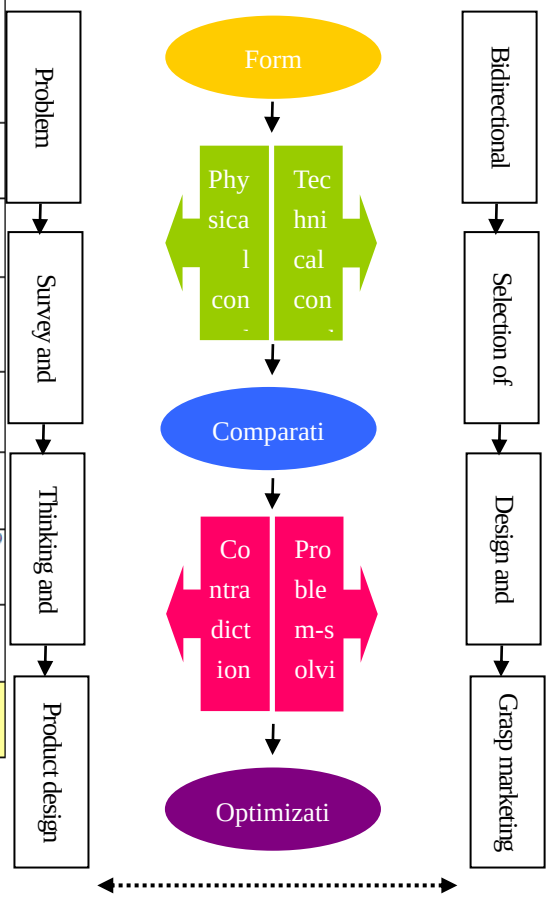


Figure 12 TRIZ systematic innovation procedures for designing customized handbags

(4) Analysis of main points in materials and techniques

(1) Use different materials, shapes, forms, and techniques to compare the materials that lead to different quality feels of handbags.

(2) Consider using new materials for examination and creation, introducing new forms in experimental creation, then ascertain the feasibility of materials, and the final purpose is for production of the actual products.

Table3 Common categorizations of customization techniques

Material / technique	Glass crystal	leather	Cloth or wool	Cotton or wool rope	Wood and bamboo	plastic	Silk fiber
Weaving	◎	◎	◎	◎	◎	◎	◎
Printing		◎	◎	◎	◎	◎	◎
Sewing or embroidery	◎	◎	◎	◎		◎	◎
Pasting or embedding	◎	◎	◎	◎	◎	◎	◎
Coloring or filling	◎	◎	◎	◎	◎	◎	◎
Tying or knotting	◎	◎	◎	◎	◎		◎
Sculpting or hold-punching	◎	◎			◎	◎	

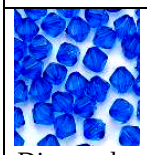
Source of data: compiled by this study

Table 4 Analysis of wool materials

Name	Price	Special points, strengths, and weaknesses
Cashmere wool	(100% most expensive, one roll 1000~1300)	Lightweight, most insulating
Merino wool	(100%Merino cheap 140~as expensive as 380)	Lightweight, insulating
Wool	Wool (100%Wool, 45~100)	Insulating, low price
Baby Alpaca	Alpaca (100% is about 130~160)	Good insulation
Alpaca	Alpaca (100% is about 85~110)	Good insulation
Acrylic	100%ACRYLIC 30 NT	Weakness: does not absorb sweat, unsuitable for wearing

Source of data: compiled by this study

Table 5 Compilation of various materials

Various types of rope and string		
 Hemp rope	 Silk strings	 Five-color strings
 Sewing thread	 Mink wool balls	 Fishing wire
Handle images		
 Bamboo knot handle	 Synthetic leather	 Acrylic handles
Various plastic beads		
 Diamond-shaped beads	 Glow-in-the-dark beads-yellow	 Solid-color candy
 Plated round beads	 Colorful plastic beads	 Rice beads
 Earth beads	 Trapezoid wooden beads	 Oil Beads
 Bead-in-	 letter beads	 Glass pearls

bead		
 Marbles	 Oil beads	 Glass pearls
Various glass crystal beads		
 Rice beads	 Pointed beads	 Fish-shaped beads
 UFO beads	 Water drop beads	 Heart-shaped
 Sky beads	 Wavy circles	 Snowflakes
 Artistic pendants	 Sea star/coral	 cross
 Square	 Butterfly-shaped	 Flower-shaped
 Earth beads	 moon/star	 Maple leaves

Source: compiled by this study, photo from http://swarovskicrystal.webdiy.com.tw/index.asp?lang=1

(5) Results of product design

Table 6 Case of creative process of handmade customized handbags

Process technique	Images Design of glamorous customized handbag Austria crystal bead materials
Weaving, knotting	

Source: compiled by this study

Table 7 Completed handmade customized handbags

(1) Glamorous Styles	(2) Pure Years
	
(3) Colorful Murmurs	**(4) Green Fields and Magical Shoes**
	
(5) Amber fields	**(6) Mysterious Night**
	

Source: compiled by this study

5. Conclusions and Suggestions

(1) Conclusions

（a）Product demands of consumers have transformed from "need" to "worth" the added value

Modern consumers are a unique group, which has financial capability and distinct tastes. They desire for quality products, are generous to themselves, and take social responsibilities. Their pursuit for fashion may be influenced by others, but still holds their exclusive tastes. They have abundant consumption knowledge, and know their own consumer needs. Once our products can touch their heart and satisfy their needs, they would spend money to buy these products and even become loyal consumers. They are a rising force among consumer groups, and are the main group of customers that the fashion industry

should emphasize and be concerned about.

Consumers in the new age are concerned with "emotional consumption." They do not only buy function, but also want the positive emotions brought by this product, including self-confidence, carefree, happiness, and price (Lin, 2002). Thus, "emotions" have gradually come to play the main role in consumption. Emotional consumption generally buys fashionable products or "luxury goods," and they hope to buy a unique product that can express the ideal self.

（b）Consumers are concerned with product hand feel design, style aesthetics, intricate quality, unique innovation, and experiential services

This is an age of pursuit for hand feel. Handmade eyeglasses, jeans, knit-bags, figurines, soap, and cookies are some of the consumer products that are "made by hand," and the prices are not cheap. Even though some products are not a hundred percent "made by hand," they intricately extend the emotions, temperature, and tactile sense from "hands" into design concepts. Hand feel transmits the temperature in the hands of designers, and are deep experience processes, these are also sources of vendor pursuits for differentiation under market competition.

The popularity of hand feel products mean that people hope to use their hands to create something to prove one's existence to fight against mass production rather than being a part of capitalism. The advent of the age of hand feel expresses that more consumers choose to be loyal to personal style rather than brand. Meanwhile, this reflects a dissatisfaction and protest for their life environments, protesting against an age with mass production and too many choices.

（c）Use TRIZ systematic innovation theories and concepts, as well as the thought framework on customized handbags for creative design is feasible and visionary

This study finds that in terms of the design semantics, procedures, and conceptualization of creative customized handbag products: the four steps of "designer and consumer communication", "material selection and production techniques", "design and production procedure", and "marketing strategy" are parts that require more systematic establishment for the reference and selection by micro-corporations and brands. Thus, this study uses the 39 contradiction matrices and 40 innovative problem-solving principles in TRIZ Theory to find the parameters and solutions that conform to the four steps above. This study finds that there are 8 contradiction parameters that conform; which are shape (12): formal design, durability of moving parts (15): durability, waste of material (23): material test, waste of time (25): order and production process, precision of manufacturing (29): communication gap, manufacturability (32): ease of production, convenience of usage (33): usage needs, maintainability (34): post-sale service.

Thus, using the theoretical concepts and ideas of the framework of TRIZ systematic innovation in the creative design of customized handbags is feasible and visionary. Later studies can use Delphi method or experiment method to again confirm whether the innovative problem-solving principles of the eight contradiction parameters and be applied on the creative design of customized handbags, so that this innovative system would be more comprehensive.

（d）Handbag customization service should establish the procedures and systems so designers, workshops, or micro-corporations can refer to them and apply them

Currently, handbag customization service is not just a marketing strategy of well-known luxury brands. For consumers in the new age, the uniqueness, creativity, or personal styles of customized products are all marketing trends in future fashion. Thus, the establishment of a procedure and system for the creative design of customized handbag can help designers, workshops, or micro-corporations to effectively control the customization process, to dispel or improve upon problems encountered in the customization process.

(2) Suggestions

（a）Use the process of customized experiences to satisfy the emotional demands of customers

Since feeling "worth" has gradually become a part of what consumers expect, products or services with emotional appeal can better move people. This is because when products themselves or their added value can form a connection with an emotional need of consumers, it would better satisfy them, and they would think it was more "worth having," and be more willing to spend money.

Thus, in the experience process of customization, if it is possible to understand consumer feelings, with "emotions," "contexts," and "feelings" as the key points in consumption, to take care of emotional needs and the objectives desired by consumers, make considerations based on their position, and engage the consumer's points of benefit, provide consumer with the economic value of in-depth experiences and

high-quality aesthetics with the core knowledge and professional ability to integrate the beauty of life with creativity. With the uniqueness of "customization" for customers, they can "be fully willing" and "buy generously," so that they can be "satisfied" and feel that their money was "worth it." (Lin, 2009), and further promote customized products as life necessities after being packaged by emotional appeal.

（b）Use customized products to create added commercial value in "hand feel economy"

For modern people, slowness is the real luxury, this is an age in the pursuit of "hand feel. More and more 100% "handmade" products, or those that emphasize a sense of touch, temperature, and exclusive production receive more attention in the market. More people are spending money to buy "works," rather than "merchandise." This type of consumer trend means that craft art is returning. People come to workshops in small alleys to find totally unique original works.

When "hand feel" is a new marketing element, then how is it possible to communicate with consumers? How to create a unique "hand feel brand"? This is an important issue that requires deep thought. Thus, hand feel economy is an experiential economy, with deep communication between consumer and designer as well as deep aesthetic experiences, emphasize that the "humanity" and "touch" of "customization" cannot be mechanized and mass produced, in turn causing consumers to be loyal to the individual and not the product. Taiwan has entered a new economic age of hand feel consumption, where creative design and marketing management have to be combined with culture, and use a sense of quality to correspond to the consumption needs of certain groups; hand feel is a kind of subtractive aesthetic. If it possible to perfectly balance traditional and modern elements, and extract the beautiful elements of history, memory, and emotion (Wu et al., 2006) to get closer to the senses of the consumers, grasp a feeling of being moved in their hearts, this would be successful addition of value via hand feel.

（c）Suggestion to use KJ method to find the contradiction parameters in design of handmade customized handbag to establish comprehensive principles for the creative design of TRIZ systematic innovation

This study only finds eight TRIZ contradiction parameters that conform to the procedures of creative design for customized handmade handbags. Future studies can use KJ method or other methods to construct more contradiction parameters and problem-solving principles that conform to customized creative design, so that the usage of TRIZ systematic innovation principles in the professional field of creative design can gradually become more comprehensive and assist in the development of cultural and creative industries.

（d）Establish a database system for materials and techniques for customized handbags to facilitate communication between designers and consumers

Using the forms of creative design, novel colors, development of unique materials and practical functions, integrating new technological production methods, and production of personalized styles can all accentuate product originality and uniqueness to attract the attention and preference of consumers. Future studies can further test the various materials and techniques, and use the processes and results to construct a database system for convenient checking, applying, comparing, and analyzing. It would help designers and consumers communicate and exchange opinions at any time, to jointly participate and design the creative products that both sides are satisfied with.

（e）Establish online marketing platforms for creative design of customized handbags, allow consumers to participate in design with internet databases

Allowing consumers to experience the design process is one of the emotional demands for consumers. It is suggested that businesses should use internet interaction platforms and context simulation methods, so that consumers can participate in the complete creative process, so that they can deeply experience a sense of reality and value.

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Designing a Drinks Maker Machine Based on TRIZ Systematic Innovation Method

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Abstract

In this research, the principles of TRIZ are applied to design a drinks maker machine set for bar operating. From the Method of 9 window, the following three ideas are developed: (1) Ease of Recycling: Use different color for different material so that it will be easy to recycle. (2)Energy Saving: Use solar chargeable batteries or wind power. (3) Ease of cleaning: all the ingredients pipes which connect front and back of house will be in a button-up designed channel to easy to change and clean those pipes. From the Method of Contradiction Matrix, another two designing ideas are found: (1) Space saving by use Inventive Principle 35 Parameter change: Redesign the bottle shape to increase the base of mix-drinks source. (2) Time saving by use Inventive Principle 10 Preliminary action: To speed up the drink making, some mostly common drinks can be premix before usage. And then, the super system bar of drinks maker was designed, another two designing ideas are found: (1) Inventive Principle 5 Combining: Combed the storage drinks source and operation of mix-drinks source. (2) Floor plan saving by using Inventive Principle 17 Another dimension: Remove the less usage ingredients to back of house and enlarge the operation area.

Keywords: Drinks maker, Method of 9-window, Contradiction Matrix, Inventive Principle

1. Prologue

1.1Motive of Research

The globalization era has come, without any doubt, it has changed swiftly the life style of the modern human society. The constantly innovated technology keeps challenging traditional values. Drink industry emerges as a leading economic business. (Hong, Chun-Ju 2007) In such a quick-change environment, modern consumers are developing a particular drinking hobby of their own. The drink business could be seen as an indicator of the

national economic growth, the higher is the economic growth, the bigger is the drink business, in other words, it is born on the demand of the consumers, and the technical innovations has further pushed its development. In one word, the development of drink industry could help us to understand the evolution of an economic unity.

The control of dosage has been a main problem to the drink mixing. It is extremely hard to get the precise dose of each drink ingredients to mix them up manually. It turns out that every cocktail will be of slight different taste, according to different bartenders. That is, in order to get a constantly stable taste, to make sure the drinks is smooth, bartenders usually need a lot of hard working and long-term practice. The traditional drink mixing also means a lot of manual labor investment. If it can be replaced by machine, not only the taste could maintain stable, the labor cost could be reduced as well.

In the past, some of the kitchen equipments were designed on the basis of traditional cuisine methods; some were even copies of the existing product designs. No one seemed to try to follow a systematic innovation way to invent a real new product. Therefore, most existing design variations would hardly be ranked as original innovations; also, developing a new design needs time and well trained personnel to cope with it, instead of letting the machine to cope with the non-experienced workers. This explains why a brand new design is rarely found in the market. We here try to invent a new drink mixing machine based on the TRIZ systematic methods, and let's find out what we get.

1.2Purposes of Research

Our purpose is to innovate the drink mixing machine via a systematic way, and hopefully have the market accept it.

2. Research of documents

2.1 Alcoholic drink

Under the current globalization trend, most of metropolitan innovation plans and city marketing projects include leisure units, such as theme restaurant、theme bar and cafeteria, etc…These sites are gaining more and more importance in the modern city life as the city planning focus more and more on forming delicate consumption cultures and civilized residential spaces. (Su, Chin-Huai, 2002) We could conclude that while the consumers get an alcoholic drink, it is not only a simple choice of what to drink, but also a choice of knowing people and having fun.

2.2Consumers behavior

Target the right market segment and innovate the new products accordingly. The new products will surely satisfy the consumers' expectations, then gain higher market share and finally create their own loyal customers.

『Market segmentation, market target and market position (STP)』are considered by the drink industry as the key elements of the market strategy.(Hong, Chun-Ju 2007) While consumers are making a low interference (low–cost) deal,(Leung, kuo-rai, 2009), it is found that the product brand will be affected by their trust and satisfaction after the consumption, that is, through their consumption, their trust and satisfaction to the products will increase or decrease, which impacts their will of consumption in the future, the reputation of such brand and their loyalty to the product.

2.3 Development of new products

Leung, kuo-rai(2009) found out during the development of new products, it seemed that the quality of product design is the key to the success of a brand. The new product strategy must focus on the consumer loyalty in order to attract consumers and to make consumers the loyal clients.

There are a great variety of products in the drink market. The competition is tough. The marketing plans usually concentrate on brand images and attractive packing, using different packing designs to catch consumers' eyes. (Lo, Chui-pin, 2010) noticed that consumers pay a lot of attention to the brand image and packing design on drinking products. Except that, the design of the new product itself also influences their will to purchase.

2.4New service

Kao Chui-yin and Lin Yu-sho(2004) thought the food and beverage industry in Taiwan will march towards the product innovation, it is a irreversible trend. In fact, to satisfy customers' curiosity is since long a leading tactic of the marketing strategy in the food and beverage field. Jan Cheng-yi (2002) pointed out we must invent unique and original products to bring our customers back again, therefore we must keep developing new products, define precise market segment and maintain the advantage.

The market is versatile. The 『versatility』 is normal, (Cheng, Tong- yuan, 2007)discovered the consuming hobbies of the alcoholic drinks were easily influenced by outside stimulus, so the new service would have great chance to be accepted by the existing clients. (Wu, Wei-yin, 2002) clearly expressed that in the highly manpower invested business such as the cooking or drink mixing industries, if the new service tends to provide some kind of high- tech simulation interface, more customers will accept it.

2.5TRIZ Systematic Innovation Method

TRIZ which means Inventive Problem Solving, this theory provide algorithmic approach to solving technical problems began in 1946 when the Russian engineer and scientist Genrikh Altshuller studied thousands of patents

and noticed certain patterns. From these patterns he discovered that the evolution of a technical system is not a random process, but is governed by certain objective laws. (Clausing, 2001；Mann, 2003;宋明弘，2009;趙敏等 2010)

Systemic innovation has incorporated the knowledge and experiences of the world's finest inventive minds. This method is that it will take us through a systematic procedure that will progressively help us to define what our situation is and what we should do to improve it, this method has been configured in such a way as to allow users significant flexibility, offering both an over-riding structure and access to individual problem definition and solving tools.

(1) Problem Solving Tools (Conflict & Trade-Off Elimination/Inventive Principles) which detail the mechanics whereby the successful trade-off eliminating business solutions of others can be legitimately transferred to our situations. As we try and improve one aspect of a system, some other aspect gets worse or prevents us. The tools also includes a reference detailing the 40 known strategies for eliminating trade-off solutions. (Tan Ruen Hua，2010)。

(2) Problem Solving Tools (Contradiction Elimination) which focus on problem situations which contain a contradiction for example, where we want something to be 'present and absent' or 'big and small', 'independent and attached' and detail strategies for their elimination. (Tan Ruen Hua，2010)。

(3) System Operator (12-Windows) detailing a specific tool to assist in the process of thinking in terms of space, time and relationship. This chapter forms a bridge between the overview chapters and the other specific tools – the 9-Windows representing a tool in their own right, but the underlying concepts are used extensively in every other aspect of systematic innovation.

3. Bar design

Different bar functional designs needs different equipments. Basically, in a lounge bar, the drinks and the entire atmosphere created by the bar are equally important. Different bar designs attract different segments of clients. The target market must absolutely determined before the bar get installed. The products of the bar must be adjusted according to the hobbies、 preferences、ages 、 sex and education levels of the main segment of the clients. They must be able to satisfy their expectations, catch their hearts and get attached to them.

3.1Personnel of the bar

The personnel of the bar is organized on the basis of the services provided by the lounge bar. The more services provided, the more labors needed. The bar needs sufficient man power, because customers order directly from bartenders. The number of bartenders decide the space design of the bar, such as how many service areas、water supplies; how many set of mixing tools、equipments. Each bartenders on duty must follow precise operation procedures, avoid mutual disturbance. Also each bartender should has his own set of mixing tools and glassware, to get the maximum use of a limited space.

3.2Bar space design

The bar are generally divided into 3 main areas, the functions of each are as follows:

(1)The front bar

It is the space for customers, either standing or sitting, to have a drink leisurely or to get acquainted with each other. Here, we emphasized on comfortable environment and atmosphere, the common equipments include:

Draft beer machine、necessary glassware、customer's supplies、pick up stations、POS machine.

(2)The under bar

Under bar is the bartender's major working area. Most of the professional mixing tools and equipments are installed here, the common ones are:

Speed rack、ice bin、necessary inventory、glass washing machine、refrigerator、blender、soda gun、draft beer supply system、soda gun supply system.

(3)The back bar

It is the logistic support area for the front bar sales window, such as wares storage、alcohol temporary storage , the equipments we often see in this area are:

Beverage stored bin、separate for wine、beer and liquor、glass wears storage closet、coffee machine、refrigerator.

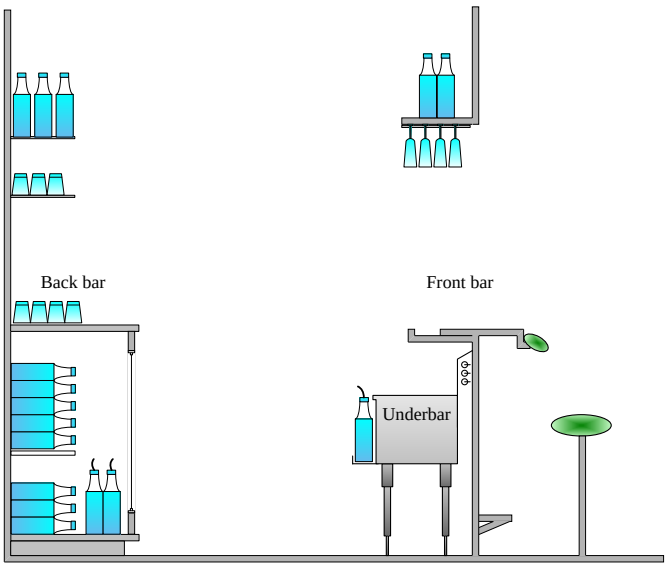


Diagram of bar function areas

4. The demand and the efficiency of the drink making machine

4.1Motive of the design of the mixing machine

(1) Cocktail recipe is precise, however the manual control of dosage is usually hard to keep that precision

A good bartender requires not only professional cocktail mixing techniques, but also the ability to control the cost. Bartenders use jiggers to measure wines / liquors. The measurement are easily affected by the vision angles and their personal tastes, which means sometimes there is too much or less wines / liquors in it. Let along, in American bars, the free pouring is the most frequent usage. It turns out that the same cocktail tastes different. The mixing machine offers a total solution to maintain the consistence of the flavor.

(2) Integration of supplies and minimize the required operation space of bartenders

The space cost is high. To minimize the operational space and release more space for customers and tables is the goal of each business units. More customers mean more incomes. However, to cope with all kinds of orders, the bar must prepare a large variety of liquors / wines of different brands. These necessary supplies usually limit the bartender's operational space , as a result, the bartender's performance would be reduced, then follow up the complaints and the decline of incomes .

(3) Machine is extremely helpful to speed up the mixing, while special ingredients required.

Dealing with special ingredients such as syrup and dairy products, the bartenders need to spend more efforts and time to get them completely melt or foamed. And the machine never feels tired, in the other words,

it definitely helps speeding up the serving. Also, the machine could help a lot, while handling the ice cubes.

(4) Integration of the supporting machines

There are many supporting machines in the cocktail market, and they are widely used now, such as draught beer pump、soda gun、mechanic arm of the mixer、multi-functional ice breaker. All these machines only support a part of the bartender's job. Besides, to install them all will require a lot of space in the bar. It is obviously necessary and cost- saving to integrate them in one.

(5) Less dependence on experienced bartenders

An experienced bartender can easily deal with different orders from numerous customers, mix up the cocktails quickly and never keep them wait. As a result, the experienced bartenders mean high personnel cost. Generally speaking, most orders can be done by simple techniques, such as pouring or stirring, which after second thought, can be done by the machine. It can do it even faster and more precisely, which means a reduction of personnel cost.

4.2 Expectation of Efficiency

(1) Reduce bartenders' workload. Most of the basic cocktails can be taken care of by the machine, and then given to the waiters to serve. Speed up the serving time.
(2) Better control of the wines / liquors quantity. It helps to maintain the consistence of taste, meaning a better control of cost as well.
(3) Reduce front bar space. All wines / liquors will come through the pipeline settled behind the front bar, no bottle shows up on the bar racks.
(4) Lessen preliminary work. Fewer supplies to be transported, bartenders can pay more attention to meet customers' requirements.
(5) Lower the manpower demand. It means lower cost.
(6) Serving of cocktails connected to the point of sales system, it simplifies the order procedure, raised the serving efficiency, avoid manual mistakes.

5.Systematic Innovation Method Application

5.1 System Operator (12-Windows)

System Operator (9-Windows) detailing a specific tool to assist in the process of thinking in terms of space, time and relationship. This chapter forms a bridge between the overview chapters and the other specific tools – the 9-Windows representing a tool in their own right, but the underlying concepts are used extensively in every other aspect of systematic innovation. System Operator (12-Windows) also examining where systematic innovation

itself may be expected to evolve in the future in its business and management contexts.

(1)Life cycle of 9-windows

Table2 life cycle of 9-windows of Drink making machine

Time / System	Past	Present	Future
Super System	sales、floor plan、building	bar、training school、working station、glassware、mixing tools	recycle、resources classification、color
System	factory fabrication、store exhibition、warehouse storage	Drink making machine	resources recycle、waste、maintain lifetime useage
Sub-system	production	plasic、glass、PC circuit board、keystroke	re-usage *1

(2)Trend of 9-windows

Table3 trend cycle of 9-windows of Drink making machine

Time / System	Past	Present	Future
Super System	Training、skills、experience	blender、glassware、shaker、stirrer、basic liquors	automatic equipment
System	function of machines、hand make drinks	Drink making machine	Function of machines combination(variety)*2
Sub-system	Front bar、Storage、pipes	machines combination	solar or wind power *3 *4

(3)Innovation Concept

a. Recycle：Base on the different material painted on different color to help the classification and recycle.

b. Function combination：Combine the different machines needed to save bar operation space.

c. Green power：Use solar chargeable batteries or wind power to save energy.

d. Wind power：Base on the radiation system to reuse the power while the fan rolling.

5.2 Conflict & Trade-Off Elimination/Inventive Principles

It successful trade-off eliminating business solutions of others can be legitimately transferred to our situations.

(1) Conflict & Trade-Off

Design a machine can bring in more ingrendient bottles; however it also can fit in limited space and easy to move around.

(2) Contradiction Elimination

a. Improved parameter：fixed volume(engineering parameter 8) deteriorated parameter：fixed weight(engineering parameter 2)

The bigger the machine is the more bottles bring in; however the bigger the machine is the weight is heavier.

b. Improved parameter：fixed volume(engineering parameter 8) deteriorated parameter：fixed weight(engineering parameter 2)：fixed square measure(engineering parameter 6)

The bigger the machine is the more bottles bring in; however the more bottles bring in the space need is bigger.

c. Improved parameter：fixed volume(engineering parameter 8) deteriorated parameter：fixed weight(engineering parameter 2)：fixed square measure(engineering parameter 26)

The smaller the machine is the easier the shift is; however the smaller the machine is the bottles capacity is less.

5.3 Contradiction Elimination matrix

deteriorated parameter / Improved parameter	2 fixed volume	6 fixed square measure	26 substance quantity
8 fixed square measure	35,10,19,14	—	35,3

5.4 Improved parameter

35 change parameter、10 pre action、19 periodicity movement、14 curved measure、3 partial quality.

5.5 Innovation Concept

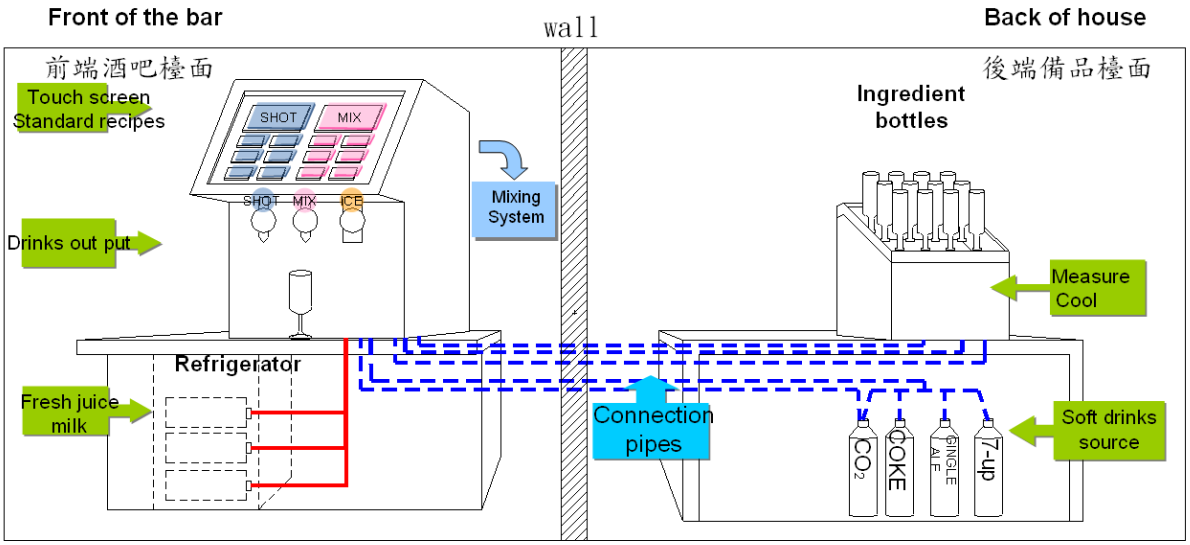
(1) Improve parameter –change width (length) of the source bottle

To narrow the width of the ingredient bottle (increase the length) and to bring in more variety of source bottles of ingredient with less space need.

(2) Pre Action

Get ready for the most common drinks pre mixing in order to reduce the variety bottles and the process time need.

6. Design of the mixing machine



Concept diagram of the mixing machine

Our design of the mixing machine includes all the above innovation ideas, aims to move the bulky wine / liquor bottles to the back preparation area. We also adopt slim bottles to maximize the storage quantity. Besides, we can preliminarily mix the alcohol that the most popular cocktail drinks need in order to reduce the bottle numbers stored inside. It is more convenient for workers to reload alcohol supplies and other ingredients. The machine can replace a lot of manpower, the front bar is no longer need to be equipped with various tools and electronic devices, and the space gained there could bring far more benefits than you can imagine.

7. Result and suggestion

In order to speed up the beverage service, many supporting machines are widely used at bar now, such as draught beer pump, soft drinks soda gun, mechanic arm of the mixer, multi-functional ice breaker. Customers are well accepted and recognize the professional image. The new drinks making machine combines all those existed functions and extend them. To enlarge the front bar space usage, all ingredient liquors will be moved back to

storage area and connect through the pipeline to the front. There are no bottles showing up on the bar racks need.

Making and Serving of cocktails by the machine which connects to the point of sales system simplifies the order procedure, raises the serving efficiency, and avoids manual mistakes.

In this design, the following three ideas are developed from the Method of 9 window, : (1) Ease of Recycling: Use different color for different material so that it will be easy to recycle. (2)Energy Saving: Use solar chargeable batteries or wind power. (3) Ease of cleaning: all the ingredients pipes which connect front and back of house will be in a button-up designed channel to easy to change and clean. Another two designing ideas are found from the Method of Contradiction Matrix, : (1) Space saving by use Inventive Principle 35 Parameter change: Redesign the bottle shape to increase the base of mix-drinks source. (2) Time saving by use Inventive Principle 10 Preliminary action: To speed up the drink making, some mostly common drinks can be premix before usage. And then, the super system bar of drinks maker was designed, another two designing ideas are found: (1) Inventive Principle 5 Combining: Combed the storage drinks source and operation of mix-drinks source. (2) Floor plan saving by use Inventive Principle 17 Another dimension: Remove the less usage ingredients to back of house and to enlarge the operation area.

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Research on the Suction-tape Feeding Technology Maturity of Printing Press Based on TRIZ

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Abstract

TRIZ is a theory and method to solve innovation problem. In this paper, the patents of the suction-tape feeding technology of printing press in the world were analyzed. To find the basic patent, core patents and epitaxial patents, we used the way of the patents excluding analysis. Then, the patents were graded in five levels. The suction-tape feeding technology maturity of printing press were predicted with the TMMS software which can predict the technology maturity of product based on patent analysis and the results were analyzed with the TRIZ conflict resolving theories, which could find innovative solutions. This method can make enterprises forecast the technical development of the product fast and accurately and realize the technical innovation of product. It would provide an important guideline for making strategic decision and trading technology.

Keywords: Suction-tape feeding technology, Technology maturity of product, Patent analysis, Conflict

1. Introduction

Famous press manufacturers, such as Roland, Heidelberg and Mitsubishi, are successively using the suction-tape feeding technology in the press, which have used the suction-tape feeding technology in the printing press successively. Chinese enterprises mostly take use of foreign technology to improve their product quality, they do not make breakthroughs in innovating the suction-tape feeding technology. Therefore, there is practically a significant meaning to formulate the new product development strategy and shorten the gap among the enterprises by analyzing the suction-tape feeding technology and the maturity.

2. Classification, analysis and excluding ways of patents

Any one technology patents could be divided into basic, core and epitaxial patents. They could be determined by the citation numbers and the citation relations among patents. The patent is founded on the basis of the cited patents, if it cites number of other patents. Its technology is

a improvement one, and already a maturity technology. The patent with the core value is the basis of the subsequent patents, if it is cited by number of other patents. Core patents generally could change the efficiency, perfect the function or cure the symptom, so that they can reduce the cost and increase profits. The technologies of epitaxial patents are often used in the other fields. The study found that, if a patent is cited 5 or more times, Kodak's experts classify it into a higher level. The relationship shows in figure 1 between the importance and index number.

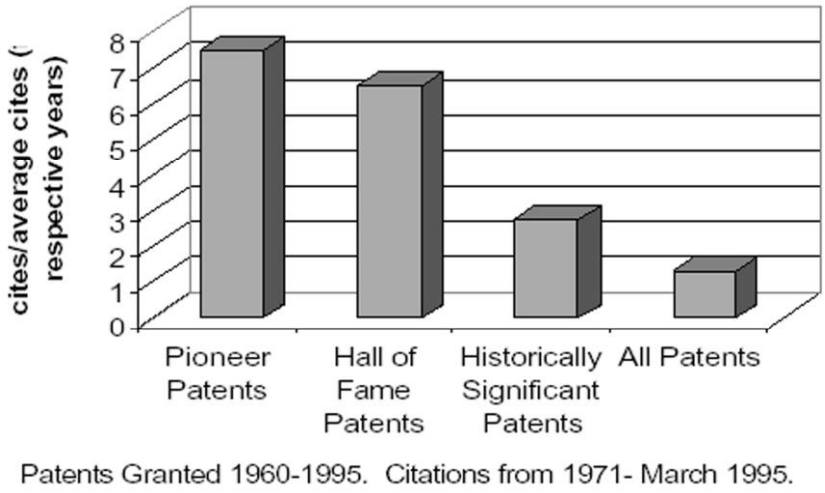

Fig. 1 Very high citation indices found for selected patents

3. Forecasting techniques and systems of maturity based on patent analysis

Norman's study pointed out that the product which meet the average demand of the customer on the product efficiency represent the technology maturity. In May 1966, Professor Vernon of Harvard University first proposed the theory of the life cycle, which is divided into introduction, growth, maturity and decline. The maturity of the product technology could be predicted by S-curve, or on the basis of analyzing the patents directly. Altshuller's mode was the study of the relationship among Efficiency, Level of Inventions, Number of Inventions and Profit to predict the maturity. Darrell Mann's model determined the maturity by the investigating two special patents, which are the patents of reducing cost and symptom curing, in the distribution of the S- curve. Aurigin's model mainly studied the relationship between the number of citations that is related to the maturity and the value of patent citation counts and the maturity of the product technology. On the basis of integrating the research fruits of Altshuller and Darrell Mann, Professor Zhang Huan-gao developed the technology maturity of product prediction software (TMMS).

The system of TMMS selected the number of patents (PN), level of patent (PL) and the number of symptom curing patents (SCP) as the indicators of the prediction model, which shows in fig 2, and refined the life cycle into pre-1st stage(pre-infancy), post-1st stage(postinfancy),

pre-2nd stage (pre-growing), pre-2ndstage (post-growing), pre-3rd stage(pre-maturity), post-3rd stage(post-maturity) and 4th stage (recession).

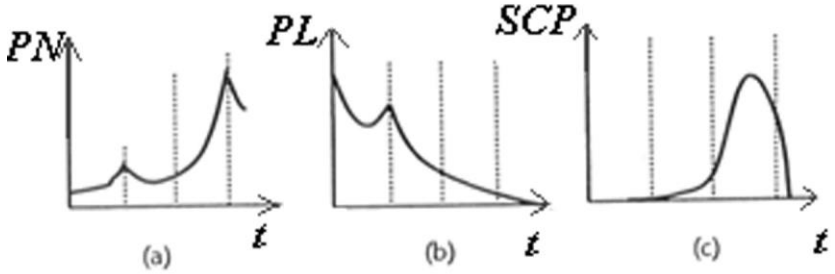

Fig.2 Curve of patent characteristic

Technology Maturity forecast of products is classified eight parts, which are searching patent data, filtering patent data, classifying and grading patent, patent summary statistics, generating the graph, forecasting the technology maturity, evaluating the prediction results，solving technical problems .

3.1 Maturity of suction-tape feeding technology of printing press

The suction-tape feeding technology of sheet-fed press is a new way of feeding. Feed table generally could be classified as ordinary type and suction-tape type. Suction-tape feeding equipment uses the negative pressure of the suction room to generate friction between the paper and suction tape, so the equipment could complete the transmission of the paper on the feed board, as figure 3 shows. The feed board leaves out the parts of the pressuring roller, so the structure has been simplified. This design improves the product efficiency. The study focuses on the structure-innovation of suction-tape feeding table.

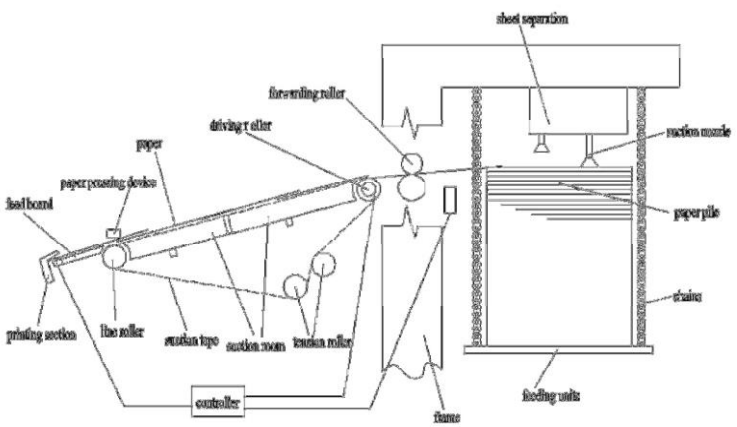

Fig.3 Sketch of Suction-tape feeding equipment

3.2 Maturity prediction of suction-tape feeding technology of printing press

In the analysis the patents of suction-tape feeding technology of printing press, we search the related patents of suction-tape feeding technology nearly 50 years, which are based on the patent database, which includes the US Patent and Trademark Office (USPTO), the European Patent Office (EPO), the Japan Patent Office (JPO) and State Intellectual Property Office of the P. R.C(SIPO). We use the key word 'suction-tape feeding technology of printing press' or 'vacuum paper feeding technology' have searched 468 patent primary data, containing 389 utility models and 79 inventions. Then, we filter and classify the patents which we have got, by two key technologies that have mentioned in above. In the further, we get the final data--213 patents by the way of excluding analysis.

The basic data is summarized, which is filtered the patents of suction-tape feeding technology. The results are shown in table 1. Then, we input the data to the system of TMMS, which is fitting the result by cubic curve. The results are shown in figure 4.

Tab.1 Summary of patent information of suction-tape feeding technology

Time	PN	APL	SCP	Time	PN	APL	SCP
1962-1972	2	2.15	0	1996	19	1.98	4
1976	4	2.00	0	1998	21	2.00	5
1980	6	1.90	2	2000	30	1.80	7
1984	8	1.95	13	2004	38	1.46	14
1988	13	1.97	6	2008	45	1.10	32
1992	15	1.93	5	2012	44	1.05	32

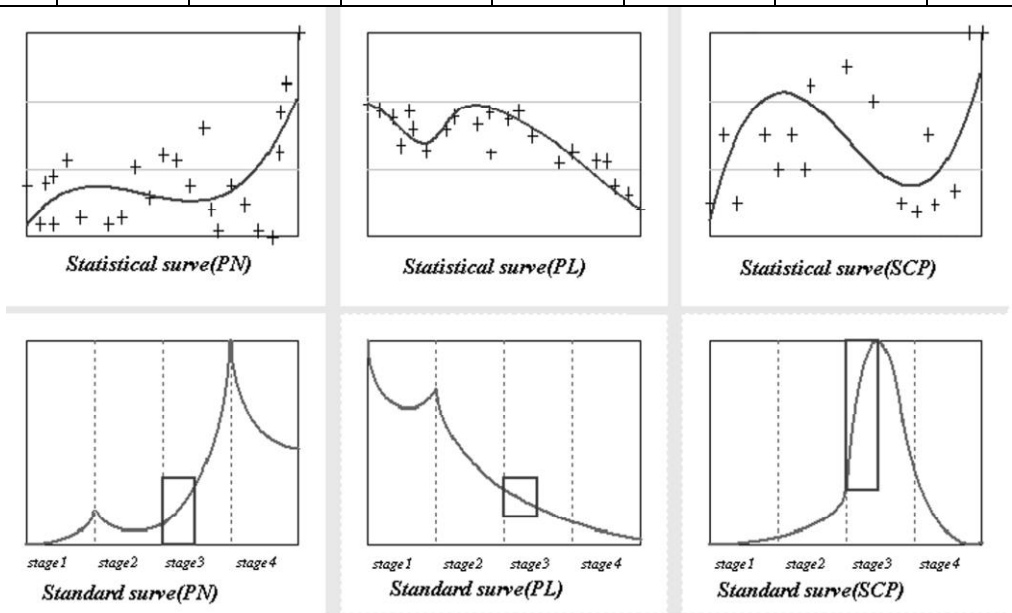

Fig.4 Map of mapping technology maturity of suction-tape feeding

3.3 Result of Maturity prediction

The result shows that, the efficiency of the product close to the limit, which is supported by the suction-tape feeding technology, the competition is fierce among the enterprises, the inventions are rapidly increasing, but the level of inventions is declining, the profit close to the maximum , and the product technology is in the early maturity (pre-3rd stage) .

The suction-tape feeding technology in the press have been developing many years, the product has the limited efficiency, maximum profit and a downward trend. The pace of product development begins to slow down and the product cost is nearly the least. Therefore, the prediction results are credible that these two key technologies of suction-tape feeding of the press are in the early maturity. The results could help the enterprises find the gap, improve their own technology targetedly, look for the innovation, and provide the information for the next strategy of the enterprises.

3.4 Technical conflicts and resolution

In the TRIZ (Theory of Invention Problem Solving) theory, the sign of the product innovation is to solve the design conflicts and arise from the new competitive solution. G.S.Altshuller classified conflicts into three categories, management conflict, physical conflict and technical conflicts. Technical conflict often appears in the machine design. Technical conflict always involves two basic parameters A and B, B becomes worse when A is improved. Through years of research, analysis and comparison, Altshuller put forward conflict matrix, which established correspondence between the 39 engineering parameters and 40 inventive principles. It could solve the problem of selecting the inventive principles in design.

As the air is the working medium in the suction-tape feeding technology, and the air could be compressed. The adsorption force of paper would be change, when the external conditions change. The feed board leaves out the parts of the pressuring rollers, the structure has been simplified. But the pull of paper changes in the process, and it often appears the paper skew condition. These could affect the feeder rate of the overall print. So the conflicts can be certain, the improved parameters are stability (13) and reliability (27), deterioration parameter is the complexity of the system (36). Searching the contradiction matrix, the corresponding principles can be found, the part of the conflict matrix shows in the table 2.

Tap.2 Contradiction matrix

Improved parameters	Deterioration parameters		
	35	36	37
	Adaptability, versatility	Complexity of the system	Complexity of control and measurement

13	Stability	35,30,34,2	2,35,22,26	35,22,39,23
14	Strength	15,3,32	2,13,25,28	27,3,15,40
……	……	……	……	……
26	Amount of substance	15,3,29	3,13,27,10	3,27,29,18
27	Reliability	13,35,8,24	13,35,1	27,40,28

By searching the matrix, the corresponding innovation principles are as follows: Segmentation (1), Separation (2), Do it in Reverse (13), Convert harm into benefit (22), Copying (26) and Parameter changes (35). Using the above principles could get a range of innovative solutions.

Scheme 1: using the Segmentation, the entire input cardboard is divides into two parts. Adjust the size of the two gas chamber volume, which can adjust the speed of two feeding tape to eliminate of the paper skew condition.

Scheme 2: the principle of Do it in Reverse. In order to eliminate of the paper skew condition, it is added to the mechanical differential in advance.

Scheme 3: using the principle of Parameter changes, the material of feed tape changes nylon fiber. And the holes of feed board are long round ones, the holes of feed tape are circular ones. Assume the radius of feed board hole is R, center distance is a, the radius of feed tape is r, the vertical distance of the feed tape hole center and the feed board hole center is D. Due to limited paper format, the result is only list. After designed, the result is R = 8mm, a = 59mm, r = 8mm, D = 0.5mm.

4. Summary

On the basis of analysis-ing the technology characteristics and patent applications of the suction feeding, we predict the key technology maturity of the suction-tape feeding of printing press, the results were analyzed with the TRIZ conflict resolving theories, which could find innovative solutions. This method can make enterprises forecast the technical development of the product fast and accurately and realize the technical innovation of product. It would provide an important guideline for making strategic decision and trading technology.

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The Collaboration Effects on New Product Development

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Abstract

Activities of new product development (NPD) in B to B and B to C collaborative context are involves more than one departments or companies. Although a software platform environment was usually designed for enables product designers to communicate and collaborate with each other across different operating systems and networks.

In this case study that an electrical communication technology company grown up with a national company to enhance their technology capability and create unique skills to create their performance during the financial crisis time. The case company developed several types new products, such as company's new product, product line extension, the improvement of existing products through licensing or joint venture to create new products and breakthrough innovation.

Some factors that are need, information, cooperation enterprise, and customer are used to construct the software platform in real NPD process. These factors format a real time system for making decisions. This study found the type of new product should adjust the factors of software platform to development products.

Keywords: Collaboration, New Product Development (NPD), Real Time Information

1. Introduction

The product life cycle is much short as the fast changing market. The enterprise must develop new products for enterprise value. The new product development process may say also is the information processing process, How to share information is important for the industrial cooperative. Porter (1985) proposed the concept of Value Chain, which linking enterprise, supplier and customer to create common value and obtains the competitive advantage. The value chain also benefit for reducing the uncertainty during new product development.

New product development not only happens inside value chain but also take care the collaboration within cooperation relationship. Schuh et al. (2006) emphasis collaboration at the highest level could be viewed as a framework to connect People, Processes and data (Information).

This integration cannot happen without the underlying Product Life cycle Management (PLM) framework since People, process and data is all centered on a product and the product lifecycle management involves interaction between people, process and information. Stark (2005) thought information technology (IT) is used to solve management issues, such as Computer Integrated Manufacturing (CIM). Ruekert and Walker (1987), Kahn and McMonough (1997) suggested that new product development is a process of information sharing, communication, plan meeting, document, to exchanges information between the relevant departments.

Products life cycle management (PLM) is the system can let enterprise to co figurate all resources to entire process. PLM also can let all products life cycle process to do real-time response of new products development mechanisms. Interactive relationship is important of PLM, as Figure 1. The all manufacturers of entire new products development process are can real-time received market needs message, and the development process through access and use the reference information for the different stages. The decision making of the policy as a partner in this process of knowledge sharing, message that needs constant attention throughout the process, real-time mechanism of supply chain integration, even after of customer's reaction feedback on the need to the demand side of the products development.

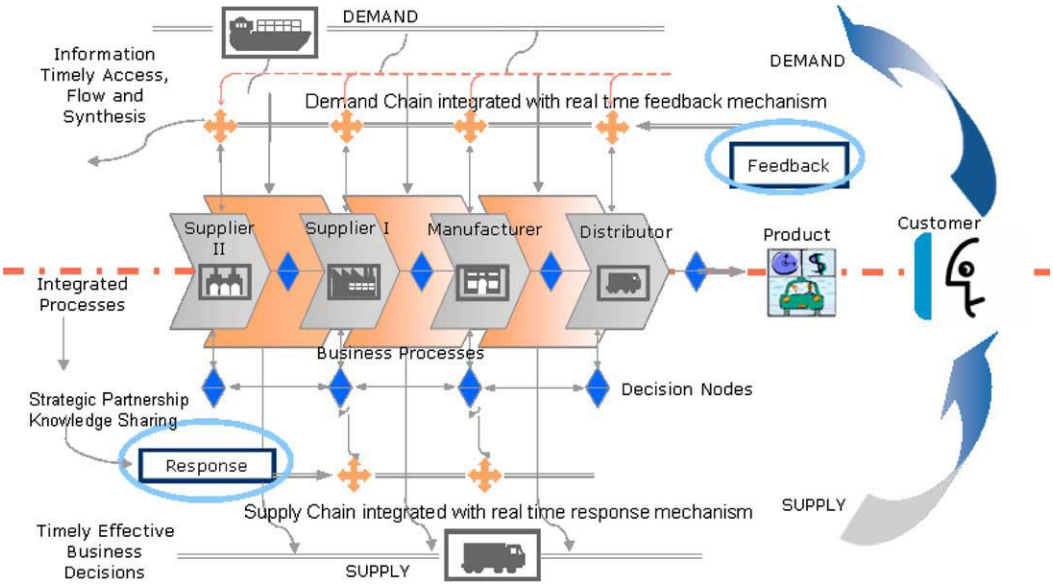

Fig. 1 Integrated PLM framework (Sharma, 2005).

The study expected to understand NPD collaboration based on the life cycle management framework (Product Lifecycle Management, PLM) by a local electronic communication company. The purposes as below:

1. How the NPD information sharing within the relationship of value chain?
2. What differences of new product development in the PLM framework?
3. For the different types of new product development, what are the important factors?

2. Methodology

This qualitative research is a single case study by in-depth interview. Yin (2001) mentions case study can be divided into "single" and "multi", the so-called "single case studies" refers to the entire course of study, is designed for an individual case to work on data collection and research. At the time of a single case study, there are three principles for reference that are critical case, unique case and revelatory case.

Single case studies are better than multiple case studies in contrast to the in-depth research, in the case on the collection of data, analysis and interviews. Creswell (1998) highlighted the single case study stress on depth. When for more case studies and depth of each case may be affected, so do not use multiple case-study research on depth approach.

Consider about the content of PLM is a depth study. This study selected a unique case for in-depth interview for collaborative cooperation on new products development. The characteristics of case are international market, new products, close and multiple cooperation and high-tech technology.

Case company is a electric communication company, the technologies are related to Blue Tooth,Wireless LAN.Mobile Phone Melody IC,USB Flash Disk Controller,CRT Monitor Controller,LCD Monitor Scaler,DSC,Audio Codec,Audio Processor,Optical Fiber Transceiver, DRAM,LCD Driver and so on.

This successful case, the turnover was continuously growing upper than 10% , working steady in financial crisis and a close partner with specific global company.

3. Discussion

To analyze this case accord to Fig 1 framework, firstly we defined new products to different innovation types. And case discussed by important dimensions which are demand side, Information, partners, customers, real-time supply chain and. decision points.

3.1 innovation types

Kuczmarski (1992) divided new product innovation types into the following seven categories: (1) new products introduce to market, (2) the company's new product, (3) product line extension, (4) the improvement of existing products, (5) to reduce production costs, (6) new product positioning, (7) through licensing or joint venture to create new products. And Schumann (1994), who proposed innovation activities will be organized in accordance with the essence of innovation and innovative

level are divided into six categories: (1) product innovation, (2) process innovation, (3) method innovation, (4) incremental innovation, (5) independence innovation, 6.breakthrough innovation.

There are five types of new products in this case. The comparisons between the case company and the NPD studies of Kuczmarski (1992) and Schumann (1994) are shows as table 1. It showed the case development new products include complete NPD types.

Table 1 The comparisons between the case company and the NPD studies

New products of this case	Studies of Kuczmarski（1992）& Schumann (1994)
TypeI existed products and stable customers	the company's new product, product line extension, the improvement of existing products
TypeΠ stable customers and developing product by contract with cooperation company	The company's new product, product line extension, the improvement of existing products through licensing or joint venture to create new products
Type III unstable customers and developing product by improvement of existing products to meet need	The company's new product, product line extension, the improvement of existing products, breakthrough innovation
Type IV customization products，R&D cost paid by customer	The company's new product, the improvement of existing products, the improvement of existing products through licensing or joint venture to create new products, breakthrough innovation
Type IX annual plan(TypeI& II)	The company's new product, product line extension,the improvement of existing products, the improvement of existing products through licensing or joint venture to create new products, breakthrough innovation

3.2 The collaboration effects

The collaboration effects were discussed individual as table 2. Sometimes, the cooperation company in the role of value chain could be more than one.

Table 2 The collaboration effects within value chain

Construction	Value chain	Content
Demand	Customer (Dealers & consumers)	● initiative problem solution suggestions ● The higher complexity, the higher relationship and technology capability

	Cooperation company (suppliers, dealers and manufacturers)	● Accumulating technology abilities to convince their customers by product development competence. ● Increase breakthrough technology ● To be a key suppliers ● Make long term and reliability relationship with upstream
Information	Settle faculty in the new market place	● Come from demand ● Built information filtering, pilot product (customization) to test markets for find new opportunities. ● Information from downstream demand
	Demand from customers	
	Cooperation company	● Find the match cooperation partner ● Visit laboratories, telephone communications, correspondence, communications, and provide component for cooperation partner testing for interaction ● See a niche market, then assessment development possibility from the cooperation company
Customer		● demand feedback and real-time mechanism for supply chain integration ● customer is the role of cooperation company ● not always believe customer idea ● create new demand if capacity is allowed ● introduce customers opinion to product design as soon as company can ● find complementary partner
Real-time supply chain	Feedback from national cooperation company	● cooperation company make Real-time market information to case company ● amount of Sales, and inventory
	Information integrate	● National faculty feedback the sales data and competition information
Make decision	Cooperation company (suppliers, dealers and manufacturers)	● rush order
	Information access and integrate	● Daily table meeting for make decision of any problem, especially cross-sector issues

Case company usually applies information technology to advance communication inside. Company products within the total types of research and development, all workers can always easily to make every stage results, process, all records in the cloud computing. R&D department would bring together all the technology shaping to the final outcome for market successfully. Products cases for security, confidential data and compensation mechanisms, taking into account, through the virtual mechanism, the internal network of the cloud computing platform, which is a private cloud computing

services, to meet the actual needs of the enterprise, such as: Server backup, and protection of intellectual property of the new product.

For case company, it is necessary to confirm the target customer groups and reaching company objects. Case company collects market information from downstream vendors to meet company's business model.

Besides, the commissioner of research and development usually is the company owner who makes the decision of NPD affairs by personal experience and knowledge. Marketing department provides correct and complete information, including customer's background. Product performance is not the issues in this study. Table 3 will give some idea for further study.

Table 3 New Product Performance

performence / value chain	Finance	Achievement	Customer	Product	Market
Supplier	v	v	v	v	v
R & D	v	v	v	v	v
Product	v	v	v	v	v
Customer	v	v	v	v	v
Real- time feedback	v	v	v	v	v
Real- time reaction	v	v	v	v	v

The collaboration dimensions are all related to performance as table 3. The performance variables include finance, achievement, customer and product Market. This case review NPD performance is concern the long-term strategy not by these variables

4. Conclusion

This study found that PLM is not only a information platform architecture. Companies must have quality technical ability to using the system. In particular, there are more internal communication channels for frequently and openly communication to reach real time interaction.

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Based on Quality Function Deployment Research Product Development

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Abstract

In the information age, the progress of science and technology accelerates the formation and development of economic integration, making market competition more and more intense worldwide. An enterprise no matter how its original basis is which wants to be long at an advantage must follow the same scale, namely the principle of user selection. Today the economic society is consumer leading, in which consumer demand is the key, and the ability of insight into market demand decides whether product development is successful. This paper studies the application of customer-focused quality function deployment in product development, introducing the KANO customer demand model, which discusses the product development process based on quality function deployment, and highlights the advanced management system which combines enhanced quality function deployment with concurrent engineering.

Keywords: Quality function deployment; Customer demand; Product development; Concurrent engineering.

基于质量功能配置的产品开发

1. 引言

随着信息时代的到来，科技进步加速了经济一体化的形成与发展，使得世界范围内市场竞争越来越激烈。一个企业想要长久处于优势地位，不论其原来的基础如何，都遵循着同一尺度，即用户选择的原则，洞悉市场需求的能力决定着产品开发的成败。美国工业会议对新产品开发失败的原因进行了分类，结果表明由于市场营销方面的原因导致产品开发失败的比例占 67%，也就是说，新产品开发失败，半数以上并非技术性方面的原因，而是由于开发的产品没有满足顾客的需求。而质量功能配置（Quality Function Deployment, QFD）就是以顾客为中心,将产品开发建立在满足顾客需求基础上，被认为是产品开发阶段进行质量保证的有效方法。1996 年，分别对美国和日本 400 家企业进行的一项 QFD 应用状况调查研究表明：31.5%的日本企业和 68.5%的美国企业在开发过程运用 QFD 方法(Hsiao S. W., 2002) 。

2. 质量功能配置理论

▪2.1 质量功能配置

质量功能配置最早起源于 20 世纪 60 年代的日本,1966 年三菱重工•神户造船所针对产品可靠性,提出了质量表的雏形。随后,福特汽车公司于 1985 年在美国率先采用 QFD 方法,使福特汽车公司的产品市场占有率得到改善(刘鸿恩,张列平, 2000)。20 世纪 80～90 年代,有关质量功能配置的研究相继展开；我国于 20 世纪 90 年代经一些专家、学者引入,现在正引起各界高度重视。

质量功能配置的核心思想是注重从开始的可行性分析研究到产品的生产都以市场顾客的需求、偏好和期望为驱动。通过定义“做什么”和“如何做”将关键的市场顾客的需求、偏好和期望通过一定的过程和方法转换成工程设计人员所能执行的各种工程指标，并逐步部署到产品设计开发、工艺设计、生产控制中去的一种方法,从而使产品具有令顾客满意的稳健性能(孔造杰,郝永敬,王云峰, 2001)。

▪2.2 顾客需求的 KANO 模型

如图 1 所示顾客需求的卡诺模型是由卡诺博士提出的，他将顾客需求分为三种类型:基本型需求、期望型需求和兴奋型需求。

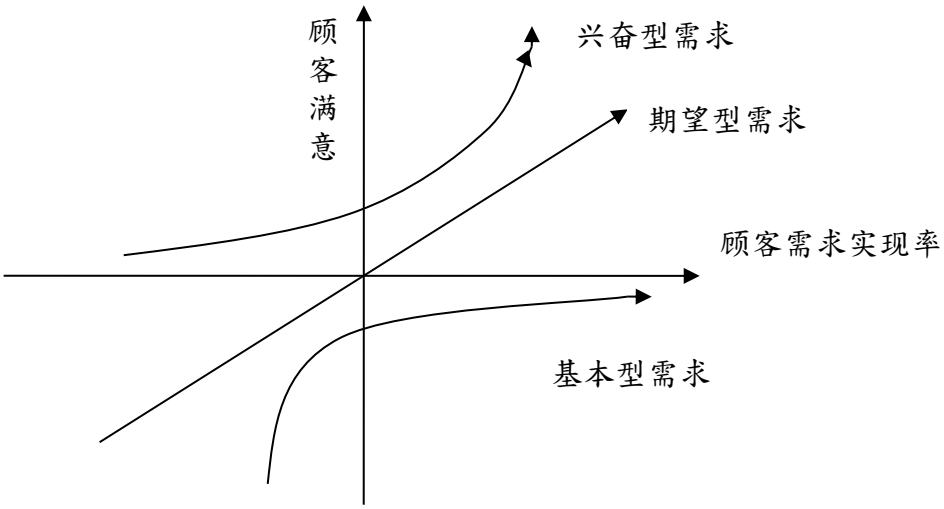

Figure 1. KANO model of customer demand

基本需求作为产品应具有的最基本的功能，如果没有得到满足顾客会相当不满意。相反，它的充分实现也不会来带来顾客满意水平的提高。期望需求是指顾客对产品或服务质量的具体要求，它的实现程度与顾客满意水平同步增长。当不能满足这些期望需求时，顾客就会不满意。兴奋需求是指令顾客意想不到的产品特征。如果产品没有提供这种特征，顾客不会不满意，顾客使用一段时间后发现这个特征会非常满意。随着时间的推移，兴奋需求会向期望需求和基本需求转变(龚益鸣, 2007)。卡诺理论对于企业的新产品开发和质量改进工作有十分重要的启发意义，在激烈的竞争中，企业应该想方设法开发自己的产品兴奋型需求，并确保落实期望需求和基本需求。

3. 基于 QFD 的产品开发

是否能及时地获取顾客需求，以及获得的顾客的需求是否是全面、真实,是成功应用实施 QFD 的基础. 一般的产品开发过程包括规划阶段、零部件阶段、工艺设计阶段和生产阶段。在应用 QFD 方法时要先建立各阶段的质量屋, 再针对已提取整理的顾客需求进行需求变换, 最后形成明确的生产要求, 从而完成产品开发的质量功能配置的全过程。应用质量屋开发产品的流程如图 2 所示。从顾客需求开始，经过四个阶段得出产品的工艺和质量控制参数。第一阶段的质量屋也是狭义的质量屋,是最完整的质量屋，其它阶段的质量屋都是广义的质量屋。并不是所有的质量功能展开都需要完整的四个阶段(蔺麦田,曹岩, 2008)，可以根据具体的情况剪裁或者扩充。

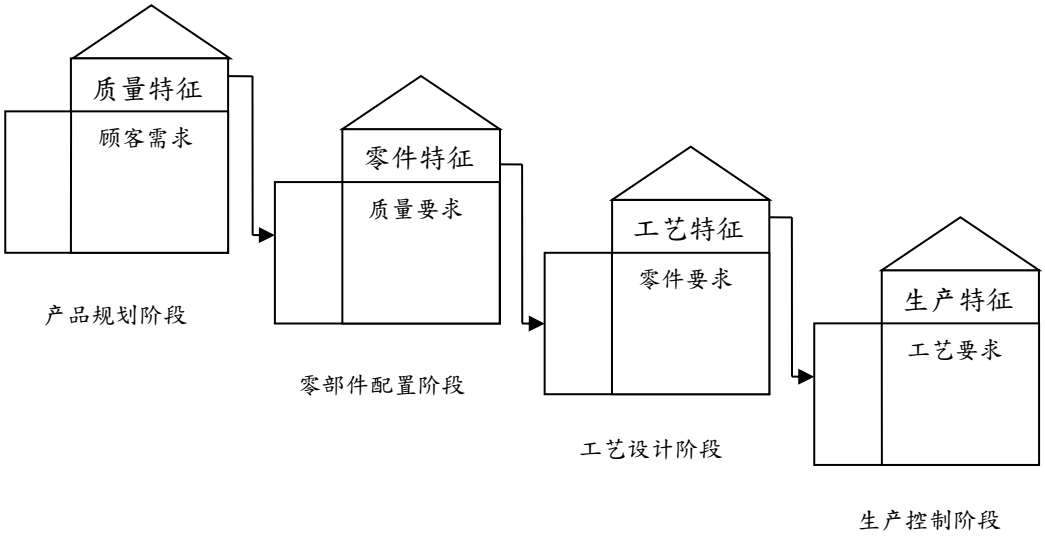

Figure 2. Four stages of quality function deployment

(1) 规划阶段质量屋

该质量屋是从顾客需求向关键产品特征的配置过程，即产品规划决策过程，因此，这个质量屋的配置质量是最为重要的。评价该质量屋有两个关键矩阵，一个是位于房间的关系矩阵，另一个是位于屋顶的相关矩阵。质量屋的屋顶,在数学上是一个三角形矩阵，它表示的是工程特征之间的相关关系。对相关程度一般分为强相关、一般相关和弱相关几种关系，并给以标度值来表达相关程度。据此可以对工程特征进行分析研究，发现各种工程特征之间可能存在的矛盾,由此重新进行设计，避免矛盾的产生。

此外，在规划阶段还有反映市场顾客对产品的各种需求的一个若干行一列的列阵、用来描述对应于市场顾客需求的工程特征要求的一个一行若干列的行矩阵、表示要开发的产品针对各项市场顾客需求的竞争能力估价值的产品可行性评价矩阵以及产品规划阶段的技术和成本评估矩阵。

(2) 零部件阶段质量屋

零部件设计阶段的质量屋的最终输出是能保证实现工程特征要求的零部件特征要求。

(3) 工艺设计阶段质量屋

工艺设计阶段质量屋的输入是零部件特征要求，输出是制造工艺特征要求。通过这一过程完成产品的零部件设计要求向工艺流程设计的转换。

(4) 生产阶段质量屋

工艺规划阶段质量屋的输出是制造工艺特征要求。为满足这些要求，要有生产计划安排以形成明确的生产要求。对应地建立 QFD 的生产计划阶段的质量屋。此阶段质量屋的输入是产品的制造工艺特征要求，为实现制造工艺特征要求则要有明确的生产计划安排，在生产计划安排中包含诸多的生产要求。按这些要求就可以去组织产品的具体生产了。生产计划阶段质量屋的输出就是生产要求信息。

4. CE 与 QFD 集成管理体系框架

随着科技和计算机技术的迅速发展，企业开发的产品越来越复杂，通信障碍增加，各部分的信息共享成为瓶颈，致使开发周期延长，产品质量下降，为了克服这些障碍需要由计算机工具/环境支持 CE 与 QFD 的集成。CE 与 QFD 的集成，需要建立一个支持产品开发中设计、管理、制造、信息沟通等活动的，由人、过程、工具组成的完整的、一体化的系统框架，可分为三层：信息层、过程层、人员层，如图 3 所示。

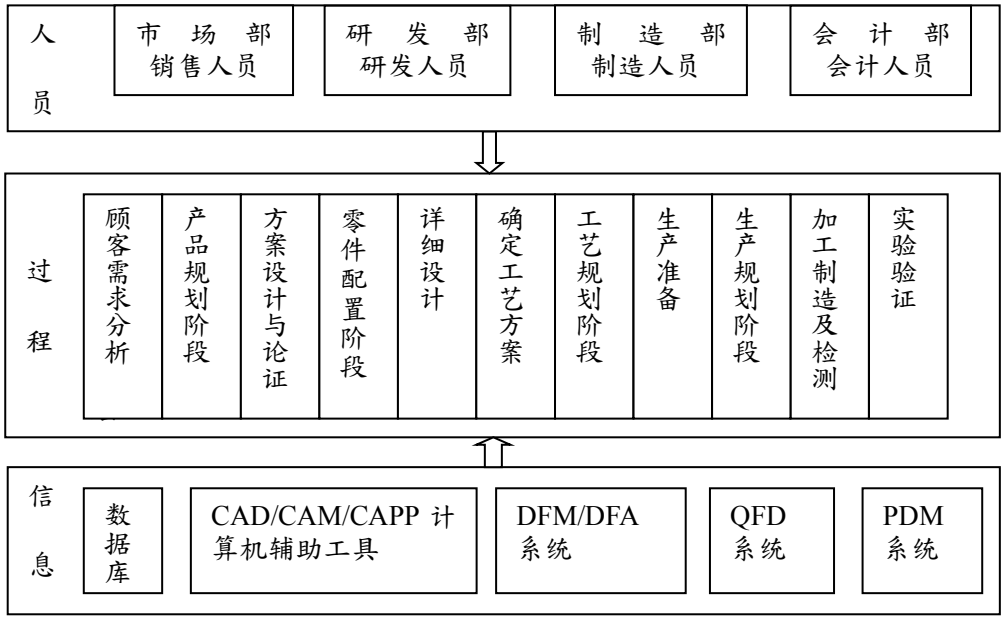

Figure 3. Integrated management system framework of CE and QFD

基于 CE 与 QFD 的信息集成，使所有的信息组织和资源管理都是围绕产品展开。协调组织整个产品生命周期的过程事件；使得分布在企业不同地方、各个应用程序中运行的所有产品数据得以高度集成、协调、共享，所有产品研发过程得以高度优化或重组. 集成产品开发团队采用矩阵试的组织结构，增强了专业横向联系，消除不同部门不同专业的壁垒和隔阂。集成 CE 与 QFD 的优势，有效降低产品的开发周期并提高产品开发的质量与竞争力。

5. 结论

本文进一步研究了产品开发过程中质量功能配置的运用问题，并突出研究并行工程和质量功能配置的集成体系。将创新概念的选择体现在把顾客需求转换为技术要求的过程中，强调创新概念在产品研究和开发中的重要作用。当今市场竞争激烈，企业的竞争将会逐步渗透到供应链之间的竞争，将顾客的要求通过拓展的质量屋转换为产品设计、流程设计和供应链设计，来缩短新产品设计到产品上市的时间，同时在质量上来满足顾客个性化的要求，这将会是企业赢得胜利的重要途径之一。

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Paper ID: 44

TRIZ-Based Solution to Social Conflicts: Early-Warning Model and Solution Mechanism

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Abstract:

This study was to put forward an early-warning model and a mechanism for resolution of social conflicts based on TRIZ theory that is a useful tool to solve conflicts in technological fields. In the early-warning model, there are 5 indices in the first level, and total 12 sub-indices in the second level. Social conflicts are classified into 3 grades: mild, serious, and critical, according to available international standards and the social and economic situations in China. A comparison between social and technological conflicts indicates that they have some common characteristics. Therefore it is natural that TRIZ theory could also be a useful tool for resolution of social conflicts. The resolution strategies for technological conflicts in TRIZ, such as ideal final result, resource analysis, function analysis, trimming, root cause analysis, another dimension principle and so on, could be used to solve social conflicts; and the 4 separation principles for solving physical conflicts could also be an effective mechanism for resolution of social conflicts.

Keywords: social conflicts; early-warning; conflict resolution; TRIZ theory

基于 TRIZ 理论的社会冲突预警模型与解决机制

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[摘 要] 本研究的目的是提出基于技术创新领域的有效工具——TRIZ 的社会冲突的预警模型和解决机制。在预警模型中，参考国际标准和中国经济社会情况，把社会冲突分为轻微、较重、严重三个警示等级。对社会领域和技术领域的冲突的比较显示，它们有一些共同的特点。因此，TRIZ 理论中的一些方法也可以作为解决社会冲突的工具。TRIZ 理论中解决技术性冲突的策略，如最终理想解、资源利用、功能分析、功能裁剪、根原因分析和维度变换原理等，也可用于解决社会冲突；TRIZ 理论中解决技术性冲突的四大分离原理可成为社会冲突的解决机制。

[关键词] 社会冲突 冲突预警 冲突解决 TRIZ 理论

1 导论

1.1 社会冲突：概念基础与发生机理

冲突研究本身是一个从社会学、政治学到经济学、人类学、心理学的跨学科的研究领域。社会冲突的各种定义可以帮助我们清楚界定研究对象和范围，以便我们深入分析社会冲突发生、发展的机理、类型，分析如何对社会冲突进行预警和提出有效的解决机制。

社会冲突（social conflict）伴随整个人类历史发展过程。人与人，群体与群体，民族与民族，乃至国家与国家都为了争夺各种资源而不断发生冲突。研究者提出了各种社会冲突定义来概括这些冲突现象。

最被广泛认同的定义是社会冲突理论的主要代表人物科塞提出的，他认为社会冲突："是对价值、对稀有地位的要求、权力和资源的斗争，在这种斗争中，对立双方的目的是要破坏以至伤害对方"（科塞，1989）。社会冲突理论的另外一个代表人物达伦多夫提出，社会冲突指："有明显抵触的社会力量之间的争夺、竞争、争执和紧张状态"（达仁道夫，2000）。

社会冲突按照冲突的主体进行分类可以分为人际（interpersonal）冲突、群体（group）冲突、组织（organization）冲突、社区（community）冲突、乃至于地区和国家之间的冲突（Oberschall，1978）。

按照冲突的本身属性进行分类，可以分为阶级（class）冲突、种族（racial）冲突、宗教（religious）冲突等等。各种属性的冲突其产生的根源在于所体现社会属性的差异性和分化，不同的阶级、不同的种族（民族）、不同的宗教之间因为种种的差异，从而产生利益和思想、

价值观之间的冲突。

按照冲突的形式进行分类，可以分为合法的、制度化的行为，如罢工和社会失序（strikes and civil disorders），游行（marches），示威（demonstrations），抗议集会（protest gatherings）等。与此对应的是不合法的、非制度化的行为，如骚乱（riots），造反（rebellions），革命（revolutions）（Oberschall，1978）。当然，还可以按照不同的理论视角、制度文化背景将各种冲突现象做更多的划分，如群体内冲突和群体外冲突，经济冲突、政治冲突和文化冲突等等。

社会冲突的根源是什么？20 世纪 50 年代开始，两位德裔美国社会学家科塞和达伦多夫提出了现代社会冲突理论（Coser，1956；Dahrendorf，1958、1959）。以便对社会冲突的发生机理进行解释。此后，社会学中的冲突理论（Conflict Theory）对各种社会冲突的相关研究产生了较大的影响，成为社会学中与功能理论分庭抗礼的两大理论流派之一。

尽管科塞和达伦多夫建立了现代社会学冲突范式，但其理论的思想渊源一方面可以上溯到 19 世纪德国的三位重要社会学思想家：马克思、齐美尔和韦伯。另外一方面，现代冲突理论产生的原因是对功能理论的批评。二战以后占据西方社会学统治地位的帕森斯社会学功能理论认为，社会系统的整合功能在社会系统中发挥了重要作用，冲突是一种病态的社会现象。功能理论的解释掩盖了社会中的冲突，对很多社会问题缺乏解释力。因此受到了很多批评。

科塞的冲突理论最重要是贡献是区分了冲突的反功能和正功能（科塞，1989）。反功能是不言而喻的，冲突本身带来的负面后果人所皆知。科塞认为，冲突是一个社会中重要的平衡机制。因此冲突具有“社会安全阀”这种“正功能”。好比锅炉上的安全阀一样。通过常规的低度冲突可以使社会的怨恨、不满情绪得到缓解，从而不至于破坏整个社会结构（Coser，1956）。

达伦多夫对冲突发生机理的解释则从社会结构的角度人手。他认为在任何社会中都存在“强制协调体”（Imperative coordinated Association）这种强制性权威结构。由于任何人都永远居于一种受支配、受统治的压迫地位，因而对立的两种角色之间必然会为自己的利益或维持或争夺权威结构中的支配权，社会冲突就将出现（达仁道夫，2000）。

基于这种前提，他提出了用来分析冲突的“冲突强度”(The Intensity of Conflict)和“冲突烈度”(The Violence of Conflict)两个重要概念。前者是指“冲突各方的力量消耗及其卷人冲突的程度”；后者是指“冲突各方在追求其利益时所使用的手段。”达伦多夫进一步提出了影响冲突强度与烈度的 4 个相关变量。包括：“相对剥夺”变量、“社会角色分化程度”变量、“社会流

动”变量和“自组织化程度”变量（Dahrendorf，1959：212-240）。这些变量为进一步利用实证数据对具体的冲突进行测量和预警提供了途径。

科塞和达伦多夫之后，最有影响力的社会冲突论者是柯林斯，他认为必须建立一门以冲突为主题的社会学。社会结构是社会行动者的互动模式（互动仪式链），是在行动者不断地创造和再创造中产生并得以持续的。科林斯力图为宏观社会学奠定微观冲突基础（Collins，1975）。遗憾的是，科林斯之后，社会学冲突理论本身陷入了停滞状态，没有再产生具有整个学科影响力的研究。

1.2 问题的提出：社会冲突的预警与解决机制

社会冲突是普遍存在的社会现象，在中国有规模扩大、数量激增、方式多元以及从利益相关冲突到利益不相关冲突演进的趋势；美国社会冲突表现出体制化、组织化、显性化和领域化的特点。在现实中，冲突的预警与解决机制仍然是困惑人们的问题，主要是一套集信息采集、传递、处理、反馈为一体的完整的科学有效的预警管理机制尚未最终形成；冲突的解决没有超出政府与社会层面的政策与组织调整，冲突解决方式比较单一。

冲突预警可以界定为“及时提供相关信息以便对潜在的冲突发出警报”（Rupesinghe and Kuroda，1992）。定性研究往往采用案例分析法（case study），参与观察等人类学方法，分析具体社会文化背景下，冲突发生、发展和结束的过程，为冲突以及潜在冲突的发生发展提供一种深入的解释。

定量研究则通过调查数据和统计数据发现一些关键的统计变量和指标，如人口、阶层、教育程度等对于冲突发生的影响，为社会冲突的发生提供一种普遍解释（Weidmann and Ward，2010；Humphreys，2005）。而且定量研究越来越重视如幸福感、信任、认同感等对于冲突发生的预警，避免了单纯利用客观指标，尤其是经济指标的局限性（Brecke，1998）。

中国学者也对社会冲突预警问题进行了研究。王二平（2006）提出社会预警系统是指长期追踪公众社会态度变化的调查。通过了解公众的生活和职业满意感，对各级政府和基层干部工作的满意度，对社会问题的判断，以及应对社会问题的行为意向来对冲突预警，同时，也有学者提出了一系列的冲突预警指标，这些指标涉及经济、社会、政治、价值观等多个维度（邓伟志，2003）。

除此之外，还有学者利用博弈论（game theory）、图论（graph theory）等数理分析方法（Acemoglu，2003；Fang etal，1993；Schelling，1963）、模拟仿真（stimulation）方法（Hammond and Axelrod，2006）、实验（experiment）等手段进行冲突预警和解决方案的研究。

但是，关于冲突预警和解决机制的研究也存在一些有待解决的问题。首先是预警所需要

的数据其及时性、动态性和全面性往往难以得到保障（Harff and Gurr，1998）。一方面是微观数据的缺失，另外一方面是数据拥有部门对于数据使用和获得的限制，因此预警本身的时效性和针对性就存在一定的障碍。

对于冲突的解决机制来说，博弈论和其他方法如实验提供的方案，如第三方介入（Third party mediation）等（Fisher，1983），由于其要么产生于纯粹的数理推导，有较强的研究前提条件假设，要么产生于高度控制的环境下，因此很难应用于真实的社会环境中。

社会冲突的产生和发展是非常复杂的，受到很多因素的影响。而且许多冲突解决技术和方法受到社会科学概念的局限，其概念的精确性和标准化程度往往较自然科学和工程技术领域低，这些都将影响相应解决手段的有效性和可行性。如何建立一套具有普遍适用性的冲突预警和解决机制成为一个迫切需要解决的问题。

在本文中，我们将引入一些在工程实践领域得到证明行之有效的方法和思路如 TRIZ 等来解决日益严重的社会冲突，为社会冲突解决机制提供一种崭新的方法论支持。虽然社会冲突和 TRIZ 理论中的技术冲突有一定的差异性，但是这种差异性本身并不能掩盖冲突（conflict）在本质上的共同性。因此可以建立社会冲突与技术领域冲突之间的一种对应机制，为进一步提出具体的、基于 TRIZ 理论的社会冲突解决技术方案奠定理论基础。

必须提出的是，任何对于冲突的预警机制和解决方法的研究，都必须考虑到具体的文化和制度背景。例如中国社会中各种冲突的具体形式、发生机制、发展模式和社会后果都与西方有着显著的差异（Cai，2008；Read and Michelson，2008；Yu，2007）。在这种情况下，任何冲突预警和解决机制都必须具有跨文化的稳健性。我们相信，基于 TRIZ 理论和方法基础上的冲突解决机制，有助于我们探索社会冲突最核心的本质属性，为社会冲突的解决提供一种崭新的、具有极大学术和现实潜力的思维方式。

2 社会冲突预警

2.1 文献回顾

20 世纪 60 年代，美国、日本、法国等国家就建立了经济层面的警报指标，以监测经济运行。如美国的“富兰德指数”、“景气动向指数”与“痛苦指数”。埃.蒂里阿基提出了测定社会动荡发生的三大经验指标（1961）；艾茨和莫根则主张从 6 个方面来估量社会的稳定程度（1976）；理查德. 艾茨确定了社会不稳定性六项指标（1984）；西方七国于 1986 年建立的“经济指标相互监测”指标体系等。经济发展过程中的全球性风险、现代社会政治风险和军事风险的日益加剧等现实问题，都促使各国加快建立综合性的社会预警机制。

20 世纪 80 年代以来，随着中国社会转型的加剧和国外社会指标研究的导入，国内有关

社会冲突预警方面的研究逐步展开；我国社会学者朱庆芳设计的计量社会发展协调程度的“社会发展综合评价指标体系”（1990）；王地宁和唐均设计的计量社会发展水平的“社会发展指标体系”（1991）；宋林飞设计的计量社会风险的“社会风险指标体系”（1995），“中国社会风险预警系统”（1999）等。

在社会预警指标体系的建立方面，具有影响力的较早的代表作是美国社会学家 R•A 鲍尔于 20 世纪 60 年代中期出版的《社会指标》一书，该书采用实证方法详细构建了社会预警指标，提出了运用科学方法建立指标的理念。此后，西方国家兴起一股“社会指标运动”，例如美国“哈佛景气动向指数”，美国外资政策研究所制定的“政治监测指标”，七国首脑联合建立的“经济监测指标”等。中国近年来，由于社会不稳定性增大，社会预警指标的研究开始引起重视。其中取得较大影响力的研究包括 1988 年中国社会科学院社会学所的社会指标预警课题组提出的社会安全与风险指标体系，涵盖经济指标、生活质量指标、社会问题指标、主观指标等四大类，40 多个具体指标。宋林飞从 1989 开始构建了“社会监测与报警指标体系”，在 2000 年确定将收入稳定性、贫富分化、失业、通货膨胀、腐败、社会治安、突发事件等 7 大类 40 多个指标纳入该体系。此外，2002 年仇立平创建了 “社会稳定指标体系”，由 17 方面 70 多个具体指标构成。2004 年，阎耀军（2005）提出社会稳定模型，建立了一个涵盖 6 大类共计 55 个指标的预警系统。刘旭东（2011）提出需要对其中敏感性较大的，对社会安全和稳定起直接作用的少数指标进行重点把握，以便及早发现问题，并指出其中 9 项指标具有这种特征，包括社会贫富差距、失业率、犯罪率、腐败案件发案率、通货膨胀率、贫困线以下人口率、公共安全事件发生率、群众上访率、最低保障覆盖率。

刘旭东（2011）认为这 9 大指标不仅能够反映出社会深层次存在的突出矛盾和问题，而且对社会的安全和稳定具有重大的直接影响，掌握了这 9 项指标的变动情况， 就可以基本察觉所面临的社会安全和风险的危机程度，从而为社会风险控制和治理赢得时间。将上述 9 项指标与我国现实情况对照，发现我国社会已经进入高风险频发期。

这些指标体系，大部分涵盖全面，内容广泛、监测细微，力求对社会做完整性、详细性的预警，但不免存在一个问题，即所列条目很多，过于繁杂，不便于常规性、抽样性的社会监测，也不利于及早发现问题（刘旭东，2011））。同时，这些指标囊括了宏观层面的社会预警因素，而对社会冲突预警的集中度不够。

2.2 预警指标体系的构建原则与权重确定

（1）可测性原则：需要选择在实际操作中能够进行量化处理的指标。

（2）可靠性原则：具备可靠性与灵敏性的指标是指在社会风险即将或刚发生时，能表

现这种变动的征兆或特征（宋林飞，1995）。

（3）充分性原则：所选择的指标需要能够完备地反映随时随地可能发生于整个社会系统的特殊社会现象和复杂结构系统。本研究的指标体系也符合这一原则。

（4）最小性原则：社会冲突具有多种多样的形成因素与外在形式，反映社会冲突的指标相应也是多样化的，但入选指标必须减少到最小限额。

（5）一致性原则：该原则是评价总指标体系的具体分解和体现情况。每个指标应从一定的侧面、一定角度反映评价目标，与评价目标紧密相关、同时指标总体对目标应具有足够的覆盖面，即能够与社会冲突预警这个总体目标保持高度的一致性（洪颖和李培，2002）。

社会冲突预警指标的权重由专家评估法确定。对照指标选择的五个原则， 组织专家逐一对指标进行评分，然后对若干专家的评分结果用平均法进行综合，并按综合得分值将指标从大到小排序赋百分比值。计算每一指标权重得分的公式如下：设所有指标累计权重分数为100%，在此基础上根据其可测性、可靠性、充分性、最小性、一致性的要求，分别为每个指标的权重评分。之后，使用加权平均法计算每一指标的权重得分值，就获得本研究表 1 中所示的最后权重分布。

2.3 社会冲突预警指标体系

2.3.1 指标体系的形成

本研究设计了包括 5 大类 12 项指标在内的社会冲突预警指标体系，如表 1 所示。这 12 项指标吸收了宋林飞（2000）和刘旭东（2011）的研究成果，保留了他们提出的大部分指标，并对这些指标重新归类，例如可支配收入和通货膨胀率归为经济发展指标；把宋林飞（2000）提出的贫富分化和刘旭东（2011）提出的失业率整合为财富分配大类；对社会贫富差距与贫富分化两个相同的概念进行了合并，把贫困线以下人口率简称为贫困人口率，与最低保障覆盖率合并归为社会保障大类指标；对公共安全事件发生率与突发事件这两个类似的概念只取前者，把犯罪率、公共安全事件发生率、群众上访率这三个显著反应社会风险的指标归为风险控制大类；此外，本研究构建了社会心理这一新概念，包括腐败案件发案率、政府信任和满意指数、社会公正和发展信心。采纳政府信任和满意指数、社会公正和发展信心这两个新的指标，一方面是由于这两个指标都可以通过社会调研的方式获得，另一方面人们一切行动的产生都是心理主导先行的，这两个指标用于反应民众对政府心理层面的信任和信心，能够更敏感地提前预知人们的行为，对社会冲突预警指标体系具有重要价值。

表 1　社会冲突预警指标体系

社会冲突领域	预警指标	指标说明
1.经济发展（权重 15%）	1.1 可支配收入（60%）	直接反应社会在经济基础方面的运行和居民生活水平。可支配收入越高，通货膨胀率越低，社会产生冲突的可能性越小。
	1.2 通货膨胀率（40%）	
2.财富分配（权重 30%）	2.1 失业率（40%）	分配问题是社会运行中最为敏感和棘手的问题，社会分配结构越不合理，产生社会冲突的可能性越大。
	2.2 贫富分化率（60%）	
3.社会保障（权重 25%）	3.1 贫困人口率（50%）	反应生活居民的经济保障水平，贫困人口越低，最低保障覆盖率越高，社会冲突越少。
	3.2 最低保障覆盖率（50%）	
4.风险控制（权重 20%）	4.1 社会治安犯罪率（35%）	反应社会稳态运行的调控机制和能力，风险控制越好，社会冲突越容易得到解决。
	4.2 公共安全事件发生率（40%）	
	4.3 群众上访率（25%）	
5.社会心理（权重 10%）	5.1 腐败案件发案率（40%）	反应社会稳定运行的政府健康运行程度和社会心理状况。积极平和的社会心理意味着社会冲突发生的可能性低，反之，大规模社会冲突爆发的可能性增大。
	5.2 政府信任和满意指数（30%）	
	5.3 社会公正和发展信心（30%）	

*指标根据文献资料整理，权重由专家评估法确定。

2.3.2 指标体系的诠释

（1）经济发展包括居民可支配收入和通货膨胀率两个指标，详细说明如下：

①居民可支配收入（NDI）是衡量一个国家最终所得收入的总量指标，GDP 代表的是生产总量；NDI 代表的是收入总量。生产总量并不等于收入总量，通常情况下发达国家的 NDI 往往大于 GDP，而发展中国家 NDI 往往小于 GDP，这反映了生产和收入之间的分配关系。

②通货膨胀率；通货膨胀（CPI）指物价水平出现持续性的上升和货币因超量发行导致贬值。通货膨胀的变化对宏观经济运行有着重要的影响，因此成为衡量经济稳定性和健康状况的重要指标。国际上对通货膨胀的测量分为三个区间，0.3～0.5 为安全区域，称为绿灯区；0.5～0.9 为温和通涨，为黄灯区；0.9 以上为严重通涨，为红灯区。这样，通货膨胀的警戒线有两个参考值，低度警戒线（0.5）与高度警戒线（0.9）。

（2）财富分配包括失业率和贫富分化率两个指标。

①失业率：失业问题也是对社会安全和稳定有重大威胁的因素，因此成为世界各国密切

关注的预警指标。失业率警戒线的说法不一。最初确定失业率警戒线的是美国经济学家萨缪尔森，他根据菲利普斯曲线确定的失业率警戒线为 5.5%。萨缪尔森认为 5.5%的失业率是社会所能承受的合理失业率。

②贫富分化率：贫富分化率反映了社会两极分化程度，是对社会稳定和安全影响最大的因素， 因此在国际上这一指标是社会冲突预警最重要的参考指标。衡量贫富差距的指标有多种，主要和常用的是吉尼系数以及最高收入层与最低收入层的财富比。吉尼系数的合理浮动范围在 0.25～0.4 之间，0.4 为国际警戒线。0.4 以上，说明社会贫富差距过分拉大，贫困层的承受力已接近极限，社会稳定将受到较大影响。

（3）社会保障可以用贫困人口率和最低保障覆盖率两个指标来显示。

①贫困人口率：贫困线以下人口数反映的是社会贫困范围的大小。贫困人数越多，说明社会存在的不稳定因素越多，安全问题越严重。贫困线以下居民数指标的警戒线是 10%。即贫困线以下的居民数不应当超过总人口的 10%。

②最低保障覆盖率：社会保障是预防社会风险、降低风险损失、缓解风险危机的重要制度安排。在市场条件下，由于竞争加剧、市场失灵和天灾人祸，使一部分人经常陷入生存危机，同时也给社会带来不稳定因素。通过社会保障的救助和保险，使风险得到释放，个人和社会都可以获得安全保护。如果要保障社会的基本稳定，最低社会保障覆盖率的警戒线是覆盖 70%人口。

（4）风险控制为社会治安犯罪率、公共安全事件发生率和群众上访率三个指标，分别说明如下：

①社会治安犯罪率：犯罪现象的产生不仅是社会问题的原因，也是社会问题的结果。一般来说，社会存在着较大的内在矛盾，如贫困、腐败、法律不健全、两极分化，等等，都会通过高犯罪率表现出来，同时，高犯罪率反过来又破坏社会秩序和稳定。所以，犯罪率的高低能直接预警社会安全情况。关于犯罪率的警戒线，有两种衡量方法，其一是以国际平均犯罪率为参考，从可以查到的资料看，2000 年世界平均犯罪率为 3000 起/10 万人。

②公共安全事件发生率：公共安全是指在社会生活中，突发的、严重危及社会安全秩序，给社会造成较大损失和恶劣影响的事件，如生产、交通、食品、药品、医疗等安全事故、环境污染问题、社会治安、重大疫情爆发等。公共安全事件频发反映出社会公共领域中存在诸多隐患，对社会安全构成重大威胁。

按着国际惯例，警戒线可以比照事件发生的平均数作参考。十几年来，我国平均每年发生各类事故 100 万起，死亡 13 万多人，伤残 70 多万人，经济损失达 2500 亿元。

③群众上访率：群众上访包括两种形式，信函上访和人员上访，也称来信来访。近 10 年这是我国社会转型加速、问题较多、矛盾不断激化的 10 年，也是各方学者对社会现实问题关注较多的时期，这说明群众反映的问题和学者关注的问题都达到一种临界高度，以总人口与 2003 年的群众上访数量之比测算，达到 110（件次）/万人，我们可以设定警戒线为 100（件次）/万人。

（5）社会心理由腐败案件发案率、政府信任和满意指数、社会公正和信心构成。

①腐败案件发案率：腐败主要指国家公职人员循私舞弊、贪污腐化、以权谋私行为。腐败案件发案率警戒线国际上通常以每万公务员中腐败人数 100 作为参照，即 100/万人。

②政府信任和满意指数、社会公正和信心：虽然政府信任和满意以及社会公正和信心是社会冲突监测的重要指标，但是，从现有的资料中还未发现其警戒线参考值，这可能与政府与社会的心理评估涉及面广，难以汇总有关。

社会冲突预警指标体系具有重要的监测功能，主要体现在社会冲突预警指标体系能够对有关的社会冲突问题进行评估，通过指标分析能够及时有效地监测社会冲突问题的发展现状，进而采取有效地措施预防社会冲突的发生。

2.3.3 指标体系的应用

本研究的冲突预警体系中五个大类所占的权重分别为 15%、30%、25%、20%、10%，具体指标的权重在表 1 中都有标注。运用如下社会冲突风险计算公式：

$$SC=\sum I_nW_n=I_1*W_1+I_2*W_2+\ldots\ldots+I_{12}W_{12} \qquad (1)$$

式（1）中 SC 代表社会冲突程度，I 代表指标，W 代表指标在整个社会冲突预警体系中的权重，n 是指标的序号。社会冲突预警的各指标值都以五级计算法计分，都设 10、20、30、40、50 五个分值，指标值大小与社会冲突风险为正比关系，依次运用科学计量的方法对社会冲突问题的轻重缓急程度进行评估。借鉴宋林飞（1995）、李殿伟和赵黎明（2006）的研究，进一步根据加权综合计算的得分把社会冲突分为正常状态、中级警示、严重警示三个等级，分别对应用绿灯、黄灯、红灯三种彩灯颜色动态描述社会冲突预警监测情况，如表 2 所示。

表 2 社会冲突预警评估等级

SC 值	0-10	10-30	30-50
警级	正常状态	中级警示	严重警示
信号灯	绿灯	黄灯	红灯

表 2 中绿灯代表社会处于正常稳定状态，社会冲突在正常范围内，不需要采取行动；黄灯代表社会冲突正在动荡出现，社会处于一定的混乱状态，有可能社会冲突会进一步加剧，需要采取应对行为把社会冲突及时平息；红灯代表社会冲突已经非常严重，影响到社会稳定和社会秩序，随时可能出现重大社会动荡事件，必须立刻采取大幅度的措施保障社会的稳定。因此，本文建立了社会冲突预警监测信号系统，并以此作为是否采取行动以及应该采取何种等级的应对措施的依据。

3 基于 TRIZ 的社会冲突解决

3.1 TRIZ 理论中的冲突

TRIZ（Theory of Inventive Problem Solving）是一门起源于前苏联、专门用于解决发明性问题的理论，其理论支柱和核心观点包括技术系统、技术系统进化、最终理想解、功能、冲突和资源等。TRIZ 理论的精髓可以简要的概括为(Nakagawa,2001) “技术系统是在几乎不引入外部资源的条件下，通过克服冲突的方式朝着提高理想度的方向实现其进化的。对于创造性问题的解决，TRIZ 提供了一种辨证的思考方式，即：将问题当作一个系统加以理解，然后设法解决相关冲突”。TRIZ 理论中的冲突包括技术冲突和物理冲突，不同类型的冲突有不同的解决机制。

所谓技术冲突，就是当我们试图引入技术系统或者其子系统的某种有用功能时，总是不可避免地恶化技术系统或其它子系统的另一种有用功能，或者产生新的有害功能及导致技术系统复杂化。TRIZ 理论为解决技术冲突，开发了一个专门的冲突矩阵。

所谓物理冲突，就是对技术系统中的同一个参数提出了互相冲突的要求。较之技术冲突，物理冲突是更为尖锐的冲突，而且一般而言物理冲突是产生技术冲突的根源。TRIZ 理论认为，解决物理冲突的基本机制是四大分离原理。

3.2 社会冲突的社会学分析

当前中国社会冲突产生的一般机理是（朱力，2009;姜建成，2012）：在社会中存在某种冲突源；围绕这一冲突源，多个相关主体进行利益博弈，导致部分主体利益受到损害；利益受损主体因此产生某种挫折感和失落感，随之出现某种牢骚性和抱怨性言语，并引发针对其他社会主体的冲突性行为，从而爆发社会冲突。

目前中国的社会冲突主要可以分为经济型的直接社会冲突和社会型的间接社会冲突两种类型（朱力，2009）。

经济型的直接社会冲突源于利益受损群体寻求补偿的努力。我国因城市国有企业下岗职

工失业、劳资纠纷、城市建设搬迁、集体土地征收征用、水库移民搬迁、环境污染等问题产生了各种利益受损群体。经济型直接社会冲突主要表现为这些利益受损群体与利益获益群体之间的直接冲突，冲突的本质在于这些社会群体之间即“冲突方”存在此消彼长的利益冲突关系（如图 1 所示）。

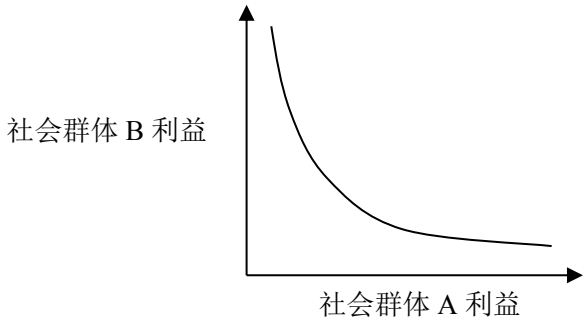

图 1 经济型社会直接冲突利益关系示意图

社会型的间接社会冲突源于某种突发性社会治安事件，在这种社会冲突中，参与主体与引发事件的当事人之间并不存在直接的利益联系，与冲突的双方也没有直接的利益冲突。

从表面上看，间接社会冲突中的各参与群体并不存在显著的此消彼长利益冲突关系。然而，对该类冲突进行进一步分析可以发现，其参与主体之所以卷入社会冲突，主要是因为冲突群体中的一方长期以来对社会不公、腐败滋生等问题集聚了相当的不满，或者该方本身即为社会不公等问题中的利益受损群体。因此，归根结底，绝大多数的间接社会冲突仍然可以归结为不同社会群体之间关于利益的冲突。社会冲突在本质上表现为各个冲突单元间利益的互不相容性（如图 2）。

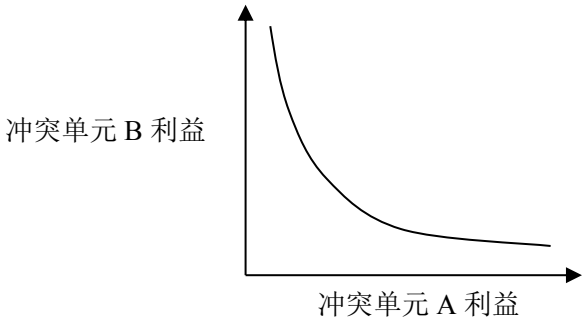

图 2 社会冲突单元利益关系示意图

3.3 社会冲突的技术学的分析

社会领域冲突与技术领域冲突具有许多相似之处。首先，从冲突发生的背景或原因看，社会领域冲突与技术领域冲突之所以发生，都是因为系统中存在着多个具有相异功能或目标（利益诉求）的子系统，这些子系统之间存在着相互联系、相互制约的关系。其次，社会冲突与技术领域冲突的产生，都受到系统进化规律的制约。不论是社会系统还是技术系统，都是在冲突不断产生、获得解决、新的冲突又重新产生的过程中实现进步与进化。最后，社会

系统与技术系统的进步与进化都表现为，从长期来看系统的多重功能或目标逐步得到实现，而且功能或目标实现的成本与耗费日趋降低的过程。

社会冲突与技术领域冲突存在以下共同特点：

第一，在现有的制度条件或技术条件下，都存在无法进行简单调和的冲突双方或多方，或者说存在一些具有互不相容关系的冲突单元；

第二，具体的冲突难以在现有的制度条件或技术条件下，通过已有相关参数的简单调整得到有效解决，而必须对系统进行某种创造性的设计，方可使其彻底消失；

第三，化解社会冲突或技术领域内冲突的高水平方案，需要通过突破某种思维障碍，对各自系统中子系统或冲突单元相关功能及其存在的合理性进行分析与界定，从而以最少的资源耗费实施某种设计或变换，解决隐藏在冲突背后的真正问题，得到接近最终理想结果的实际解决方案。

3.3 基于 TRIZ 的社会冲突解决思路与社会管理政策启示

3.3.1 基于 TRIZ 的社会冲突解决思路

社会冲突与 TRIZ 理论提出的技术领域的冲突具有许多类似之处，因而我们可以借鉴 TRIZ 理论解决冲突的基本思路，化解各种社会冲突。

1. 最终理想解和资源利用的基本思路

（1）最终理想解思路

可以借鉴 TRIZ 理论中“最终理想解”理念。即跳出当前社会冲突具体解决方案的传统思路，而是对冲突的根本利益进行重新界定，构建一个可以有效解决冲突双方对立的，几乎没有任何资源浪费的制度，即将原来两方的利益对立消除，即没有任何矛盾的地方，原来的冲突自然而然就不存在了，如 20 世纪 90 年代，普遍存在的乡镇政府与农民的矛盾很大程度上是农业税费造成的，而农业税费作为国家宏观制度，本身不是对立的双方能够决定的，因此中央取消农业税，实际上从根本上解决了这一问题。

（2）资源利用思路

为获得接近理想解，但又具有现实可行性的解决方案，可以进一步借鉴 TRIZ 理论的资源思想，挖掘和利用社会中相关的闲置资源和潜在资源（potential resources），将这些以往没有认识到、或者没有利用起来的资源，用于社会冲突的解决中，如闲置的土地安置特殊人群，给予某些群体以特别的待遇，而这些待遇之前是没有人需要的，以弥补损失和消除不满。

2．功能分析和功能裁剪的基本思路

（1）功能分析思路

技术系统存在的主要目的是为了完成某种有用功能，按照社会学功能理论（functionalism）的视角，社会各个部分存在的根本原因同样也是为了实现某种对社会群体的功能。在许多情况下，之所以会产生社会冲突，是因为社会完成某种正功能需要某些副功能的支撑，但这些副功能同时会对社会产生一定的有害作用，例如城管部门的设立是为了解决城市占道、违章、乱搭乱建等问题，但是城管本身也有自己的利益，可能与社会整体利益不一致，如随意罚款、态度粗暴等等，因此，我们需要在制度设计之初就考虑到这些问题，将其副功能和正功能的冲突减少到最低程度。

（2）功能裁剪思路

在功能分析的基础上，可以考虑运用 TRIZ 功能裁剪的方式，寻求消除社会冲突的有效方法。对于社会中纯粹产生有害功能的机构，则可以直接撤销，例如原来的收容遣送制度本身已经成为了限制人身自由，侵犯公民权利的来源，因此对其相关部门的撤销和转型本身并没有任何负面影响，反而有诸多正面积极作用。

3．根原因分析和维度变换的基本思路

（1）根原因分析思路

我们可以运用 TRIZ 理论解决冲突常用的根原因分析方法。通过对社会冲突发生的具体机理和根本原因进行分析，并对其采取某种适应性调整，从而将这一社会冲突消除在萌芽状态，例如，近年来土地征用中出现的失地农民与开发商和地方政府的矛盾，归根结底是由于中国农村土地的集体所有制，使得政府可以很容易的通过名义上是自治，实际上依附于政府的村委会，在没有村民充分知情、同意和参与的情况下，将集体土地进行征用，如果我们将土地所有权利（ownership）明确到个人，取消户籍制，允许城市居民到农村拥有土地，开发商和地方政府征用的程序和成本就会非常高，一旦强制征用就是和全社会作对，所谓失地农民问题自然就不存在了，没有失地问题，也没有农民问题。

（2）维度变换思路

社会冲突产生的原因在于不同社会主体之间利益的冲突。利益包括了多个维度的现象，如经济利益、政治权力、文化保护、社会认同、价值观念等等。如果在某些冲突中，包涵了多个维度的利益。可以应用 TRIZ 理论中维度变换的思路，将不同利益维度之间进行一个取舍和权衡，例如，对于某些群体来说，政治权力是最重要的，而经济利益无关紧要，那么我们可以通过增加其权力分配，而减少其经济补偿，而对另外一方则进行相反的安排，就可以减少冲突。

3.3.2 解决社会冲突的分离机制

对于技术领域的冲突问题而言，TRIZ 强调的是使冲突彻底地消除，而不是在两个相互冲突的目标或者评价参数之间做出简单的妥协或折衷。TRIZ 解决冲突的基本方法是四大分离原理。

TRIZ 分离原理的基本作用机理是构建或寻找某个界面，实现互相冲突需求的相对独立性，通过在界面的两侧分别实现两种需求消除其冲突关系。根据社会冲突与技术领域冲突的类似性，同样可以考虑借鉴 TRIZ 理论的分离原理构建或寻找某个界面，使社会冲突中冲突单元的各自利益要求在界面的两侧分别得到满足。

第一，解决社会冲突的空间分离原理。如果发生社会冲突的双方需求可以在空间中分离，则可成功解决社会冲突。例如我们在面对种族冲突和宗教冲突时，由于冲突往往发生在接触的群体之间，因此，如果我们能够将两个对立的而且分布在一定范围内，边界清楚的群体进行分离，双方接触的机会和接触的范围就会被限制，发生大规模冲突的可能性随之而减少，至少在短期内可以避免严重暴力冲突如种族屠杀的发生，如联合国派出维和部队设立隔离带、非武装区的含义正是如此，在一些国家中，将对立的民族和宗教分别成立自己的国家，实现分治也是解决冲突的途径，如前南斯拉夫分为几个国家。但是，必须指出，冲突的长期解决和消除不能仅仅通过分离方式，根本的还是需要种族和宗教之间的融合、共处和宽容。

第二，解决社会冲突的时间分离原理。同样包含两层基本含义：如若冲突双方的利益诉求存在较大弹性，则可以在不同的时间段上分别满足一方的利益诉求；也可以将短时期内的、大规模的社会冲突，减少为若长时期内、小规模的社会冲突，也可以减少冲突的暴力程度和危害程度。这种思路类似于冲突的安全阀思想，只不过更加强调时间维度在冲突中的意义。

第三，解决社会冲突的条件分离原理。如若冲突双方或者某一方的利益诉求依赖于某种条件（经济、政治、社会、文化），消除这种冲突产生的必要条件，来消除二者之间存在的冲突。例如，很多非洲地区的国家间和国内的冲突来源于贫困和对于自然资源的争夺，如果我们通过解决贫困问题，合理划分自然资源的产权，解决民众的生活问题，可以消除冲突发生的条件，使得冲突本身被消除。

第四，解决社会冲突的整体与部分分离原理。如若冲突双方的利益诉求分别可以在不同的系统层次上得到满足，则可以采用整体与部分分离原理解决这一社会冲突。即整体上的冲突，可以划分为部分冲突得到解决。例如，地方性的社会冲突如果能够分别得到控制，就不会演变成更大规模和范围的社会冲突，因此，如果冲突即使在各部分范围内发生，只要部分与整体是分离的，就不会形成整体的冲突，危及整个系统的存在。如目前中国地方政府如果能够有效的解决冲突，使得民众的不满不会指向中央，就不会危及整个体制。

3.3.3 TRIZ 工具对于社会冲突解决方法的启示

由于社会系统与技术系统、社会冲突与技术冲突之间存在一定的类似性，因而可以对 TRIZ 理论中的技术系统进化、发明原理、分离原理等相关工具，进行社会学意义上的诠释与解读，从而得到解决社会冲突的有效方案或相关社会管理政策启示。

1.技术系统进化理论的社会学诠释及管理政策启示

详见附录 1。

2．TRIZ 发明原理的社会学诠释及管理政策启示

详见附录 2。

4 结论

社会冲突是普遍存在的社会现象，在中国有规模扩大、数量激增、方式多元以及从利益相关冲突到利益不相关冲突演进的趋势；美国社会冲突表现出体制化、组织化、显性化和领域化的特点。在现实中，冲突的预警与解决机制仍然是困惑人们的问题，主要是一套集信息采集、传递、处理、反馈为一体的完整的科学有效的预警管理机制尚未最终形成；冲突的解决没有超出政府与社会层面的政策与组织调整，冲突解决方式比较单一。

科塞（Coser，1956）和达伦多夫（Dahrendorf，1958、1959）对现代社会冲突研究有杰出的理论贡献。此后，最有影响力的社会冲突论者是柯林斯（Collins，1975），他提出建立一门以冲突为主题的社会学。认为社会结构是社会行动者的互动模式（互动仪式链），是在行动者不断地创造和再创造中产生并得以持续的。科林斯力图为宏观社会学奠定微观冲突基础。遗憾的是，科林斯之后，社会学冲突理论本身陷入了停滞状态，没有再产生具有整个学科影响力的研究。

当前关于冲突预警和解决机制的研究存在一些有待解决的问题。冲突预警研究所需要的数据的及时性、动态性和全面性往往难以得到保障（Harff and Gurr，1998）。一方面是微观数据的缺失，另外一方面是数据拥有部门对于数据使用和获得的限制，因此预警研究本身的时效性和针对性存在一定障碍。

在现实中，冲突的预警与解决机制仍然是困惑人们的问题，主要是一套集信息采集、传递、处理、反馈为一体的完整的科学有效的预警管理机制尚未最终形成；冲突的解决没有超出政府与社会层面的政策与组织调整范畴，冲突解决方式比较单一。

在文献分析基础上，根据冲突监测的可测性、可靠性、充分性、最小性、一致性原则，本研究设计了包括 5 大类 12 项指标在内的社会冲突预警指标体系，包括：（1）经济发展（包括居民可支配收入和通货膨胀率两个指标）；（2）财富分配（包括失业率和贫富分化率两个

指标)；(3）社会保障（包括贫困人口率和最低保障覆盖率两个指标)；(4）风险控制（包括社会治安犯罪率、公共安全事件发生率和群众上访率三个指标)；(5）社会心理（包括腐败案件发案率、政府信任和满意指数、社会公正和信心三个指标)。前四项为客观指标，第五项为主观指标。

根据相应指标权重对上述 5 大类指标的 12 项指标进行加总，便形成对社会冲突风险进行预警的计算公式。在该计算公式中，社会冲突预警的各指标值都以五级计算法计分，都设 10、20、30、40、50 五个分值，指标值大小与社会冲突风险为正比关系，依次运用科学计量的方法对社会冲突问题的轻重缓急程度进行评估。 借鉴宋林飞（1995)、李殿伟和赵黎明（2006）的研究， 进一步根据加权综合计算的得分把社会冲突分为正常状态、中级警示、严重警示三个等级，分别对应用绿灯、黄灯、红灯三种彩灯颜色动态描述社会冲突预警监测情况。

通过社会冲突的社会学和技术学的分析，引入冲突方概念表征当今中国社会“经济型的直接社会冲突”和“社会型的间接社会冲突”两种冲突类型。基于 TRIZ 的冲突解决思路与方法，应用最终理想解、资源利用、功能分析、功能裁剪、根原因分析和维度变换等思想说明社会冲突解决的基本思路;应用 TRIZ 理论“四大分离原理”,提出解决社会冲突的分离机制；通过技术系统进化理论与 40 条发明原理的社会学诠释及管理政策启示，发掘相关 TRIZ 工具对解决社会冲突的社会学与政策含义。

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附录 1 TRIZ 技术系统进化理论的社会学诠释及政策涵义

技术系统进化规律（杨清亮，2006）	社会学释义	社会管理政策涵义
1、技术系统的 S 曲线进化规律：一个技术系统的进化一般会经历四个阶段：婴儿期、成长期、成熟期、衰退期	社会冲突发展的周期性和循环性	（1）在不同的进化阶段，重点解决该阶段出现的主要社会冲突； （2）成熟（成长）期也是冲突凸显期，需要有舒缓与严控相结合的管理政策
2、理想化水平提高进化规律：技术系统总是朝着理想化水平提升的方向进化，具体表现为系统实现的有用功能越来越多，而有害作用和成本则越来越少。	社会系统在进化的过程中，有益的社会功能越来越多，有害的社会功能和社会系统运行相应的成本耗费越来越少。	在社会管理制度设计阶段，即根据“理想解”特征，分析规划社会子系统的有用、有害功能及成本耗费，减少社会冲突发生的可能性
3、子系统的不均衡进化规律：每个子系统沿着各自的S曲线、各自的时间进度进行进化，它们在不同的时间点到达各自的极限，因而会产生矛盾，且最先到达极限的子系统将一直整个系统的进化。	社会系统中各个子系统，如技术经济子系统、政治制度子系统、社会文化子系统都会在不同的时间点到达各自的极限。政治-文化子系统滞后于技术经济子系统是导致社会冲突的原因之一	尽可能推进各个社会子系统的均衡发展，在技术经济子系统进化到一定程度的同时，适时推动政治子系统、文化子系统等方面的适应性发展与进化
4、动态性和可控性进化规律：在进化过程中，技术系统的动态性和可控性程度增加。	社会变迁的过程中，控制和治理必须是一种动态的过程	进行动态化管理，实时监督和控制社会冲突，并形成社会冲突预警机制和动态控制机制
5、增加集成度而后进行简化规律：一般而言，技术系统首先向集成度增加的方向发展，紧接着再进行简化。如先集成系统功能的数量和质量，然后用更简单的系统提供相同或更好的性能进行替代。	社会制度进行中，先出现满足各种管理的复杂制度，然后在运行中不断规则与简化，最后找到最合适的制度	在社会管理体系设计过程中，根据社会系统发展状况，适时调整和精简自系统数量与功能。
6、子系统协调性进化规律：在技术系统进化过程中，子系统的匹配和不匹配交替出现，以改善性能或补偿不理想作用。技术系统的进化沿着各子系统相互之间更协调的方向发展，即系统各部件在保持协调的前提下，充分发挥各自功能。	在社会系统进化过程中，子系统的匹配与不匹配交替出现；社会冲突与冲突的解决交替出现	正视社会冲突的客观存在及其有益功能，在各社会子系统“匹配-不匹配-再次匹配-再次不匹配”的发展过程中，提升各社会子系统的协调程度。
7、向微观级和场的应用进化规律：技术系统趋向于从宏观系统向微观系统转化，在转化过程中，使用不同的能量场来获得更佳的性能或控制性。包括向微观级转化、转化到高效场、提高场的效率以及分割四种进化路径。	社会的治理从宏观向微观转化。社会冲突解决机制应该与微观社会背景相适应。	在社会冲突解决过程中，减少宏观系统如政府职能部门的实体性干预程度，充分发挥网络、舆论等信息场的调节作用。
8、减少人工介入的进化规律：系统的发展用来实现那些枯燥的功能，以解放人们去完成	一个良好的社会冲突预警和解决机制应该是有较高	在社会冲突解决过程中，减少政府部门的人工刚性干预

更具有智力性的工作。	的自组织能力的。尽量避免人为的干扰	程度，充分发挥社会系统的自组织功能。

附录 2 TRIZ 发明原理的社会学诠释及政策涵义

TRIZ40 条发明原理(Altshuller，2008)	社会学释义	社会管理政策涵义
1、分割原理：a. 将物体分成独立的部分；b. 使物体成为可拆卸的；c. 增加物体的分割程度。	将冲突双方或“冲突单元”分隔不相干的部分。	政府对于有潜在冲突的社会群体，将他们在空间上进行隔离。
2、抽取原理：从物体中拆出"干扰'部分("干扰"特性)或者相反，分出唯一需要的部分或需要的特性。	将冲突中的主要矛盾和核心问题抽取出来，单独优先解决。其他部分就可以迎刃而解。	政府对社会冲突中的核心问题进行调研，制定有针对性的对策，进行优先安排。
3、局部质量原理：a. 从物体或外部介质(外部作用)的一致结构过渡到不一致结构；b. 物体的不同部分应当具有不同的功能；c. 物体的每一部分均应具备最适于它工作的条件。	对于冲突的预警和解决过程中，要有偏向性，对于不同的群体和群体的不同成员，要有所侧重。	政府在进行管理时，要有所为而有所不为，不能平均使用资源和力量。要优先解决最迫切的问题。
4、不对称原理：a. 将物体的对称形式转为不对称形式；b. 如果物体不是对称的，则加强它的不对称程度。	将势均力敌的冲突两方，转化为力量悬殊的两方，可以在某种程度上避免冲突的发生。	政府主动干预冲突双方的事务，不要等到冲突爆发才采取行动。在公正的前提下，优先保护弱势群体的利益，站在其一方，威慑另外一方。
5、合并原理：a. 把空间上相同或完成类似操作的物体合并起来；b. 把时间上相同或类似的操作合并起来。	将具有同样功能的政府机构进行合并，来统一的解决和预警冲突，避免相互的矛盾和推卸责任。	政府部门机构改革必须考虑到职能的统一性，避免相互扯皮和推诿。
6、一物多用原理：一个物体执行多种不同功能，因而不需要其他物体。	社会冲突解决部门和机制的多功能，多用途。日常调解和危机管理结合。	政府可以设立一些多功能部门，担任多种职能。
7、嵌套原理：a. 一个物体位于另一物体之内，而后者又位于第三个物体之内，等等；b. 一个物体通过另一个物体的空腔。	社会的各个组成部分关系是非常复杂的。各种社会冲突交织在一起。	政府在解决社会矛盾时，要全方位，多角度考虑问题，避免一个问题的解决反而引发更多的问题。
8、配重原理：a. 将物体与具有上升力的另一物体结合以抵消其重量；b. 将物体与介质(最好是气动力和液动力)相互作用以抵消其重量。	利用各种政策手段，将利益的冲突进行消除。如税收与财政转移结合。	政府需要将其公共政策进行合理搭配，以抵消各种政策的冲突，减少各自的不良作用。
9、预先反作用原理：如果按课题条件必须完成某种作用，则应提前完成反作用。	预先对于冲突的可能结果进行预防，避免冲突一旦发生，出现更糟糕的后果。	政府可以预计冲突可能的后果，预先安排对策。一旦出现不利后果，可以进行补救。
10、预先作用原理：a. 预先完成要求的作用(整个的或部分的)；b. 预先将物体安放妥当，使它们能在现场和最方便地点立即完成所需要的	预先对冲突进行干预，以避免冲突的形成和发展。	政府需要预先对冲突进行预警，并及时采取干预措施，设立隔离带、派遣军队等。

作用。		
11、预先应急措施原理：以事先准备好的应急手段补偿物体的低可靠性。	对于政府解决冲突的能力，有所保留，如一旦某个政府不能够解决冲突，有其他政府部门接替。	政府部门冲突解决有备份和替换机制，各个单位之间功能可以临时交换。
12、等势原理：改变工作条件，使物体无需上升或下降。	冲突解决尽量在冲突发生的范围内进行，不要将冲突引向更高的层级或者更低的层级。	地方政府必须能够有效的解决冲突，避免冲突最终指向中央政府。
13、反向作用原理：a、不实现课题条件规定的作用而实现相反的作用；b、使物体或外部介质的活动部分成为不动的，而使不动的成为可动的；c．将物体颠倒。	不消除冲突，反而使冲突扩大，导致更高层面的重视和干预，反而有利于冲突得到解决。	政府有意的将冲突提交更高一级政府和媒体，使得冲突受到各方面的关注，有利于冲突的解决。
14、曲面化原理：a．从直线部分过渡到曲线部分，从平面过渡到球面，从正六面体或平行六面体过渡到球形结构；b．利用棍子、球体、螺旋；c．从直线运动过渾到旋转运动，利用离心力。	将剧烈的冲突转化为非剧烈的冲突。减少直接的接触和对立。	政府通过一定的方法，将暴力冲突变成非暴力冲突。
15、动态原理：a、物体(或外部介质）的特性的变化应当在每一工作阶段都是最佳的；b．将物体分成彼此相对移动的几个部分；c．使不能移动的物体成为移动的。	冲突解决的动态机制。政府应当对于冲突规律有所认识。理解冲突发生的偶然性和动态性。	政府必须有一系列完整的工作方案，及时发现问题的所在，动态进行政策调整。
16、部分或超额行动原理：如果得到规定效果的 100%很难，那么就完成得多一些或少一些。	冲突的解决不一要完全符合预期，政府应当对于解决具有一定的灵活性，如进行退让和妥协。	政府在冲突解决时，要有一定的空间，不能够过于限制和僵化。
17、转变到新维度原理：a．如果物体作线性运动（或分布）有困难，则使物体在二维度(即平面)上移动。相应地，在一个平面上的运动(或分布)可以过渡到三维空间；b．利用多层结构替代单层结构；c．将物体倾斜或侧置；d．利用指定面的反面；e．利用投向相邻面或反面的光流。	改变冲突原来的目标，将冲突延伸到另外的角度。如原来的冲突是为了政治目的，而改变为经济利益冲突。	政府提供的资源和解决手段应该是多方面的，政治、经济、文化等都可以利用。
18、机械振动原理：a、使物体振动；b、如果已在振动，则提高它的振动频率(达到超声波频率)；c．利用共振频率；d．用压电振动器替代机械振动器；e．利用超声波振动同电磁场配合。	社会本身的运作过程中，有些机制要认为的扩大和提高其影响力。	政府可以将冲突的的效应放大。以引起全社会的关注。
19、周期性作用原理：a．从连续作用过渡到周期作用(脉冲)；b．如果作用已经是周期的，则改变周期性；c．利用脉冲的间歇完成其他作用。	冲突本身具有周期性，因此必须把握冲突周期。	政府要在冲突的潜伏期、发生期、扩大期和结束期采取不同对策。

20、连续有用作用原理：a．连续工作(物体的所有部分均应一直满负荷工作); b．消除空转和间歇运转.	冲突解决必须具有连续性，不能时断时续，可能激化原本消除的冲突。	政府的政策具有连续性，不能因为领导人的改变而改变。
21、快速通过原理：非常快速地实施有害的或危险的操作。	冲突解决的及时性。	政府要用很短的时间对冲突进行反应。
22、变害为利原理：a．利用有害因素(特别是介质的有害作用)获得有益的效果；b．通过有害因素与另外几个有害因素的组合来消除有害因素；c．将有害因素加强到不再是有害的程度。	将冲突的负面作用转化为正面作用。例如利用小规模的冲突来团结和激励群体。	政府可以利用冲突，解决一些一直没有解决的问题。如宗教冲突解决过程中，同时解决贫困问题。
23、反馈原理：a.引入反馈；b.如果已经有反馈，那么改变它。	建立社会的舆论和信息机制。	政府不能隐瞒真实信息，反而应当公开和有效的传达真实。
24、中介物原理：a.使用中间物体来传递或者执行一个动作；b.临时把初始物体和另一个容易移走的物体组合。	社会第三方，不同群体之间的中介，政府和民众的中介。	引进非政府组织（NGO）帮助政府解决冲突。
25、自服务原理：a.物体在实施辅助或维修操作时，必须能自我服务；b.利用废弃的材料或能量。	社会群体自我更新和维持的功能。	政府要培养各种社会群体自己的能力，而不能全部由政府包办。
26、复制原理：a.用简化的、便宜的复制品来替代易碎的或不方便操作的物体；b.如果已经使用了可见光的复制品，那么使用红外光或紫外光的复制品；c.用光学图像替代物体（或物理，系统），然后缩小或放大它。	其他国家和社会的制度可以复制过来。借鉴良好的做法。	政府应当集思广益，主动借鉴不同国家的经验教训，将行之有效的制度引进。
27、一次性用品原理：用廉价物品替代昂贵物品，在某些属性上（如寿命等）作出妥协。	临时性的制度安排。	政府对于特殊事件有特殊制度。
28、替代机械系统原理：a,用光、声、热、嗅觉系统替代机械系统；b.用电、磁或电磁场来与物体交互作用；c.用移动场替代静止场，用随时间而变化的场替代固定场，用结构化的场替代随机场；d.使用长，并结合铁磁性颗粒。	信息技术的广泛使用，代替了面对面的沟通和交流。	政府要减少对于媒体的控制，保障言论和新闻自由。
29、气动或液压结构原理：用气态或液态部件来代替固体部件。可以用空气或水，也可以用气垫或水垫，使这些部件膨胀。	用非常设（虚体）的组织机构代替常设（实体）。	政府可以设立一些各方面参加的组织，提高其灵活性和代表性。
30、柔性膜或薄膜原理：a.用柔性膜或薄膜代替常用的结构；b.用柔性膜或薄膜将物体与它的外部环境分	社会控制的柔性管理，不要采用强制力和暴力。	政府和民众之间的矛盾，不能使用暴力。

隔开。		
31、多孔材料原理：a.让物体变成多孔的，或使用辅助的多孔部件（如插入、覆盖等）；b.如果一个物体已经是多孔的，那么事先往孔里填充某种物质。	对于冲突的双方，通过某种手段，进行内部的结构分化，降低其稳固性。	政府可以对于冲突群体进行分类治理。不同的情况不同解决方法。
32、改变颜色原理：a.改变物体或其环境的颜色；b.改变物体或其环境的透明度；c.对于难以看到的物体或过程，使用颜色添加剂来观测；d.如果已经使用了这样的添加剂，那么使用发光追踪或原子追踪。	改变对于冲突的界定，如不能把任何民众与政府之间的冲突都以政治威胁的角度来看，而应该看成是一致合理的利益诉求。	政府在事件定性时，不能将群众置于对立面，否则不能解决冲突，还会扩大。
33、同质性原理：与主物体交互的物体，应该由主物体的同种材料（或具有相似属性的材料）制成。	政府解决冲突的时候，应当尽量派和	政府解决冲突时，要考虑到群体的特殊性，如宗教、民主，职业，尽量派同样的人，有利于冲突的和解。
34、抛弃与再生部件原理：a.物体的部件在完成其功能，或者变得没用之后，就被扔掉（丢弃、溶解、挥发等），或者在工作过程中已经改变；b.物体已经用掉的部件，应该在工作期间恢复。	社会制度的废除和改造	政府对于落后的政策，效率低下的部门要撤销和更新。
35、改变特性原理：a.改变系统的物理状态；b.改变浓度或密度；c.改变柔韧程度；d.改变温度或体积。	改变社会群体的规模、人口密度。	政府要通过其他政策，保护居民的人口、经济特征。
36、状态转变原理：利用状态转变时的现象，如体积变化、热量的吸收与释放等。	利用社会变迁的关键时期，剧烈变化。	政府需要把握好解决时机。
37、热膨胀原理：a.改变材料的温度，利用其膨胀或收缩效应；b.利用具有不同热膨胀系数的多种材料。	不同社会群体具有不同的积极性与能力	政府要针对群体特定来帮助其解决冲突。
38、加速氧化原理：从氧化的一个级别，，转变到下一个更高的级别。	社会的跨越式发展过程	政府要提高社会发展水平。
39、惰性环境原理：a.用惰性环境代替通常环境；b.往物体中增加中性物质或添加剂；c.在真空中实施过程。	将冲突解决双方放在另外的第三方环境中，脱离原来的环境。	政府可以安排独立的会议和谈判。
40、复合材料原理：用复合材料代替同性质的材料；	社会的多元化结构代替单一结构	政府要保障社会多元性，不要将社会结构和文化变成单一的，这样可以融合各种矛盾。

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Performance-oriented Perception Relationship Analysis for Organizational Conflict Identification and Resolution

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Abstract

This research proposes a set of methods to analyze the relationships among people's perceptions and organizational goals thus identifying and solving complex organization conflicts using modified TRIZ Perception Mapping, Function Relationship Analysis, Solution Directions, and Business Inventive Principles. Organizational Perceptions are usually fuzzy and obscure. It's difficult to detect the conflicts among them in complex organizational system. However, they may cause frictions among colleagues and significant negative impacts on the organizational performances. This research proposes an augmented perception analysis and links organizational perceptions with phenomena and performance indices to form a functional relationship diagram thus enabling a structured unequivocal identification of conflicts within an organization. TRIZ (Theory of Inventive Problem Solving) tools such as Cause Effect Contradiction Chain Analysis (CECCA), Solution Directives, and Business Inventive Principles can then be used to locate root conflicts and resolve the complex organizational problem.

Contributions of this research include:

(1) Enhancing Perception Mapping Method. An "Inhibit" relation is added to the existing "Lead to" relation. With the additional relaxation of one-to-one relationship to multiple-to-multiple relationships and the introduction of organizational phenomena/performance indices into the perception map, this method is able to clearly identify organizational conflicts in a structured way. Objective logical reasoning instead of subject feeling can now be used to identify conflicts in complex perception relationships in organizations.

(2) Enabling us to link individual perceptions to organization performances through Function Relationship Diagram. It helps us identify the perceptions causing performance problems allowing us to solve problem at its root cause. It also help us to locate the conflicts among perceptions from people allowing us to resolve or prevent frictions among people.

(3) Structured application of TRIZ technical tools such as CECCA, Solution Directives, Inventive Principles on solving fuzzy business problems.

Keywords: TRIZ, Perception Map, Conflict identification, Conflict Resolution, Function Relationship Diagram.

績效導向的觀點關係分析以辨識和解決組織衝突

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摘要

TRIZ 理論當中，用來定義問題的工具相當多，本研究特別針對決策模式，如組織策略及人員決策的衝突問題探討，提出一套分析的方法，可將此類複雜且無法顯而易見的意識觀點(Perception)，展開轉化成相互關連且可識別的關係圖，以功能關係圖((Functional Relationship Diagram, FRD)繪製關連圖，並且結合績效因子進行衝突辨識， 再經由解答指引、矛盾矩陣與發明原則尋找可依循的解決方案。

本研究主要貢獻為:

(1) 強化原有的觀點映射圖，進一步完善其方法與應用: 觀點映射圖方法論，僅以促成(lead to)的關係，描述不同觀點之間有正面的關係，本研究方法，則採用促成(lead to)及抑制(inhibit)兩種關係，描述觀點之間正面與負面的關係。透過正面與負面的關係描述，更能清楚的表示出不同觀點間所存在的衝突點。

(2) 採用觀點與績效的結合，藉由「強化的觀點映射圖」，找出觀點不利於績效的成份, 進行改善，進而達到提升組織績效的目的，並透過「因果衝突鏈分析」找出關鍵衝突。

(3) 擴大功能關係分析(Function Relationship Analysis, FRA) 的應用範圍：功能關係分析 以往通常是應用在解決工程方面的問題上，卻少有研究指出將功能關係分析運用在解決管理方面的問題上。本研究便是將功能關係分析與觀點映射圖結合，應用在解決及分析管理性的問題。

關鍵詞： 萃智、辨識衝突、解決衝突、功能關係圖、組織衝突

一、緒論

(一)研究背景與動機

現實中，多數組織並不如企業家所期望的是一個具有高度凝聚力的個體，相對於組織的整體利益，各個部門的成員往往對於所屬單位被賦予的目標及利益更為重視。以致於對於問題的反應，不同單位的成員，想法不同，訴求的目標和看重的利益也不同，往往因此產生不同程度的內部衝突，也因此削弱了整體組織績效的表現。

本研究主要是強化 Darrell Mann 觀點映射圖(Perception Mapping)方法論，以人的觀點為出發點，探索組織內不同部門成員對問題各自持有的訴求與想法，並且結合其對組織績效的影響，藉此，辨識出組織內部的衝突並管理衝突。

(二)研究目的

本研究有三項主要的目的：

1. 提供結構化的方式, 解析組織內不同觀點與組織績效之間的關係：以往管理的問題，大都憑藉少數決策人員的經驗或直覺, 判斷問題的解決方式，缺乏以結構化及系統化的方式來評量問題本身與外在影響因子之間的關係。

因此，本研究即提出一套有系統且結構化的方法，來分析組織內不同觀點對組織績效影響，作為辨識組織衝突的基礎，並找出可能的解決方案。

2. 辨識出不同類型的組織衝突，再透過因果衝突鏈分析(Cause-Effect & Contradiction Chain Analysis；CECCA)找到關鍵衝突：

區分出下列三種不同的衝突類型

(1) 觀點與組織績效之間存在的衝突

(2) 觀點與觀點之間存在的衝突

(3) 組織績效與組織績效之間存在的衝突

3. 透過 TRIZ 所提供系統化的工具及方法，找出解決組織衝突的可能方案：

(1) 功能關係分析：解答指引

(2) 技術衝突：衝突矩陣及發明原則。

使用者可透過以上二種方法，循序找到解決組織衝突的觸發解，再依問題所需將觸發解轉換為特定解。

二、文獻探討

(一) 觀點映射圖

觀點映射圖，是一種經由解析觀點的相互關係, 進行辨識機會與解決問題的方法。Darrell Mann 提出觀點映射圖方法論，透過訪談的方式，取得問題相關單位人員所持有觀點，藉由「促成」的關係，將不同的觀點連結起來，即可形成「觀點映射圖」。使用者利用觀點映射圖，尋求 loop、collector、conflict chain 這三種鏈結模式，給予不同的權重，依照權重來決定觀點對解決問題的重要性。針對其中辨識到的衝突鏈，則採用衝突矩陣與發明原則(Contradiction Matrix & Inventive Principles)，找到衝突的觸發解，使用者則再將觸發解轉為符合問題所需的特定解。

1. 細步流程

觀點映射圖的細部流程說明如下，共有 8 個步驟：

(1) 定義問題：針對此一特定問題，定義一個需要回答的問句，因為需要收集各單位的觀點，所以問句，必需設計成需要回答的問句模式。

(2) 針對這個問句，詢問相關單位，取得相關單位的觀點。並且為每個觀點進行編號。

(3) 替每一個觀點（因），找出被影響的觀點（果），並且在促成欄標示觀點（果）編號，表示此兩觀點有「促成」的關係。如表 2-1 所示。這裡所謂的「促成」強調的是一直(Always)會發生，而不是可能會或應該會發生的促成關係。

(4) 成對的比較，觀點之間是否有衝突的存在，若有衝突存在，則在衝突欄標示觀點編號，表示此兩觀點有衝突存在。如表 2-1 所示。

表 2-1 觀點分析表

編號	觀點(Perception)	促成(Lead To)	衝突(Conflict)
A	Perception_1	C	
B	Perception_2	D	
C	Perception_3	B	E
D	Perception_4	C	
E	Perception_5	D	C

(5) 將每個觀點以促成(lead To)的關係串連起來，以有方向性的箭頭連接成觀點映射圖。如圖 2-1 所示。

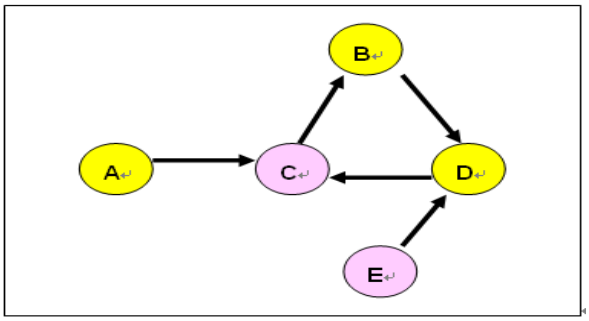

圖 2-1 觀點映射圖

(6) 分析觀點映射圖，尋求觀點之間的 Conflict chain / Collector point / Loop 鏈結模式(如圖 2-2 所示)

- 衝突鏈(Conflict chain)：有衝突存在於兩個觀點上，將兩個觀點所形成的鏈稱為衝突鏈。要注意的是，衝突鏈，只重視兩觀點有衝突存在的事實，而不重視衝突鏈當中箭頭符號的方向性，如圖 2-2 Conflict Chain 所示，A 與 B 有衝突存在，但不表示衝突發生在觀點 C，而是僅僅表示 A 與 B 有衝突，A 到 B 當中所存在的箭頭符號，不具有方向性的意義。
- 集中點(Collector point)：表示有多個觀點促成或導致此一觀點，此觀點為多個觀點所影響，此觀點即為集中點。
- 迴路(Loop)：任何一個觀點依照箭頭方向前進到下一個觀點，最終又會再回到原來的觀點，此鏈即形成迴路。在觀點映射圖中，有要求至少要有一個迴路存在，但沒有限制迴路當中結點(node)的個數，也沒有限制觀點映射圖中迴路的數量。

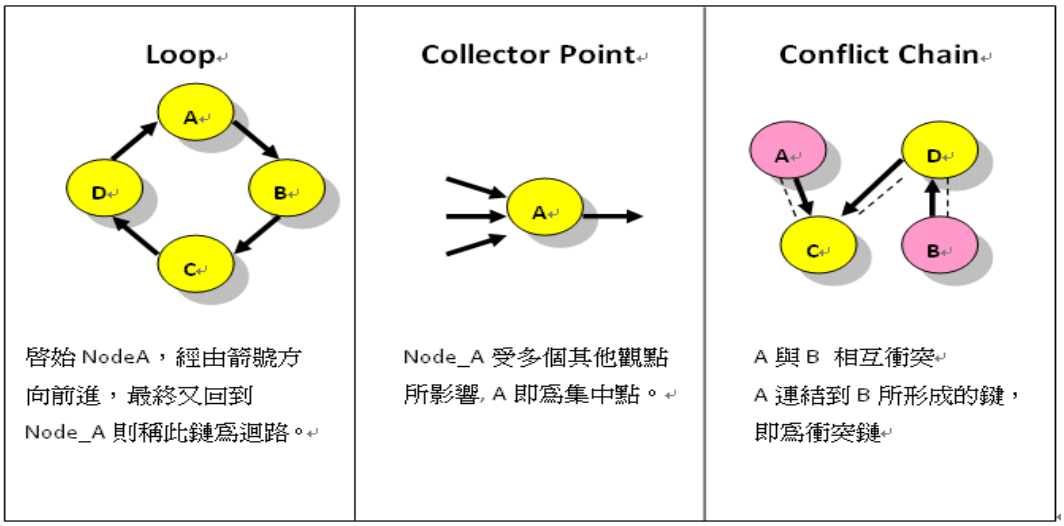

圖 2-2 鏈結模式圖

(7) 針對步驟(6)定義的三種鏈結模式，分別給予不同的權重：

- ◆ Loops ：4 點(Score)分數，Loop 內的每個結點都給 4 分。
- ◆ Collectors ：(n-1) 點(Score)分數，n 是連結到該結點的箭頭數，集中點有(n-1)分。
- ◆ (Conflict Chain ：3 點(Score)分數，有衝突的兩個結點，分別給 3 分。
- ◆ 不屬於以上三種鏈結模式者，不給分

依照上述方式給分，計算每個觀點分數，分數愈高，表示該觀點對特定問題而言愈重要。

(8) 衝突鏈當中，衝突點的兩觀點，則透過衝突矩陣與發明原則找到相對應的觸發解，使用者可依觸發解找到相對應問題的特定解。

2. 觀點映射圖的優缺點：

◆ 觀點映射圖之優點：

(1) 將看不見的觀點，轉化為看得見的邏輯化的圖形，釐清不同觀點之間的關係。

(2) 透過觀點映射圖，了解其他單位的觀點與立場，讓溝通變得更容易。

◆ 觀點映射圖之缺點：

(1) 僅透過「促成」關係，描述組織間不同單位成員觀點與觀點之間存在的正向關係，卻沒有描述不同單位成員觀點間存在的負向關係。

(2) 觀點映射圖在衝突辨識方面，僅以主觀的認定並標示此兩項觀點有衝突存在，卻無法直接透過圖形辨識出衝突點。

(3) 沒有結構化觀點的訴求，因此也無法說明觀點所引起的衝突背後的原因。

(二)功能關係分析

功能關係分析，是一種解決問題的方法。John Terninko 認為這裡所提到的「功能」不只是件功能，而是更廣的將「功能」定義為「任何使用者想達成的…」，可能是一個事件或活動等等。功能關係分析方法，是將問題拆解成一個個的功能，並區分功能為有益功能及有害功能，再透過「關係」，將各功能的因果關係連結起來，形成了功能關係圖，藉由探索系統中有用及有害的功能，進而找到系統內的問題點。再利用解答指引找到問題點的觸發解，提供改善及解決問題的方案。

功能關係分析透過功能(Function) 及關係(Relationship)兩個元素來描述問題，以下分別針對功能與關係加以說明：

1. 功能：

功能，可以是一項活動、流程、操作、狀況或一項必需被執行的動作，並且以動詞或動詞片語表示。功能有分為 2 種，有用及有害的功能，外型及顏色加以區別。功能，是以 Box 圖形呈現，並以文字說明該項功能。

(1) 有用的功能：對系統有用的功能，以綠色方框 Box 表示。如圖 2-3 所示。

圖 2-3 有用功能圖

(2) 有害的功能：對系統有害的功能，以紅色圓角 Box 表示，如圖 2-4 所示。

圖 2-4 有害功能圖

(3) 衝突：該功能同時產生有害及有用的功能，以黃色方框 Box 表示，如圖 2-5 所示。

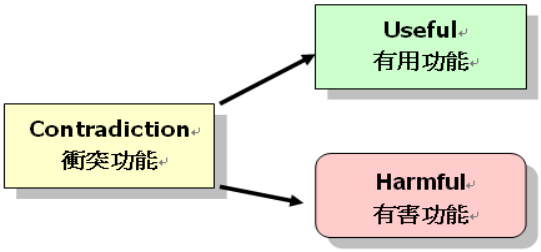

圖 2-5 有害功能圖

2. 關係：

關係，用以連接二個功能 Box，用以說明功能 Box 之間的關連性，關係可分為促成(lead to) 及 抑制(inhibit)二種，如圖 2-6 所示

(1) 促成關係，表示箭頭符號的原點端的功能增加（減少），箭頭端的功能也同時增加（減少），是同向的關係。促成又可分為有用及有害的促成，若箭頭端的功能連結的是一個有用的功能，則此促成為有用的促成。若箭頭端的功能連結的是一個有害的功能，則此促成為有害的促成。

(2) 抑制關係，以箭頭符號再加一橫槓表示，說明原點端的功能增加（減少），箭頭端的功能會同時減少（增加），是反向的關係。抑制也分為有用及有害的抑制，若箭頭端的功能連結的是一個有用的功能，表示抑制了有用的功能，是為有害的抑制。若箭頭端的功能連結的是一個有害的功能，抑制有害功能，是為有用的抑制。

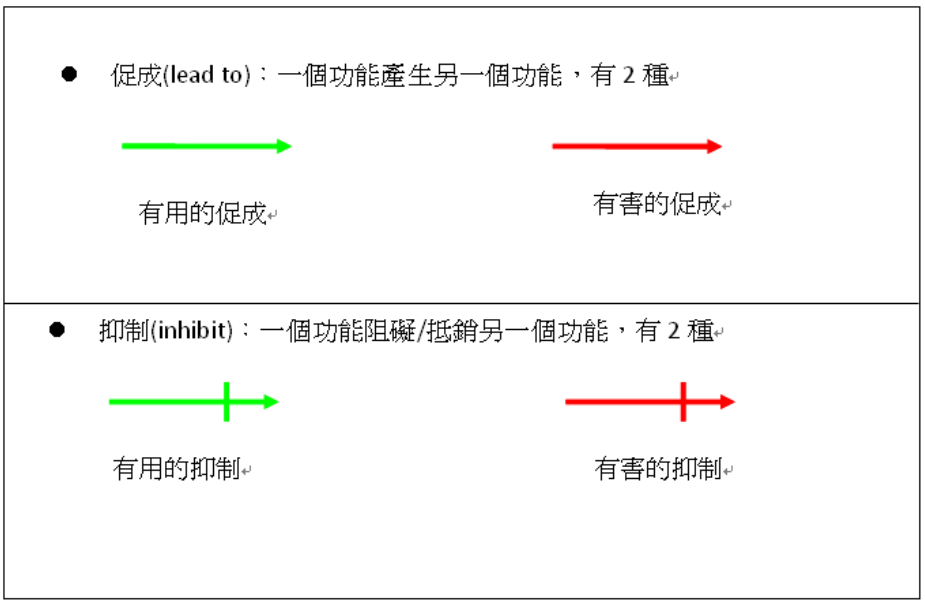

圖 2-6 促成與抑制有用與有害關係圖

3. 功能與關係排列組合的類型

將功能與關係排列組合，會有以下 8 種的情形產生。（如圖 2-7 所示）分別說明如下： 首先，依照關係來分類，有促成與抑制兩種。

促成關係當中，有用的促成有二種：(1) 有用的功能產生有用的功能(2) 有害的功能產生有用的功能，但此時有害的功能是一個衝突功能，因為有害功能卻能產生有用的功能，是有衝突存在的。有害的促成有二種：(1) 有用的能產生有害的功能，此時有用的功能是一個衝突功能，因為有用的功能卻會造成有害的功能(2) 有害的功能產生有害的功能。

抑制的關係當中，有用的抑制有二種：(1) 有用的功能抑制有害的功能(2) 有害的功能抑制有害的功能，此時前者有害功能，是一個衝突功能，因為有害功能卻產生有用的功能：抑制有害。有害的抑制有二種：(1) 有用的功能抑制有用的功能，此時前者有用功能，是一個衝突功能，因為有用功能卻抑制另一個有用的功能(2) 有害功能抑制有用功能。

透過此 8 種組合，可以清楚的定義出功能關係圖中有無衝突的存在。

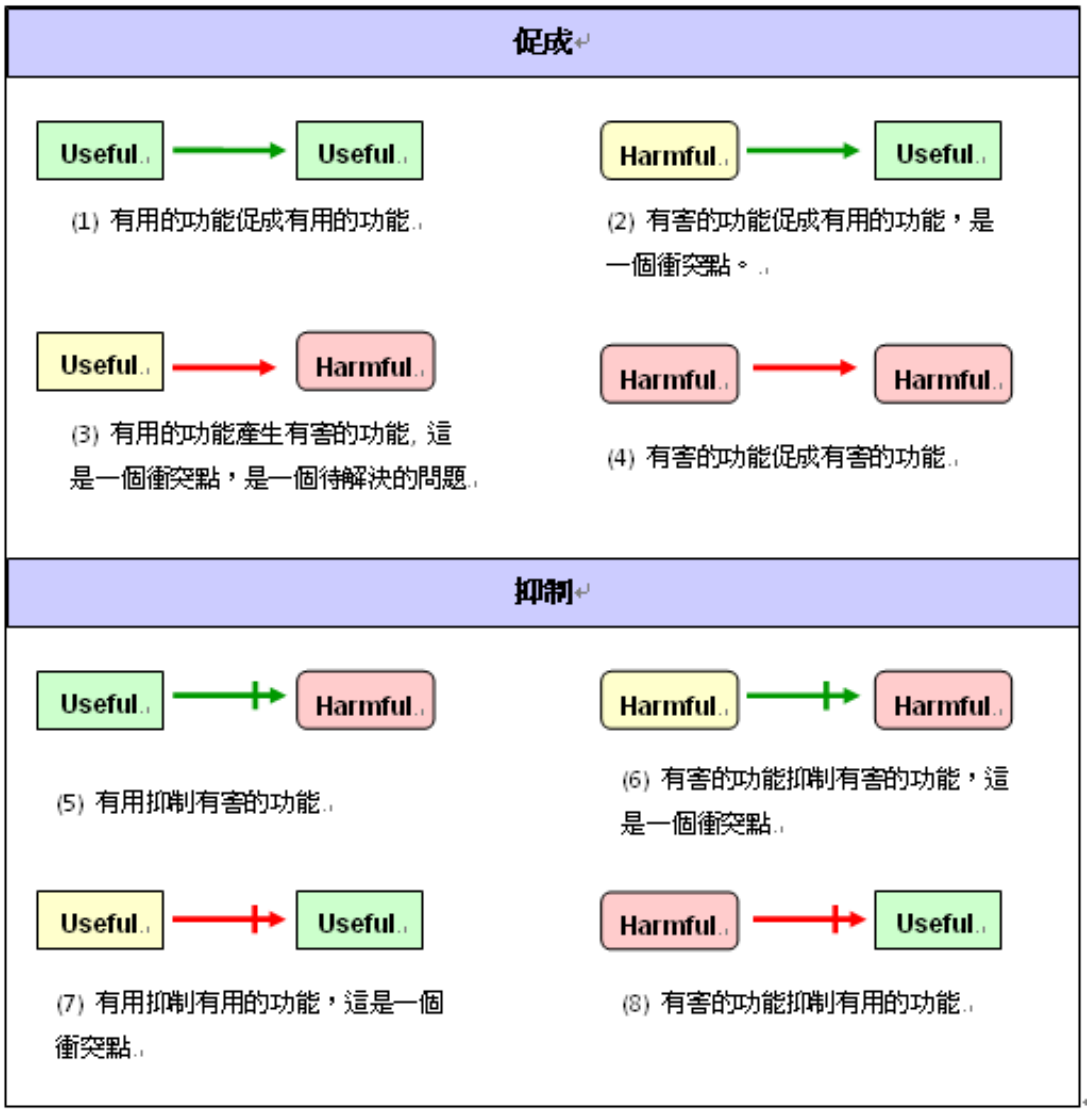

圖 2-7 功能關係圖之 8 種基本功能關係圖

4. 解答問句

透過功能關係圖，辨識出系統內的有用功能、有害功能與衝突功能。分別針對有用功能、有害功能及衝突的功能，提供不同的解答指引。以系統化的方式提供解答指引予使用者，使用者可依照解答指引的提示，找出適合問題的特定解。以下分別針對有用功能的解答指引、有害功能的解答指引及衝突的解答指引加以說明。

(1) 有用功能的解答指引：

針對系統內有用的功能，要提出改善的方案，可依照以下的方式想出改善的方針：(a)提供有用的結果(b)不要提供任何有害的結果(c)不需其他功能預先提供有用的功能(d)不被有害功能所影響。(參考圖 2-8)

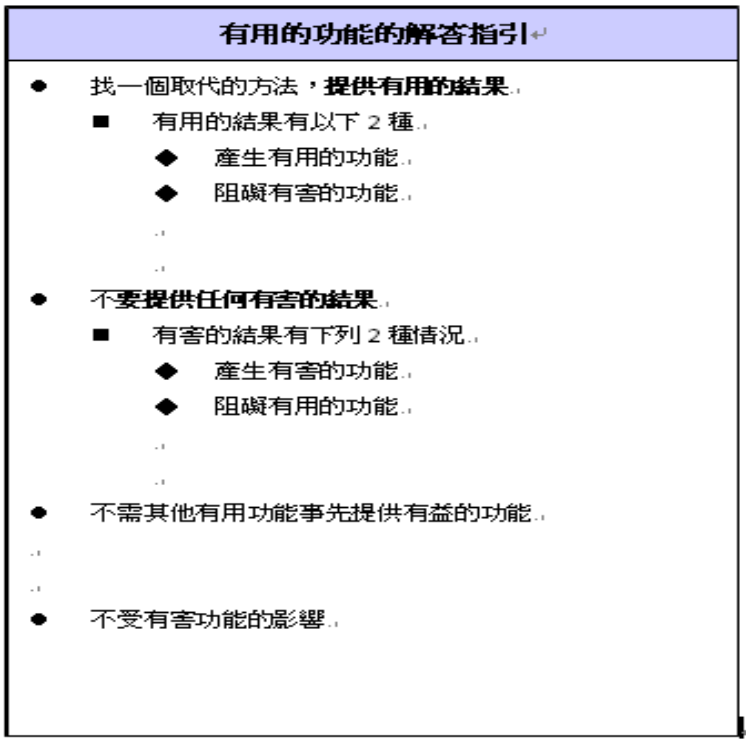

圖 2-8 有用功能之解答指引

(2) 衝突功能的解答指引：

針對系統內衝突的功能，要提出改善的方案，可依照以下的方式想出改善的方針： (a)有用的功能應該存在，當有用的功能產生有用的結果時，此有用的功能關係應該存在。(b)當有用功能產生有害結果，則此有用功能則不應存在，應設法排除。(參考圖 2-9)

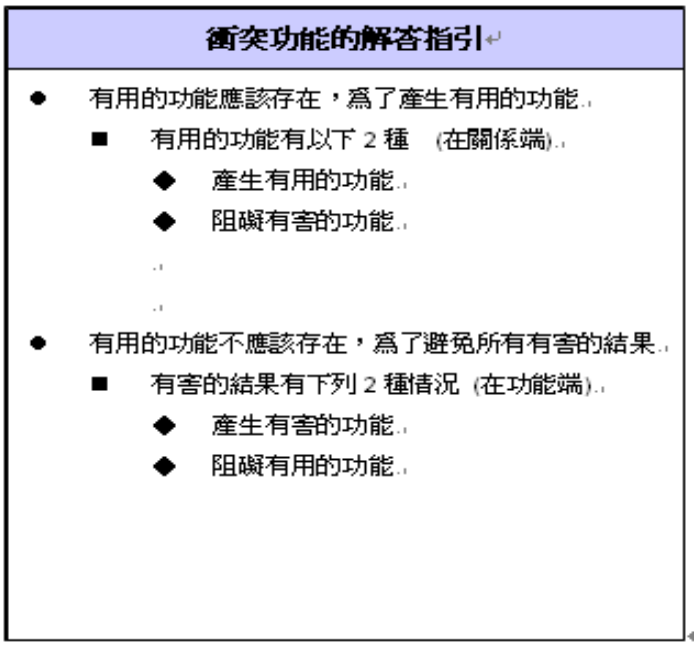

圖 2-9 衝突功能之解答指引

(3) 有害功能的解答指引：

針對系統內有害的功能，要提出改善的方案，可依照以下的方式想出改善的方針：設法尋找一個取代的方法，來排除、降低或阻止有害的結果，或是設法尋找一個取代的方法，來排除、降低或阻止其他有害條件下，提供的有害功能。(參考圖 2-10)

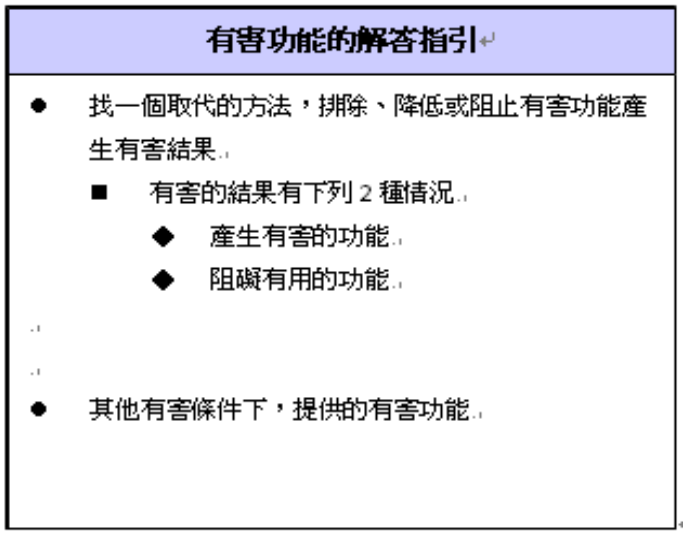

圖 2-10 有害功能之解答指引

5. 功能關係優點與缺點

功能關係分析的優點是，將工程問題轉化為一個個的功能，並利用有用、有害的功能，幫助使用者找到問題點。並提供相對應的解答指引，以系統性的方式提供尋找問題的觸發解。

功能關係分析的缺點是，功能關係分析通常是應用在分析工程方面的問題，少有研究指出將功能關係分析運用在複雜的管理問題。因此，本研究希望將功能關係分析運用到管理的問題上，將原先的功能元素，以人的觀點、現象與績效取代，透過關係來描述觀點、現象及績效的關係，並分析不同人的觀點表現在組織績效上所存在的衝突，並採用功能關係分析提供的解答指引，找到衝突的解決方案。

三、研究方法

本研究主要是強化 Darrell Mann 觀點映射圖(Perception Mapping)方法論，以結構化的方式，探索不同組織內所屬成員的觀點訴求結構、以及這些訴求活動如何與績效建立互動的關係，並透過觀點訴求結構與績效之間的關係結合起來，找出(1)觀點與績效的衝突(2)觀點與觀點的衝突(3)績效與績效的衝突，再利用 TRIZ 提供的工具因果衝突鏈分析找到關鍵衝突，並且採用(1)功能關係分析：解答指引(2)技術衝突：衝突矩陣與發明原則，為關鍵衝突尋找觸發解，使用者再依照問題所需，透過觸發解提供解決組織衝突的特定解。

1. 基本名詞定義

首先分別對觀點、現象，與組織績效下定義：

- **觀點(Perception)**：指的是「想要的訴求及對事情的看法」。人們對事情的觀點，決定人們對事情會採取

的作法，由於不同的人想要的訴求不同以及對事情的看法也不同，所以會採取的作法也會不同。

- **現象(Phenomenon)**：指的是「為了達到觀點訴求的目標，所產生的一連串事件或事實的狀態」。由於觀點是內在的想法，不容易觀察得到，而現象則是顯現於外的事件或事實的狀態，可以看得到。因此，要觀察人們的觀點，可以透過觀察顯現於外的現象互動關係來瞭解人們的觀點。
- **組織績效(Organization Performance)**：組織績效，指的是「組織內各單位及人員，為達成企業組織所賦予的目標而做的努力活動之情況或結果，加以衡量與評估，當作獎懲與控管的依據」。 對企業而言，最重要的莫過於追求最高的組織績效，達成預定的營運目標，提升企業本身的競爭力。企業中各類的活動，最終主要的目的即在績效的提升，而績效的改進，更是管理的核心。藉由找出影響組織績效的原因所在，並提供改善的方法，進而達到改善組織績效。本研究即是透過觀點與組織績效結合，探討觀點對組織績效的影響，進而找出削弱績效的原因所在，並提供解決方案，進而達到改善組織績效。

2. 研究流程

研究流程分四個階段，（1）問題描述（2）觀點分析（3）辨識衝突（4）尋找衝突解。請參考圖 3-1

第一階段為問題描述，主要目的是為了確定問題的範圍、限制及目標，找對問題，則問題就解決了一半，所以這個階段非常重要，是以下各階段的基石。

第二階段是觀點分析，主要是介紹觀點關係分析（Perception Relationship Analysis；PRA），如何利用圖形工具，將觀點與績效結合，完成觀點關係圖(Perception Relationship Diagram；PRD)。以提供給下一個階段辨識衝突使用。

第三階段是辨識衝突，主要是透過觀點關係圖，分析觀點到績效，抑制關係發生次數，決定觀點對績效產生有益或有害影響。透過有益與有害影響，找到(1)觀點對績效的衝突(2)觀點與觀點的衝突(3)績效與績效的衝突。並且利用因果衝突鏈分析，找到關鍵衝突。再透過下一個階段找尋衝突解、

第四階段是尋找衝突解，透過 TRIZ 工具，為衝突點尋找觸發解，使用者再依問題所需將觸發解轉為特定解。TRIZ 工具有(1) 觀點關係分析：解答指引 (2) 技術衝突：衝突矩陣及發明原則。

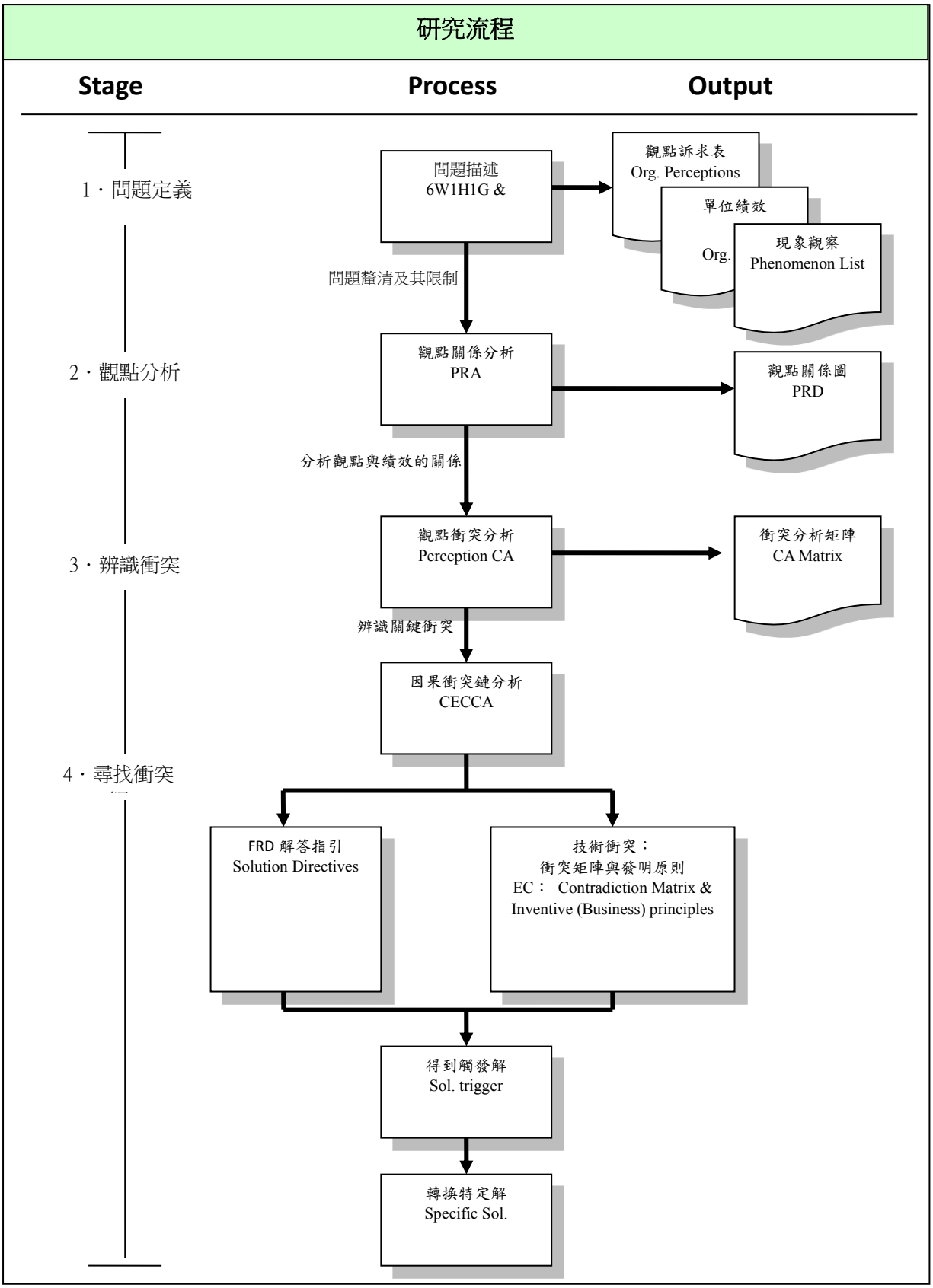

圖 3-1 研究流程

以下針對此四個階段加以說明：

(1) 問題描述：第一階段為問題描述，主要目的是為了確定問題的範圍，使用者可以透過 5W1H1G 問題詢問方式，幫助使用者定義問題、限制及目標。利用「單位績效表」、「單位觀點訴求表」以及「現象觀察表」，幫助使用者記錄問題相關單位所屬成員，各自持有的觀點、現象與績效。

表 3-1 單位績效表

問題：如何….? (5W1H1G 問句模式詢問)	
單位	**績效因子（組織績效目標）**
單位 1	績效因子_1
單位 1	績效因子_2
單位 1,單位 2	績效因子_3
單位 2	績效因子_4
單位 2	績效因子_5
單位 3	績效因子_6

表 3-2 單位觀點訴求表

問題：如何….? (5W1H1G 問句模式詢問)		
單位	**觀點：想要的訴求?**	**說明**
單位 1	觀點_1	
單位 1	觀點_2	
單位 2	觀點_3	
單位 2	觀點_4	
單位 3	觀點_5	

表 3-3 現象觀察表

問題：如何….? (5W1H1G 問句模式詢問)			
單位所屬成員	**時間/地方**	**現象**	**說明**
單位 1		現象_1	說明訪談時觀察到的現象或訪問時聽到看到的事情
單位 1		現象_2	
單位 2		現象_3	
單位 2		現象_4	
單位 3		現象_5	
單位 3		現象_6	

(2) 觀點關係分析：問題描述完成後，第二階段目的，主要是介紹觀點關係分析方法，如何利用圖形工具，將觀點、現象與績效結合起來，完成觀點關係圖。觀點關係分析方法，利用二項圖形工具，一個是元素，另

一關係。觀點關係分析方法，是透過關係將一個個的元素連結起來，就形成觀點關係圖(Perception Relationship Diagram；PRD)。以下則針對元素、關係及觀點關係圖加以說明：

◆ **元素：**

元素，可以分為三大類，觀點、現象以及績效。觀點關係分析，最主要就是要設法釐清這三大類元素之間的關係，進而找出影響組織績效的原因。元素，可再區分為「有益的元素」與「有害的元素」。有益的元素，指的是對組織單位而言，該元素是想要(like)的事件。有害的元素，指的是對組織單位而言，該元素是不想要(dislike)的事件。

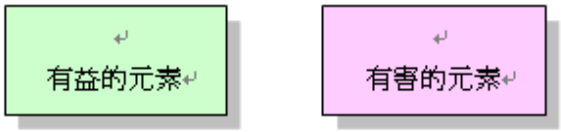

圖 3-3 有益與有害元素

◆ **關係：**

關係，用以描述兩個元素之間的互動。有促成與抑制二種描述方式。以箭頭圖（→）來表示。原點表示影響的元素（因），終點表示被影響的元素（果）。

促成，表示因與果的元素具有同向變動的關係，同時增加或同時減少的關係。抑制，表示因與果的元素具有反向變動的關係，一個元素增加（減少）另一個元素則減少（增加）的關係。

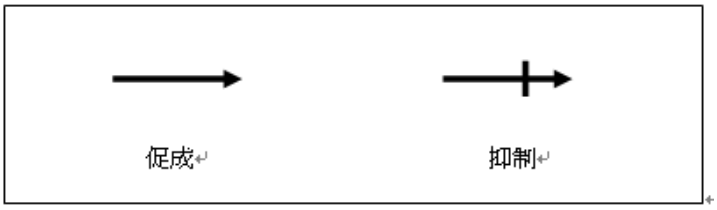

圖 3-4 促成與抑制符號圖

促成關係有二種，「益的促成」與「有害的促成」。有益的促成，表示促成組織單位想要的事件，以綠色表示。有害的促成，表示促成組織單位所不想要的事件，以紅色表示。

抑制關係有二種，「有益的抑制」與「有害的抑制」。有益的抑制，表示抑制組織單位不想要的事件，以綠色表示。有害的抑制，抑制組織單位想要的事件，以紅色表示。如圖 3-5 所示

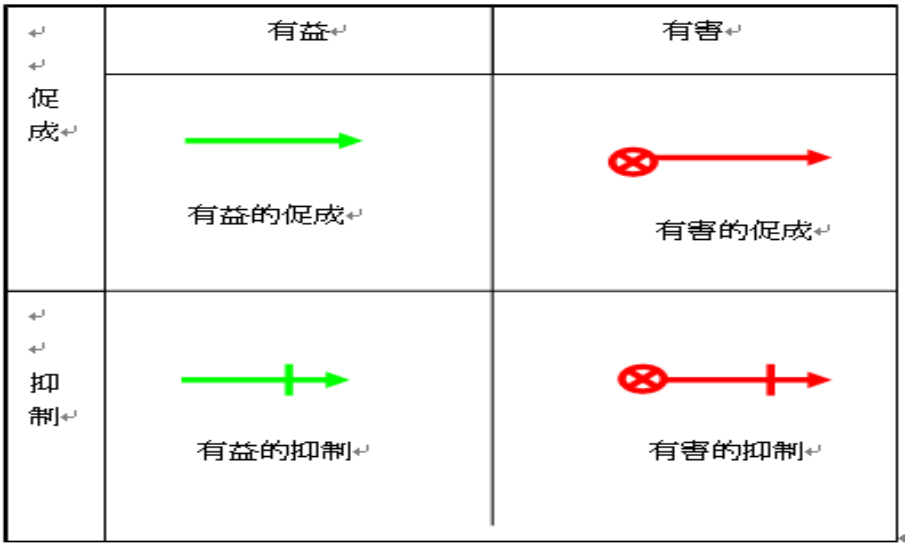

圖 3-5 促成與抑制－有益與有害符號圖

◆ **觀點關係圖**(Perception Relationship Diagram)

觀點關係圖，是圖解觀點與績效之間所構成的關係圖，以關係來連結觀點、現象及績效三個結構(如圖 3-6 所示)。透過觀察觀點到績效之間相互的關係，看見觀點漸漸變化的事件，訴說著人們的觀點，如何影響到組織績效，也訴說著不同單位所屬人們觀點之間的交互關係，是強化了組織績效呢？或是削弱了組織績效？都可由觀點關係圖一窺究竟。

因此，人的觀點，也不再是只存在於人的想像之中，而是已經轉換成一系列看得見的現象，並且還可以連結到組織績效上，透過績效的消長，觀察到那個觀點對那些績效是有益的，對那些績效卻因為引起了副作用，以致於弱化了某些績效。

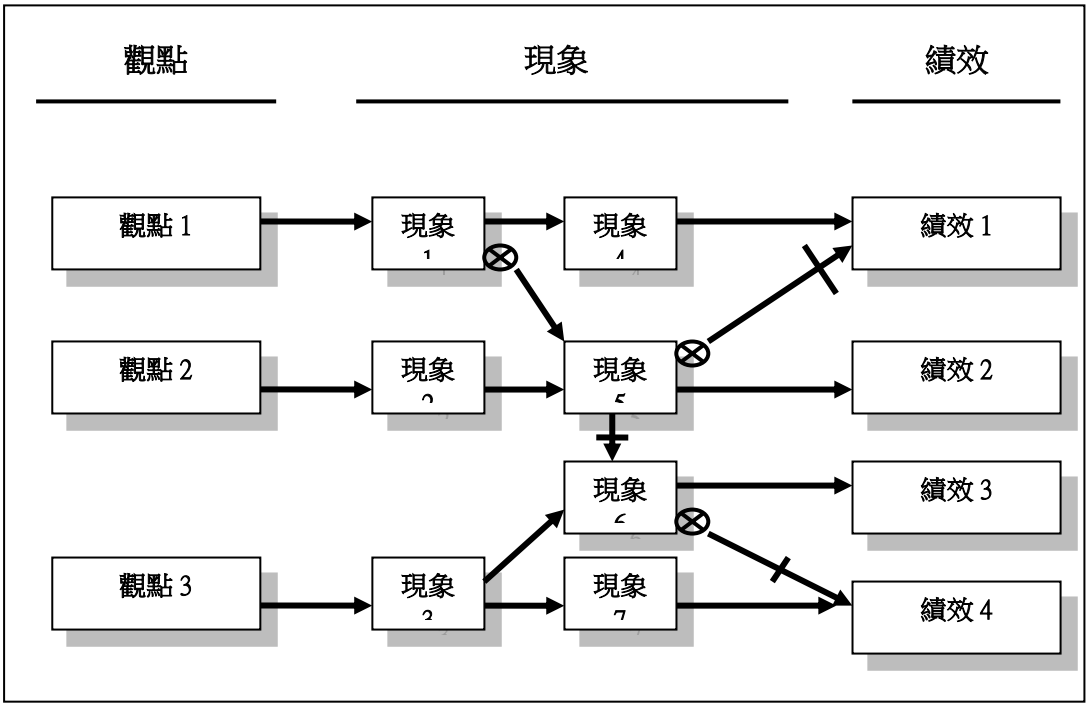

圖 3-6 觀點關係圖

觀點關係圖之範例說明：如圖 3-6 的問題：「增加固網公司營業收入」，觀點「(A)提高業務員作業績效為目標」的訴求結構為，追求「(1)客戶數量的增加」以促成「(2)銷售數量提升」，進而達到「(P1)增加營業收入」的目的。但是，也由於「(1) 客戶數量的增加」，同時促成「(3) 服務需求增加」，而抑制了績效「(P2)服務品質提升」功效，由於在業務員數量不變的情形下，服務需求的增加會導致服務品質會下降。

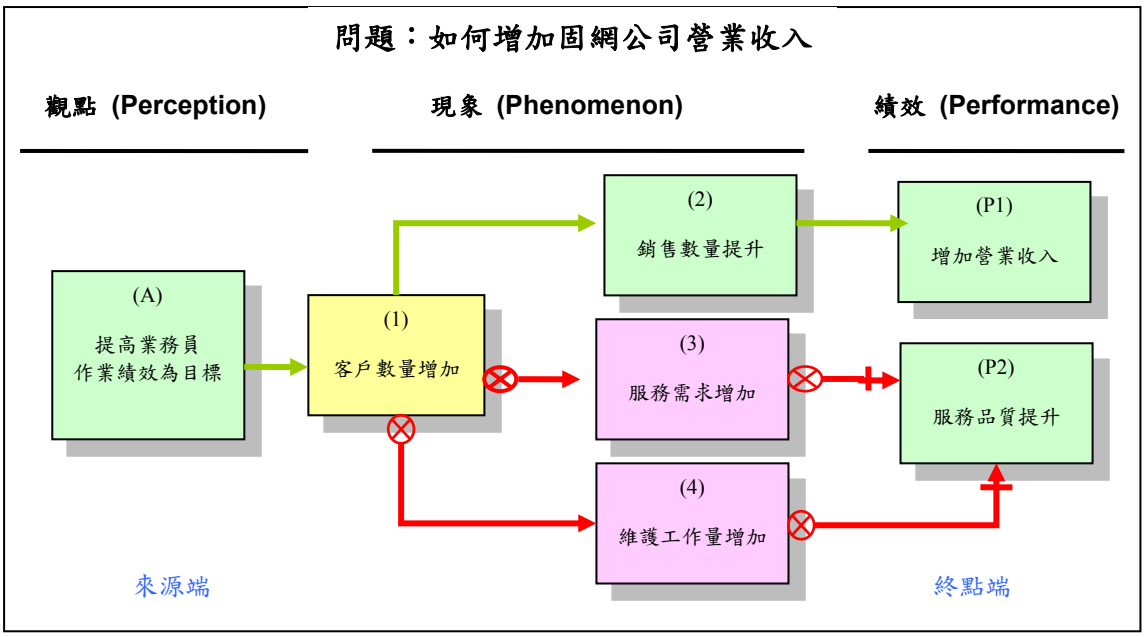

圖 3-5 觀點關係圖

(3) 觀點衝突分析

由於現象不是控制因子，觀點才是控制因子，因此若要找出影響組織績效的原因所有，並提供改善的方法，進而達到改善組織績效的目的，應透過觀察觀點對績效的衝突，找出觀點不利於績效的原因，透過改善觀點結構，達到改善組織整體績效的目的。

◆ 衝突種類

觀點與績效間的衝突，可分為三種：(1)觀點對績效間的衝突(2)觀點與觀點間的衝突(3)績效與績效間的衝突。

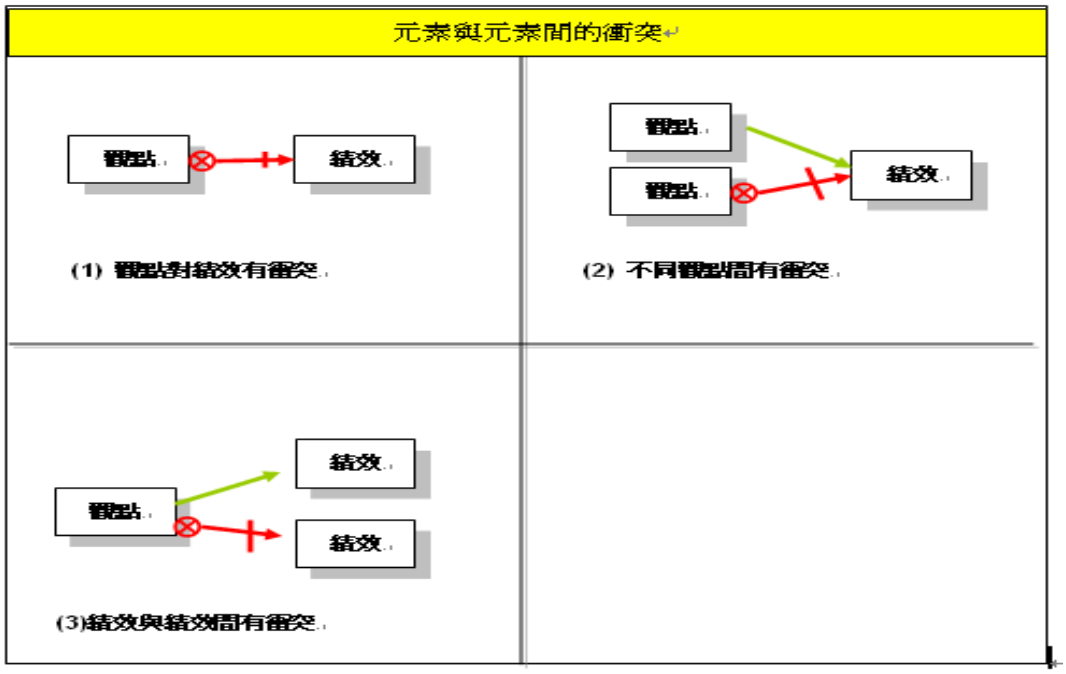

圖 3-6 觀點與績效－衝突種類

◆ 衝突分析矩陣

透過衝突分析矩陣，辨識出衝突種類。首先必需先透過觀點關係圖，觀察觀點到達績效，如果有單數個抑制，就給予「－」符號，若有雙數個(含零個)抑制，就給予「＋」符號。透過觀察每個觀點到達績效的抑制關係，即可完成「衝突分析矩陣」。如圖 3-7 所示。

觀點＼績效	(P1)	(P2)	(P3)	(P4)
A	－		＋	
B	－		＋	
C	＋		－	
D		＋	－	－
E		＋	－	
F			－	＋
G			－	＋

圖 3-7 衝突分析矩陣

透過衝突分析矩陣，可以分辨出以下三種衝突：

- **觀點對績效間的衝突**：從觀點的角度看過來，如果有「＋」出現，表示此觀點與該績效沒有衝突，如果有「－」出現，表示此觀點與該績效有衝突，若沒有「＋」或「－」，表示此觀點與該績效沒有關係。
  - 從觀點 A 看過來，與績效 P1 有「－」，因此，觀點 A 與績效 P1 有衝突。
  - 從觀點 A 看過來，與績效 P2 是空白，因此，觀點 A 與績效 P2 沒有關係。
  - 從觀點 A 看過來，與績效 P3 有「＋」，因此，觀點 A 與績效 P3 沒有衝突。
- **觀點與觀點間有衝突**：從績效的角度來看，兩個觀點間一個是「＋」的符號，一個是「－」的符號，就表示這兩個觀點有衝突存在。

- 從績效 P1 來看，觀點 A 與觀點 C 之間，一個是「－」，一個是「＋」，就表示觀點 A 與觀點 C 有衝突存在。

➢ **績效與績效間有衝突**：從觀點的角度來看，兩個績效間一個「＋」的符號，一個「－」的符號，就表示這兩個績效有衝突存在。

- 從觀點 F 來看，與績效 P3 之間是「－」的符號，與績效 P4 之間是「＋」符號，就表示這兩個績效有衝突存在。

在組織內，人們觀點與觀點間的衝突或是組織績效與織織績效間的衝突，並不是顯而易見，但透過「衝突分析矩陣」，就能夠以結構性且系統化的方式，幫助使用者達到辨識「觀點與績效間的衝突」、「觀點與觀點間的衝突」與「績效與績效間的衝突」。

◆ 因果衝突鏈分析

透過衝突分析矩陣分析之後，會發現觀點與績效間存在著許多的衝突，但是，並不是每個衝突都需要解決，而是要找到關鍵的衝突，針對關鍵的衝突設法解決，才是有效的衝突解決方案。因此，本研究即是將衝突分析矩陣找到的衝突，再經過因果衝突鏈分析(CECCA)，辨識出關鍵的衝突，再根據關鍵衝突，設法找出相對應的衝突解。痛處就是指被削弱的績效因子，利用層層探索危害績效因子的原因，找出根源原因。再根據根源原因找出相對應的解決方案。

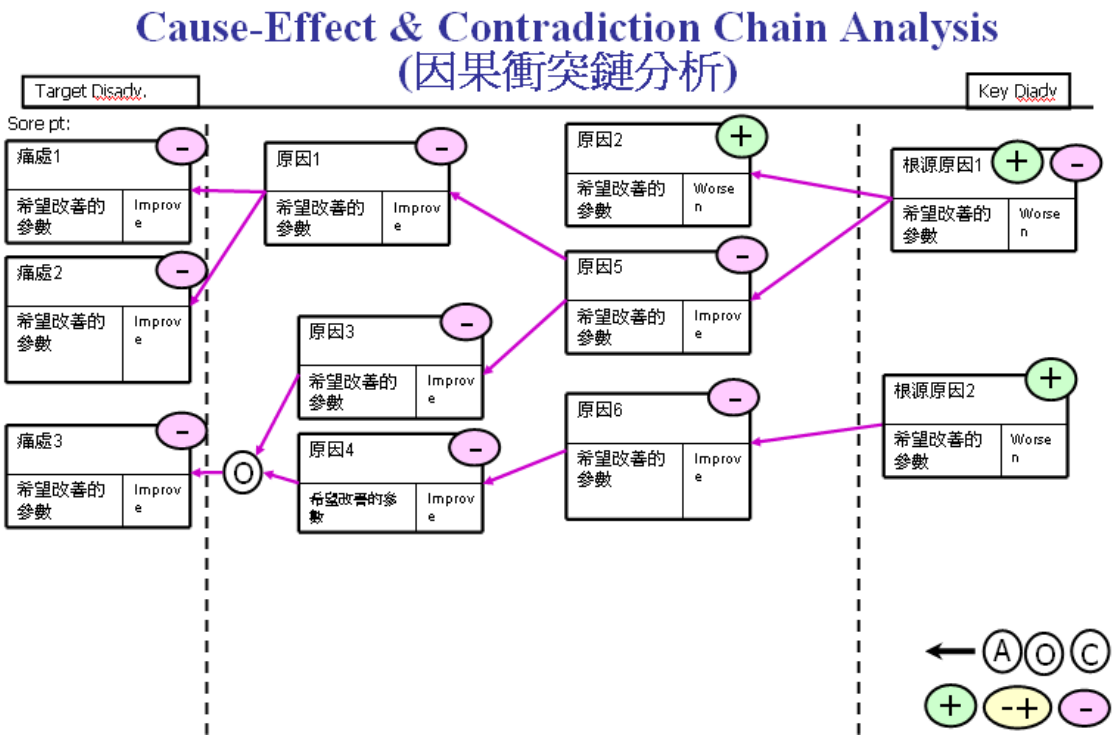

圖 3-8 因果衝突鏈分析

(4) 尋找衝突解

利用解答指引、衝突矩陣與發明原則來找到關鍵衝突的觸發解及相對應的特定解。

◆ 解答指引：觸發解

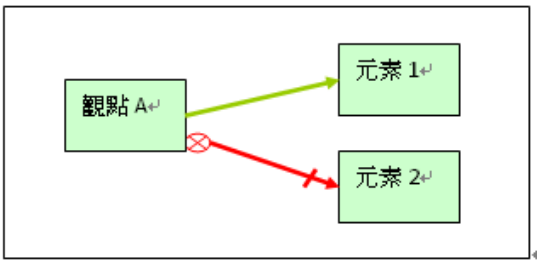

圖 3-9 解答指引

- ✧ 尋找一個替代方法來獲得【有益觀點 A】：提供或強化【有益的影響】，但不會導致【有害的影響】。
- ✧ 尋找一個替代方法來獲得【有益的影響】，但不會導致【有害的影響】。
- ✧ 特定解：透過觸發解，找到相對於問題的特定解

◆ 技術衝突：衝突矩陣與發明原則

表 3-4 關鍵衝突－衝突矩陣

Worsen / Improve	Parameter_3	
Parameter_1	發明原則 (1,2,…,n)	
Parameter_2	發明原則 (1,2,…,n)	

- ✧ 利用改善及惡化參數找出衝突矩陣相對應的發明原則，由發明原則提供觸發解。
- ✧ 特定解：透過觸發解，找到相對於問題的特定解

四、案例驗證

根據【7】個案背景，某家固網公司於某一時期製定的策略目標，增加營業收入，業務及工程單位針對如何達到策略目標，各自提出該單位想法及作法。業務部門為了達到公司的策略目標，提出增加顧客及銷售數量來達成增加營業收入的目標。工程單位則提出，以提升網路品質與服務品質的方案，進而增加顧客以達到營業收入增加的目標。

1. 問題描述

透過詢問的方式取得問題相關單位的觀點、現象及績效。問句可以透過 5W1H1G 的問題詢問方式設定。

(1) 設計需要回答的問句：如何提升營業收入？

(2) 記錄相關單位的績效，如表 4-1 所示

表 4-1 單位績效表

問題：如何增加固網公司營業收入	
單位	績效因子（組織績效目標）
工程	品質提升
業務	增加營業收入
業務、工程	員工滿意度提升
工程	增加生產力
業務、工程	加快回應速度

(3) 記錄相關單位的觀點，如表 4-2 所示

表 4-2 單位觀點訴求表

問題：如何增加固網公司營業收入		
單位	觀點：想要的訴求?	說明
業務	以提高業務員作業績效為目標	透過增加顧客的方式增加公司營收
工程	減少客戶等待安裝時間為目標	希望提高顧客滿意度，提高營收
工程	降低硬體故障次數為目標	同上
工程	維修單位維修為目標	同上
工程、業務	提供績效獎金，提供員工工作效率為目標	透過激勵方式，提高員工服務效率以增加顧客

(4) 記錄訪問時所看到、聽到的現象，如表 4-3 所示

表 4-3 現象觀察表

問題：如何增加固網公司營業收入			
單位	時間/地方	現象	說明
業務		顧客數目增加	業務員業績增加是靠顧客數增加來評定
業務		銷售數量的提升	顧客數目增加同時也帶動銷售數量的提升
業務		增加營業收入	銷售數量的提升，就可以增加營業收入
工程		安裝時間縮短	可以增加網路品質提升
工程		故障次數減少	可以增加網路品質提升
工程		修復時數縮短	可以增加網路品質提升
工程		網路品質提升	可以增加網路品質提升

問題：如何增加固網公司營業收入			
單位	時間/地方	現象	說明
工程		增加生產力	網路品質提升，維修減少則員工有更多時間，可以從事更多工作
工程、業務		獎金激勵	提升員工作業效率，可以透過獎金激勵來激發
工程、業務		員工作業效率提高	獎金激勵，員工更邁力工作
工程、業務		服務品質提升	員工的作業效率提高，更有更多時間來服務客戶
工程、業務		服務需求增加	客戶數量的增加，同時帶來更多需要服務案件
工程、業務		維護工作量加增	客戶變多，需要維護的案件也增多
		離職率增加	維護工作量增加，導致人員離職情況

2. 觀點關係分析

透過現象觀察表，建立元素與元素之間的關係，是促成或抑制關係。並區別促成或抑制關係是有益或有害，如此就完成觀點關係圖。如圖 4-1 所示

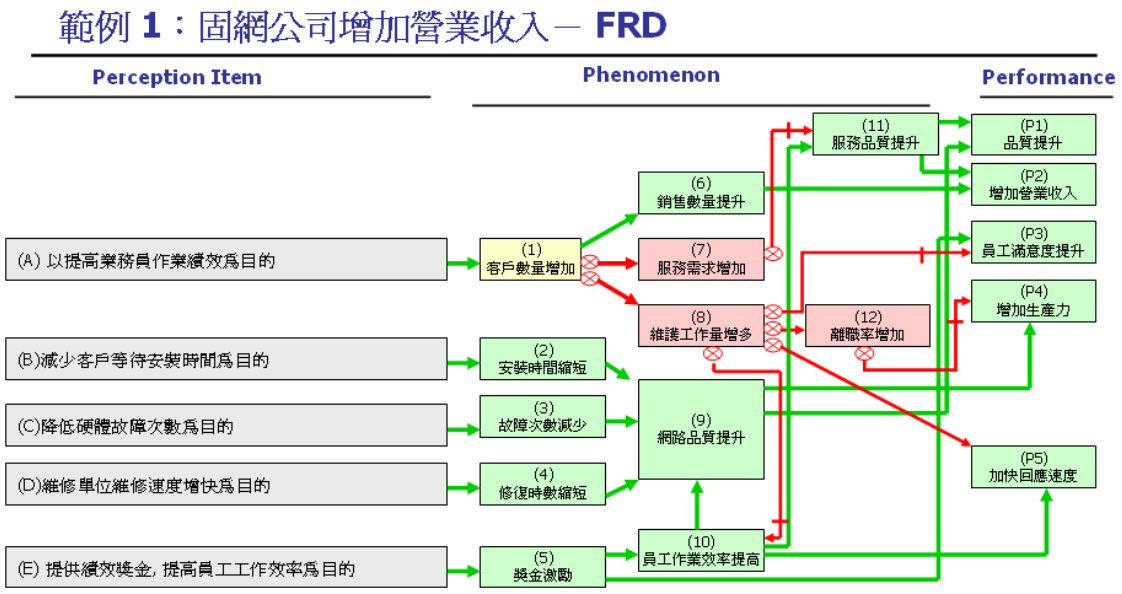

圖 4-1 固網公司增加營業收入－觀點關係圖

3. 觀點衝突分析

透過觀點關係圖，詳細計數從觀點到績效的路徑當中，抑制關係發生的個數，並填入相對應的衝突分析矩陣。如表 4-4 所示。

表 4-4 固網公司增加營業收入－衝突分析矩陣

績效 / 觀點	(P1)	(P2)	(P3)	(P4)	(P5)
A	—	+/—	—	—	—
B	+			+	
C	+			+	
D	+			+	
E	+		+		+

(1) 透過衝突分析矩陣，分析以下三型衝突：

◆ 衝突類型Ⅰ：觀點與績效間的衝突類型

以座標方式來表示(觀點,績效)間的衝突：

(A,P1) (A,P2) (A,P3) (A,P4) (A,P5)

◆ 衝突類型Ⅱ：觀點與觀點衝突

以座標方式來表示(觀點,觀點)間的衝突：

(A,B) (A,C) (A,D) (A,E)在績效 P1 有衝突

(A,E) 在績效 P3 有衝突

(A,B) (A,C) (A,D)在績效 P4 有衝突

(A,E) (D,G) 在績效 P5 有衝突

◆ 衝突類型Ⅲ：績效與績效衝突(績效,績效)

以座標方式來表示(績效,績效)間的衝突：

(P1,P2) 在觀點 A 有衝突

(P2,P3) 在觀點 A 有衝突

(P2,P4) 在觀點 A 有衝突

(P2,P5) 在觀點 A 有衝突

(2) 因果衝突鏈分析

透過衝突分析矩陣，找到問題的所有衝突點，將所有的不利因素(Disadvantage Relationship)加入有害關係列舉表(如表 4-5 所示)。再定義出希望解決的目標不利因素(Target Disadvantage)。

表 4-5 有害關係列舉表

Chk	Disadv. Relationship		T/K Disadv.
V	提高作業績效有害於品質提升	觀點→績效	Target Disadv.
V	提高作業績效有害於增加營業收入	觀點→績效	Target Disadv
V	提高作業績效有害於員工滿意度增加	觀點→績效	Target Disadv
V	提高作業績效有害於增加生產力	觀點→績效	Target Disadv
V	提高作業績效有害於快速回應速度	觀點→績效	Target Disadv
V	服務需求增加有害於服務品質提升	現象→現象	
V	客戶數量增加有害於維護工作量增加	現象→現象	
V	客戶數量增加有害於服務需求增加	現象→現象	
V	維護工作量增多有害於員工滿意度提升	現象→績效	
V	維護工作量增多有害於離職率增加	現象→現象	
V	維護工作量增多有害於快速回應速度	現象→績效	
V	維護工作量增多有害於網路品質提升	現象→現象	
V	離職率增加有害於提高生產力	現象→績效	

再透過因果衝突鏈分析找到關鍵衝突，透過目標不利因素(Target Disadvantage)一步步推導出關鍵不利因素(Key Disadvantage)。如圖 4-2 所示。

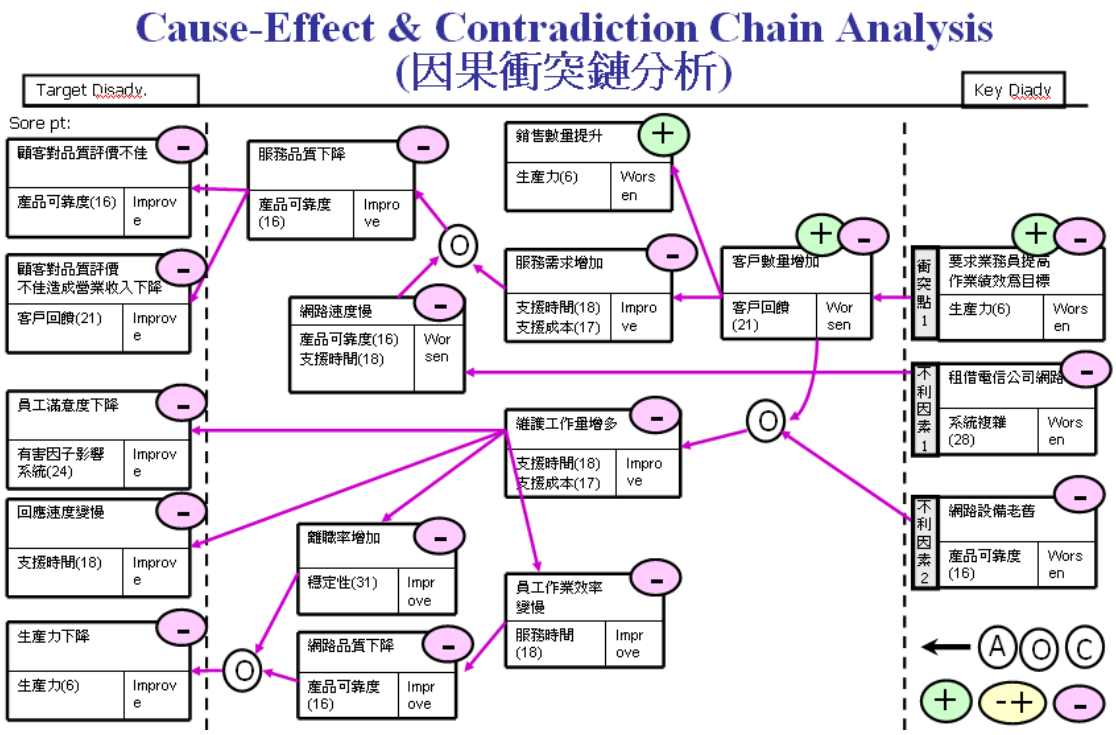

圖 4-2 固網公司增加營業收入－因果衝突鏈分析

利用因果衝突鏈分析，辨識出一項衝突，二項不利因素。關鍵衝突為觀點「要求業務員提高作業績效為目標」，不利因素為「租借電信公司網路」與「網路設備老舊」。

衝突為要求業務員提高作業績效為目標則導致服務需求因而增加，以致於「顧客對品質評價不佳」與「顧客對品質評價不佳造成營業收入下降」，但由於「要求業務員提高作業績效為目標」，可以提升客戶數，進而提升銷售數量，達到提升營收的公司目標，因此造成衝突。

由於租借電信公司網路，以至於在基礎網路頻寬會受限於電信公司頻寬的大小，頻寬太小而導致網路速度慢而影響到顧客對品質評價不佳的負面效應。網路設備老舊也是造成維護工作量增加的原因。

4. 尋找衝突解

◆ <u>不利因素 1</u>：租借電信公司網路所導致的頻寬太小，以致於影響到顧客對品質評價不佳的負面效應

特定解：租借光纖網路，以提升整體網路速度，減少因為電信公司網路速度不佳所導致的網路速度慢的問題。

◆ <u>不利因素 2</u>：網路設備老舊的問題所導致的維護工作增加

特定解：更換新款且穩定性高的設備，以降低維護的工作量。

◆ <u>衝突點 1</u> 之**解答指引**：

- 尋找一個方法來獲得【要求業務員提高作業績效為目標】：提供或強化【銷售數量提升】但不會導致【服務需求增加】與【維護工作量增多】

  特定解：使用介面簡化，即可減少服務需求的增加，即可以增加營業收入，又不會阻礙品質的提升。

- 尋找一個方法來獲得【銷售數量提升】，但不會導致【服務需求增加】與【維護工作量增多】

  特定解：網路可靠度增加，使得在顧客增加情況之下，也不會降低品質。

◆ <u>衝突點 1</u> 之**技術衝突**：衝突矩陣及發明原則

表 4-6 固網公司增加營業收入－衝突矩陣

Worsen / Improve	客戶回饋(6)
溝通流程(18)	5,6,10,12
服務能力(18)	5,6,10,12

發明原則　5：合併(Merging)

特定解：將某些同質性的服務項目進行合併以減少需要提供服務或維護的次數。

發明原則　6：多功能性(Universality)

特定解：訓練相關人員具有多工的能力，可以協助其他人員，以減緩服務需求量增加，業務處理不完的情況。

發明原則 12：消除緊張(Remove Tension)

特定解：服務需求自動化，就可以消除服務量增加所造成的緊張。

發明原則 2：抽出/分離(Take Out/Separation)

特定解：建立語音查詢服務系統，將容易且具有固定處理方式的服務抽離出來，由電話語音系統提供服務，以降低人員的服務量。

五、結論與建議

(一)結論

本研究主要是(1) 提供一種分析人們觀點的方法，將原先看不到的觀點，轉化為看得到的現象，再與績效結合，就可以觀察與評估，觀點對績效的影響，是提升或削弱了那些績效。(2) 透過本研究所提供的方法，分析不同觀點之間的關係，進而找到其中存在的衝突點。將原先看似無關的觀點，經由結構化的方法，將觀點展開成一連串相關的現象，透過現象之間的互動關係，找到觀點之間的衝突。

本研究主要貢獻為:

(1) 強化原有的觀點映射圖，引入「抑制」進一步完善其方法與應用: 觀點映射圖方法論，僅以促成(lead to)的關係，描述不同觀點之間有正面的關係，本研究方法，則採用容許多數個促成(lead to)及抑制(inhibit)的關係，描述觀點之間正面與負面的關係。透過正面與負面的關係描述，更能清楚的表示出不同觀點間所存在的衝突點。

(2) 採用觀點與績效的結合，引入績效及現象於觀點觀點映射圖，因而得以觀察出觀點與績效的關係，藉由觀點及績效的衝突辨識找到化解衝突及改善組織績效的方法。

(3) 擴大功能關係分析的應用範圍：功能關係分析 以往通常是應用在解決工程方面的問題上，卻少有研究指出將功能關係分析運用在解決管理方面的問題上。本研究便是將功能關係分析與觀點映射圖結合，應用在解決及分析管理性的問題。

(二)建議與未來研究方向

(1) 本研究在探討觀點、現象及績效之間所構成的關係時，只有描述其間的互動關係，而沒能表示互動的程度，然而如能加入系統動力學(System Dynamic)，將其間的關係，透過模擬的方式，量化觀點對績效的影響程度。因而可以辨識出觀點對績效影響的大小，容許使用者集中資源於解決重大問題點。

(2) 結合限制理論，找到核心問題，並針對策略方針是否符合組織所需進行評估與執行。限制理論認為一個系統的限制通常只存在少數的環節當中，然而卻是對組織系統的產出與效能有高度的影響而具有關鍵性的限制因素稱為核心問題。其經由一套結構化的思考流程，推論事件的因果關係，以樹狀圖具體的呈現因果關係，抽絲剝繭找到問題的核心。以三段式的思考模式擬定策略方針(一)要改變什麼：現況樹(Current Reality Tree)描述現況，找問題背後的原因(二)要改變什麼：撥雲見日圖(Evaporating Cloud)或稱為解決衝突系統圖(Conflict Resolution Diagram)以及未來樹，許多瓶頸無法立即對症下藥，是由於必要條件間存在有矛盾與衝突，因此，解決衝突系統圖來分析矛盾所在。未來樹則是用來測試欲採取的方案是否能促成組織最終所要的結果。(三)如何改變：要件樹(prerequisite Tree)與轉變樹(Transition Tree)，確認方案應具備的所有要件，以及實際執行之細項。

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Using TRIZ to Solve Lead Frame Delamination in Component Package

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ABSTRACT

Delamination of package for lead frame type is an important reliability problem.Joint Electron Device Engineering Council (J-STD-020D) Moisture Sensitivity Level 3 of reliability test is for customer or surface-mount technology (SMT) to apply at board level or in module assembly. This implies that the floor life of Level 3 components can be guaranteed for 168 h under a 30^0C and 60% RH production environment after opening a dry pack.

In this study, applied function attribute analysis of TRIZ problem-define methods to research clamping preheating, transfer molding, open mold and ejection that brought harmful or insufficient functions in the molding process. The integration of contradiction matrix, 39 engineering parameter, 40 inventive principles, and separation strategies, substance-field analysis 76 standard solutions generating concepts and applies to the lead frame package type.

At first, to verify IC whether it is delaminated after conceptual design, then base on JEDEC-MSL-3 test condition to confirm whether it pass MSL-3. Finally, to estimate each stage of contribute which can reduce delamination. The research results were as bellows:

1. The concepts design of these process relate to the Inventive Principles which includes 39.Inert Atmosphere, 24.Intermediary, 3.Local Quality, 14. Spheroidality- Curvature, 30.Flexible shells and thin films, separation strategies in space, 76 standard solutions of substance-field analysis.

2. The package component of SOT223 passes JEDEC-MSL-3.

3. The idea were effective to improve delamination of package component for lead frame.

Keywords：TRIZ、Package、Delamination、Inventive Principles

應用萃智工具解決封裝元件導線架脫層問題

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Abstract

脫層(Delamination)在導線架型封裝元件是重要的可靠度問題。J-STD-020D 的濕度敏感度水準-3 等級(Moisture Sensitivity Level 3，MSL-3)的可靠度測試是為了客戶或表面黏著廠，應用於電路面板或組裝環境的考量，量測單位要求通過 MSL-3 的半導體元件在防濕包裝拆封後，可以適應在 300C /60% RH/168 小時生產環境。

本研究是應用 TRIZ 理論中，定義問題的功能屬性分析法，來探討模壓過程的合模預熱、注膠固化、開模頂出所產生有害或不足的功能。整合矛盾矩陣與發明原則及分離原則、物質-場分析的 76 個標準解所產生的概念，將概念具體化並應用在導線架封裝型態上。首先，確認目前改良後的產品是否有脫層，再根據前 JEDEC-MSL-3 做為測試條件，來確認是否通過 MSL-3；最後，則評估各個改良階段對於減少脫層的貢獻度。研究成果如下:

1. 在概念化設計中應用的發明原則 39.鈍性環境、24.中介物、3.局部品質、14.曲度、30.彈性薄膜、分離原則的空間分離、物質-場分析的 76 個標準解。

2. SOT223 封裝元件通過 JEDEC-MSL-3。

3. 有效的改善導線型封裝元件脫層現象。

關鍵字：萃智(TRIZ)、封裝(Assembly)，脫層，發明原則，萃思

1. 緒論

脫層(Delamination)在導線架型封裝元件中是重要的可靠度問題，隨著電路板的接合方式演進，因熱膨脹係數(Coefficient of Temperature Expansion，CTE)產生熱應力以及吸濕效應，使得封裝脫層問題一直是所關切的議題，而此脫層問題無法重工(Rework)，如果被懷疑是脫層必須被召回那麼 IC 製造商可能遭受到嚴重的成本損失。J-STD-020D 的濕度敏感度水準-3 等級(Moisture Sensitivity Level 3，MSL-3)可靠度測試是為了客戶或表面黏著廠的製程環境考量，這表示通過 MSL-3 的半導體元件在防濕包裝(Dry packing)拆封後，保證在 30 0C /60% RH/168 小時的生產環境內不受濕氣的侵入，解決封裝脫層問題成為 IC 設計公司以及封裝產業如何面對客戶元件承認的一大挑戰。本研究使用 TRIZ 模式化問題去除系統中的矛盾，應用技術矛盾、物理矛盾、物質－場分析的技巧以解決問題。

愛因斯坦曾經說過:「你的解答與問題的觀點不會停留在同一層次」。有鑑於此，本論文之研究目的透過 TRIZ 較有系統之流程分析方法，探討封裝模壓製程中那些衝突是造成膠體結合力的降低並且提出可行方案，進而提高

目前導線架型封裝元件的結合力，最後則以個案方式確認改良成效，以便能通過的 J-STD-020D/MSL-3 的嚴峻考驗。.

2. 文獻探討

本章中主要探討封裝製程產生的脫層問題及 TRIZ 理論的發明原則、矛盾矩陣(Contradiction Matrix)、技術矛盾（Technical Contradiction）物理矛盾(Physical Contradictions)物質場分析(Substance-Field **analysis)**等相關文獻及其應用方法來加以探討。

2.1 脫層問題

脫層是指在不同材料的介面間出現縫隙或者經過高溫迴焊後所造成的材料間隔，導線架型封裝IC已發展迄今近已相當成熟，直到表面黏著技術(**Surface Mount Technology**，SMT)逐漸普及，再加上表面黏著元件(**Surface Mount Devices**，SMD)比插件式元件(**Pin-Through-Hole)**更容易發生脫層現象，更嚴重的將會造成膠體裂痕，即所謂的爆米花現象（Popcorn Cracking Phenomena）其原因在於銲接作業一定要發生在與SMD元件同一面的板面上；相對於插件式元件，銲接作業發生在基板的下面，因而將元件遮蔽隔離了高熱的銲料。

封裝膠體的脫層原因為吸收到內部的潮氣以及熱膨脹係數不同。當封裝元件其固定到PCB板上時，回流焊快速加熱將在內部形成壓力。這種高速膨脹，取決於不同封裝結構材料的熱膨脹係數速率不同，可能產生封裝所不能承受的壓力，目前封裝元件成型品出貨，採用真空包裝以及使用前烘烤以對抗成型品的吸濕效應；再者，加強其膠體的結合力以對抗不同封裝結構材料的熱膨脹係數，以避免在製程中產生的脫層現象。

2.2 萃智(TRIZ)相關理論與半導體上應用

TRIZ 是一種系統化的方法論其目的是：透過有系統、有規則的方法來解決創新過程中所可能碰到的種種問題並且努力於澄清和強調系統中存在的矛盾。Altshuller 認為每一個具有創意的專利，基本上都是在解決「創新性」的問題，所謂「創新性」的問題，是指系統內包含至少一衝

突的問題，也就是他所謂的「矛盾 Contradictions」或「瓶頸 Bottleneck」。因此 **TRIZ** 提供一套系統化的矛盾解決方式方法，在解決系統問題的過程中，必須清楚的瞭解這個問題的矛盾點是技術上的衝突；還是物理上的衝突，並利用 40 個創新的原理找出其中可能解決此矛盾點的原理，利用這些創新原理及類比思考的方式來提供我們解決矛盾，所謂的類比思考即是:『通過識別事物之間的異同，善於利用外物來起發思維予以啟示，從而捕捉富有啟發性的靈感，產生有用而且可行的創造性構想』，並得出解決問題的方案。然而物質－場分析是 **TRIZ** 理論中重要的問題描述和分析工具之一，用以建立與已經存在的系統或新技術系統問題相聯繫的功能模型，利用一個簡單的圖解模型用以描述最初的情況以及解決問題過程的工具。

3. 研究方法與研究步驟

本研究以 **TRIZ** 理論的功能屬性分析(**FAA**，**Function and Attribute Analysis)**定義模壓製程中有那些有害或不足的功能會影響封裝膠體的結合力，並依據每個階段問題描述找出技術上的衝突參數，更進一步推論是否有物理上的衝突並找出相對應的發明原則，另外也運用物質**-**場分析法，建立起物質和場的關係，找尋適合的標準解，最後結合這三種 **TRIZ** 解決問題的觸發解，增加推論過程的嚴謹度並且能夠很明確的了解改良方向，才能有效改善脫層問題。最後，以 **SOT-223** 的封裝型態做為個案討論與分析。

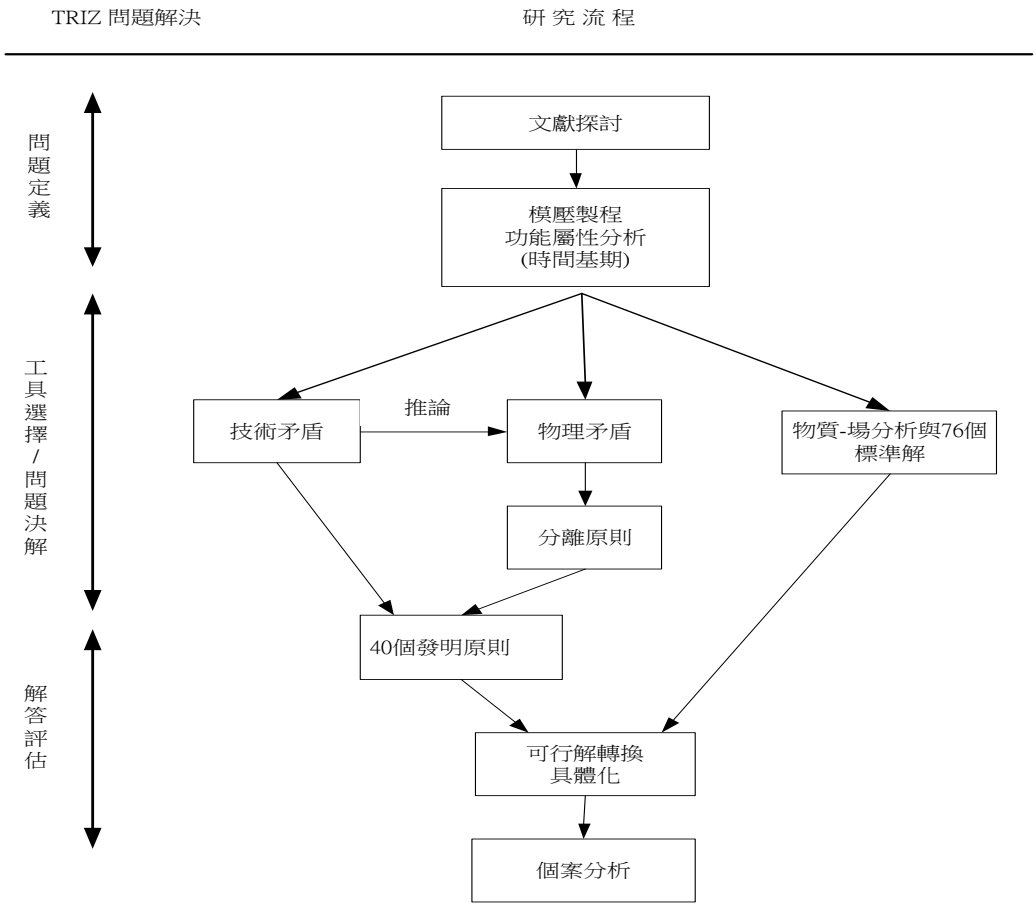

圖1 研究流程

圖 1 研究流程

4. 研究方法與研究步驟

一般模壓機及模具的構造，而模壓機的功用是利用模壓轉注的方式把經過焊線的半成品包覆起來。圖 2.顯示打線完半成品之導線架置於模穴，此時導線架與模膠材料(Molding Compound)一同投入預熱，同時閉合模具；當膠粒達到最佳黏度時，開始擠膠並注入膠流道 (Runner)，再由注膠口(Gate)填入模穴(Cavity)形成膠體，同時在模內固化處理(Post Mold Curing，PMC)後，開模後由頂針(Ejector Pin)頂起成型品。

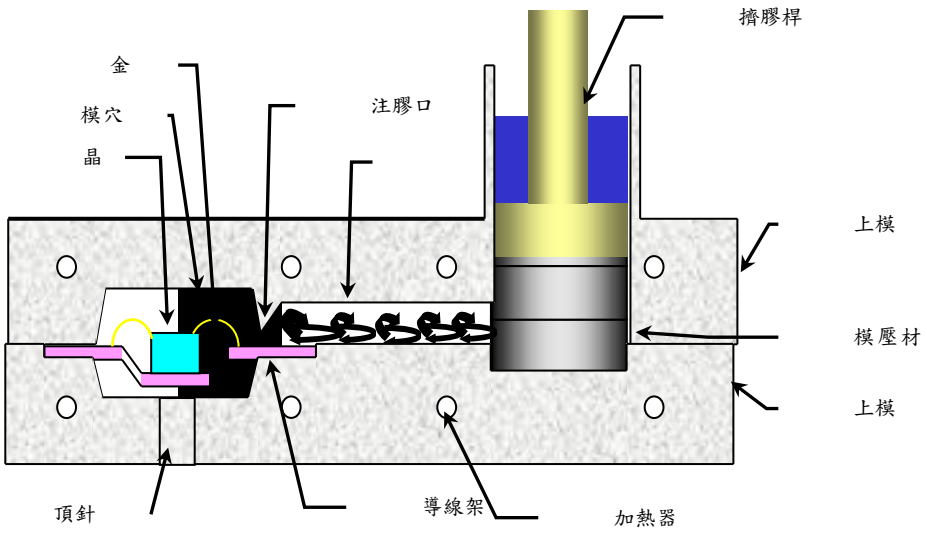

圖 2 模壓轉注

本研究利用功能屬性分析考慮時間起點(Time-Base)的觀念，將模壓製程區分為合模預熱、注膠固化、開模頂出階段；對每個階段進行功能屬性分析，並且消除有害的功能，提高不足的功能。圖 3 一個完整的壓模製程概念流程，並且考量時間變異，檢視製程中影響膠體結合力的原因。

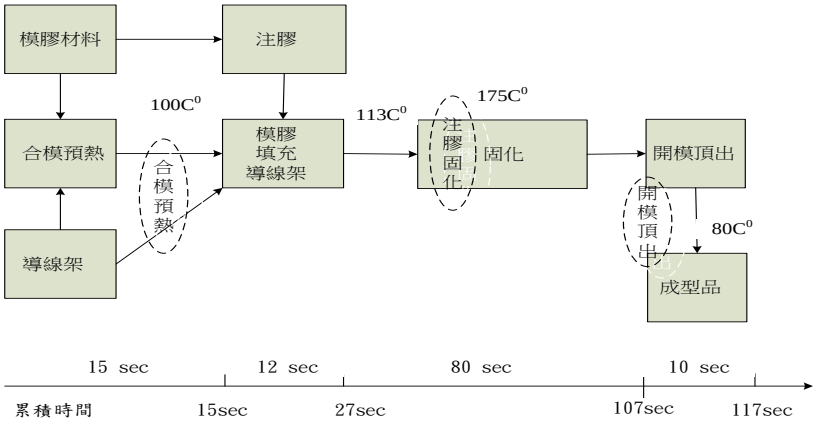

圖 3 一個完整的壓模製程概念流程

合模預熱是將半成品與模膠一同投入預熱，同時閉合模具其中加熱的功能須由模具溫度來完成模膠預熱，使用模具當熱源時，因為模具直接與導線架接觸且受到外在環境-空氣影響，空氣與加熱兩者間的作用(L)造成導線架氧化的有害功能，而產生導線架與模膠的附著力不足，如圖 4。

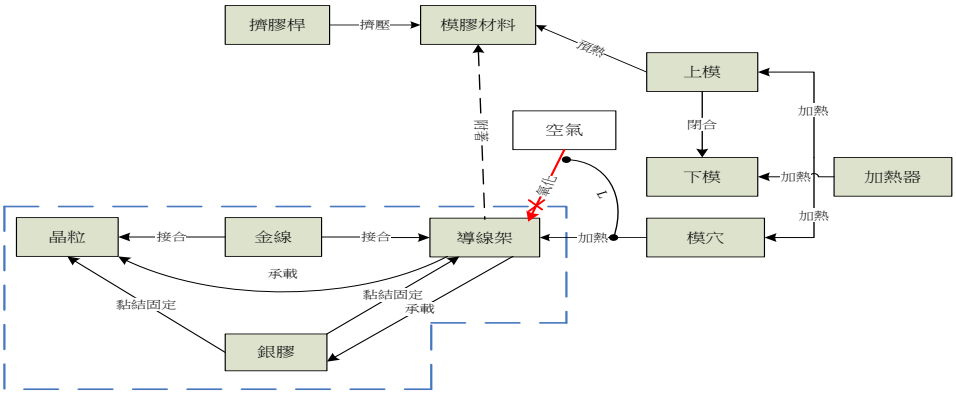

圖 4 合模預熱功能屬性分析

圖 5 注膠固化則是將模膠加熱至最佳黏度時(即玻璃態改變至橡膠態)，擠膠桿對軟化的模膠開始加壓，在注膠固化過程中，模膠在轉脆溫度 1130C 以下有較低的熱膨脹係數；而在 Tg 以上則有一較高的熱膨脹係，使得模膠與元件間因熱膨脹係數的差異而造成一個有害的功能。

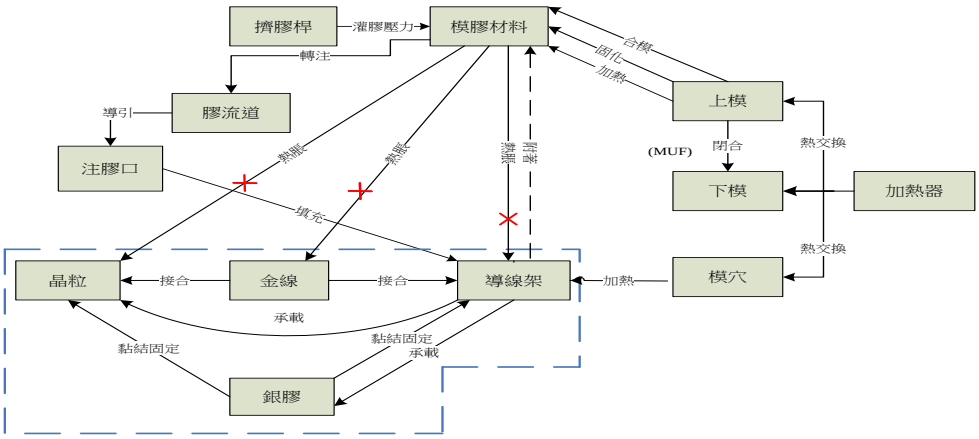

圖 5 注膠固化功能屬性分析

圖 **6** 開模頂出部份，由於成型品在模穴內高溫高壓的環境下完成包覆晶片，產生黏著效應的有害功能；另外成型品在模穴內完成封膠後，需利用頂針(ejector pin)頂起成型品並取出，但卻會造成封裝元件破裂之有害功能。

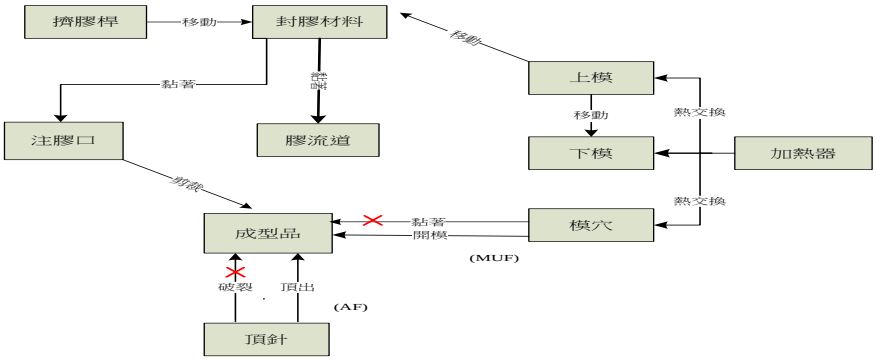

圖 6 開模頂出功能屬性分析

4.1 技術、物理矛盾推論與物質-場分析方法找出可行解

本研究運用根源矛盾分析(Root Contradiction Analysis)的方式，不停反覆的訊問自己是否為真正的問題所在，藉由此一系統性的抽絲剝繭，找出根本原因。一般而言，越底層的參數越能夠達到解決問題的根本。當選擇的衝突參數確定後，嘗試著轉換成物理上的矛盾，如果有物理矛盾，則利用分離原則尋找合適的創新原理；其次，應用物質-場分析方法建立現有系統的物質－場模型，然後選擇相應的第一、二、三類標準解法。

4.1.1 合模預熱技術、物理矛盾推論及物質-場分析

合模預熱過程中，加熱是主要有用且必要的功能，但是會造成導線架氧化而產生模膠與導線架的附著力不足。經由其描述我們從表 1 循序漸進的找出改善與惡化參數，模膠附著力不足是因為導線架氧化，而造氧化的原因為合模預熱的溫度太高，因此選擇 **27**、**30**、**31**，**17** 為改善參數；在選擇惡化參數方面，則是改善導線架氧化會遇到什麼阻礙？模具加熱不足，模膠難以達到熔融狀，流動性不佳等因素，而影響產品生產週期，所以惡化參數為 39.；最後我們選擇合適的改善參數 31.有害的副作用，惡化參數 39.生產力，其技術矛盾的描述：31.有害的副作用(導線架氧化)減少，但 **39.**生產力(模膠預熱)阻礙了導線架氧化的改善。使用矛盾矩陣所得到的發明原理為：**22.** 有害變成有利 **35.**參數改變 **18.**機械振動 **39.**鈍性環境。

表 1 合模預熱原因分析

為什麼	答案	改善參數	惡化參數(阻礙因素)
為什麼合模預熱會模膠附著力不足？	導線架氧化	27.可靠度/30.物體有害因素/31.有害的副作用	
造成導線架氧化原因?	溫度高	17.溫度	
為什麼會溫度高？	模膠預熱		39.生產力

轉換為物理衝突可描述為：溫度增加，有害的副作用(導線架氧化)增加；溫度(C)減少，生產力 (模膠預熱不足-膠體空洞/氣泡/金線偏移)減少，因為物理矛盾參數-溫度在不同的地方分別需要高溫與低溫與，即可應用空間

分離中所對應的發明原理，選擇解決方案**: 1.**分割 **24.**中介物整理技術與物理上的矛盾所得到的發明原理如圖**7**。

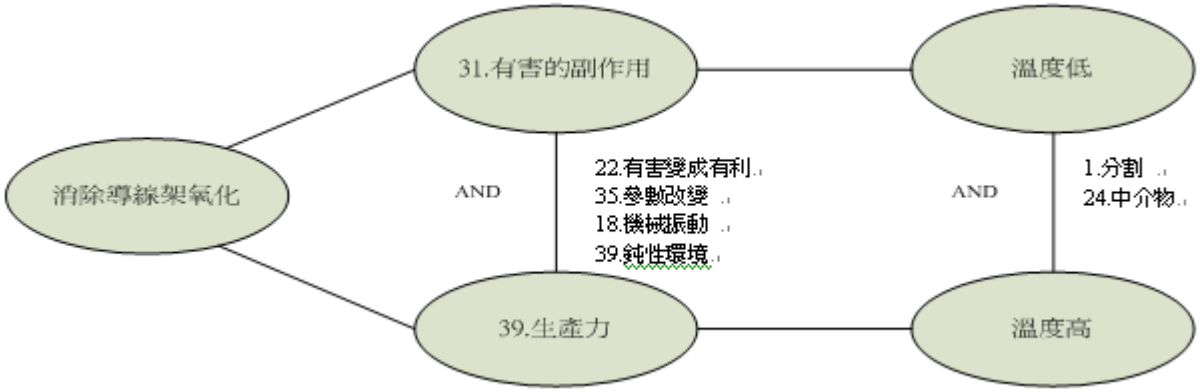

圖 7 消除導線架氧化的發明原則

在合模預熱之物質-場分析部份:物質 S1、物質 S2、物質 S3 分別是模穴、導線架與空氣，而作用場是模穴給予的加熱以及空氣的氧化作用，根據 TRIZ 的 76 個標準解所提到的第一類型：不改變或少量改變來改良系統，其原則 1.2.3：有害效應是一種場引起的，則引入物質 S3 吸收有害效應，因此如圖 8 加入氮氣以改善氧化問題。

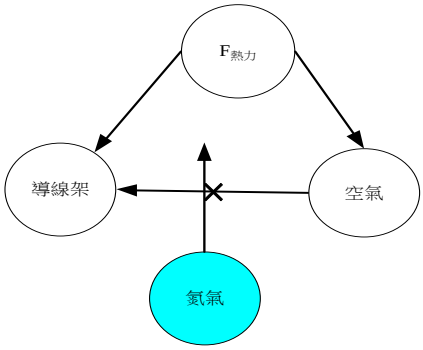

圖 8 加入氮氣以改善氧化問題

4.1.2 注膠固化技術、物理矛盾推論及物質-場分析

在注膠固化中預熱完成的模膠材料從固態轉為溶融狀，此時有較低的熱膨脹係數、低黏度、流動性佳的特性，溶融狀的模膠材料流經注膠口直到完全包覆後開始加溫固化，此時有較高熱膨脹係數。表 2 循序漸進找出改善與惡化參數，最後我們選擇合適的改善參數 30.物體上有害因素，惡化參數 29.製造精確度，其技術矛盾的描述：30.物體上有害因素**(**材料熱應力**)**減少，但 **29.**製造精確度**(**產品特性**)**阻礙了材料特性的改變。使用矛盾矩陣所得到的原理為**: 26.**複製 **28.**置換機械系統 **10.**預先作用 **18.**機械振動。

表 2 注膠固化原因分析

為什麼	答案	改善參數	惡化參數(阻礙因素)
為什麼固化造成脫層？	熱應力以及收縮率差異	08 固定體積/27.可靠度	
造成熱應力以及收縮率的原因？	晶粒、金線、導線架與模膠的熱膨脹差異	30.物體上有害因素	
改善熱膨脹係數會遇到什麼阻礙？	產品特性		29.製造精確度

轉換為物理衝突可描述為：溫度高，物體上有害因素(材料熱應力)增加；溫度低，製造精確度減少(固化不完全)，核心參數-溫度在不同的地方分別需要高溫與低溫，即可應用空間分離中所對應的發明原理，選擇解決方案: 3.局部品質 14.曲度，整理技術與物理上的矛盾所得到的發明原理如圖 9。

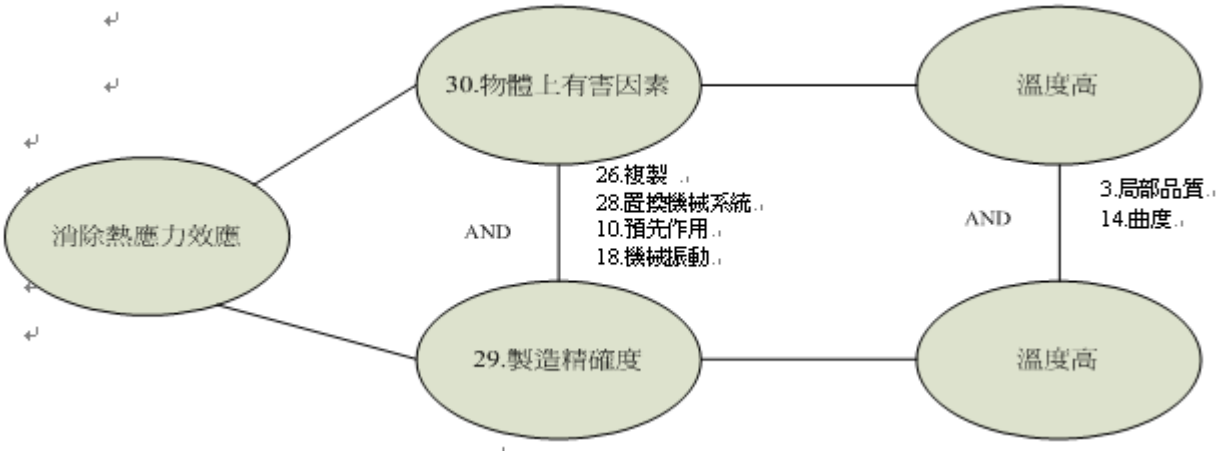

圖 9 消除熱應力的發明原則

注膠固化之物質-場分析部份:物質 S1 模膠材料，物質 S2 導線架，而熱膨脹為作用場 F，根據 TRIZ 的標準方法所提到的第二類改變系統來改良，其中原則 2.2.3：S2 改變為允許氣體或液體通過的多孔或具有毛細孔的材料，如圖 11 改變導線架的樣式

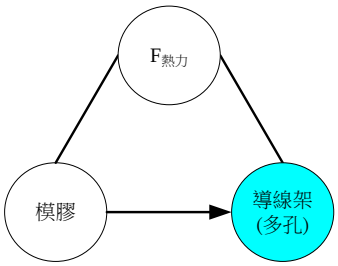

圖 10 改變導線架的樣式

4.1.3 開模頂出化技術、物理矛盾推論及物質-場分析

在模具開啟方面：其最主要的矛盾即為必須開啟模具將成品取出，但易造成脫層、破裂、缺角的有害功能。從表 3 我們選擇合適的改善參數 11.張力/壓力，惡化參數 8.固定體積。其技術矛盾的描述：11.張力/壓力減少(合模壓力)，造成 8.固定件體積惡化(膠體溢膠)。使用矛盾矩陣所得到的原理為：**35.**參數改變 **24.**中介物

表 3 模具開啟原因分析

為什麼	答案	改善參數	惡化參數(阻礙原因)
為什麼模具開啟會造成脫層、破裂、缺角	模膠沾黏模具	30.物體上有害因素/31.有害的副作用/14.強度	
造成模膠沾黏模具的原因？	合模壓力	11.張力/壓力	
改善合模壓力有什麼阻礙？	膠體溢膠		8.固定件體積

物理衝突可描述為：黏著力高，晶片、導線架，金線及模膠附著力增加（11.張力/壓力）；黏著力低，膠體(模具)殘屑減少：黏著力既應該高又應該低，物理衝突的核心參數-黏著力在不同的地方分別需要黏著力高與低，即可應用空間分離中所對應的創新原理，選擇空間分離解決方案：24.中介物，整理技術與物理上的矛盾所得到的發明原理如圖 11。

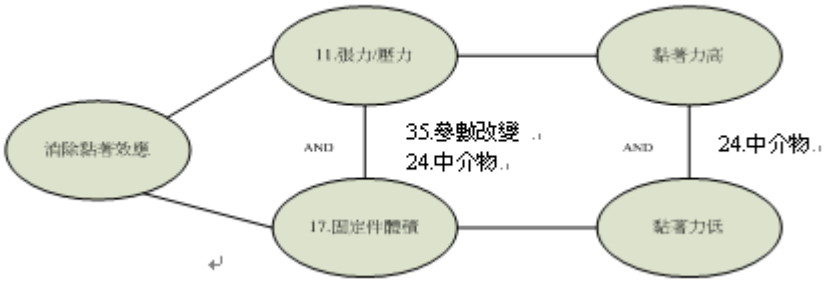

圖 11 消除黏著效應

頂出機構方面：在頂出時容易造成成型品的脫層、破裂、缺角。經由表 3 選擇合適的改善參數 30.物體上有害因素，惡化參數 39 生產力。使用矛盾矩陣所得到的原理為：22.轉有害變成有利 35.參數改變 13. 逆轉 24.中介物。

表 4 頂針頂出原因分析

為什麼	答案	改善參數	惡化參數(阻礙因素)
為什麼會造成成型品脫層、破裂、缺角？	頂針頂出	31.有害的副作用/30.物體上有害因素	
造成頂針頂出的原因？	模具與膠體黏合造成成型品取出困難		39.生產力

物理衝突可描述為：頂針力量大，會造成型品破裂、缺角；力量小，成型品不容易取出：核心參數－力量在不同的地方分別需要力量大與小，即可應用空間分離中所對應的創新原理，選擇合適解決方案: 3.局部品質 30 .彈性薄膜。整理技術與物理上的矛盾所得到的發明原理如圖 12。

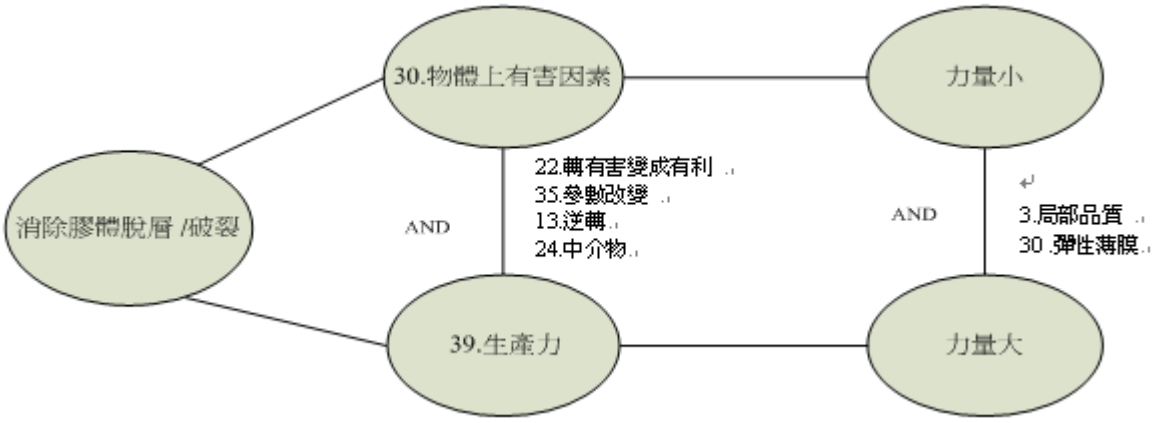

圖 12 消除膠體脫層/破裂

在模具開啟方面之物質-場分析：物質 1 與物質 2 分別是模具與成型品，在開模時因黏著效應產生一個作用場-黏著，根據 TRIZ 的標準方法所提到的第一類不改變或少量改變來改良系統，其中原則 1.2.3：有害效應是一種場引起的，則引入物質 S3 吸收有害效應，圖 13 則引入脫模劑(物質 3)來減少黏力(機械力)，另一個原則 1.1.3：如果修改物質-場有困難，可導入一個不受限制的附加物到其中一個物質外部，圖 14 則是在模具表面加入鍍層以減少模具的粗糙度以及增加模具的滑動性。

在頂出機構方面，物質 1 與物質 2 分別是頂針和成型品，而其中間作用的場即為頂針向成型品所施加的一個力，根據 TRIZ 的標準方法所提到的第一類不改變或少量改變來改良系統與第二類改變系統來改良，其中原則 1.2.4：S1 及 S2 必須處於接觸狀態則增加場 F2 使之抵消 F1 的影響，或者得到一個附加的有用效應，所以加入一個場以抵消 F 的有害效，如圖 15；圖 16 則是 2.2.4：使系統更具有柔性或適應性，所以加入彈簧使系統更具有柔性。

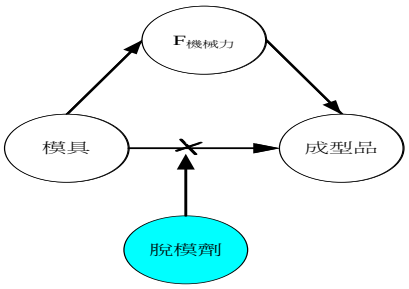

圖 13 引入脫模劑

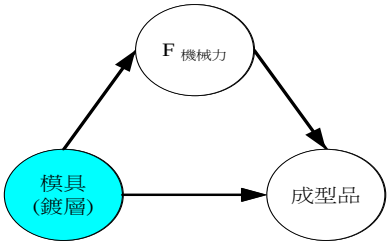

圖 14 模具表面加入鍍層

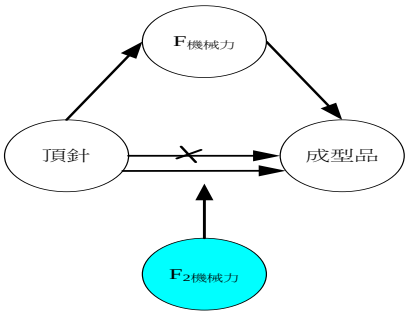

圖 15 加入一個場以抵消 F

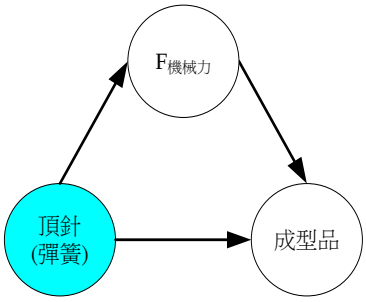

圖 16 系統更具有柔性或適應性-彈簧

4.2 彙整技術、物理矛盾推論與物質-場分析方法之可行解

根據 TRIZ 的矛盾矩陣得到的原理以及物質-場分析的標準解，整理表 5 整合可行解的意函。

表 5 彙整可行解

階 段	技術矛盾	物理矛盾	物質-場分析	應用說明
合模預熱	22.有害變成有利 35.參數改變 18.機械振動 39.鈍性環境	1.分割 24.中介物	1.2.3 有害效應是一種場引起的，則引入物質 S3 吸收有害效應。	結合 24.中介物與標準解 1.2.3 的概念，利用目前封裝廠的現有資源-氮氣來產生 39.鈍性環境改善導線架氧化。
注膠固化	26.複製 28.置換機械系統 10.預先作用 18.機械振動	3.局部品質 14.曲度	2.2.3 將 S2 改變為允許氣體或液體通過的多孔或具有毛細孔的料。	預先將導線架作曲度或多孔設計，使膠流流入導線架內部以抵抗熱應力的拉扯，另暫不考慮發明原理 28、26 因為此概念需對模壓機台做翻新設計會產生相當多的改善成本，其次在 18.機械振動改良則會引起膠流在導線架的流動性不佳故不於考慮。
開模頂出	24.中介物 35.參數改變 (模具開啟)	24.中介物	1.1.3 如果修改物質-場有困難，可導入一個不受限制的附加物到其中一個物質外部，此附加物可暫時或永久來解決問題。 1.2.3 有害效應是一種場引起的，則引入物質 S3 吸收	在模具(物質)上添加一個附加物(24 中介物)使其降低模膠與模具間的黏性，另外減少開模壓力(35.參數改變)，雖然可以減少脫層 發生，但同時膠體與上模具無法有效的脫模。

			有害效應。	
	22.有害變成有利 35.參數改變 13.逆轉 24.中介物 (頂針頂出)	3.局部品質 30.彈性薄膜	1.2.4 在一個系統中，有用、有害效應同時存在，但 S1 及 S2 必須處於接觸狀態，增加場 F_2 使之抵消 F_1 的影響，或得到一個附加的有用效應。 2.2.4 使系統更具有柔性或適應，常見的方式是由鋼性材料變為一個連接，再到連續柔性的系統。	頂針是有用、有害效應同時存在，因此在頂針與膠體間引入一軟性的物質或場(24.中介物/30.彈性薄膜)以消除硬性碰撞的有害效應，另外由於每個膠體與模具的黏性強度並不一致，因此改變力量大小（35.參數改變）並不能全面性的改善頂針頂出所造成型品無法取出或破裂，其次 發明原理 22、13 需要將頂出機構做翻新設計，考量成本效益問題，故不考慮

4.3 概念化設計

合模預熱創新概念中，整合技術矛盾之創新原理 39.鈍性環境與 **76** 個標準方法之 1.1.3 以及 24.中介物，提出一個加入氮氣的新概念。圖 18 在導線架放置在模具後經由投膠口通入氮氣，其目的在於用氮氣隔絕氧氣的作用以減緩溫度變化的氧化作用，最後再放入模膠預熱。

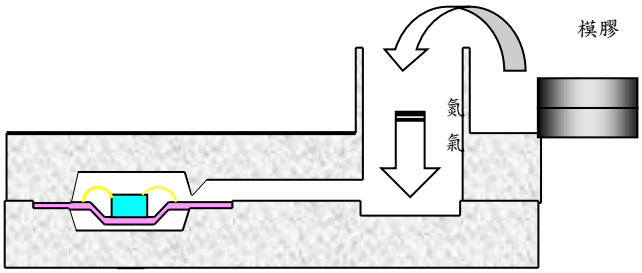

圖 17 投膠口通入氮氣

在注膠固化創新概念中，以空間分離之創新原理 14.曲度，以及 **76** 個標準方法之 2.2.3 導線架(S2)改變多孔材料的概念，提出如圖 **18-19** 導線架創新設計 預先將膠流導入到物體(10.預先作用)；除此之外，不同的導線架型封裝型態或者不同的脫層位置，也都同樣可應用此創新的設計。

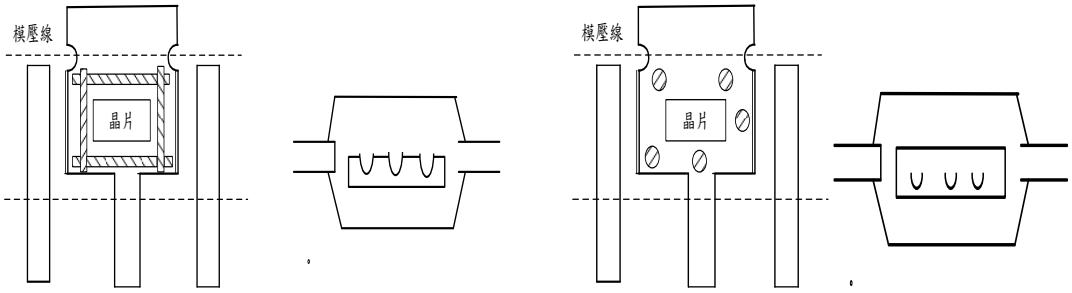

圖 18 導線架-曲度　　圖 19 導線架-多孔

在開模頂出創新概念中，開模部份以技術矛盾之創新原理 24 中介物的概念，在模具表面增加鍍層以降低模膠對模具之黏著力。

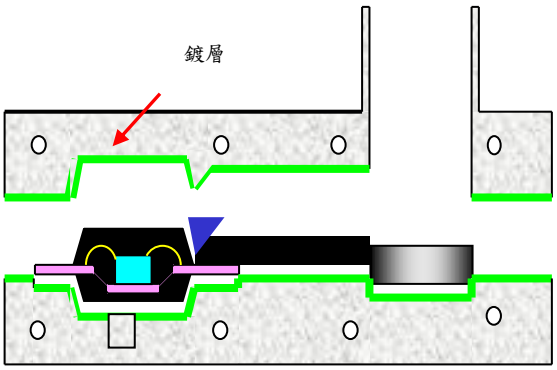

圖 20 模具鍍層

在頂出方面，則以空間分離之創新原理 30.彈性薄膜的概念，在頂針上增加一層耐高溫的薄膜，使頂針與膠體接觸時，能吸收力量過大的衝擊，與硬性碰撞所造的損害。

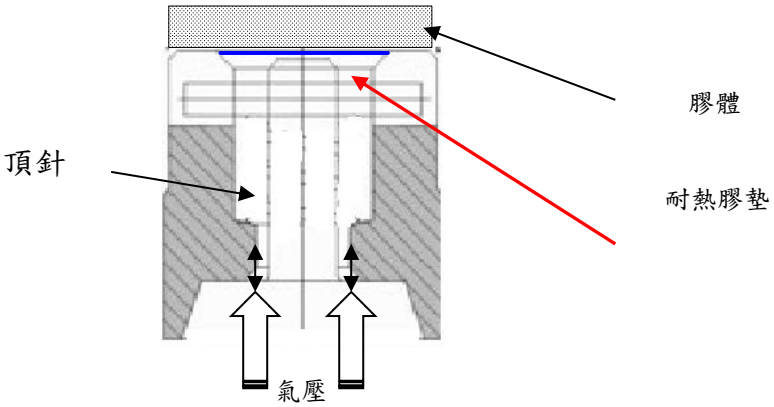

圖 21 頂針上增加一層耐高溫的薄膜

5. 財務效益

財務效益分析如下，每個月會經過 SOT223 封裝元件的產量有 2KK(110 lots)，不良的成本為 USD$0.08/IC，若採用改善的方法，加入氮氣，則氮氣成本為 USD$1000/年。

Before the improvement		After the improvement	
Item	Cost (monthly)	Item	Cost (一次性)
Loss due to delimination. (Loss rate 0.5%)	20KK *0.5%*USD $ 0.08= 8,000	molding compound pre-heating device (to add N2)	USD $ 2,5000
Precondition Test (reliability monitor by lots)	110 Lots *USD $ 50=5,500	Design new lead frame and new ejector pin	USD $ 2,0000
electronic tests (sampling for testing monitor)	500k* USD $ 0.005=2,500	Cavity Plating	USD $ 1,0000
Total savings/mo.	USD $ 16,000	Total cost (Over 5 year depreciation)	USD $ 55,000

在尚未改善前，因脫層而產生的成本有 USD$8,000(以損失率 0.5%來估算)，事先測試的成本為 USD$5,500，電子測試成本為 USD$2,500，每月成本總共需花費 USD$16,000。

但是若採用改善後的方法，成本只需花費 USD$55000，且是一次性的成本。因此由此可以計算出其成本效益為(16,000*12)-(55,000/5)-1,000 = 180,000/年，每年可以為公司節省 180,000 美金。

6. 結論與建議

利用 TRIZ 的功能屬性分析配合技術矛盾推論其背後的物理矛盾以及物質－場分析方法，依照其步驟一步一步的推進，得到了一些創新的方向，配合目前的市場需求，針對在模壓製程之合模預熱、注膠固化與開模頂出，進行導線架型封裝元件脫層的改善之設計，得到以下之結論：

1. 本研究發現技術矛盾的存在往往隱含著物理矛盾的存在，有時物理矛盾的解決比技術矛盾的解決更容易且更明確，並整合技術矛盾推論物理矛盾過程及物質-場分析方法的觸發解，能更清楚了解創新的方向與意涵。
2. 在導線架型封裝元件脫層的改善之設計，提出模壓預熱加入氮氣、導線架的曲度設計、頂針上端增加耐熱膠墊以及頂針機構增加彈簧等改善。
3. 在設計概念轉換為原型設計後，實際應用在 **SOT223** 封裝元件並進行 **JEDEC-020D-MSL-3** 高溫高濕測試，其結果無發現任何脫層現象**(**紅色為脫層**)**，這顯示此改善能有效的克服半導體元件在防濕包裝拆封後，保證可適應在 **30 0C /60% RH/168** 小時的生產環境，如圖 **22-23**。

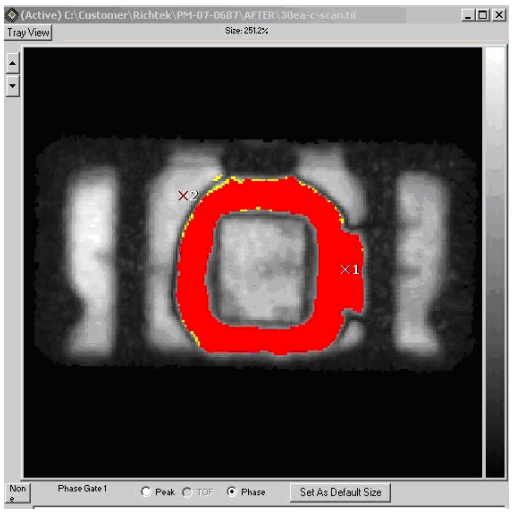

圖 22 製程改良前-脫層

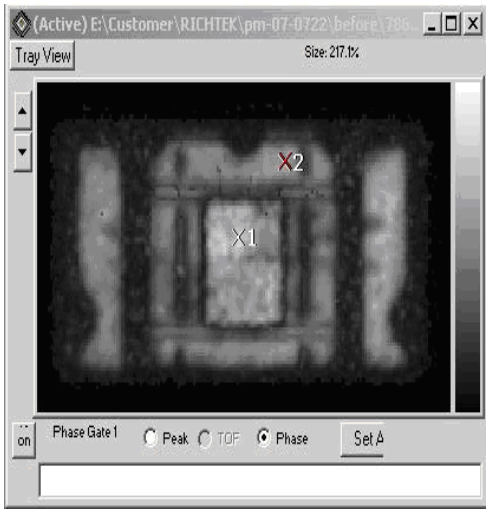

圖 23 製程改良後-無脫層

4. 導線架的曲度設計能有效提升膠體結合力以對抗因溫度所產生的熱應力，其次為模具鍍層及頂針附加軟膠墊，而合模預熱加入氮氣則對導腳部位的脫層有些許的幫助。
5. TRIZ 設計法所扮演的是產生設計概念與概念具體化的部分，如果在設計概念具體化後、再用田口法或最佳化設計得到一組最佳參數、將產品最佳化，則製程品質會更加完善。

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