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Table of Contents

Forward

The organizers of the International Conference on Systematic Innovation (ICSI) are pleased to present the proceedings of the conference, which includes 72 papers/presentations out of more than 80 submissions. Authors are from 14 countries.

This conference is organized by The Society of Systematic Innovation, the University of Cincinnati, the China Institute of Innovation, and the Journal of Systematic Innovation (IJoSI) which is an affiliation of the Society. 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 wait 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 a special or general issue of the IJoSI, or another peer-reviewed journal.

The organizers are indebted to a number of people who gave their time to make the conference a reality and to publish these proceedings. 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.

The conference is intended to be annual and international conducted among various countries. The venues of next several conferences under consideration are Korea, Hong Kong, and Japan. The Society welcomes proposals for future conference venues. Please submit your proposal to sheu.daniel@gmail.com. In addition, you are cordially invited to submit scholarly papers to the IJoSI at www.IJoSI.org. The conference and the journal are synergetic and closely related. The journal is intended to be with academic rigor while addressing real-world problems and opportunities.

Since this is a conference regarding innovation, we've introduced innovative new activities with the conference. The first time ever, the Global Competition on Systematic Innovation (GCSI) is conducted. GCSI is the ONLY and First-Ever 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. 40 projects were received for the 1st GCSI. 25 projects passed first screening. You will see the 25 finalist projects in the conference exhibition site. The final winners of Gold, Silver, and Bronze medal projects will be published in the GCSI web and the awards will be presented to the winners in the closing ceremony of the ICSI conference.

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 let the attendant(s) at the service desk know. We are here to serve you.

With best regards,

D. Daniel Sheu, Ph.D., MBA, CMfgE
General Co-Chair & Chair of Organizing Committee
The 1st International Conference on Systematic Innovation
Professor, National Tsing Hua University, Taiwan, R.O.C.
President, the Society of Systematic Innovation
Editor-in-Chief, the International Journal of Systematic Innovation
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Editorial Board, Computers & Industrial Engineering, an SCI indexed international journal

Paper List

Full Papers in English

Paper ID: 12

Cause Effect and Contradiction Chain Analysis for contradiction Identification and Problem Solving

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Abstract

This research proposes a contradiction analysis and problem solving process based on contradiction analysis and TRIZ problem solving approaches. The approaches integrate both Cause-Effect Chain and Root Contradiction Analysis to quickly identify the key functional disadvantages and the underlying contradictory parameters simultaneously. Three process flows were identified and integrated for contradiction identification and problem solving. Inventive principles, separation/transition principles, and solution directives are used in the processes to solve the contradictions. The proposed Cause-effect and Contradiction Chain Analysis (CACCA) also identifies contradiction families and provides a quantitative method that can used to evaluate contradictions for prioritization.

Contributions of this research include: 1) providing an integrated method which can identify key contradiction and contradictory parameters simultaneously; 2) Integrating a 3-passages integrated approach for problem analysis and problem solving; 3) identifying a new "Combine" relation in addition to the existing AND and OR relationship; 4) Identifying Families of contradictions; and 5) Providing a quantitative method to prioritize the importance of contradictions.

Keywords: TRIZ, Contradiction Analysis, Cause-Effect Chain, Root Contradiction Analysis

1. Introduction

1.1Background and Motivation

Because the current system of products and processes become more complex, it is not easy to find root contradictions or important contradictions from a complex system or problem. There are many contradictions involved many different problems in a complex system while using TRIZ(Theory of Inventive Problem Solving) method to solve practical design problems of products【3】. Souchkov and Blcokmans 【14】 study more than one hundred issues and found that number of contradictions in many cases are more than 15 to 20, some even over 50 and the contradictions associated with each other.

Related researches in TRIZ indicate that there are many methods can be used to identify the key functional disadvantages, contradictions and root contradictions. But contradictions that founded form a complex system are usually family relationship. In this situation, solving all contradictions of family is not necessary, just solving key contradictions will be able to solve the related contradiction families. By the way, many methods for identifying contradiction are lack of metric concept. It's not easy for user to compare importance between different contradictions and select a contradiction to solve.

1.2 Research Objective

This research presents a complete analysis process of TRIZ for identifying contradiction and solving problem. The process is integration of Cause-Effect Chain Analysis (CECCA) and Root Contradiction Analysis (RCA) that will be able to help solvers understand the causal relationship between functional disadvantages within system, and find out family relationship between key functional disadvantages, potential physical contradictions, technical contradictions and contradictions within systems. After that, solver can quantify and evaluate importance of contradictions to get general solution for solving problems.

1.3 Research results and contribution

Establish a process of identifying and solving contradiction can help user identify contradictions within system and solve problem. The results of this study are as follows:

1. Providing an integrated method which can identify key contradiction and contradictory parameters simultaneously.
2. Integrating a 3-passages integrated approach for problem analysis and problem solving.
3. Identifying a new "Combine" relation in addition to the existing AND and OR relationship.
4. Identifying Families of contradictions.
5. Providing a quantitative method to prioritize the importance of contradictions.

2. Literature Review

2.1 Current Reality Tree

Current Reality Tree is one method of Theory of Constraint (TOC) used to find core issues. There are two steps in Current Reality Tree. List all undesired effects(UDE) in current and sequentially construct the causal relationship of UDE and derive core problem【6】. Domb and Dettmer 【5】 thought that combines TOC and TRIZ tools can make up some lacks of traditional tools and Current Reality Tree can find the core problem in system. Mann and Stratton 【12】also combines Current Reality Tree and TRIZ tools to solve contradictions in engineering and management problems.

2.2 Cause-Effect Chain Analysis

Cause-Effect Chain Analysis can identify the key functional disadvantage in engineering systems and its derived from the target problem back to functional disadvantage until find out the root functional disadvantage【8】. Functional disadvantage may be redundant, harmful or unsatisfied function. Remove key functional disadvantage then sequential functional disadvantages will be removed. Identifying key functional disadvantage is the most important purpose of cause-effect chain analysis.

2.3 Root contradiction analysis

Root contradiction analysis (RCA) can help user find sore-point which is happened when improving target problem cause engineering parameter to become more harmful. User determined the relationships between five engineering parameters to find contradictions. RCA help user reach root problem and improve related parameters. 【1】【10】.

2.4 RCA+

RCA + (Root Contradiction Analysis) is one method of identifying contradiction. Use cause-effect chain analysis to analyze all functional disadvantages and relationships of the system, and find out potential effects from these functional disadvantage then identify contradictions【13】. In addition, contradiction identified by RCA+ will be able to sort by comparing with each other【15】.

Compared advantages and disadvantages of these methods in Table 2.1 below:

Table 2.1

	Cause-effect chain analysis (Current Reality Tree)	Root contradiction analysis	RCA+
Advantages	1.functional disadvantages link between the causal relations	1. Identify the root contradictions and the engineering parameters	1. Functional disadvantages link between the causal relations 2. Identify contradictions
Disadvantages	1. No corresponding engineering parameters 2. Can't identify contradictions	1. No causal relationship 2. No the impact and scope of contradiction	1. No corresponding engineering parameters

3. Problem-solving process of contradiction

3.1 Identifying contradiction and problem solving process

This paper will propose a process of contradiction analysis to help users identify the contradictions in the system and get the trigger solution. The framework of the process is shown below (Figure 3.1). First, problem statement is used questions of 6W1H1G to help users clearly define problem environment, constraints and objectives. Description of the problem includes the following:

1. What are problem / need / opportunity / sore point?
2. When was it happen?
3. Where is it found?
4. Why?
5. Who?
6. How was it happen?
7. What?
8. Specific Project Objectives Itemize

After define problem environment and constraints, there are three paths of identifying and solving contradiction (Figure 3.1). The first path is direction of function and attributes analysis, the second path is direction of Cause-effect and Contradiction Chain Analysis, and the third path is direction of the functional relationship analysis. This approach proposes Cause-effect and Contradiction Chain Analysis to identify and quantify contradiction, which will be described in the chapter 3.3.

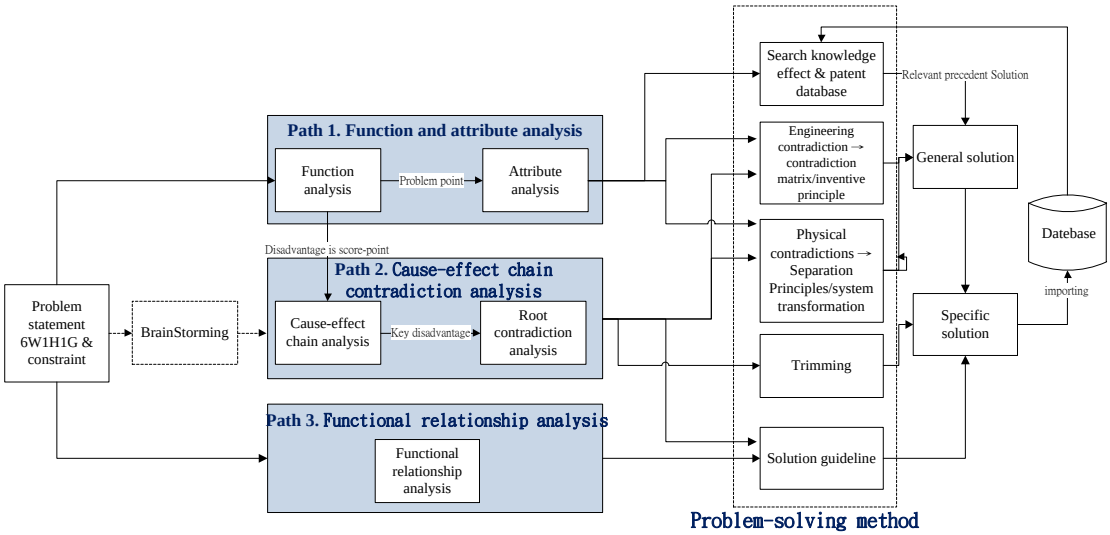

Figure 3.1 contradiction analysis and problem solving process

3.1.1 Function and attribute analysis

After problems in defining and solving environmental restrictions, followed by function and attribute analysis to identify the property or the demands of the points of contradiction and properties. In function and attribute analysis, if both components have a useful and

harmful feature is the little point of contradiction. Point of contradiction itself is a physical contradiction, and then the system can use the principle of separation method of separating the trigger to get the corresponding solution. The point of contradiction arising from the useful features and harmful feature is the construction of contradiction, and then you can use the contradiction matrix and inventive principles to get the trigger solution. Finally, the trigger solution and then be converted into a specific solution. If the analysis of functional properties, the properties of the core components to start, allowing users to in-depth understanding of the problems or contradictions, and then use the knowledge effect and patent search to identify the needs of the database features and attributes.

3.1.2 Cause-effect and Contradiction Chain Analysis

After problems in defining and solving environmental constraints, the functional analysis to identify the functional disadvantage which will function as the pain made them think negatively, then use cause-effect contradiction chain analysis. Users can also use brainstorming ways to get the desire to solve the problem. If selected for the physical contradiction, you can use the principle of separation methods and systems to be separated corresponding to the trigger solution; if selected for engineering contradiction, you can use contradiction matrix and inventive principles to get the trigger solution. For The key functional disadvantage, you can use Trimming way to solve problems.

3.1.3 Functional relationship analysis

After problems in defining and solving environmental constraints, the functional relationship analysis model of the system or problem (Functional Modeling), the functional relationship diagram of complete guidelines can be used to answer a series of trigger solution is more, the last from this series among the trigger solution to think of possible solutions. Modeling the problem and generate the corresponding answer guide can be used Innovation WorkBench ® software to perform 【7】.

3.2 Symbol definitions

Subscript notation：

i：Functional disadvantage i

j：Contradiction j

Symbols：

$D_{(i)}$：Importance of functional disadvantage i in Cause-effect and Contradiction Chain Analysis

$C_{(j)}$：Importance of contradiction j in Cause-effect and Contradiction Chain Analysis

$\alpha_{(i)}$：Adjusting coefficient for accumulating importance of functional disadvantage i

$\beta_{(j)}$：Adjusting coefficient for accumulating importance of contradiction j

$AD_{(i)}$：Cumulative importance of functional disadvantage i in Cause-effect and Contradiction

Chain Analysis

$AC_{(j)}$: Cumulative importance of contradiction j in Cause-effect and Contradiction Chain Analysis

γ : Coefficient is combined with the adjusting coefficient

SD : A set is included all functional disadvantages form target.

SC : A set is included all contradictions form target.

3.3 Cause Effect and Contradiction Chain Analysis

Cause-effect contradiction chain analysis is integration of cause-effect chain analysis and root contradiction analysis .This method is used to identify the functional disadvantage, causal relationship, root contradiction and contradiction family. The proposed method divide conditions of occurrence into AND, OR, Combine, and Straight Cause, while also quantify contradiction. The analysis of the steps shown in Figure 3.2:

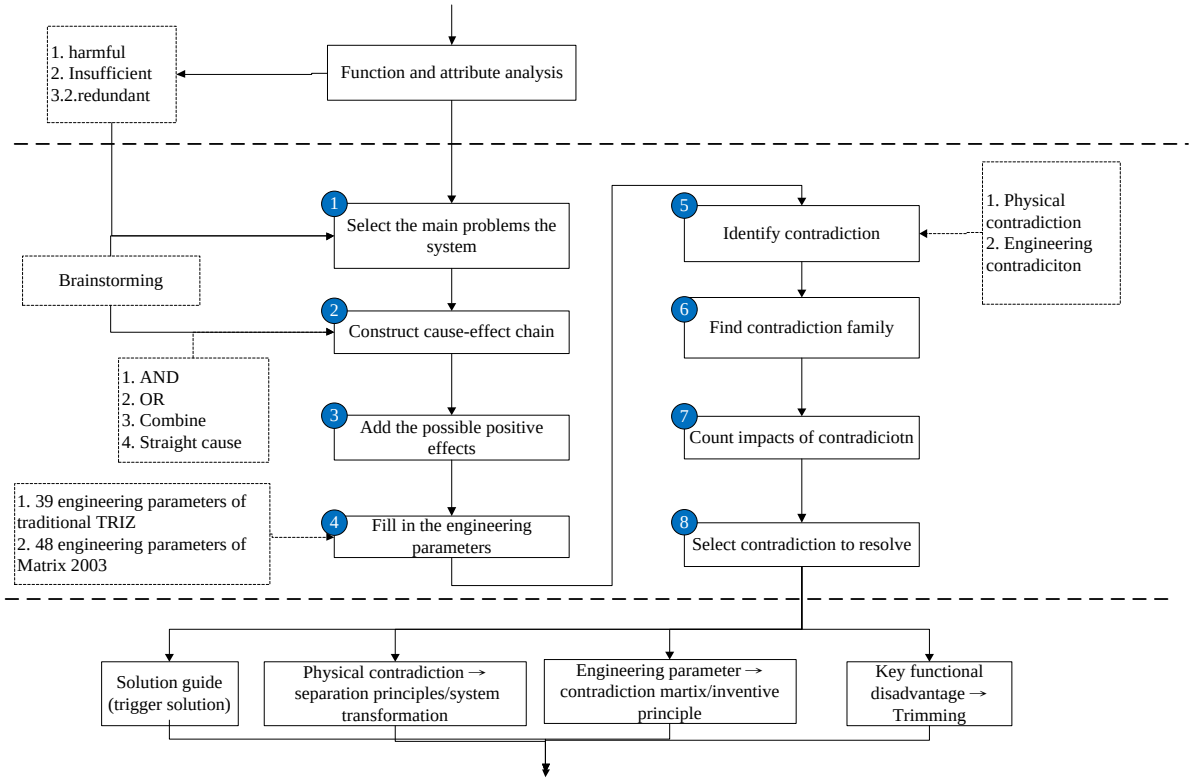

Figure 3.2 Cause-effect contradiction chain analysis procedures

1. Select the main problems the system

Cause-effect contradiction chain analysis must first select the system's main problem; you can complete the analysis of functional properties, resulting in the identification of adverse features in the list of features to choose our main problem. Alternatively, you can use the brainstorming method to get the main problem.

2. Construct cause-effect chain

In order to continue to ask "what caused this result? why?"approach to layer by layer from top to bottom from the start the main problems and find all the possible negative features, then the causal link between adverse functional Relationship marked by arrows. If a negative feature of the result is more than two adverse features caused, it must be defined in terms of their place and mark the nodes in the intersection between the arrows. This condition occurred in a total of 4 types: 1. AND, 2. OR, 3. Combine, 4. Straight Cause. This would construct a causal chain diagram. The following 4 types, respectively, to illustrate the conditions:

(1) AND: to represent the node. This represents a specific negative function is composed of two or more adverse features caused.

(2) OR: to represent the node. This represents a specific negative function is composed of two or more adverse features caused by

(3) Combine: to represent the node. This represents a negative function of a particular generation, is two or more of the adverse impact of integrated functions.

(4) Straight Cause: adverse features in the arrow which is no link between the nodes.

3. Add the possible positive effects

Analyze of each “functional disadvantage” and think about whether it could potentially “positive effect”. Found all the potential positive effects and mark to indicate them.

4. Fill in the engineering parameters

In all of the positive effects identified, the next we have to find all of the positive effect of the negative features and the TRIZ engineering parameters involved in this can use traditional TIRZ 39 engineering parameters 【21】, while this study suggests that using Matrix 2003 48 engineering parameters【9】【11】.

5. Identify contradiction

There are three types of effects in cause-effect contradiction chain analysis:

(1) Functional disadvantage : by as the mark indicates. This represents a particular function can not provide the useful adverse effects.

(2) Useful impact : to express as a marker. In the causal chain which, it is impossible to separate existence, this useful effect is that we function from the chain generated by the negative inside out.

(3) Contradiction : by to as flags. If a functional disadvantage provides functional disadvantage and useful impact in the same time, it will be a contradiction.

6. Find out group of contradiction

In recognition of all the contradiction, then you can have these contradictions between each other, if a relationship between the contradictions can be viewed as a contradiction family. Contradiction family is defined as the contradiction in the causal chain of interrelated contradictions and resolve the contradiction if the root causes of contradiction family in the entire population also will be to resolve the contradiction.

7. Calculation of the importance of contradiction

As the contradiction in the causal chain identified by the contradiction and the negative features may be many months, but their degree of influence on the system or not the same, so the first for each contradiction and the negative impact of a given function. Figure 3.3 as the causal impact of the contradiction between the individual chain and the corresponding adjustment factor is shown below:

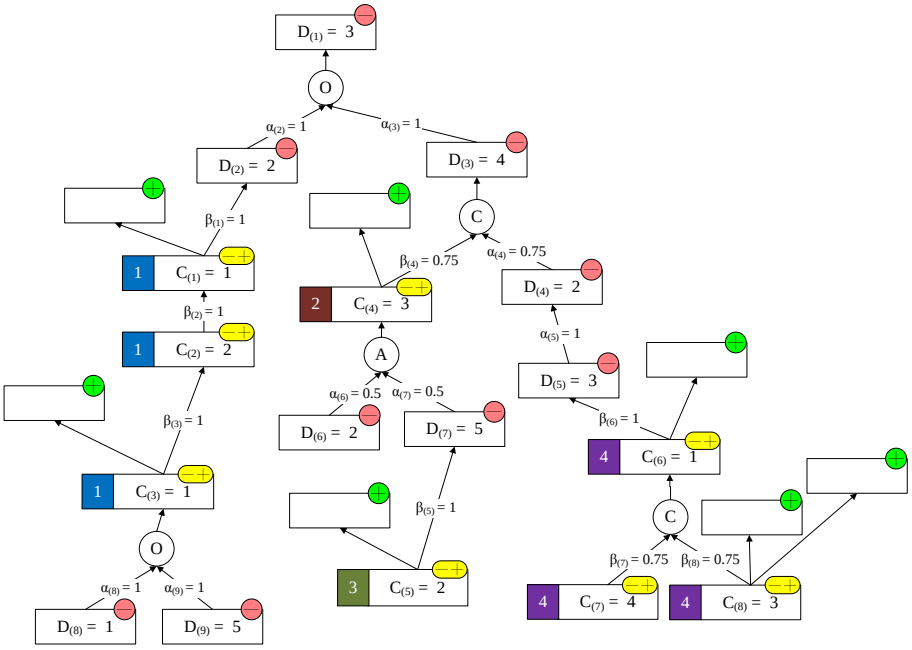

Figure 3.3 Cause Effect and Contradiction Chain Analysis with corresponding importance.

8. Select contradiction to resolve

The importance of contradiction in the calculation of the following can be used problem-solving are the importance of contradiction as an alternative reference to the contradiction. Importance in the calculation of the after all the contradictions within the system function and adverse effects of, and the respective cumulative impact of post-contradiction communities, to compile a list of contradiction (Table 3.1) and the list of functional disadvantage (Table 3.2).

Table 3.1 List of contradiction in the system

contradiction	impact C(j)	Cumulative impact AC(j)	contradiction family
1	1	6	1
2	2	8	1
3	1	9	1
4	3	9.25	2
* 5	4	13.75	3
6	1	12.5	4
* 7	4	15.5	4
* 8	3	14.75	4

* means that root contradiction

Table 3.2 List of functional disadvantage in the system

Functional disadvantage	impact D(i)	Cumulative impact AD(i)
1	3	3
2	2	5
3	4	7
4	2	8.5
5	3	11.5
6	2	10.25
7	5	11.75
* 8	1	10
* 9	5	14

* means key functional disadvantage

If the cumulative number of candidates the importance of contradiction in the same, refer to the following principles to assist decision-making:

1. Select to go to the more micro (Micro) level of contradiction or negative features.
2. Choose more easily modified.
3. Choice and more consistent overall strategy or goals

4. Case studies

4.1 Case statement

When dealing with a large number of computer operations, computer often crashed due to poor cooling. Due to the current requirements of computing speed more quickly, which will make computers more prone to overheating; and volume requirements for the computer is

some hope that smaller, but more and more functions, which means that the internal parts Should be placed in more intensive. These requirements are made more difficult to deal with heat issues.

4.2 Cause-effect contradiction chain analysis

Regardless of what path the way problem solving, the problem description is necessary, so in the case are starting from a description of the problem, then solving the re-use a different path. Asked the first question fill the form described (Table 4.1), describes the contents of this issue should be covered 6W1H1G problem.

Table 4.1 problem statement

What problem?	When dealing with a large number of computer operations, often occur due to poor heat dissipation caused by computer crashes. Due to the current requirements of computing speed more quickly, which will make computers more prone to overheating; and volume requirements for the computer is some hope that smaller, but more and more functions, which means that the internal parts Should be placed in more intensive. These requirements are made more difficult to deal with heat issues.
What?	
When was it happen?	
Where is it found?	
Why?	
Who?	
How was it happen?	
(Specific Project Objectives. Itemize)	Improved computer cooling problem

After the description of the problem, this system uses the functional analysis of the problem out of the picture (see Figure 4.1). Because the large number of computer components, are listed here only the important components and issues related. Functional analysis of the fan cooling effect for the lack of chips, this is a lack of function, to understand the core issues and potential contradiction identification system, the next step is to use the causal chain to in-depth analysis of contradiction issues.

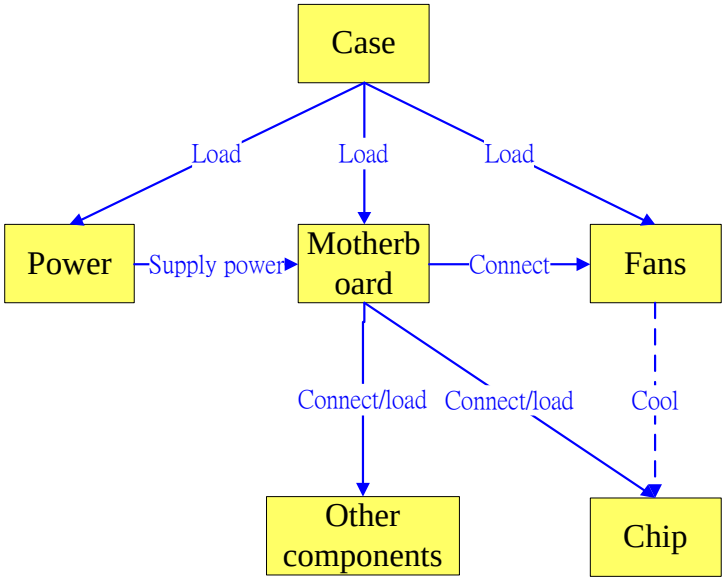

Figure 4.1 Function analysis

The main problem in this case the computer crashes, and then according to the steps in the causal chain analysis of contradiction, the problem is to draw the causal chain of contradiction (Figure 4.2). From the system can identify the two contradictions, the first contradiction in parts of the computer motherboard, I hope part display-intensive, they also do not want to part too dense; another contradiction is about the size of the fan power.

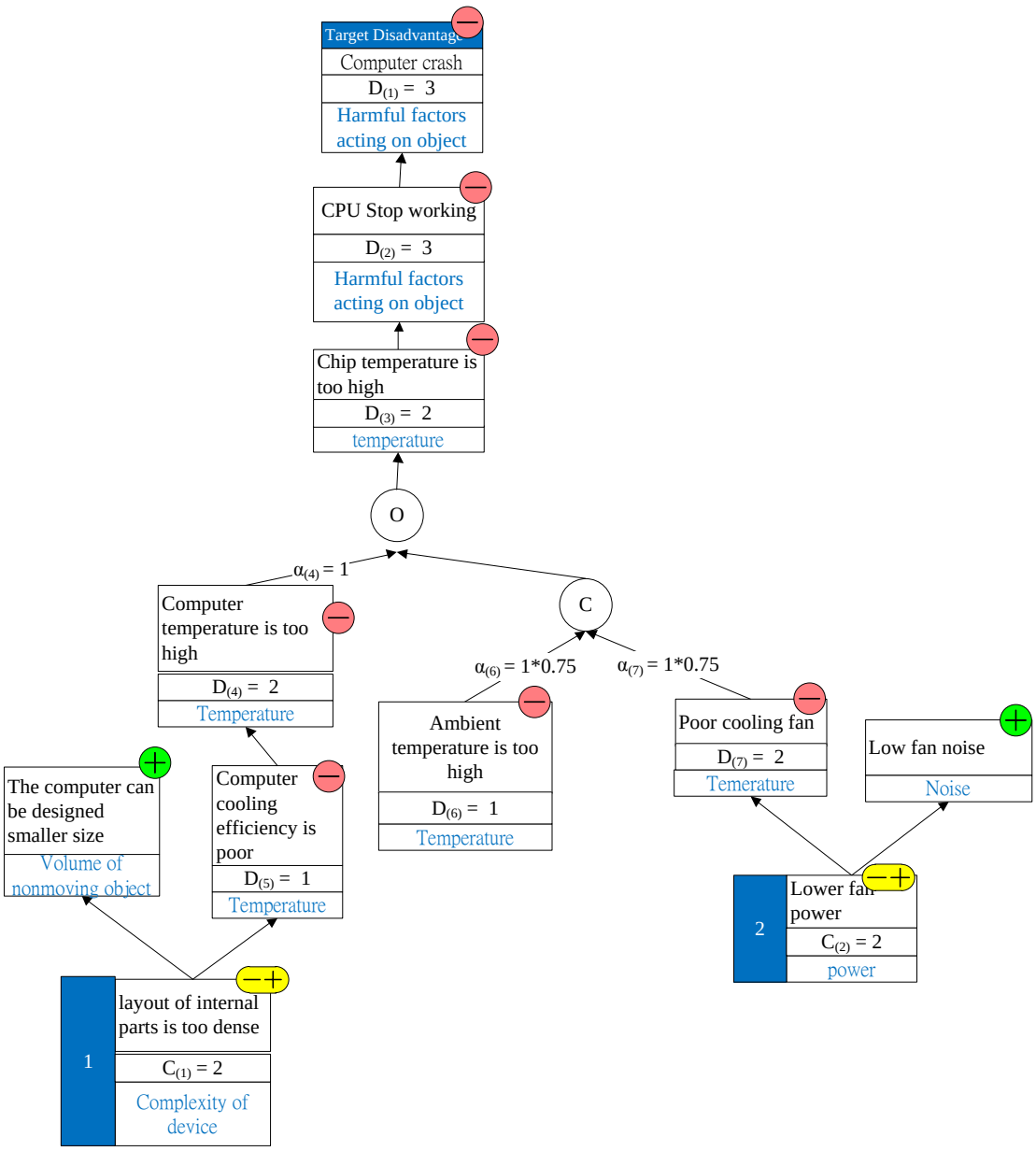

Figure 4.2 cause-effect contradiction chain analysis

According to Disadvantage effects of the contradiction between function and calculate the cumulative impact of their contradiction, and then draw out the contradiction list (as shown in Table 4.2) and the list of Disadvantage features (such as shown in Table 4.3) and scatter plot (Figure 4.3 Shown).

Table 4.2 list of contradiction

Contradiction *j*	Importance $C_{(j)}$	Cumulative importance $AC_{(j)}$	Contradiction family
* 1	2	13	1
* 2	2	11.5	2

Table 4.3 List of functional disadvantage

Functional disadvantage *i*	Importance $D_{(j)}$	Cumulative importance $AD_{(j)}$
1	3	3
2	3	6
3	2	8
4	2	10
5	1	11
6	1	8.75
7	2	9.5

By the scatter plot shows, the impact of the contradiction the highest 1, it is suggested to resolve this contradiction. In this case, use Matrix 2003 and traditional Matrix to find the corresponding inventive principles (Table 4.4).

Table 4.4 Inventive principles

contradiction	Improving feature	Worsening feature	Inventive principle
1	temperature	Volume of stationary	35. Parameter changes 40. Composite materials 31. Porous materials 3. local quality 4. Asymmetry 6. Universality 30. Flexible shells and thin films

The invention in solution in the contradiction, after searching the database can also be found to have similar quality and function of local concepts related patents. ROC patent bulletin No. I320693, an IC substrate with a cooling structure of the patent (Figure 4.4), using the IC

work features a hot spot, and can be localized to the special structure of the heat through the export of this invention can improve the temperature Parameters and not the volume parameters worse.

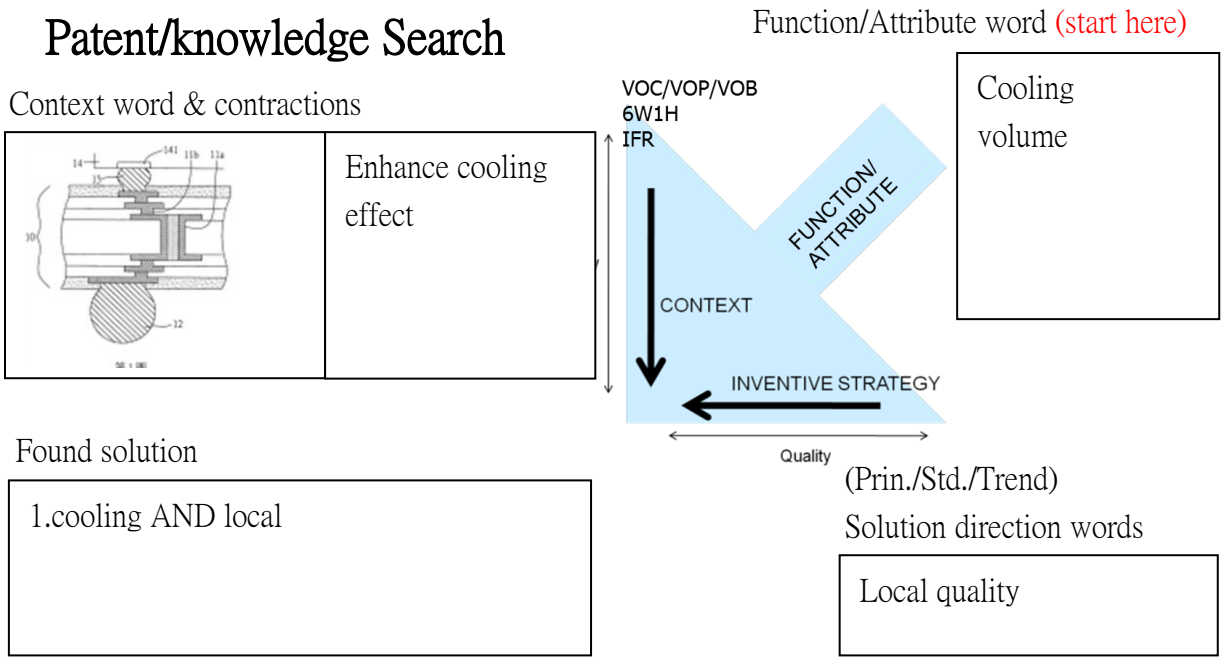

Figure 4.4 related patent search

Cause-effect contradiction chain analysis of the problem-solving path shown in Figure 4.5:

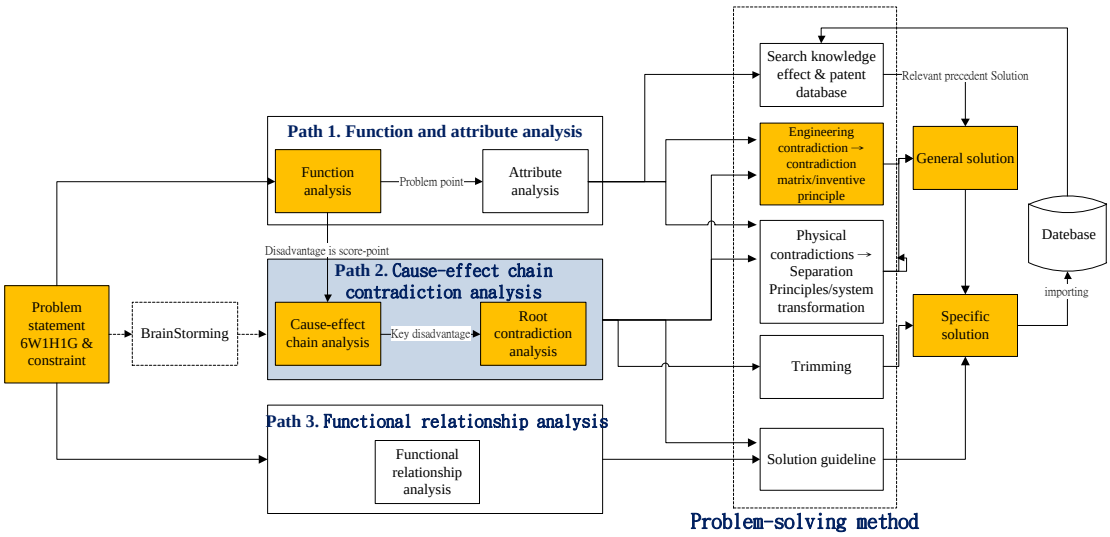

Figure 4.5 Cause-effect contradiction chain analysis of the problem-solving path

5. Conclusion

This research proposes a contradiction analysis and problem solving process based on contradiction analysis and TRIZ problem solving approaches. Conclusions of this study are summarized as follows:

1. Providing an integrated method which can identify key contradiction and contradictory parameters simultaneously.
2. Integrating a 3-passages integrated approach for problem analysis and problem solving.
3. Identifying a new "Combine" relation in addition to the existing AND and OR relationship.
4. Identifying Families of contradictions.
5. Providing a quantitative method to prioritize the importance of contradictions.

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Analysis of the Preference Shift of Customer Brand Selection among Multiple Genres of Jewelry/Accessory and Its Matrix Structure

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Abstract

It is often observed that consumers select upper class brand when they buy next time. Suppose that former buying data and current buying data are gathered. Also suppose that upper brand is located upper in the variable array. Then transition matrix becomes upper triangular matrix under the supposition that former buying variables are set input and current buying variables are set output. Takeyasu et al. (2007) analyzed the brand selection and its matrix structure before. In that paper, products of one genre are analyzed. In this paper, brand selection among multiple genre of Jewelry/Accessory purchasing case and its matrix structure are analyzed. For example, there is a case that customer selects bracelet or earrings besides selecting upper brand of necklace she already has. There may be also the case that customer selects lower brand to seek suitable price when she already has higher ranked brand. Then the transition matrix contains items in lower triangular part. Utilizing purchase history record of jewelry / accessory on-line shopping (Necklace/Pendant, Pierced earrings, Ring, Bracelet/Bangle) over three years, above matrix structure is investigated and confirmed. Analyzing such structure provides useful applications. Unless planner for products does not notice its brand position whether it is upper or lower than another products, matrix structure makes 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.

Keywords: brand selection, matrix structure, brand position, jewelry, accessory

1. Introduction

It is often observed that consumers select upper class brand when they buy next time after they are bored to use current brand. Suppose that former buying data and current buying data are gathered. Also suppose that upper brand is located upper in the variable array. Then the transition matrix becomes upper triangular matrix under the supposition that former buying variables are set input and

current buying variables are set output. The analysis of the brand selection in the same brand group is analyzed by Takeyasu et al.[6].

In this paper, we expand this scheme to products of multiple genres and examine them by utilizing the case of jewelry/accessory purchasing. For example, we consider the case of necklace. If she is accustomed to use necklace, she would buy higher priced necklace. On the other hand, she may buy bracelet or earring for her total coordination in fashion. Hearing from the retailer, both can be seen in selecting upper class brand and selecting another genre product. There may be also the case that customer selects lower brand to seek suitable price when she already has higher ranked brand. Then the transition matrix contains items in lower triangular part. Utilizing purchase history record of jewelry / accessory on-line shopping (Necklace/Pendant, Pierced earrings, Ring, Bracelet/Bangle) over three years, above matrix structure is investigated and confirmed.

Therefore, this analysis is very meaningful for the practical use, which occurs actually. If transition matrix is identified, we can make various analysis using it and s-step forecasting can be executed. Unless planners for products notice its brand position whether it is upper or lower than other products, matrix structure makes it possible to identify those by calculating consumers' activities for brand selection. Thus, this proposed approach makes it effective to execute marketing plan and/or establish new brand.

Quantitative analysis concerning brand selection has been executed by Yamanaka[5], Takahashi et al.[4]. Yamanaka[5] examined purchasing process by Markov Transition Probability with the input of advertising expense. Takahashi et al.[4] made analysis by the Brand Selection Probability model using logistics distribution.

Takeyasu et al.[6] analyzed the preference shift of customer brand selection for a single brand group. In this paper, we try to expand this scheme to products of multiple genres, and the analysis for the jewelry/accessory purchasing case is executed. Actually, this scheme can often be seen. Such research is quite a new one.

Hereinafter, matrix structure for a single brand group is clarified for the selection of brand in section 2. Expansion to multiple brand selection is executed and analyzed in section 3. s-step forecasting is stated in section 4. Numerical calculation is executed in section 5. Remarks are stated in section 6.

2. Brand Selection and Its Matrix Structure

2.1 Upper Shift of Brand Selection

Now, suppose that x is the most upper class brand, y is the second upper class brand, and z is the lowest class brand. Consumer's behavior of selecting brand might be $z \to y$, $y \to x$, $z \to x$ etc. $x \to z$ might be few.

Suppose that x is current buying variable, and x_b is previous buying variable. Shift to x is executed from x_b, y_b, or z_b. Therefore, x is stated in the following equation. a_{ij} represents transition probability from j-th to i-th brand.

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

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 following data, which are all consisted by the data in which transition is made from lower brand to upper brand,

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

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

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

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 minimize following J

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

$\hat{\mathbf{A}}$ 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 which are all consisted by the data in which transition is made from lower brand to upper brand, estimated value $\hat{\mathbf{A}}$ should be upper triangular matrix. If following data which shift to lower 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 of triangle.

2.2 Sorting Brand Ranking by Re-arranging Row

In a general data, variables may not be in order as $\mathrm{x, y, z}$. 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 upper triangular matrix, and the small value parts are gathered in lower triangular matrix.

$$\begin{array}{c} \\ \begin{pmatrix} x \\ y \\ z \end{pmatrix} \end{array} \overset{\hat{\mathbf{A}}}{\begin{pmatrix} \bigcirc & \bigcirc & \bigcirc \\ \varepsilon & \bigcirc & \bigcirc \\ \varepsilon & \varepsilon & \bigcirc \end{pmatrix}} \quad \underset{\Longleftarrow}{\text{Shifting}} \quad \begin{array}{c} \\ \begin{pmatrix} z \\ x \\ y \end{pmatrix} \end{array} \overset{\hat{\mathbf{A}}}{\begin{pmatrix} \varepsilon & \varepsilon & \bigcirc \\ \bigcirc & \bigcirc & \bigcirc \\ \varepsilon & \bigcirc & \bigcirc \end{pmatrix}} \tag{8}$$

2.3 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 intermediate class brand. We suppose v, w, x, y, z brands (suppose they are laid from upper position to lower position as $v > w > x > y > z$). In the above case, selection shifts would be:

$v \leftarrow z$

$v \leftarrow y$

Suppose they do not shift to $\mathrm{y, x, w}$ from z, to $\mathrm{x, w}$ from y, and to w from x, then Matrix structure would be as follows.

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

We confirm this by numerical example in section 5.

3. Expansion Of The Model To Multiple Genre Products

Expanding Eq.(2) to multiple genre products, we obtain following equations. First of all, we state the generalized model of Eq.(2).

$$\mathbf{X} = \mathbf{A}\mathbf{X_b} \tag{10}$$

Where

$$\mathbf{X} = \begin{pmatrix} x^1 \\ x^2 \\ \vdots \\ x^p \end{pmatrix}, \quad \mathbf{X_b} = \begin{pmatrix} x_b^1 \\ x_b^2 \\ \vdots \\ x_b^p \end{pmatrix} \tag{11}$$

$$\mathbf{A} = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1p} \\ a_{21} & a_{22} & \cdots & a_{2p} \\ \vdots & \vdots & & \vdots \\ a_{p1} & a_{p2} & \cdots & a_{pp} \end{pmatrix} \tag{12}$$

Here

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

If the brand selection is executed towards upper class, then $\mathbf{A}$ becomes as follows.

$$\mathbf{A} = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1p} \\ 0 & a_{22} & \cdots & a_{2p} \\ \vdots & \vdots & & \vdots \\ 0 & 0 & \cdots & a_{pp} \end{pmatrix} \tag{13}$$

Expanding above equations to products of 3 genres, we obtain following equations.

$$\begin{pmatrix} \mathbf{X} \\ \mathbf{Y} \\ \mathbf{Z} \end{pmatrix} = \begin{pmatrix} \mathbf{A}^{11} & \mathbf{A}^{12} & \mathbf{A}^{13} \\ \mathbf{A}^{21} & \mathbf{A}^{22} & \mathbf{A}^{23} \\ \mathbf{A}^{31} & \mathbf{A}^{32} & \mathbf{A}^{33} \end{pmatrix} \begin{pmatrix} \mathbf{X_b} \\ \mathbf{Y_b} \\ \mathbf{Z_b} \end{pmatrix} \tag{14}$$

Where

$$\mathbf{X} = \begin{pmatrix} x^1 \\ x^2 \\ \vdots \\ x^p \end{pmatrix}, \quad \mathbf{X_b} = \begin{pmatrix} x_b^1 \\ x_b^2 \\ \vdots \\ x_b^p \end{pmatrix}, \quad \mathbf{Y} = \begin{pmatrix} y^1 \\ y^2 \\ \vdots \\ y^q \end{pmatrix}, \quad \mathbf{Y_b} = \begin{pmatrix} y_b^1 \\ y_b^2 \\ \vdots \\ y_b^q \end{pmatrix}, \quad \mathbf{Z} = \begin{pmatrix} z^1 \\ z^2 \\ \vdots \\ z^r \end{pmatrix}, \quad \mathbf{Z_b} = \begin{pmatrix} z_b^1 \\ z_b^2 \\ \vdots \\ z_b^r \end{pmatrix} \tag{15}$$

$$\mathbf{A}^{11} = \begin{pmatrix} a_{11}^{11} & a_{12}^{11} & \cdots & a_{1p}^{11} \\ a_{21}^{11} & a_{22}^{11} & \cdots & a_{2p}^{11} \\ \vdots & \vdots & & \vdots \\ a_{p1}^{11} & a_{p2}^{11} & \cdots & a_{pp}^{11} \end{pmatrix}, \quad \mathbf{A}^{12} = \begin{pmatrix} a_{11}^{12} & a_{12}^{12} & \cdots & a_{1q}^{12} \\ a_{21}^{12} & a_{22}^{12} & \cdots & a_{2q}^{12} \\ \vdots & \vdots & & \vdots \\ a_{p1}^{12} & a_{p2}^{12} & \cdots & a_{pq}^{12} \end{pmatrix}, \quad \mathbf{A}^{13} = \begin{pmatrix} a_{11}^{13} & a_{12}^{13} & \cdots & a_{1r}^{13} \\ a_{21}^{13} & a_{22}^{13} & \cdots & a_{2r}^{13} \\ \vdots & \vdots & & \vdots \\ a_{p1}^{13} & a_{p2}^{13} & \cdots & a_{pr}^{13} \end{pmatrix},$$

$$\mathbf{A}^{21} = \begin{pmatrix} a_{11}^{21} & a_{12}^{21} & \cdots & a_{1p}^{21} \\ a_{21}^{21} & a_{22}^{21} & \cdots & a_{2p}^{21} \\ \vdots & \vdots & & \vdots \\ a_{q1}^{21} & a_{q2}^{21} & \cdots & a_{qp}^{21} \end{pmatrix}, \quad \mathbf{A}^{22} = \begin{pmatrix} a_{11}^{22} & a_{12}^{22} & \cdots & a_{1q}^{22} \\ a_{21}^{22} & a_{22}^{22} & \cdots & a_{2q}^{22} \\ \vdots & \vdots & & \vdots \\ a_{q1}^{22} & a_{q2}^{22} & \cdots & a_{qq}^{22} \end{pmatrix}, \quad \mathbf{A}^{23} = \begin{pmatrix} a_{11}^{23} & a_{12}^{23} & \cdots & a_{1r}^{23} \\ a_{21}^{23} & a_{22}^{23} & \cdots & a_{2r}^{23} \\ \vdots & \vdots & & \vdots \\ a_{q1}^{23} & a_{q2}^{23} & \cdots & a_{qr}^{23} \end{pmatrix} \tag{16}$$

$$\mathbf{A}^{31} = \begin{pmatrix} a_{11}^{31} & a_{12}^{31} & \cdots & a_{1p}^{31} \\ a_{21}^{31} & a_{22}^{31} & \cdots & a_{2p}^{31} \\ \vdots & \vdots & & \vdots \\ a_{r1}^{31} & a_{r2}^{31} & \cdots & a_{rp}^{31} \end{pmatrix}, \quad \mathbf{A}^{32} = \begin{pmatrix} a_{11}^{32} & a_{12}^{32} & \cdots & a_{1q}^{32} \\ a_{21}^{32} & a_{22}^{32} & \cdots & a_{2q}^{32} \\ \vdots & \vdots & & \vdots \\ a_{r1}^{32} & a_{r2}^{32} & \cdots & a_{rq}^{32} \end{pmatrix}, \quad \mathbf{A}^{33} = \begin{pmatrix} a_{11}^{33} & a_{12}^{33} & \cdots & a_{1r}^{33} \\ a_{21}^{33} & a_{22}^{33} & \cdots & a_{2r}^{33} \\ \vdots & \vdots & & \vdots \\ a_{r1}^{33} & a_{r2}^{33} & \cdots & a_{rr}^{33} \end{pmatrix}$$

$$\mathbf{X} \in \mathbf{R}^p, \mathbf{X_b} \in \mathbf{R}^p, \mathbf{Y} \in \mathbf{R}^q, \mathbf{Y_b} \in \mathbf{R}^q, \mathbf{Z} \in \mathbf{R}^r, \mathbf{Z_b} \in \mathbf{R}^r, \mathbf{A}^{11} \in \mathbf{R}^{p\times p},$$
$$\mathbf{A}^{12} \in \mathbf{R}^{p\times q}, \mathbf{A}^{13} \in \mathbf{R}^{p\times r}, \mathbf{A}^{21} \in \mathbf{R}^{q\times p}, \mathbf{A}^{22} \in \mathbf{R}^{q\times q}, \mathbf{A}^{23} \in \mathbf{R}^{q\times r}, \mathbf{A}^{31} \in \mathbf{R}^{r\times p}, \mathbf{A}^{32} \in \mathbf{R}^{r\times q}, \mathbf{A}^{33} \in \mathbf{R}^{r\times r}$$

Re-writing Eq.(14) as :

$$\mathbf{W} = \mathbf{A}\mathbf{W}_{\mathbf{b}} \tag{17}$$

Then, transition matrix $\mathbf{A}$ is derived as follows in the same way with Eq.(7).

$$\hat{\mathbf{A}} = \left(\sum_{i=1}^{N} \mathbf{W}^{i} \mathbf{W}_{\mathbf{b}}^{iT} \right) \left(\sum_{i=1}^{N} \mathbf{W}_{\mathbf{b}}^{i} \mathbf{W}_{\mathbf{b}}^{iT} \right)^{-1} \tag{18}$$

Here,

$$\mathbf{W} = \begin{pmatrix} \mathbf{X} \\ \mathbf{Y} \\ \mathbf{Z} \end{pmatrix}, \quad \mathbf{W}_{\mathbf{b}} = \begin{pmatrix} \mathbf{X}_{\mathbf{b}} \\ \mathbf{Y}_{\mathbf{b}} \\ \mathbf{Z}_{\mathbf{b}} \end{pmatrix} \tag{19}$$

$$\mathbf{A} = \begin{pmatrix} \mathbf{A}^{11} & \mathbf{A}^{12} & \mathbf{A}^{13} \\ \mathbf{A}^{21} & \mathbf{A}^{22} & \mathbf{A}^{23} \\ \mathbf{A}^{31} & \mathbf{A}^{32} & \mathbf{A}^{33} \end{pmatrix} \tag{20}$$

$$\mathbf{W}^{i} = \mathbf{A}\mathbf{W}_{\mathbf{b}}^{i} + \boldsymbol{\varepsilon}^{i} \qquad i = 1,2,\cdots,N \tag{21}$$

$$\boldsymbol{\varepsilon}^{i} = \begin{pmatrix} \varepsilon_{1}^{i} \\ \vdots \\ \varepsilon_{p}^{i} \\ \varepsilon_{p+1}^{i} \\ \vdots \\ \varepsilon_{p+q}^{i} \\ \varepsilon_{p+q+1}^{i} \\ \vdots \\ \varepsilon_{p+q+r}^{i} \end{pmatrix} \qquad i = 1,2,\cdots,N \tag{22}$$

If the brand selection is executed towards upper class brand in the same genre, transition matrix, for example, $\mathbf{A}_{11}, \mathbf{A}_{22}, \mathbf{A}_{33}$, become upper triangular matrix as seen in 2. Suppose $\mathbf{X}$ as necklace, $\mathbf{Y}$ as pierced earring and $\mathbf{Z}$ as ring. If we only see $\mathbf{Z}$, we can examine whether there is an upper brand shift in $\mathbf{A}_{33}$. But there is a case that brand selection is executed towards other genre products. There occurs brand selection shift from a certain brand level of $\mathbf{Z}$ to a certain brand level of $\mathbf{X}$ or $\mathbf{Y}$. For example, suppose there are five levels in each $\mathbf{X}$, $\mathbf{Y}$, $\mathbf{Z}$ and their levels include from bottom

to top brand level. In that case, if there is a brand selection shift from the middle brand level in $\mathbf{Z}$ to another genre product, we can obtain interesting result by examining how the brand selection shift is executed toward the same level or upper or lower level of another genre product. If we can see the trend of brand selection shift, we can foresee the brand selection shift towards another genre brand. Retailer can utilize the result of this to make effective marketing plan. We confirm this by the numerical example in 5.

Next, we examine the case in brand groups. Matrices are composed by Block Matrix.

3.1 Brand shift group — In the case of two groups

Suppose brand selection shifts from Necklace class to Ring. Selection of jewelry/accessory is executed in a group and brand shift is considered to be done from group to group. Suppose brand groups at time n are as follows.

$\mathbf{X}$ consists of p varieties of goods, and $\mathbf{Y}$ consists of q varieties of goods.

$$\mathbf{X_n} = \begin{pmatrix} x_1^n \\ x_2^n \\ \vdots \\ x_p^n \end{pmatrix}, \qquad \mathbf{Y_n} = \begin{pmatrix} y_1^n \\ y_2^n \\ \vdots \\ y_q^n \end{pmatrix}$$

$$\begin{pmatrix} \mathbf{X_n} \\ \mathbf{Y_n} \end{pmatrix} = \begin{pmatrix} \mathbf{A_{11}}, & \mathbf{A_{12}} \\ \mathbf{0}, & \mathbf{A_{22}} \end{pmatrix} \begin{pmatrix} \mathbf{X_{n-1}} \\ \mathbf{Y_{n-1}} \end{pmatrix} \tag{23}$$

Here,

$$\mathbf{X_n} \in \mathbf{R}^p \ (n = 1,2,\cdots), \quad \mathbf{Y_n} \in \mathbf{R}^q \ (n = 1,2,\cdots), \quad \mathbf{A_{11}} \in \mathbf{R}^{p\times p}, \quad \mathbf{A_{12}} \in \mathbf{R}^{p\times q}, \quad \mathbf{A_{22}} \in \mathbf{R}^{q\times q}$$

Make one more step of shift, then we obtain the following equation.

$$\begin{pmatrix} \mathbf{X_n} \\ \mathbf{Y_n} \end{pmatrix} = \begin{pmatrix} \mathbf{A_{11}}^2, & \mathbf{A_{11}A_{12}} + \mathbf{A_{12}A_{22}} \\ \mathbf{0}, & \mathbf{A_{22}}^2 \end{pmatrix} \begin{pmatrix} \mathbf{X_{n-2}} \\ \mathbf{Y_{n-2}} \end{pmatrix} \tag{24}$$

Make one more step of shift again, then we obtain the following equation.

$$\begin{pmatrix} \mathbf{X_n} \\ \mathbf{Y_n} \end{pmatrix} = \begin{pmatrix} \mathbf{A_{11}}^3, & \mathbf{A_{11}}^2\mathbf{A_{12}} + \mathbf{A_{11}A_{12}A_{22}} + \mathbf{A_{12}A_{22}}^2 \\ \mathbf{0}, & \mathbf{A_{22}}^3 \end{pmatrix} \begin{pmatrix} \mathbf{X_{n-3}} \\ \mathbf{Y_{n-3}} \end{pmatrix} \tag{25}$$

Similarly,

$$\begin{pmatrix} \mathbf{X_n} \\ \mathbf{Y_n} \end{pmatrix} = \begin{pmatrix} \mathbf{A_{11}}^4, & \mathbf{A_{11}}^3\mathbf{A_{12}} + \mathbf{A_{11}}^2\mathbf{A_{12}}\mathbf{A_{22}} + \mathbf{A_{11}}\mathbf{A_{12}}\mathbf{A_{22}}^2 + \mathbf{A_{12}}\mathbf{A_{22}}^3 \\ \mathbf{0}, & \mathbf{A_{22}}^4 \end{pmatrix} \begin{pmatrix} \mathbf{X_{n-4}} \\ \mathbf{Y_{n-4}} \end{pmatrix} \tag{26}$$

$$\begin{pmatrix} \mathbf{X_n} \\ \mathbf{Y_n} \end{pmatrix} = \begin{pmatrix} \mathbf{A_{11}}^5, & \mathbf{A_{11}}^4\mathbf{A_{12}} + \mathbf{A_{11}}^3\mathbf{A_{12}}\mathbf{A_{22}} + \mathbf{A_{11}}^2\mathbf{A_{12}}\mathbf{A_{22}}^2 + \mathbf{A_{11}}\mathbf{A_{12}}\mathbf{A_{22}}^3 + \mathbf{A_{12}}\mathbf{A_{22}}^4 \\ \mathbf{0}, & \mathbf{A_{22}}^5 \end{pmatrix} \begin{pmatrix} \mathbf{X_{n-5}} \\ \mathbf{Y_{n-5}} \end{pmatrix} \tag{27}$$

Finally, we get generalized equation for $\mathbf{S}$ -step shift as follows.

$$\begin{pmatrix} \mathbf{X_n} \\ \mathbf{Y_n} \end{pmatrix} = \begin{pmatrix} \mathbf{A_{11}}^s, & \mathbf{A_{11}}^{s-1}\mathbf{A_{12}} + \sum_{k=2}^{s-1}\mathbf{A_{11}}^{s-k}\mathbf{A_{12}}\mathbf{A_{22}}^{k-1} + \mathbf{A_{12}}\mathbf{A_{22}}^{s-1} \\ \mathbf{0}, & \mathbf{A_{22}}^s \end{pmatrix} \begin{pmatrix} \mathbf{X_{n-s}} \\ \mathbf{Y_{n-s}} \end{pmatrix} \tag{28}$$

If we replace $\mathrm{n-s \to n, n \to n+s}$ in equation (28), we can make s -step forecast.

3.2 Brand shift group — In the case of three groups

Suppose brand selection is executed in the same group or to the upper group, and also suppose that brand position is $\mathrm{x > y > z}$ (x is upper position). Then brand selection transition matrix would be expressed as follows.

$$\begin{pmatrix} \mathbf{X_n} \\ \mathbf{Y_n} \\ \mathbf{Z_n} \end{pmatrix} = \begin{pmatrix} \mathbf{A_{11}}, & \mathbf{A_{12}}, & \mathbf{A_{13}} \\ \mathbf{0}, & \mathbf{A_{22}}, & \mathbf{A_{23}} \\ \mathbf{0}, & \mathbf{0}, & \mathbf{A_{33}} \end{pmatrix} \begin{pmatrix} \mathbf{X_{n-1}} \\ \mathbf{Y_{n-1}} \\ \mathbf{Z_{n-1}} \end{pmatrix} \tag{29}$$

Where

$$\mathbf{X_n} = \begin{pmatrix} x_1^n \\ x_2^n \\ \vdots \\ x_p^n \end{pmatrix}, \qquad \mathbf{Y_n} = \begin{pmatrix} y_1^n \\ y_2^n \\ \vdots \\ y_q^n \end{pmatrix}, \qquad \mathbf{Z_n} = \begin{pmatrix} z_1^n \\ z_2^n \\ \vdots \\ z_r^n \end{pmatrix}$$

Here,

$\mathbf{X_n} \in \mathbf{R}^p\ (n = 1,2,\cdots)$, $\mathbf{Y_n} \in \mathbf{R}^q\ (n = 1,2,\cdots)$, $\mathbf{Z_n} \in \mathbf{R}^r\ (n = 1,2,\cdots)$, $\mathbf{A_{11}} \in R^{p\times p}$, $\mathbf{A_{12}} \in R^{p\times q}$, $\mathbf{A_{13}} \in R^{p\times r}$, $\mathbf{A_{22}} \in R^{q\times q}$, $\mathbf{A_{23}} \in R^{q\times r}$, $\mathbf{A_{33}} \in R^{r\times r}$

These are re-stated as

$$\boldsymbol{V}_{\mathbf{n}} = \mathbf{A}\boldsymbol{V}_{\mathbf{n-1}} \tag{30}$$

where,

$$\boldsymbol{V}_{\mathbf{n}} = \begin{pmatrix} \mathbf{X}_{\mathbf{n}} \\ \mathbf{Y}_{\mathbf{n}} \\ \mathbf{Z}_{\mathbf{n}} \end{pmatrix}, \qquad \mathbf{A} = \begin{pmatrix} \mathbf{A}_{11}, & \mathbf{A}_{12}, & \mathbf{A}_{13} \\ \mathbf{0}, & \mathbf{A}_{22}, & \mathbf{A}_{23} \\ \mathbf{0}, & \mathbf{0}, & \mathbf{A}_{33} \end{pmatrix}, \qquad \boldsymbol{V}_{\mathbf{n-1}} = \begin{pmatrix} \mathbf{X}_{\mathbf{n-1}} \\ \mathbf{Y}_{\mathbf{n-1}} \\ \mathbf{Z}_{\mathbf{n-1}} \end{pmatrix}$$

Hereinafter, we shift steps as is done in the previous section.

In the general description, we state them as follows.

$$\boldsymbol{V}_{\mathbf{n}} = \mathbf{A}^{(\mathbf{s})}\boldsymbol{V}_{\mathbf{n-s}} \tag{31}$$

Here,

$$\mathbf{A}^{(\mathbf{s})} = \begin{pmatrix} \mathbf{A}_{11}{}^{(\mathbf{s})}, & \mathbf{A}_{12}{}^{(\mathbf{s})}, & \mathbf{A}_{13}{}^{(\mathbf{s})} \\ \mathbf{0}, & \mathbf{A}_{22}{}^{(\mathbf{s})}, & \mathbf{A}_{23}{}^{(\mathbf{s})} \\ \mathbf{0}, & \mathbf{0}, & \mathbf{A}_{33}{}^{(\mathbf{s})} \end{pmatrix}, \qquad V_{\mathbf{n-s}} = \begin{pmatrix} \mathbf{X}_{\mathbf{n-s}} \\ \mathbf{Y}_{\mathbf{n-s}} \\ \mathbf{Z}_{\mathbf{n-s}} \end{pmatrix}$$

Generalizing them to m groups, they are expressed as follows.

$$\begin{pmatrix} \mathbf{X}_{\mathbf{n}}^{(1)} \\ \mathbf{X}_{\mathbf{n}}^{(2)} \\ \vdots \\ \mathbf{X}_{\mathbf{n}}^{(m)} \end{pmatrix} = \begin{pmatrix} \mathbf{A}_{11} & \mathbf{A}_{12} & \cdots & \mathbf{A}_{1\mathbf{m}} \\ \mathbf{A}_{21} & \mathbf{A}_{22} & \cdots & \mathbf{A}_{2\mathbf{m}} \\ \vdots & \vdots & & \vdots \\ \mathbf{A}_{\mathbf{m}1} & \mathbf{A}_{\mathbf{m}2} & \cdots & \mathbf{A}_{\mathbf{mm}} \end{pmatrix} \begin{pmatrix} \mathbf{X}_{\mathbf{n-1}}^{(1)} \\ \mathbf{X}_{\mathbf{n-1}}^{(2)} \\ \vdots \\ \mathbf{X}_{\mathbf{n-1}}^{(m)} \end{pmatrix} \tag{32}$$

$$\mathbf{X}_{\mathbf{n}}^{(1)} \in R^{k_1}, \quad \mathbf{X}_{\mathbf{n}}^{(2)} \in R^{k_2}, \quad \cdots, \quad \mathbf{X}_{\mathbf{n}}^{(m)} \in R^{k_m}, \quad \mathbf{A}_{\mathbf{ij}} \in R^{k_i \times k_j} \ (i = 1, \cdots, m)(j = 1, \cdots, m)$$

4. S -STEP FORECASTING

Now, we see Eq.(14) in time series. Set $\mathbf{X}, \mathbf{Y}, \mathbf{Z}$ at time n as :

$$\mathbf{X_n} = \begin{pmatrix} x_1^n \\ x_2^n \\ \vdots \\ x_p^n \end{pmatrix}, \quad \mathbf{Y_n} = \begin{pmatrix} y_1^n \\ y_2^n \\ \vdots \\ y_q^n \end{pmatrix}, \quad \mathbf{Z_n} = \begin{pmatrix} z_1^n \\ z_2^n \\ \vdots \\ z_r^n \end{pmatrix} \tag{33}$$

Then, Eq.(14) can be re-stated as :

$$\begin{pmatrix} \mathbf{X_n} \\ \mathbf{Y_n} \\ \mathbf{Z_n} \end{pmatrix} = \begin{pmatrix} \mathbf{A}_{11} & \mathbf{A}_{12} & \mathbf{A}_{13} \\ \mathbf{A}_{21} & \mathbf{A}_{22} & \mathbf{A}_{23} \\ \mathbf{A}_{31} & \mathbf{A}_{32} & \mathbf{A}_{33} \end{pmatrix} \begin{pmatrix} \mathbf{X_{n-1}} \\ \mathbf{Y_{n-1}} \\ \mathbf{Z_{n-1}} \end{pmatrix} \tag{34}$$

Where suffix is written in the lower part of right hand side because there arises a multiplier in the equation of forecasting.

s -step forecasting is executed by the following equation.

$$\begin{pmatrix} \mathbf{X_{n+s}} \\ \mathbf{Y_{n+s}} \\ \mathbf{Z_{n+s}} \end{pmatrix} = \begin{pmatrix} \mathbf{A}_{11} & \mathbf{A}_{12} & \mathbf{A}_{13} \\ \mathbf{A}_{21} & \mathbf{A}_{22} & \mathbf{A}_{23} \\ \mathbf{A}_{31} & \mathbf{A}_{32} & \mathbf{A}_{33} \end{pmatrix}^s \begin{pmatrix} \mathbf{X_n} \\ \mathbf{Y_n} \\ \mathbf{Z_n} \end{pmatrix} \tag{35}$$

5. NUMERICAL EXAMPLE

First of all, the framework of jewelry/accessory purchasing via on-line shopping is as follows (Table 1).

Table 1. Outline of on-line shopping

On-line shop	Ciao! / Happy gift
Host site	http://www.happy-gift.jp/
Branch site	http://www.rakuten.co.jp/ciao/, http://store.shopping.yahoo.co.jp/b-ciao/index.html
Managed	Cherish Co.Ltd.
Customers	all over Japan (Every Prefecture)
Data gathering period	October 2006 – May 2009
Order number	2438 (limited to the order number which has repeated order)
Main residents of customers	Tokyo12.9%, Kanagawa8.8%, Chiba6.9%, Osaka5.9%, Saitama5.8%, Aichi5.0% (The share of Tokyo capital area consists of 34.4%.)
Sales goods	Necklace / Pendant, Pierced earrings, Ring, Bracelet / Bangle, Brooch, Necktie Pin, Miscellaneous （Package/Ribbon etc.）

Table 2. Classification of goods by price

Rank	Price(Yen)	Rank	Price(Yen)	Rank	Price(Yen)	Rank	Price(Yen)
Necklace/Pendant		Pierced earrings		Ring		Bracelet/Bungle	
N6	40,001~	P6	24,001~	R6	40,001~	B6	40,001~
N5	~40,000	P5	~24,000	R5	~40,000	B5	~40,000
N4	~30,000	P4	~16,000	R4	~28,000	B4	~28,000
N3	~20,000	P3	~10,000	R3	~22,000	B3	~22,000
N2	~15,000	P2	~6,000	R2	~15,000	B2	~15,000
N1	~10,000	P1	~2,000	R1	~10,000	B1	~10,000

We consider the case of four variable blocks $\boldsymbol{N}, \boldsymbol{P}, \boldsymbol{R}$ and $\boldsymbol{B}$. The variable $\boldsymbol{N}, \boldsymbol{P}, \boldsymbol{R}$ and $\boldsymbol{B}$ stands for Necklace/Pendant, Pierced earring, Ring and Bracelet/Bungle respectively.

Here, each of them consists of 6 varieties of goods.

$$\boldsymbol{N}_n = \begin{pmatrix} \boldsymbol{N}_1^n \\ \boldsymbol{N}_2^n \\ \vdots \\ \boldsymbol{N}_6^n \end{pmatrix}, \quad \boldsymbol{P}_n = \begin{pmatrix} \boldsymbol{P}_1^n \\ \boldsymbol{P}_2^n \\ \vdots \\ \boldsymbol{P}_6^n \end{pmatrix}, \quad \boldsymbol{R}_n = \begin{pmatrix} \boldsymbol{R}_1^n \\ \boldsymbol{R}_2^n \\ \vdots \\ \boldsymbol{R}_6^n \end{pmatrix}, \quad \boldsymbol{B}_n = \begin{pmatrix} \boldsymbol{B}_1^n \\ \boldsymbol{B}_2^n \\ \vdots \\ \boldsymbol{B}_6^n \end{pmatrix}$$

$$\begin{pmatrix} \boldsymbol{N}_n \\ \boldsymbol{P}_n \\ \boldsymbol{R}_n \\ \boldsymbol{B}_n \end{pmatrix} = \begin{pmatrix} \mathbf{A}_{11} & \mathbf{A}_{12} & \mathbf{A}_{13} & \mathbf{A}_{14} \\ \mathbf{A}_{21} & \mathbf{A}_{22} & \mathbf{A}_{23} & \mathbf{A}_{24} \\ \mathbf{A}_{31} & \mathbf{A}_{32} & \mathbf{A}_{33} & \mathbf{A}_{34} \\ \mathbf{A}_{41} & \mathbf{A}_{42} & \mathbf{A}_{43} & \mathbf{A}_{44} \end{pmatrix} \begin{pmatrix} \boldsymbol{N}_{n-1} \\ \boldsymbol{P}_{n-1} \\ \boldsymbol{R}_{n-1} \\ \boldsymbol{B}_{n-1} \end{pmatrix}$$

$$N_n \in R^6(n=1,2,\cdots), P_n \in R^6(n=1,2,\cdots),$$
$$R_n \in R^6(n=1,2,\cdots), B_n \in R^6(n=1,2,\cdots),$$
$$A_{ij} \in R^{6\times 6}(i=1,\cdots,6)(j=1,\cdots 6)$$

Set

$$\boldsymbol{N} = \{\boldsymbol{N}_1, \boldsymbol{N}_2, \cdots\}$$
$$\boldsymbol{P} = \{\boldsymbol{P}_1, \boldsymbol{P}_2, \cdots\}$$
$$\boldsymbol{R} = \{\boldsymbol{R}_1, \boldsymbol{R}_2, \cdots\}$$
$$\boldsymbol{B} = \{\boldsymbol{B}_1, \boldsymbol{B}_2, \cdots\}$$

Now, we investigate all cases.

Total numbers of shifts among each block are as follows.(Table 3)

Table 3. Total numbers of shifts among each block

$\mathbf{A}_{11}(N \to N)$	615	$\mathbf{A}_{21}(N \to P)$	84	$\mathbf{A}_{31}(N \to R)$	111	$\mathbf{A}_{41}(N \to B)$	38
$\mathbf{A}_{12}(P \to N)$	71	$\mathbf{A}_{22}(P \to P)$	117	$\mathbf{A}_{32}(P \to R)$	15	$\mathbf{A}_{42}(P \to B)$	5
$\mathbf{A}_{13}(R \to N)$	79	$\mathbf{A}_{23}(R \to P)$	16	$\mathbf{A}_{33}(R \to R)$	161	$\mathbf{A}_{43}(R \to B)$	12
$\mathbf{A}_{14}(B \to N)$	37	$\mathbf{A}_{24}(B \to P)$	4	$\mathbf{A}_{34}(\mathrm{B} \to \mathrm{R})$	10	$\mathbf{A}_{44}(B \to B)$	22

The shift to N3 to P4 in $\boldsymbol{N}_{n-1}, \boldsymbol{P}_n$, for example, is expressed as follows when one event arises.

$$\boldsymbol{P}_n = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \boldsymbol{N}_{n-1} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$$

Substituting these to Equation (7), we obtain following equations.

$$\hat{\boldsymbol{\Lambda}} = \begin{pmatrix}
9 & 1 & 3 & 5 & 1 & 1 & 0 & 2 & 1 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 10 & 4 & 4 & 6 & 3 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 2 & 0 & 0 & 1 & 1 & 0 & 1 & 0 \\
2 & 5 & 18 & 11 & 16 & 9 & 0 & 3 & 0 & 2 & 2 & 0 & 0 & 0 & 2 & 1 & 4 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\
5 & 7 & 10 & 36 & 26 & 16 & 0 & 3 & 1 & 1 & 2 & 0 & 0 & 0 & 1 & 5 & 8 & 2 & 0 & 0 & 0 & 0 & 2 & 3 \\
1 & 7 & 18 & 25 & 150 & 42 & 0 & 4 & 2 & 7 & 14 & 1 & 0 & 2 & 0 & 1 & 13 & 5 & 0 & 0 & 0 & 0 & 7 & 2 \\
0 & 2 & 3 & 8 & 33 & 118 & 0 & 1 & 2 & 6 & 13 & 1 & 0 & 1 & 1 & 2 & 15 & 10 & 2 & 0 & 0 & 1 & 6 & 9 \\
0 & 0 & 0 & 0 & 1 & 1 & 2 & 0 & 0 & 0 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
2 & 1 & 1 & 1 & 2 & 5 & 1 & 1 & 2 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 3 & 3 & 3 & 3 & 1 & 2 & 3 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 2 & 7 & 4 & 0 & 0 & 3 & 14 & 1 & 2 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 1 & 3 & 7 & 12 & 12 & 1 & 1 & 1 & 0 & 38 & 4 & 0 & 0 & 1 & 0 & 6 & 1 & 0 & 0 & 0 & 0 & 0 & 2 \\
0 & 0 & 0 & 0 & 3 & 4 & 1 & 0 & 0 & 1 & 4 & 29 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 1 & 1 & 1 & 0 & 2 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 0 & 2 & 0 & 1 & 2 & 0 & 1 & 0 & 0 & 0 & 0 & 2 & 6 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 3 & 1 & 2 & 2 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 2 & 3 & 3 & 0 & 0 & 0 & 0 & 2 & 0 & 1 & 3 & 0 & 4 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 2 & 1 & 9 & 32 & 15 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 2 & 1 & 1 & 64 & 4 & 0 & 0 & 0 & 0 & 5 & 1 \\
0 & 0 & 0 & 3 & 6 & 15 & 1 & 0 & 2 & 0 & 1 & 1 & 2 & 2 & 2 & 1 & 18 & 41 & 0 & 0 & 0 & 0 & 1 & 2 \\
0 & 0 & 0 & 0 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 5 & 8 & 3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 5 & 2 & 1 & 0 & 0 & 0 & 6 & 1 & \\
0 & 1 & 2 & 1 & 4 & 7 & 0 & 1 & 0 & 2 & 1 & 1 & 0 & 0 & 0 & 0 & 3 & 1 & 0 & 0 & 0 & 0 & 1 & 12
\end{pmatrix} \times \begin{pmatrix}
22 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 40 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 74 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 124 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 321 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 267 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 9 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 21 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 19 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 38 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 81 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 40 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 7 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 19 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 14 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 16 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 143 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 68 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 3 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 3 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 32 & 0 & \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 33
\end{pmatrix}^{-1}$$

$$= \begin{pmatrix}
\frac{1}{22} & \frac{1}{40} & \frac{3}{74} & \frac{5}{124} & \frac{1}{321} & \frac{1}{267} & 0 & \frac{2}{21} & \frac{1}{19} & \frac{1}{38} & 0 & 0 & \frac{1}{7} & 0 & 0 & 0 & \frac{1}{143} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \frac{1}{4} & \frac{2}{37} & \frac{1}{31} & \frac{2}{107} & \frac{1}{89} & \frac{1}{9} & \frac{1}{21} & 0 & 0 & 0 & 0 & 0 & \frac{1}{19} & 0 & \frac{1}{16} & \frac{2}{143} & 0 & 0 & 1 & 1 & 0 & \frac{1}{32} & 0 \\
\frac{1}{11} & \frac{1}{8} & \frac{1}{9} & \frac{1}{11} & \frac{16}{321} & \frac{3}{89} & 0 & \frac{1}{7} & 0 & \frac{1}{19} & \frac{2}{81} & 0 & 0 & 0 & \frac{1}{7} & \frac{1}{16} & \frac{4}{143} & 0 & 0 & 0 & 0 & \frac{1}{3} & \frac{1}{32} & 0 \\
\frac{5}{22} & \frac{7}{40} & \frac{5}{37} & \frac{9}{31} & \frac{26}{321} & \frac{16}{267} & 0 & \frac{1}{7} & \frac{1}{19} & \frac{1}{38} & \frac{2}{81} & 0 & 0 & 0 & \frac{1}{14} & \frac{5}{16} & \frac{8}{143} & \frac{1}{34} & 0 & 0 & 0 & 0 & \frac{1}{16} & \frac{1}{11} \\
\frac{1}{22} & \frac{7}{40} & \frac{9}{37} & \frac{25}{124} & \frac{50}{107} & \frac{14}{89} & 0 & \frac{4}{21} & \frac{2}{19} & \frac{7}{38} & \frac{14}{81} & \frac{1}{40} & 0 & \frac{2}{19} & 0 & \frac{1}{16} & \frac{1}{11} & \frac{5}{68} & 0 & 0 & 0 & 0 & \frac{7}{32} & \frac{2}{33} \\
0 & \frac{1}{20} & \frac{3}{74} & \frac{2}{31} & \frac{107}{267} & \frac{118}{267} & 0 & \frac{1}{21} & \frac{2}{19} & \frac{3}{19} & \frac{13}{81} & \frac{1}{40} & 0 & \frac{1}{19} & \frac{1}{14} & \frac{1}{8} & \frac{15}{143} & \frac{5}{34} & \frac{2}{3} & 0 & 0 & \frac{1}{3} & \frac{3}{16} & \frac{3}{11} \\
0 & 0 & 0 & 0 & \frac{1}{321} & \frac{2}{267} & \frac{2}{9} & 0 & 0 & 0 & \frac{2}{81} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\frac{1}{11} & \frac{1}{40} & \frac{1}{74} & \frac{1}{124} & \frac{2}{321} & \frac{5}{267} & \frac{1}{9} & \frac{1}{21} & \frac{2}{19} & 0 & \frac{1}{81} & 0 & 0 & \frac{1}{19} & 0 & 0 & \frac{1}{143} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \frac{3}{74} & \frac{3}{124} & \frac{1}{107} & \frac{1}{89} & \frac{1}{9} & \frac{2}{21} & \frac{3}{19} & \frac{1}{19} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\frac{1}{22} & \frac{1}{40} & \frac{1}{74} & \frac{1}{62} & \frac{7}{321} & \frac{4}{267} & 0 & 0 & \frac{3}{19} & \frac{7}{19} & \frac{1}{51} & \frac{1}{20} & 0 & 0 & \frac{1}{14} & \frac{1}{16} & \frac{1}{143} & \frac{1}{68} & 0 & 0 & 0 & 0 & \frac{1}{32} & 0 \\
0 & \frac{1}{40} & \frac{3}{74} & \frac{7}{124} & \frac{4}{107} & \frac{4}{89} & \frac{1}{9} & \frac{1}{21} & \frac{1}{19} & 0 & \frac{1}{38} & \frac{1}{10} & 0 & 0 & \frac{1}{14} & 0 & \frac{6}{143} & \frac{1}{68} & 0 & 0 & 0 & 0 & 0 & \frac{2}{33} \\
0 & 0 & 0 & 0 & \frac{1}{107} & \frac{4}{267} & \frac{1}{9} & 0 & 0 & \frac{1}{38} & \frac{4}{81} & \frac{29}{40} & 0 & 0 & \frac{1}{14} & 0 & 0 & \frac{1}{68} & 0 & 0 & 0 & 0 & 0 & \frac{1}{33} \\
0 & \frac{1}{40} & \frac{1}{74} & \frac{1}{124} & 0 & \frac{2}{267} & 0 & 0 & \frac{1}{19} & 0 & 0 & 0 & \frac{1}{7} & \frac{1}{19} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\frac{1}{22} & 0 & \frac{1}{37} & 0 & \frac{1}{321} & \frac{2}{267} & 0 & \frac{1}{21} & 0 & 0 & 0 & 0 & \frac{2}{7} & \frac{6}{19} & \frac{1}{14} & 0 & \frac{1}{143} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \frac{1}{40} & \frac{3}{74} & \frac{1}{124} & \frac{2}{321} & \frac{2}{267} & 0 & 0 & 0 & \frac{1}{38} & 0 & 0 & 0 & 0 & \frac{3}{14} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \frac{1}{62} & \frac{1}{107} & \frac{1}{89} & 0 & 0 & 0 & 0 & \frac{2}{81} & 0 & \frac{1}{7} & \frac{3}{19} & 0 & \frac{1}{4} & 0 & 0 & 0 & 0 & 0 & \frac{1}{32} & 0 \\
0 & \frac{1}{20} & \frac{1}{74} & \frac{9}{124} & \frac{32}{321} & \frac{5}{89} & \frac{1}{9} & \frac{1}{21} & \frac{1}{19} & \frac{1}{38} & 0 & \frac{1}{40} & 0 & \frac{2}{19} & \frac{1}{14} & \frac{1}{16} & \frac{64}{143} & \frac{1}{17} & 0 & 0 & 0 & 0 & \frac{5}{32} & \frac{1}{33} \\
0 & 0 & 0 & \frac{3}{124} & \frac{2}{107} & \frac{5}{89} & \frac{1}{9} & 0 & \frac{2}{19} & 0 & \frac{1}{81} & \frac{1}{40} & \frac{2}{7} & \frac{2}{19} & \frac{1}{7} & \frac{1}{16} & \frac{18}{143} & \frac{41}{68} & 0 & 0 & 0 & 0 & \frac{1}{32} & \frac{2}{33} \\
0 & 0 & 0 & 0 & \frac{2}{321} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\frac{1}{22} & 0 & 0 & 0 & \frac{1}{321} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{143} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \frac{1}{74} & 0 & \frac{2}{321} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{3} & 0 & 0 \\
0 & 0 & 0 & \frac{5}{124} & \frac{8}{321} & \frac{1}{89} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{5}{143} & \frac{1}{34} & \frac{1}{3} & 0 & 0 & 0 & \frac{3}{16} & \frac{1}{33} \\
0 & \frac{1}{40} & \frac{1}{37} & \frac{1}{124} & \frac{4}{321} & \frac{7}{267} & 0 & \frac{1}{21} & 0 & \frac{1}{19} & \frac{1}{81} & \frac{1}{40} & 0 & 0 & 0 & 0 & \frac{3}{143} & \frac{1}{68} & 0 & 0 & 0 & 0 & \frac{1}{32} & \frac{4}{11}
\end{pmatrix}$$

We examine all cases by setting case number.

Case 1 $\mathbf{A}_{11}(\boldsymbol{N} \rightarrow \boldsymbol{N})$

Total number of upper shift from N1	71	Total number of lower shift from N1	-
Total number of upper shift from N2	49	Total number of lower shift from N2	33
Total number of upper shift from N3	20	Total number of lower shift from N3	33
Total number of upper shift from N4	7	Total number of lower shift from N4	31
Total number of upper shift from N5	1	Total number of lower shift from N5	21
Total number of upper shift from N6	-	Total number of lower shift from N6	8

We can observe that upper shift from N1 and N2 is dominant and on the contrary, lower shift from N3, N4, N5 and N6 is dominant. This implies that customers buy rather cheap goods at first for the trial and after confirming the quality, they make upper shift in selecting brands. After reaching higher brands, they buy cheaper goods and that leads to a lower shift in brand selection.

Hearing form customers, we can also find that she buy necklace for herself and confirm the quality. After that, she makes gift by selecting upper brand. Sometimes she buys lower brand goods for herself after making gift. That scene can often be seen and the result shows its sequence well. When the shop owner introduces new brand goods, he/she has to determine the price. If it is not reasonable, customers do not select their brand position as the shop owner assumes. These are confirmed by the brand shift transition, which forces the shop owner to re-consider the price and brand position of the new brand goods.

Case 2 $\mathbf{A}_{12}(\boldsymbol{P} \rightarrow \boldsymbol{N})$

Total number of upper shift from P1	1	Total number of lower shift from P1	-
Total number of upper shift from P2	4	Total number of lower shift from P2	13
Total number of upper shift from P3	3	Total number of lower shift from P3	13
Total number of upper shift from P4	1	Total number of lower shift from P4	5
Total number of upper shift from P5	2	Total number of lower shift from P5	11
Total number of upper shift from P6	-	Total number of lower shift from P6	1

We can observe that upper shift from P1 can be seen and on the contrary, lower shift from P2, P3, P4, P5 and P6 is dominant.

Case 3 $\mathbf{A}_{13}(\boldsymbol{R} \rightarrow \boldsymbol{N})$

Total number of upper shift from R1	7	Total number of lower shift from R1	-
Total number of upper shift from R2	15	Total number of lower shift from R2	15
Total number of upper shift from R3	2	Total number of lower shift from R3	3
Total number of upper shift from R4	0	Total number of lower shift from R4	2
Total number of upper shift from R5	0	Total number of lower shift from R5	3
Total number of upper shift from R6	-	Total number of lower shift from R6	0

We can observe that upper shift from R1 is dominant and on the contrary, lower shifts from R3, R4 and R5 is dominant. This characteristic is rather common in each case, although subtle difference may occur.

Case 4 $\mathbf{A}_{14}(\boldsymbol{B} \rightarrow \boldsymbol{N})$

Total number of upper shift from B1	5	Total number of lower shift from B1	-
Total number of upper shift from B2	4	Total number of lower shift from B2	6
Total number of upper shift from B3	1	Total number of lower shift from B3	1
Total number of upper shift from B4	1	Total number of lower shift from B4	0
Total number of upper shift from B5	0	Total number of lower shift from B5	0
Total number of upper shift from B6	-	Total number of lower shift from B6	2

We can observe the similar characteristics as seen before, although there is subtle difference.

Case 5 $\mathbf{A}_{21}(\boldsymbol{N} \rightarrow \boldsymbol{P})$

Total number of upper shift from N1	25	Total number of lower shift from N1	-
Total number of upper shift from N2	13	Total number of lower shift from N2	3
Total number of upper shift from N3	4	Total number of lower shift from N3	7
Total number of upper shift from N4	1	Total number of lower shift from N4	4
Total number of upper shift from N5	0	Total number of lower shift from N5	2
Total number of upper shift from N6	-	Total number of lower shift from N6	3

We can observe clearly that the upper shift from N1 and N2 is dominant and on the contrary, the lower shift from N3, N4, N5 and N6 is dominant.

Case 6 $\mathbf{A}_{22}(\boldsymbol{P} \rightarrow \boldsymbol{P})$

Total number of upper shift from P1	6	Total number of lower shift from P1	-
Total number of upper shift from P2	4	Total number of lower shift from P2	4
Total number of upper shift from P3	2	Total number of lower shift from P3	1
Total number of upper shift from P4	2	Total number of lower shift from P4	4
Total number of upper shift from P5	0	Total number of lower shift from P5	3
Total number of upper shift from P6	-	Total number of lower shift from P6	4

We can observe clearly that the upper shift from P1 and P3 is dominant and on the contrary, the lower shift from P4, P5 and P6 is dominant.

Case 7 $\mathbf{A}_{23}(\boldsymbol{R} \rightarrow \boldsymbol{P})$

Total number of upper shift from R1	2	Total number of lower shift from R1	-
Total number of upper shift from R2	2	Total number of lower shift from R2	0
Total number of upper shift from R3	0	Total number of lower shift from R3	0
Total number of upper shift from R4	0	Total number of lower shift from R4	3
Total number of upper shift from R5	0	Total number of lower shift from R5	0
Total number of upper shift from R6	-	Total number of lower shift from R6	0

We can observe the upper shift from R1 and R2.

Case 8 $\mathbf{A}_{24}(\boldsymbol{B} \rightarrow \boldsymbol{P})$

Total number of upper shift from B1	2	Total number of lower shift from B1	-
Total number of upper shift from B2	1	Total number of lower shift from B2	0
Total number of upper shift from B3	0	Total number of lower shift from B3	0
Total number of upper shift from B4	0	Total number of lower shift from B4	0
Total number of upper shift from B5	0	Total number of lower shift from B5	0
Total number of upper shift from B6	-	Total number of lower shift from B6	0

We can observe the upper shift from B1 and B2.

Case 9 $\mathbf{A}_{31}(\boldsymbol{N} \rightarrow \boldsymbol{R})$

Total number of upper shift from N1	24	Total number of lower shift from N1	-
Total number of upper shift from N2	6	Total number of lower shift from N2	6
Total number of upper shift from N3	2	Total number of lower shift from N3	12
Total number of upper shift from N4	3	Total number of lower shift from N4	1
Total number of upper shift from N5	1	Total number of lower shift from N5	3
Total number of upper shift from N6	-	Total number of lower shift from N6	1

We can observe that the upper shift from N1 is dominant and on the contrary, the lower shift from N3, N5 and N6 is dominant.

Case 10 $\mathbf{A}_{32}(\boldsymbol{P} \rightarrow \boldsymbol{R})$

Total number of upper shift from P1	1	Total number of lower shift from P1	-
Total number of upper shift from P2	2	Total number of lower shift from P2	1
Total number of upper shift from P3	1	Total number of lower shift from P3	1
Total number of upper shift from P4	1	Total number of lower shift from P4	3
Total number of upper shift from P5	0	Total number of lower shift from P5	1
Total number of upper shift from P6	-	Total number of lower shift from P6	2

We can observe the upper shift from P1 and P2 and the lower shift from P4, P5 and P6.

Case 11 $\mathbf{A}_{33}(\boldsymbol{R} \rightarrow \boldsymbol{R})$

Total number of upper shift from R1	4	Total number of lower shift from R1	-
Total number of upper shift from R2	1	Total number of lower shift from R2	18
Total number of upper shift from R3	0	Total number of lower shift from R3	2
Total number of upper shift from R4	1	Total number of lower shift from R4	3
Total number of upper shift from R5	1	Total number of lower shift from R5	7
Total number of upper shift from R6	-	Total number of lower shift from R6	5

We can observe clearly that the upper shift from R1 is dominant and on the contrary, the lower shift from R2, R3, R4, R5 and R6 is dominant.

Case 12 $\mathbf{A}_{34}(\boldsymbol{B} \rightarrow \boldsymbol{R})$

Total number of upper shift from B1	1	Total number of lower shift from B1	-
Total number of upper shift from B2	1	Total number of lower shift from B2	1
Total number of upper shift from B3	0	Total number of lower shift from B3	0
Total number of upper shift from B4	0	Total number of lower shift from B4	0
Total number of upper shift from B5	0	Total number of lower shift from B5	0
Total number of upper shift from B6	-	Total number of lower shift from B6	0

We can observe the upper shift from B1.

Case 13 $\mathbf{A}_{41}(\boldsymbol{N} \rightarrow \boldsymbol{B})$

Total number of upper shift from N1	3	Total number of lower shift from N1	-
Total number of upper shift from N2	5	Total number of lower shift from N2	4
Total number of upper shift from N3	0	Total number of lower shift from N3	6
Total number of upper shift from N4	0	Total number of lower shift from N4	3
Total number of upper shift from N5	0	Total number of lower shift from N5	1
Total number of upper shift from N6	-	Total number of lower shift from N6	1

We can observe that the upper shift from N1 and N2 is dominant and on the contrary, the lower shift from N3, N4, N5 and N6 is dominant.

Case 14 $\mathbf{A}_{42}(\boldsymbol{P} \rightarrow \boldsymbol{B})$

Total number of upper shift from P1	0	Total number of lower shift from P1	-
Total number of upper shift from P2	0	Total number of lower shift from P2	1
Total number of upper shift from P3	0	Total number of lower shift from P3	2
Total number of upper shift from P4	0	Total number of lower shift from P4	0
Total number of upper shift from P5	0	Total number of lower shift from P5	1
Total number of upper shift from P6	-	Total number of lower shift from P6	0

We can observe the lower shift from P2, P3 and P5.

Case 15 $\mathbf{A}_{43}(\boldsymbol{R} \rightarrow \boldsymbol{B})$

Total number of upper shift from R1	2	Total number of lower shift from R1	-
Total number of upper shift from R2	1	Total number of lower shift from R2	3
Total number of upper shift from R3	0	Total number of lower shift from R3	0
Total number of upper shift from R4	0	Total number of lower shift from R4	0
Total number of upper shift from R5	0	Total number of lower shift from R5	0
Total number of upper shift from R6	-	Total number of lower shift from R6	0

We can observe the upper shift from R1 and the lower shift from R2.

Case 16 $\mathbf{A}_{44}(\boldsymbol{B} \rightarrow \boldsymbol{B})$

Total number of upper shift from B1	1	Total number of lower shift from B1	-
Total number of upper shift from B2	0	Total number of lower shift from B2	1
Total number of upper shift from B3	0	Total number of lower shift from B3	0
Total number of upper shift from B4	0	Total number of lower shift from B4	0
Total number of upper shift from B5	0	Total number of lower shift from B5	0
Total number of upper shift from B6	-	Total number of lower shift from B6	1

We can observe the upper shift from B1 and the lower shift from B2 and B6.

6. REMARKS

The retailer and customers including authors discussed about jewelry/accessory on-line shopping based upon their own experiences. Some of them imply the reason of the lower shift from the higher ranked brand. Some of them suggest the future works to be investigated. Nearly 70% customers are men and they mainly purchase jewelry/accessory for gift. Therefore analysis for men becomes dominant in the following discussion.

<In the case male buys>

a He usually has budget range in making present to his lovers. Therefore there often happens buying the same range level of brand.

b He is apt to spend much money at the first present. But from the second, it would decrease. – There are Japanese saying that he does not give much food to the fish he caught. When the lover is changed, this scheme would be repeated.

c Budget may change according to the characteristics of the event. If it is a Xmas or a birthday present, the budget is high and less for those of the white day or other events.

d If he buys presents with other goods (for example, necklace and flower etc.), jewelry/accessory price would decrease even if the total budget increases.

e Male is not so severe to the price whether it is qualified or not for its quality.

f If he buys goods at the real shop, a saleswoman would recommend the goods and he would be apt to buy much higher one than those at the virtual shop.

g In the case of the couple of separated ages, male is apt to show off, therefore brand selection of upper shift is often the case.

h After married, brand selection of upper shift is rare for his wife in making present.

i While young, he makes upper shift after having relationship with partner for about one year. After that, it tends to make lower shift.

j Male is often simple-minded. Therefore, if she is glad at the present, he repeats the item, not considering another choice.

<In the case female buys>

k She makes confirmation of the goods about how it would be at the first purchasing. If she is satisfied, then she makes repeated purchasing. If the goods is well, she also buys them for herself.

l The price of goods may not change for female whether she buys at the real shop or virtual shop.

7. CONCLUSION

Consumers often buy higher grade brand products as they are accustomed or bored to use current brand products they have. There may be also the case that customer selects lower brand to seek suitable price when she already has higher ranked brand.

In this paper, matrix structure was clarified when brand selection was executed toward higher grade brand and/or lower grade brand. Expanding brand selection from single brand group to multiple genre brand group, we could make much more exquisite and multi-dimensional analysis. Utilizing purchase history record of jewelry/accessory on-line shopping (Necklace/Pendant, Pierced earrings, Ring, Bracelet/Bungle) over three years, above matrix structure was investigated and confirmed. This new method should be examined in various cases.

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Toward Developing a Versatile Wearable Computer for Drivers : Phase I – Conceptualizing and Prototyping

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Abstract

A versatile wearable computer for drivers (VWCD) was proposed that can serve as a drowsy driving alerting system, a lane departure warning system (LDWS), a blind spot alerting system, and a u-Health system that monitors the driver's heart rate. In the first development phase, LEDs, mini video displays, earphones, and vibrators functioned as visual, auditory and tactile displays, and these were all integrated on the eyeglass frame. One electrocardiographic electrode was attached to the VWCD to obtain the driver's heart rate signal at the posterior auricular artery, and a gyro sensor was used to track the driver's head position. Finally, a Bluetooth device was included to enable communication between VWCD and its mobile phone platform.

Keywords: multi-modal display, visual display, wearable computer for drivers

1. Introduction

One of the major reasons to use a wearable computer is that it can seamlessly provide information to people on the move. While wearable computers have been used in various application areas including games, medical devices, aerospace, and automotive industry (for maintenance), there are some problems in current wearable computers that hinder their commercial success. In terms of design and human factors aspects, many wearable computers are still obtrusive and uncomfortable due to their bulky and heavy components such as control box and cables. Therefore, size minimization and wireless connection are a key factor for improving its design. In addition, many wearable devices still tend to be expensive and inefficient [1]. Currently, there is no commercialized wearable computer for drivers [2], despite surface vehicles are most commonly used to move people and objects.

Among display types, visual display is most widely used in the vehicle, followed by auditory and tactile displays. Visual information in the vehicle is usually displayed in the area placed in front of the driver (e.g., cluster, crash pad, and windshield), which is however not always included in the driver's forward field of view (e.g., when the driver look at the outside mirror or the passenger on his side). If the driver does not look ahead, it is very likely for him to miss critical information displayed on conventional in-vehicle visual displays. Therefore, it would be very effective to track the driver's head position and provide critical information right in front of the driver's eye. By doing so, the driver would be less likely to miss important information, even when the driver does not look at the forward direction of the vehicle.

There are an ever increasing number of drivers who wear eyeglasses, due to the rapidly growing aging driver population with degraded eyesight. Wearable devices which are mounted on, or integrated into, the eyeglasses, hence, seem to a promising solution to provide safety-related information for drivers.

VWCD has been conceptualized to continuously provide the driver safety-related information, as well as to monitor driver's heart rate. By integrating LEDs, speakers and vibrators on the frame of glasses as visual, auditory, and tactile displays, the driver can always be informed the direction of imminent risky objects and situations, regardless of their head position, unless their eyes are closed. With electrocardiogram sensors which are attached to the leg ends of the eyeglasses, VWCD can monitors the driver's heart rate at the bilateral posterior auricular arteries.

VWCD has been designed with the aims to minimize its size and weight, and to consider its appearance, and connection with widely used devices such as iPhone and iPod Touch. It should also improve the driver's situational awareness.

2. Related research

To implement wearable computers, a variety of display technologies have been developed together. There are various types of display technologies such as single crystal silicon, liquid crystal on silicon, high temperature poly silicon, low temperature poly silicon, laser or optical beam-scan, organic light-emitting diode, digital micro-mirror device, and micro-cathode ray tubes. For cost effectiveness and minimization, VWCD uses LEDs and mini video displays to provide visual information to both eyes.

Currently, there are five different methods to display visual information; binocular immersive, binocular see-periphery, binocular see-through (navigation/video sunglasses), monocular see-around, and monocular see-through. As a first phase of developing VWCD, binocular see-around types and mini video display have been selected to provide visual information.

There are several commercialized eyeglasses-type wearable computers such as a wearable display developed by Konica Minolta, an image overlay system for medical data visualization, the Olympus Mobile Eye-Trek model, and the Personal Display by Eyewear.

3. VWCD system development

3.1 Innovative System Concept Generation by TRIZ and Lateral thinking Tools

In order to provide drivers with context-driven information, collecting appropriate and accurate information from the driver and the vehicle is essential. One of the best ways is to use physiological data such as brain waves, heart rate, and body temperature, while minimizing the driver's distraction. Systems that measure drivers' fatigue (e.g., MIT smart car [3]) have not been successfully commercialized due to intrusiveness of the system.

According to Edward De Bono, the problem solver should explore different ways of examining a challenging task [4]. By adopting his concept, called Lateral Thinking, we can think of a system that can obtain the driver's physiological data as well as provide relevant information to the driver. As a measuring device, an eyeglass-type system appears to be less intrusive than other types of alternatives for drivers (clothes, wrist-band type,

etc), considering that many people wear corrective eyeglasses or sun glasses. In addition, VWCD provides drivers with information necessary for safe driving while allowing them to maintain their forward sight. Furthermore, multi-modal (visual, tactile, and auditory) displays enhance information transfer by redundancy gain and provide selective, effective display channels, depending on driving context, The multi-functionality and dimensionality change suggested by TRIZ to develop inventive systems are hence applied to the VWCD concept generation, resulting that it functions as input as well as output device, and extends space for visual and auditory displays and sensors to eyeglasses [5].

3.2 System Components

The VWCD system consists of a pair of see-around visual displays, mini video displays, vibrators, earphones, and electrocardiogram sensors, a gyro sensor, an operating system, two control / processing units, and a Bluetooth transceiver. Fourteen LEDs are attached around each lens (Figures 1 and 2). Gyro sensor was used to detect rotation and direction of the driver's head movement. LEDs were controlled by the control unit and when drivers turn their head to the right direction while the potentially risky object is detected from the front or left direction, then the left vibrator turns on and the left LEDs blink to alert the driver. When the driver looks at his right side, with the head rotated, left LEDs and vibrators come into play. LEDs can communicate wirelessly with a laptop via the Bluetooth module. Visual displays and earphones can be connected to a mobile application, iPod Touch, and the driver can see the icon such as traffic signals using their peripheral vision and hear the alerting sound. Two electrocardiogram sensors are connected to the processing unit and these continually record the driver's heart activities (Figure 3).

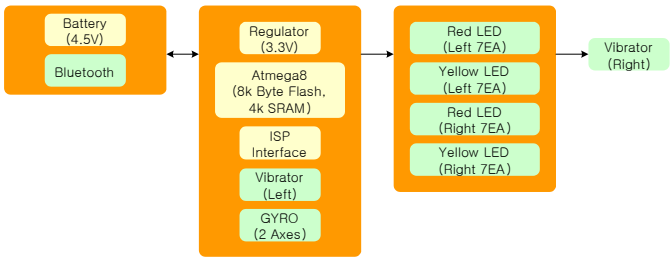

Figure 1. VWCD block diagram

Figure 2. VWCD prototype

Figure 3. Left or Right LEDs blink depending on the direction of a risky object

Figure 4. Electrocardiogram recording

4. Future work

Visually overloaded drivers can easily miss the important information. VWCD extends the visual information design space, and facilitates critical information reception, by providing multi-modal information.

However, it should be determined later what combination of input modalities is optimal for the drivers. In the current development phase, a see-around visual display type was selected majorly due to its low cost and functional simplicity, whereas an optical see-through type has not been considered due to its high cost and technological immaturity. In the future, visual displays such as video and optical see-through might be used to more effectively detect the forward driving situation and to display critical information directly on lenses during driving. VWCD always contacts with the driver's skin, which is necessary condition to continuously monitor health-related information. VWCD and its processing unit are wire connected. As a fashionable product integrated with new technologies, VWCD components should be wirelessly connected and miniaturized further to increase users' technology acceptance, and hence, the possibility of commercial success.

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Analysis of Brand Selection in an Automobile Case Study

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Abstract

It is often observed that consumers select the upper class brand when they buy the next time. 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 triangle 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 triangle matrix would be 0. A questionnaire investigation for automobile purchasing case is executed and the above structure is confirmed. 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 other products, matrix structure makes 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.

Key Words: brand selection, matrix structure, automobile industry

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 this paper, matrix structure is analyzed for the case the upper class brand is selected compared with the past purchasing case, and extensions for various applications are executed. Such research can not be found as long as searched.

Hereinafter, matrix structure is clarified for the selection of brand in section 2. A questionnaire investigation to Automobile Purchasing case is examined and its numerical calculation is executed in section 3. Application of this method is extended in section 4. Section 5 is a summary.

2. Brand Selection and Its Matrix Structure

2.1 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.

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

$$\mathbf{X}_{\mathbf{b}}^{\mathbf{i}} = \begin{pmatrix}0\\1\\0\end{pmatrix} \qquad \begin{pmatrix}1\\0\\0\end{pmatrix} \qquad \cdots \qquad \begin{pmatrix}0\\0\\1\end{pmatrix} \tag{4}$$

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

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.

2.2 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.

$$\begin{array}{c} \\ \begin{pmatrix} x \\ y \\ z \end{pmatrix} \end{array} \overset{\hat{\mathbf{A}}}{\begin{pmatrix} \bigcirc & \bigcirc & \bigcirc \\ \varepsilon & \bigcirc & \bigcirc \\ \varepsilon & \varepsilon & \bigcirc \end{pmatrix}} \quad \underset{\Leftarrow}{\text{Shifting}} \quad \begin{array}{c} \\ \begin{pmatrix} z \\ x \\ y \end{pmatrix} \end{array} \overset{\hat{\mathbf{A}}}{\begin{pmatrix} \varepsilon & \varepsilon & \bigcirc \\ \bigcirc & \bigcirc & \bigcirc \\ \varepsilon & \bigcirc & \bigcirc \end{pmatrix}} \tag{8}$$

2.3 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.

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

3. A Questionnaire Investigation and Numerical Calculation

A questionnaire investigation for automobile purchasing case is executed.

<Delivery of Questionnaire Sheets>

・Delivery Term : July 1 to 31 / 2009
・Delivery Place : Osaka, Hyogo, Tokyo in Japan
・Number of Delivered Questionnaire sheets: 500

<Result of collected Questionnaire Sheets>
・Collected Questionnaire Sheets:199
・Collected data sets:516

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 516 data sets. 201 cases are the upper shifts, 192 cases are the same rank movement, and 123 cases are the lower shifts. Lower shift is consists of 1/5 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 199 sheets

Age		Sex		Occupation		Annual income (Japanese Yen)		Marriage		Kids	
Teens	26	Male	173	Student	74	0-3 million	68	Single	100	0	117
Twenties	69	Female	26	Officer	13	3-5 million	17	Married	97	1	12
Thirties	31			Company employee	90	5-7.5 million	20	Not filled in	2	2	51
Forties	38			Clerk of Organization	1	7.5-10 million	10			3	17
Fifties	32			Independents	11	10-15 million	5			4	2
Sixties and over	3			Miscellaneous	9	15 million or more	1			5	0
Not filled in	0			Not filled in	1	Not filled in	78				
Sum	199		199		199		199		199		199

Analyzing collected sheets based on Model ranked Table (Appendix1, Appendix2), we obtained the following 516 data sets. Appendix shows the ranking Table for this calculation.

1. Shift from 5th position to 5th position : 71
2. Shift from 5th position to 4th position : 31
3. Shift from 5th position to 3rd position : 26
4. Shift from 5th position to 2nd position : 29
5. Shift from 5th position to 1st position : 10
6. Shift from 4th position to 5st position : 19
7. Shift from 4th position to 4st position : 30
8. Shift from 4th position to 3st position : 24

9.	Shift from 4th position to 2st position	:	20
10.	Shift from 4th position to 1st position	:	4
11.	Shift from 3th position to 5st position	:	15
12.	Shift from 3th position to 4st position	:	14
13.	Shift from 3th position to 3st position	:	22
14.	Shift from 3th position to 2st position	:	28
15.	Shift from 3th position to 1st position	:	12
16.	Shift from 2th position to 5st position	:	15
17.	Shift from 2th position to 4st position	:	9
18.	Shift from 2th position to 3st position	:	30
19.	Shift from 2th position to 2st position	:	55
20.	Shift from 2th position to 1st position	:	17
21.	Shift from 1th position to 5st position	:	6
22.	Shift from 1th position to 4st position	:	5
23.	Shift from 1th position to 3st position	:	5
24.	Shift from 1th position to 2st position	:	5
25.	Shift from 1th position to 1st position	:	14

Using the description as is stated in 2.1, the vector $\mathbf{X}, \mathbf{X_b}$ in these cases are expressed as follows.

1. $\mathbf{X} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X_b} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ 2. $\mathbf{X} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X_b} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ 3. $\mathbf{X} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X_b} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$

4. $\mathbf{X} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X_b} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ 5. $\mathbf{X} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X_b} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ 6. $\mathbf{X} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ $\mathbf{X_b} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

7. $\mathbf{X} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ $\mathbf{X_b} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ 8. $\mathbf{X} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X_b} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ 9. $\mathbf{X} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ $\mathbf{X_b} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix}$

10. $\mathbf{X}=\begin{pmatrix}1\\0\\0\\0\\0\end{pmatrix}$ $\mathbf{X_b}=\begin{pmatrix}0\\0\\0\\1\\0\end{pmatrix}$ 11. $\mathbf{X}=\begin{pmatrix}0\\0\\0\\0\\1\end{pmatrix}$ $\mathbf{X_b}=\begin{pmatrix}0\\0\\1\\0\\0\end{pmatrix}$ 12. $\mathbf{X}=\begin{pmatrix}0\\0\\0\\1\\0\end{pmatrix}$ $\mathbf{X_b}=\begin{pmatrix}0\\0\\1\\0\\0\end{pmatrix}$

13. $\mathbf{X}=\begin{pmatrix}0\\0\\1\\0\\0\end{pmatrix}$ $\mathbf{X_b}=\begin{pmatrix}0\\0\\1\\0\\0\end{pmatrix}$ 14. $\mathbf{X}=\begin{pmatrix}0\\1\\0\\0\\0\end{pmatrix}$ $\mathbf{X_b}=\begin{pmatrix}0\\0\\1\\0\\0\end{pmatrix}$ 15. $\mathbf{X}=\begin{pmatrix}1\\0\\0\\0\\0\end{pmatrix}$ $\mathbf{X_b}=\begin{pmatrix}0\\0\\1\\0\\0\end{pmatrix}$

16. $\mathbf{X}=\begin{pmatrix}0\\0\\0\\0\\1\end{pmatrix}$ $\mathbf{X_b}=\begin{pmatrix}0\\1\\0\\0\\0\end{pmatrix}$ 17. $\mathbf{X}=\begin{pmatrix}0\\0\\0\\1\\0\end{pmatrix}$ $\mathbf{X_b}=\begin{pmatrix}0\\1\\0\\0\\0\end{pmatrix}$ 18. $\mathbf{X}=\begin{pmatrix}0\\0\\1\\0\\0\end{pmatrix}$ $\mathbf{X_b}=\begin{pmatrix}0\\1\\0\\0\\0\end{pmatrix}$

19. $\mathbf{X}=\begin{pmatrix}0\\1\\0\\0\\0\end{pmatrix}$ $\mathbf{X_b}=\begin{pmatrix}0\\1\\0\\0\\0\end{pmatrix}$ 20. $\mathbf{X}=\begin{pmatrix}1\\0\\0\\0\\0\end{pmatrix}$ $\mathbf{X_b}=\begin{pmatrix}0\\1\\0\\0\\0\end{pmatrix}$ 21. $\mathbf{X}=\begin{pmatrix}0\\0\\0\\0\\1\end{pmatrix}$ $\mathbf{X_b}=\begin{pmatrix}1\\0\\0\\0\\0\end{pmatrix}$

22. $\mathbf{X}=\begin{pmatrix}0\\0\\0\\1\\0\end{pmatrix}$ $\mathbf{X_b}=\begin{pmatrix}1\\0\\0\\0\\0\end{pmatrix}$ 23. $\mathbf{X}=\begin{pmatrix}0\\0\\1\\0\\0\end{pmatrix}$ $\mathbf{X_b}=\begin{pmatrix}1\\0\\0\\0\\0\end{pmatrix}$ 24. $\mathbf{X}=\begin{pmatrix}0\\1\\0\\0\\0\end{pmatrix}$ $\mathbf{X_b}=\begin{pmatrix}1\\0\\0\\0\\0\end{pmatrix}$

25. $\mathbf{X}=\begin{pmatrix}1\\0\\0\\0\\0\end{pmatrix}$ $\mathbf{X_b}=\begin{pmatrix}1\\0\\0\\0\\0\end{pmatrix}$

Substituting these to equation (7), we can get the transition matrix $\hat{\mathbf{A}}$ as follows.

$$\hat{\mathbf{A}} = \begin{pmatrix} 14 & 17 & 12 & 4 & 10 \\ 5 & 55 & 28 & 20 & 29 \\ 5 & 30 & 22 & 24 & 26 \\ 5 & 9 & 14 & 30 & 31 \\ 6 & 15 & 15 & 19 & 71 \end{pmatrix} \begin{pmatrix} 35 & 0 & 0 & 0 & 0 \\ 0 & 126 & 0 & 0 & 0 \\ 0 & 0 & 91 & 0 & 0 \\ 0 & 0 & 0 & 97 & 0 \\ 0 & 0 & 0 & 0 & 167 \end{pmatrix}^{-1} = \begin{pmatrix} \frac{2}{5} & \frac{17}{126} & \frac{12}{91} & \frac{4}{97} & \frac{10}{167} \\ \frac{1}{7} & \frac{55}{126} & \frac{4}{13} & \frac{20}{97} & \frac{29}{167} \\ \frac{1}{7} & \frac{5}{21} & \frac{22}{91} & \frac{24}{97} & \frac{26}{167} \\ \frac{1}{7} & \frac{1}{14} & \frac{2}{13} & \frac{30}{97} & \frac{31}{167} \\ \frac{6}{35} & \frac{5}{42} & \frac{15}{91} & \frac{19}{97} & \frac{71}{167} \end{pmatrix} \quad (10)$$

A questionnaire investigation for automobile purchasing case is executed and the matrix structure stated in 2.1 can be confirmed on the whole. Next, we compared lower shift data with upper shift data and same rank movement data. There are the features as follows (Table 2).

Table 2. Features of lower-shift (123 cases)

Valued items in purchasing cars		
	Lower shift	**Upper shift and Same rank movement**
1. price	Important 88%	Important 83%
2. manufacturer's name	Important 68%	Important 65%
3. Running cost	Important 70%	Important 65%
About hobby and favor		
1. sports	Important 77%	Important 74%
2. shopping	Important 42%	Important 52%
3. music	Important 56%	Important 61%
4. movie	Important 39%	Important 36%
5. Internet	Important 49%	Important 44%
6. driving	Important 64%	Important 61%
About lifestyle		
1.How to spend a holiday	Outdoor 39% Indoor 26%	Outdoor 38% Indoor 27%

First of all, there is not so much distinction among lower shifts, same rank movements and upper shifts in basic attributes. About important items in purchasing cars, people who esteem price, running cost and manufacturer's name tend to shift to lower class. It seems that they shift to lower class because of the money saving and being particular about brand name.

For about hobby and favor, people who like sports and seeing movies (only in theatres) tend to shift to lower class. On the other hand, people who like listening music tend to shift to same class and upper class. Generally, outdoor type's people are apt to make lower shifts, while those who like shopping are apt to make upper shifts. Based on these data, we can assume that people who make shift to same class or upper class use their cars for the purpose of daily shopping.

Finally, percentage to lower shifts is high for the person who likes using Internet. This shows that people who search information utilizing Internet are sensitive to the price of cars. We can observe a lot of following patterns in lower shifts.

a) Honda, accord (Sedan Type, rank Ⅱ)→Cars of rank Ⅲ or rank Ⅳ
b) Cars of rank Ⅰ, Ⅱ or Ⅲ→Honda, fit (Compact car, rank Ⅴ)
c) Cars of rank Ⅰ or Ⅱ→Toyota, Prius (Sedan Type, rank Ⅲ)

The features are as follows.

a) Many people are men in fifties and company employees. They esteem design, performance, price of cars and dealer's correspondence very much. Their occupational categories are deskwork for the most part. Car design is the decisive factor for purchasing Accords. On the other hand, they esteem performance of car and their lifestyle in purchasing a new car. Therefore, they would have made lower shift because of the change of the lifestyle owing to the aging. Change of lifestyle is caused, for example, by a decrease of income from the retirement or their independence.
b) In this case, there are lot of people whose annual income is less than 3 million yen. They make much of design, performance and price of cars. Almost all of them are outdoor type (like sports and traveling) and use internet frequenly. Their occupational categories are deskwork. They purchase Fit because of its performance, price and running cost. It is possible to observe their intention not to spend money in car because they use their cars for their hobby.
c) In this case, young people in their twenties or thirties compose the majority. Percentage of the people who esteem design, performance and price of car, brand and environment is very high. It is assumed that young people who like traveling, using Internet and driving, have high awareness of environmental issues. The best reason to select Prius is its performance. We can observe that its brand has been established.

Based on these results, we also examined the influence on shifts derived by eco-car. All eco-cars are exhibited in Table 3.

Table 3. List of eco-car which holds tax reduction treatment

	Toyota	Nissan	Honda	Subaru	Suzuki	Mitsubishi	Mazda	Daihatsu
Sedan	Crown hybrid Prius	Tiida	Insight	Impreza anesis			Axela	
One box・Minivan	Isis Alphard Wish Vellfire Voxy Estima Sienta Noah	Serena	Elysion prestige Odyssey Stepwgn Stepwgn spada Stream Freed			Delica D:5	MVP Premacy	
Wagon	Mark x zio			Legacy touring-wagon			Demio	
SUV	RAV4	X-trail		Forester		Outlander		
Compact car	iQ Vitz Corolla rumion Passo	Cube Note March	Fit		Swift			
Light car		Otti Pino		Stella	MR wagon Alto Wagon R	eK wagon Minica		Mira Move

There are many eco-cars as mentioned above. Because of the tax reduction treatment and having effective gas mileage for running, lower shifts to these cars would increase. But the eco-car tax reduction treatment is only a temporary one. Therefore, removing shifts for eco-car, we re-calculated (7) and obtained the following result.

$$\hat{\mathbf{A}} = \begin{pmatrix} 14 & 17 & 12 & 4 & 10 \\ 4 & 55 & 28 & 20 & 29 \\ 4 & 14 & 22 & 24 & 26 \\ 2 & 6 & 6 & 30 & 31 \\ 3 & 7 & 9 & 10 & 71 \end{pmatrix} \begin{pmatrix} 27 & 0 & 0 & 0 & 0 \\ 0 & 99 & 0 & 0 & 0 \\ 0 & 0 & 77 & 0 & 0 \\ 0 & 0 & 0 & 88 & 0 \\ 0 & 0 & 0 & 0 & 167 \end{pmatrix}^{-1} = \begin{pmatrix} \frac{14}{27} & \frac{17}{99} & \frac{12}{77} & \frac{1}{22} & \frac{10}{167} \\ \frac{4}{27} & \frac{5}{9} & \frac{4}{11} & \frac{5}{22} & \frac{29}{167} \\ \frac{4}{27} & \frac{14}{99} & \frac{2}{7} & \frac{3}{11} & \frac{26}{167} \\ \frac{2}{27} & \frac{2}{33} & \frac{6}{77} & \frac{15}{44} & \frac{31}{167} \\ \frac{1}{9} & \frac{7}{99} & \frac{9}{77} & \frac{5}{44} & \frac{71}{167} \end{pmatrix} \quad (11)$$

Comparing (10) with (11), (11) became more clear upper triangular matrix. In fact, lower shifts to eco-car are 58 and compose 47% in all lower shifts and these have big

influences upon lower shits. Awareness of environmental issues would increase much more in the near future, therefore we can not ignore such factor.

Hearing results from the car dealers are as follows. There is a tendency to the shift to the upper brands. But some of them have the following features such as :

1. When young, they ride on the high ranked automobile. But when married, they ride on the automobile of the ordinary level.
2. Office workers are apt to buy the higher ranked automobile as they promote.
3. Recently the interior of automobile became upgraded. Therefore user can enjoy the higher ranked automobile in a rather lower grade automobile, which causes less need to upgrade.
4. People who ride on eco-car are increasing.

Therefore, there are cases that the shifts to the upper brands do not necessarily occur, especially for a)-c) cases. Anyway, 47% of lower shifts is by the reason of eco-car tax reduction treatment. Excepting these cases, the results show that 86% (Upper shift:201, Same shift:192, Lower shift:65) are the same rank movement or the upper shifts, and the transition matrix corresponds to these facts on the whole.

4. Applications of This Method

Applications of this method are considered to be as follows. Consumers' behavior may converge by repeating forecast under the above method and the total volume of sales of all brands may be reduced. Therefore, the analysis results suggest when and what to put the new brand into the market which contribute to the expansion of the market.

There may arise following cases. Consumers and producers do not recognize the brand position clearly. But the analysis of consumers' behavior let them know their brand position in the market. In such a case, strategic marketing guidance to select the brand would be introduced. Setting in order the brand position of various goods and taking suitable marketing policy, enhancement of sales would be enabled. Setting the higher ranked brand, consumption would be promoted.

5. Conclusion

It is often observed that consumers select the upper class brand when they buy the next time. 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 become an upper triangle matrix under the supposition that former buying variables are set input and current buying variables are set output. If the top brand are selected from the lower brand in jumping way, corresponding part in an upper triangle matrix would be 0. A questionnaire investigation for automobile purchasing case was executed and the above structure was confirmed.

If the transition matrix is identified, a S-step forecasting can be executed. Generalized forecasting matrix components' equations were introduced. Unless planner for products does not notice its brand position whether it is upper or lower than other products, matrix structure makes 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. Various fields should be examined hereafter.

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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

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The Impact on Customer Satisfaction of Low-Cost Carriers – Case Study Approach on Route of London to Paris

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Abstract

The low-cost carrier transportation market is known as the other options for the aviation passenger in worldwide. More than one airline provides low-cost carrier transportation in America, Europe and Asia, and most of the airline tries to increase customer satisfactions by improving the performances of the key factors. The purposes of this paper are examining all the possible key factors that will impact the customer satisfaction. The paper uses this case study method that bases on route of London and Paris. Collects data by five-scale Likert questionnaire and analyzes data with ANOVA approach. The result indicates that the top three of the key factors of customer satisfactions are: (1) booking service, (2) cabin facility, (3) cabin service personnel's efficiencies. Therefore the low-cost carrier needs to continuously improve these three factors for promoting the competitive advantages for the operational performances.

Keyword：Low-cost carrier, customer satisfaction, ANOVA

1.Introduction

The global first fair price aviation (Low Cost Carriers, LCC) - the Southwest Airlines was founded on US, before marketing of strategy the unprecedented of low cost. The low ticket price and the busy season difference manages the American domestic commercial aviation market, passenger's favor, is developed gradually broadly in the competition intense aviation industry a new low ticket price aviation passenger transportation market. The fair price aviation service is different with the traditional aviation service, the LCC is the passenger most direct feeling, the service simplification is the essential condition, but the passengers should makes the choice and between the price of tickets and service, but passenger's satisfactory service would become the lower price aviation essential service items.

It is “lower ticket price”, “above the price in value”, “meets the passenger demand” as well as “these users pay expenses” is the demand and the idea the fair price aviation flaunted in 1973. US became the fair price aviation the place of origin, was also the fair price aviation market, develops the matures region at present speaking of the passenger, the most direct feeling namely was convenient for its inexpensive ticket price and the order, but airline must maintain low ticket price under transport business condition still held the profit and maintained long-term low-cost operation could be the multiple-angle transport business measure to reduce the cost.

2.Characteristic of the Low-Cost Carriers

Airline's service should include: service quality, flies safety record, accident rate, flight delay rate, flight time coordination, amount of frequency, booking conveniences, telephone booking whether easy to dial, ticketing the place multi-dimensional, the ticket price and so on, many people consider to choice airline by the flight late probability, flight whether can coordinate with time, fly safety record, accident rate, ticket price to take consideration the factor. In fly safety record in the accident rate consideration the most people will treat as Airline's overall image, a small number of people think not important. The minority participant expressed that like some flight late probability is high, when coming to choosing does not consider any Airlines. Choosing flight most people will consider fly time coordination. But people will travel by aircraft's participant in non-official business, and will choose the low cost Airline.

The LCC need fast ground duty work, inexpensive landing expense simple fast boarding registration flow as well as the convenience of airport interline traffic system, it is the difference namely lies in “fast” and “the low expense”(Barrett, S. D., 2004). Closes right up against inexpensive ticket price attraction many passengers to travel because the price is low Airline respond the cost provides the service compares in the tradition Airline appears simple. The Airline mainly reduces transport business cost in three aspects: respectively be served, transport business and the management. Affects regarding the passenger most greatly is also most direct then serves surface, majority of fair price aviation by the sole cabin and cabin disposition has been short first-class cabin and commercial cabin service, in conforms to the legal maximum seating capacity for the premise enhances the airliner seat density, and reduces the air server population and does not provide free meal service, saves for meal the facility cost causes the total transport business unit cost to reduce, also the fair price aviation service's object is the economy class cabin passenger, do not need to rent lounge to increase the cost burden.

The route is around 120 minutes or 500 miles in flies straight the route point-to-point in the range, belongs to the short distance route then fully assigns the aircraft formations in each route the type simplifies not only increases aircraft formation utilization the elasticity benefit and fuel control may reduce the cost which effectively the airline aircraft services. The LCC also have a perfect ground duty work system after letting the airplane landing, may in the quickly time, completes the passengers to arrived downtown, hands-on movement as well as the correlation supplies work, strives for airplane more effective nesses and the commercial cropspace.

In the ticket sale aspect, LCC picks the direct sale way not sells the ticket by the travel agency, direct marketing with check in network are reduces transport cost the important secret. In service only concentrates in the passenger transportation market management is different with the tradition Airline cross in common passenger transportation the freight transportation, aircraft maintenance and the spatial kitchen and various domains, fair price aviation reduces certain investment risk relatively.
There are some characteristic of brief minute below fair price aviation by spot:

(1) Ticket price: The ticket price is low.

(2) Route: Point-to-point route. (3) Flight status: Crowded fast.

(4) Class: Economy class cabin.

(5) Sale: Network direct sale.

(6) Meal: Do not provide.

(7) Check in: Self-service check in.

(8) Seat selection: Do not delimit the position.

3. Research Methodology

By the questionnaire survey, this paper investigates passenger to establish its individual basic documents and individual consumption habits of Airline's service essential factors: booking service, counter service, baggage service, on board facility, on board serves, exception handling and service routine. The further step is to examine the performance flaw between passenger's service cognition tribute and LCC whole performance, so as to understand the quality of Airline services and to provide improvement directions which wishes the travelers buy once again. Picks the random sampling on the way, travels by some fair price aviation to travel by the London ~ Paris route passengers, take counter filling in and by network transmission questionnaire way as questionnaire provide object.

This paper take the questionnaire survey as the main tools, divides into three parts by using the five scale Likert questionnaire: (1) the passenger habit (2) the essential satisfaction factors of Airline to serve generally (3) individual material.

This paper also uses the statistical software with SPSS 15.1 to study for: “descriptive statistical analysis”, “factor analysis”, “T-test analysis”, and “ANOVA”.

4. Empirical Study and Findings

The empirical case study of this paper is focused on London ~ Paris route passengers of LCC by questionnaire survey. The respondents of questionnaire are based on London Airport passengers of fair price aviation, interview randomly sampling with London ~ Paris route flight during, January 25 to February 25 2009. This paper sent out 150 questionnaires and returned 120. The returned rate is 80%. Delete 12 invalid questionnaires; there are 108 valid questionnaires with 90% effective rate.

4.1 Statistical Analysis

Interrogates the volume request in some LCC to travel by the London ~ Paris passengers, therefore this participant, is mainly aims at the sample which in this route the passenger recycles the basic document to carry on the narrative statistical analysis, and discusses each construction surface variable. Participant basic document analysis: The statistic descriptions are shown in Table 4-1, Table 4-2 and Table 4-3.

Table 4-1 Gender Distribution

Gender	Male	Female	Total
Number	58	50	108

Table 4-2 Age Distribution

Age	Under 20 Age	21-30 Aged	31-40 Aged	41-50 Aged	51-60 Aged	Up 61 Aged	Total
Number	9	37	43	10	5	4	108

Table 4-3 Average Incomes (Euro dollars)

Average Income	Under 2,000	2,000 ～ 3,999	4,000 ～ 5,999	6,000 ～ 7,999	Up 8,000	Total
Number	7	21	70	6	4	108

Passenger consumer's behavior analysis are shown in Table 4-4, Table 4-5, Table 4-6, Table 4-7, Table 4-8 and Table 4-9.

Table 4-4 Purchasing Motivation

Purchase Motivation	Business	Travel	Visit	Other	Total
Number	37	61	8	2	108

Table 4-5 Price Aviation Type

Airline Analyzing	Tradition	LCC	Total
Number	8	100	108

Table 4-6 Travel Frequency

Frequency	1-12 Mouths	1-2 Years	Up 2 Years	Never	Total
Number	98	2	4	4	108

Table 4-7 Payment Object

Payment	Self	Company	Part Burden	Other	Total
Number	97	11	0	0	108

Table 4-8 Purchase Place

Place to Purchase	Subsidiary Company	Internet	Counter	Other	Total
number	10	98	0	0	108

Table 4-9 Purchase Reiteration

Return to Take Again	Yes	No	Total
Number	100	8	108

4.2 Cronbach's α

The questionnaire should examine the Cronbach's **α** coefficient to identify the internal uniformity within various variables. Higher **α** value is, the projects consistent will be indicated that in the questionnaire of result various hasten sly, is also **α** is higher. The empirical study **α** value of this paper is greater than 0.8, more than 0.7, indicates that collected data has good uniformity. The result is shown in Table 4-10.

4.3 Customer Satisfaction

There are twenty-one service factors and five overall satisfaction performances in LCC questionnaire. The results of collected data which survey by the participants estimated the overall degree of satisfaction by the descriptive statistics and extract the mean value from each service essential factors. The mean value indicates the level of satisfactions of the passenger in Airline's service qualities.

Table 4-10 Cronbach's α

Surface	Cronbach's α
Booking	0.942
Counter and baggage service	0.932
Ticketing	0.869
Cabin	0.902
Customer Satisfaction	0.833

The confidence interval in the overall degree of satisfaction service in essential factors may calculate by the formula below.

$$\left[\overline{X_B}-t_{0025}(n_B-1)\frac{S_B}{\sqrt{n_B}},\overline{X_B}+t_{0025}\frac{S_B}{(n_B-1)\sqrt{n_B}}\right]$$

$\overline{X_B}$: Mean value of each service quality factor

n_B : Integer

s ß : Standard deviation of service quality factor

We discovered that the degree of satisfaction somewhat low project includes: Baggage service (2.78); Meal service (2.57), as well as the entertainment serves (2.97) like Table 4-11. This creates the reason possibly is the baggage service personnel's manner is not good, or in baggage processing do not discrete, causes the baggage when loading and unloading has smears or the damage phenomenon causes the passenger to be discontented, as well as, in the baggage raises leads in the speed to have needs place of the improvement. In meal a part for all project low, this is because in the fair price aviation, supplies meal fineness is inferior to the traditional aviation, even has the possibility to save the cost not to provide meal the spot, only provides the tap water, and therefore causes the passenger to be low satisfaction aspect. In the entertainment project parts, we analyze its reason to be identical with meal a part, to save the cost to neglect this part desirably. The passenger degree of satisfaction high part includes: Booking service (3.57), cabin facility and service personnel's unkindness (3.56), cabin personnel service efficiency (3.62) like Table 4-11, but other serve the degree of satisfaction score not to be also low related. This appears, even if in the fair price aviation, staff's service attitude still took the project for this company, this is also all service industries carries out the criterion.

Because we make the analysis in view of 21 service factors, the form must demonstrate completely will be big, must therefore discuss on excerpt this article the factor will come to explain.

4.4 T test and Single Factor Changeability Analysis

During by the questionnaire survey construction surface's five whole performance and in five big construction surface 21 service quality essential factor, examines by this fair price Airline's whole performance to five big construction surface with the T examination whether to have the remarkable difference. By the distribution of gender works as variable when two kinds, T examination analyzes gender (male/female) regarding Airline its P<0.05 the value whether to have the significance difference, so as to understood, during remarkable difference reason.

Category variable (male/female) when two kinds, uses the T examination, if the significance P value is smaller than 0.05 like table 4-12, then the expression has the obvious different opinion to this service construction surface:

Table 4-11 Passenger serves the quality of satisfaction analysis to the LCC.

Essential Factor	Variable $n=108_B$	Mean Value $\overline{X_B}$
Booking	Booking service	3.57
Counter and Baggage service	Baggage service	2.78
Cabin and Service	Personnel Unkindness	3.56
	Efficiency	3.62
	Meal Service	2.57
	Entertainment	2.97

Table 4-12 Gender variables to of statistical analysis passenger degree of satisfaction

Essential Factor	Variable	Gender	Male	Female
		P	n=58	n=50
Booking	Booking Information	0.021	3.28	3.07
Counter and Baggage Service	Boarding	0.034	3.54	3.32
Cabin Service	Fly safety	0.046	3.58	3.36

(1)Provides the related information service by the booking , its statistics examine the P value are 0.021*, demonstrated that factor male and female has the different opinion, say by the average of satisfaction, the feminine mean value is 3.07, is average of satisfaction 3.28 lowly compared to the male, indicated that the female compares the male regarding this service of satisfaction not to be unsatisfied, the personnel booking should aim at the flight time, preferential benefit promotion, the flight taking off and landing time, strengthens the feminine passenger information provision.

(2)The waiting room service, personnel's board craft the guidance: The feminine passenger and the masculine passenger have the enormous difference, it examines the P value is 0.034, says by the average of satisfaction, the feminine mean value is 3.32, compared to the masculine average of satisfaction 3.54 low, indicated that the female compares the male regarding this service of satisfaction not to be unsatisfied, is specially easy in the so big airport to let the human be panic-stricken, in addition the most passenger take traveling as the main purposes, therefore the indication feminine passenger needs the service personnel's to assist vigorously, the LCC should aim at the feminine passenger to make in this service has the touch of humanity service attitude.

(3)Flight safety: Its P value is 0.046*, demonstrated that the feminine passenger 3.36 pair of LCC 'the flight safety' compares the masculine passenger 3.58 not to have the confidence, the LCC should aim at various aspects like to lead, the flight failure rate, sometimes means send a plane delay, service ability to seek improvement on time, promotes the feminine passenger to travel by airliner's confidence.

4.5 ANOVA analysis

ANOVA analysis: By variable category three kinds, when uses the ANOVA single factor variable analysis, if the P value is smaller than 0.05 expressions has the significance difference. Has the significance different feeling from Table 4-13 demonstration age level regarding the baggage service (the P value 0.038).

In addition, the level of trait anxiety has significant difference with service quality factors.

(1) Variable analyzes on various items, baggage service (2.78); Meal service (2.57) as well asthe entertainment serves (2.97) and so on three items lowly, possibly must strengthen in the service attitude, meal and entertainment facility's choice or provides or not must further consider.

Table 4-13 ANOVA analysis

Essential factor	Variable	Aged	Occupation	Income	Education
		P	P	P	P
Counter and baggage	Service	0.038	0.460	0.752	0.783
Ticketing	Staff Efficiency	0.331	0.008	0.477	0.604

(2) The customer satisfaction high part includes: Booking service (3.57), cabin facility and service personnel’s unkindness (3.56), cabin personnel service efficiency (3.62), but other serve the degree of satisfaction score not to be also low related. This appears, even if in the fair price aviation, staff's service attitude still took the project for this company, this is also all service industries carries out the jade tablet nickel.

(3) The ANOVA variable analysis aspect, in view of the age, the occupation, the month income and the education. The analysis discovered that the age level has the significance different feeling regarding the baggage service; but the different occupation has the especially profound feeling regarding the ticket clerk personnel's efficiency; as for different income, school record, regarding of this fair LCC service essential factor and degree satisfaction aspect not remarkable difference.

5. Conclusion

Low-Cost Carriers, Budget Airlines or Discount Airlines have been proven to be a profitable business model globally. This business model has been successfully implemented in Southeast Asian countries and U.S.A. The results of this study include: (1) expectancy is positively related to perceived performance and is negatively related to disconfirmation and complaint. (2) Perceived performance has a significant positive effect on customer satisfaction, disconfirmation and premium.

It is suggested future research be based on actual experience and organizations in the low-cost carrier industry. It is suggested future research extend to more than one carrier company in order to gain a more comprehensive understanding of the industry. It is alongside research on joint venture low-cost carriers, would also prove useful when considering the industry as a whole.

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Decision Support System for Supply Chain Coordination with Return Handling, Price-Sensitivity and Profit Sharing

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Abstract

In this paper, a mathematical model is developed to determine an optimal operational policy for a supply chain with return handling, price-sensitivity and profit sharing. In this study, a supply chain which consists of a retailer and a manufacturer is addressed. A single type of product is sold in four consecutive periods: the normal sales period with price-sensitivity, the discount sales period with discount-sensitivity, the secondary sales period with discount-sensitivity and the disposal sales period. As the optimal inventory-sales policy, product order quantity, retail price and discount ratio are determined. Two types of supply chain are analyzed: (Type I) the decentralized supply chain, (Type II) the centralized supply chain. In Type I, the optimal decision is made to maximize the expected profit of each player based on Stackelberg game. In Type II, the optimal decision is made to maximize the expected profit of the whole system as the integrated company. As supply chain coordination to avoid profit disequilibrium among all players under Type II, profit sharing approach is discussed. In numerical examples, the optimal inventory-sales policy and effect of profit sharing are shown. Finally, a framework of decision-support for the supply chain system discussed in this study is shown.

Keywords: Return handling, Price-sensitivity, Discount-sensitivity, Profit sharing, Supply chain coordination

1. Introduction

For many years, return handling approaches for unsold products or profit sharing approaches between a manufacturer and a retailer have been discussed. In previous studies, return handling approaches including resales of returned products, buy-back, sales of disposal sales market, secondary sales market and markdown sales market, (Vlachos & Dekker(2003), Choi & Yan, Lee(2007), Niimi et al.(2009)) have been proposed. However, the combination of above return handlings and profit sharing has not been sufficiently discussed in past literatures.

In this paper, a mathematical model is developed to determine an optimal inventory-sales policy for a supply chain with return handling, price-sensitivity and profit sharing. In this study, a supply chain which consists of a retailer and a manufacturer is addressed. A single type of product is sold in four consecutive periods: the normal sales period with price-sensitivity, the discount sales period with

discount-sensitivity, the secondary sales period with discount-sensitivity and the disposal sales period. As the optimal inventory-sales policy, product order quantity, retail price and discount ratio are determined. Two types of supply chain are analyzed: (Type I) the decentralized supply chain, (Type II) the centralized supply chain. In Type I, the optimal decision is made to maximize the expected profit of each player based on Stackelberg game where a retailer is the Stackelberg leader and a manufacturer is the Stackelberg follower. In Type II, the optimal decision is made to maximize the expected profit of the whole system as the integrated company. As supply chain coordination to avoid profit disequilibrium among all players under Type II, profit sharing approach is discussed. In numerical examples, the optimal inventory-sales policy and effect of profit sharing are shown. Finally, a framework of decision-support for the above system with supply chain coordination, return handling, price-sensitivity and profit sharing is shown.

2. NOTATION ANS MODEL ASSUMPTIONS

$Q_i\left(i=D,C\right)$: product order quantity of retailer in either the decentralized supply chain (i=D) or the centralized supply chain (i=C).

$x_j(j=1,2,3)$: customer's demand of product which either a retailer faces in either normal sales market(j=1) and discount sales market(j=2) or a manufacturer faces in secondary sales market(j=3).

$f_j(\cdot)(j=1,2,3)$: probability density function of customer's demand of product in either the normal sales market (j=1), the discount sales market (j=2) or the secondary sales market (j=3).

$F_j(\cdot)(j=1,2,3)$:cumulative distribution function of customer's demand of product in either the normal sales market (j=1), the discount sales market (j=2) or the secondary sales market (j=3).

w: wholesales price per unit of product which manufacturer sells to retailer.

c: production cost per unit of product to sell in normal sales market.

u_i : retail price per unit of product in normal sales market($u_i > w$).

r : return rate for the satisfied demand of the product in the normal sales market $(0 \le r \le 1)$.

s: collection cost per unit of returned product in the normal sales market.

C_v : inspection cost per unit of returned product in the normal sales market.

q : probability that the returns are damaged when collected from the normal sales market $(0 \le q \le 1)$.

C_e : recovery cost per unit of returned product to bring to an as-good-as-new condition.

G: shortage penalty cost per unit of product in the normal sales market.

h_{r1}: inventory holding cost per unit of unsold products per unit time after the end of the selling period of the normal sales market.

d_{dis}^i : discount ratio of sales price per unit of product in the discount sales market ($0 < d_{dis}^i \le 1.0$).

d_{2nd}^i : discount ratio of sales price per unit of product in the secondary sales market ($0 < d_{2nd}^i \le 1.0$).

c_d: maintenance cost per unit of product in the discount sales market.

h_{r2}: inventory holding cost per unit of unsold products per unit time after the end of the discount sales period.

b: buy-back cost per unit of unsold product which manufacturer pays back to retailer after the end of

the discount sales period.

m: rework cost per unit of product to sell in the secondary sales market.

h_m: inventory holding cost per unit of unsold product per unit time after the end of the secondary sales period.

v: disposal sales price in the disposal sales market per unit of unsold product after the end of the secondary sales period.

$E[\pi_k(Q_i)](i = D, S, k = M, R, S)$: The k's expected profit for Q_i. "M", "R", and "S" denote a manufacturer, a retailer, a whole system

3. MODEL DESCRIPTIONS

▪3.1 Model Assumptions

(1) An intended product is a single type and a single period product. In this study, the optimal decision is made based on Stackelberg game where a retailer is the Stackelberg leader and a manufacturer is the Stackelberg follower. The optimal decisions for the product order quantity $Q_i(i = D, C)$ and the retail price u_i of the product are made once before the beginning of the selling period in the normal sales market so as to maximize the Stackelberg leader's expected profit. An optimal decision for the discount ratio d^i_{dis} is made once before the beginning of the selling period in the discount sales market so as to maximize the Stackelberg leader's expected profit. An optimal decision for the discount ratio d^i_{2nd} is made once before the beginning of the selling period in the secondary sales market so as to maximize the Stackelberg follower's expected profit under optimal decisions for the Stackelberg leader.

(2) It is assumed that the product is sold in three consecutive periods; the normal sale period, the clearance sale period and the disposal sale period. The profit per unit is high in order of the normal sale market, the clearance sale market and the disposal sale market.

(3) A retailer faces an uncertain demand x_1 of the product in the normal sales market. Also, a retailer faces an uncertain demand x_2 of the product in the discount sales market. A manufacturer faces an uncertain demand x_3 of the product in the secondary sales market. It assumes that the demand x_1 in normal sales market is sensitive to retail price u_i, the demand x_2 in discount sales market is sensitive to discount ratio d^i_{dis} and the demand x_3 in secondary sales market is sensitive to discount ratio d^i_{2nd}. Under the above conditions, x_1, x_2 and x_3 follow the independent demand distributions with the probability density function $f_1\left(\cdot|u_i\right)$, $f_2\left(\cdot\left|d^i_{dis}\right.\right)$ and $f_3\left(\cdot\left|d^i_{2nd}\right.\right)$.

▪3.2 Model Operations

Figure 1 shows model operations of the supply chain system with return handling and dis count sales discussed in this study.

(1) A manufacturer produces a single type of product $Q_i(i = D, C)$ with c per unit. The manufacturer sells the products Q_i to a retailer with w per unit.

(2) The retailer sells the products Q_i to a customer in the normal sales market with u_i per unit.

When either excess or shortage of product inventory occurs, the retailer incurrs either the inventory holding cost h_{r1} per unit per unit time or the shortage penalty cost G per unit.

(3) During the normal sales period, some products may be returned to the retailer from the customer at a fixed return rate r. It is allowed that the return for the same product is acceptable once only to the retailer with-in the normal sales period. The retailer inspects all the returned products. The returned products are or can be in as-good-as-new condition after the recovery by the retailer if necessary. After inspecting and recovering the returned products, the retailer can resell all the returned products in the normal sales market.

(4) After the end of the the normal sales period, the retailer sells the unsold products at the discount sales price $\left(1-d_{dis}^{i}\right)u_i$ per unit in the discount sales market. When excess inventory of the product occurs, the retailer incurrs the inventory holding cost h_{r2} per unit per unit time.

(5) After the end of the selling period in the discount sales market, the manufacturer buys back the unsold products from the retailer with b per unit.

(6) The manufacturer reworks the unsold products with m per unit. After rework, the manufacturer sells the unsold products in the secondary market with $\left(1-d_{2nd}^{i}\right)\left(1-d_{dis}^{i}\right)u_i$ per unit.

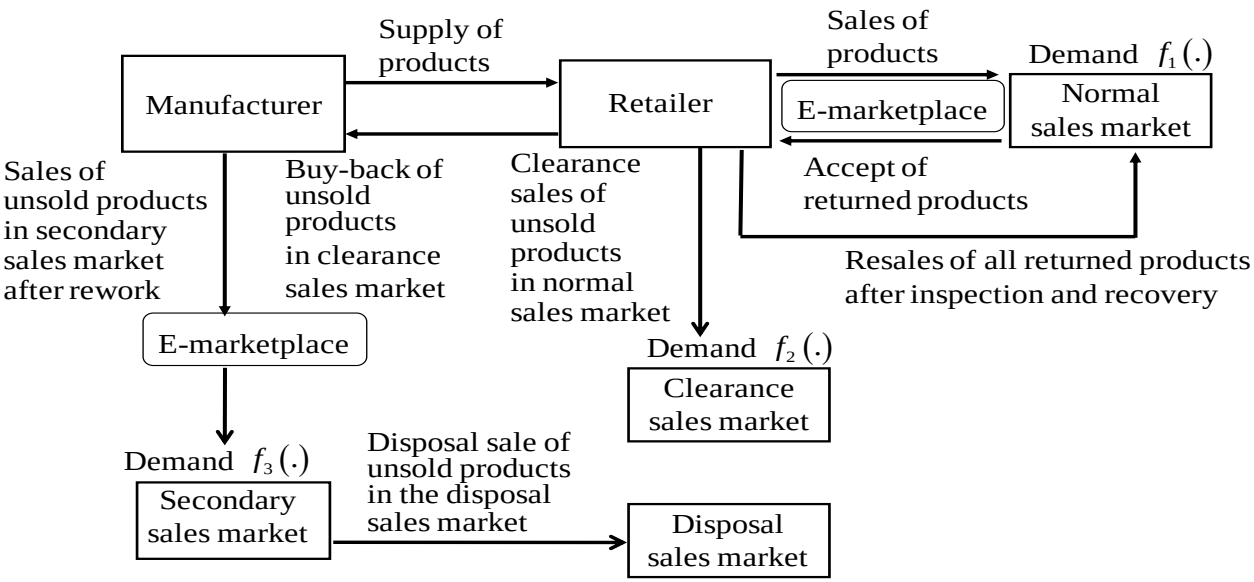

Figure 1. Model operations of the supply chain system in this study with return handling, price-sensitivity and profit sharing

When excess inventory of the product occurs, the manufacturer incurrs the inventory holding cost h_m per unit per unit time.

(7) After the secondary sales period, manufacturer sells the unsold products in the disposal sales market with v per unit of product.

4. MODEL FORMULATIONS

▪4.1 Decentralized Supply Chain

Based on Figure 1 and model assumptions in 3.1 and model operations in 3.2, the profit of the retailer consists of the purchase cost of the product from the manufacturer, the sales of the product in the normal sales market, the return handling cost of the returned products, the inventory holding cost of the unsold product after the end of the normal sales period, the shortage penalty cost of the product in the normal sales market, the sales of the product in the discount sales market, the maintenance cost of the unsold products for discount sales, the inventory holding cost of the unsold products after the end of the discount sales period, the buy-back revenue of the unsold products from the manufacturer. In consideration of the relation between the product order quantity Q_D of the retailer and the demands x_1 and x_2 of the product in the normal sales market and the discount sales market, the retailer's expected profit under a given retail price u_D and a given discount ratio d_{dis}^D in discount sales market is formulated as

$$\begin{aligned}
E\left[\pi_R\left(Q_D\right)\middle|u_D,d_{dis}^D\right] &= -wQ_D+\left(\left(1-r\right)u_D-\left(s+C_v+qC_e\right)r+ru_D\right)\int_0^{Q_D}x_1 f_1\left(x_1\middle|u_D\right)dx_1 \\
&+\left(\left(1-r\right)u_D-\left(s+C_v+qC_e\right)r+ru_D\right)Q_D\int_{Q_D}^{\infty}f_1\left(x_1\middle|u_D\right)dx_1 \\
&-G\int_{Q_D}^{\infty}\left(x_1-Q_D\right)f_1\left(x_1\middle|u_D\right)dx_1 \\
&+\left(-h_{r1}+\left(1-d_{dis}^D\right)u_D-c_d\right)\int_0^{Q_D}\left(Q_D-x_1\right)f_1\left(x_1\middle|u_D\right)dx_1 \\
&+\left(b-\left\{-h_{r1}+\left(1-d_{dis}^D\right)u_D-c_d\right\}-h_{r2}\right)\times\int_0^{Q_D}\left\{\int_0^{Q_D-x_1}\left(Q_D-x_1-x_2\right)f_2\left(x_2\middle|d_{dis}^D\right)dx_2\right\}f_1\left(x_1\middle|u_D\right)dx_1 .(1)
\end{aligned}$$

Based on Figure 1 and model assumptions in 3.1 and model operations in 3.2, the profit of the manufacturer consists of the production cost of the product, the sales of the product to the retailer, the buy-back cost of the unsold products to the retailer after the end of the discount sales period, the rework cost of the unsold products to sell in the secondary sales market, the sales of the unsold product to the secondary sales market, the inventory holding cost of the unsold products after the end of the secondary sales period, the disposal sales of the unsold products in the disposal sales market. In consideration of the relation between the discount ratio d_{2nd}^D, the demand of the product x_1 in the normal sales market and the demand of the product x_3 in the secondary sales market, the expected profit of the manufacturer under a given product order quantity Q_D and a given retail price u_D and a given discount ratio d_{dis}^D set by the retailer who is the Stackelberg leader is formulated as

$$\begin{aligned}
E\left[\pi_M\left(d_{2nd}^D\right)\middle|Q_D,u_D,d_{dis}^D\right] &= (w-c)Q_D \\
&+\left\{\left(1-d_{2nd}^D\right)\left(1-d_{dis}^D\right)u_D-b-m\right\}\times\int_0^{Q_D}\left(\int_0^{Q_D-x_1}\left(Q_D-x_1-x_2\right)f_2\left(x_2\middle|d_{dis}^D\right)dx_2\right)f_1\left(x_1\middle|u_D\right)dx_1
\end{aligned}$$

$$+\left\{v-\left\{\left(1-d_{2nd}^{D}\right)\left(1-d_{dis}^{D}\right)u_D-m\right\}-h_m\right\}\int_0^{Q_D}\int_0^{Q_D-x_1}\int_0^{Q_D-x_1-x_2}\left(Q_D-x_1-x_2-x_3\right)$$
$$\times f_3\left(x_3\middle|d_{2nd}^{D}\right)dx_3 f_2\left(x_2\middle|d_{dis}^{D}\right)dx_2 f_1\left(x_1\middle|u_D\right)dx_1 . \quad (2)$$

The whole system's expected profit under a given order quantity Q_D, a given retail price u_D, a given discount ratio d_{dis}^{D} in discount sales market and a given discount ratio d_{2nd}^{D} in secondary sales market is obtained as the sum of the expected profits of the retailer and the manufacturer in Equation (1) and Equation (2).

$$E\left[\pi_S\left(Q_D\left(i=D,C\right)\right)\middle|u_D,d_{dis}^{D},d_{2nd}^{D}\right]=E\left[\pi_R\left(Q_D\right)\middle|u_D,d_{dis}^{D}\right]+E\left[\pi_M\left(d_{2nd}^{D}\right)\middle|Q_D,u_D,d_{dis}^{D}\right]. \quad (3)$$

▪4.2 Centralized Supply Chain

In the centralized supply chain, the optimal decision is made under a situation where a retailer and a manufacturer are integrated as one company. The optimal decisions in terms of the prod uct order quantity Q_C, retail price of the product u_C, discount ratio d_{dis}^{C} in discount sales mark et and discount ratio d_{2nd}^{C} in secondary sales market is determined so as to maximize the expec ted profit of the whole system. In consideration of the relation between the product order quantity Q_C of the retailer and the demands, x_1, x_2 and x_3, of the product in normal sales mar ket, the discount sales market and the secondary sales market, the whole system's expected profit in the centralized supply chain under given retail price u_C, discount ratio d_{dis}^{C} in disco unt sales market and discount ratio d_{2nd}^{C} in secondary sales market is obtained as

$$E\left[\pi_S\left(Q_C\right)\middle|u_C,d_{dis}^{C},d_{2nd}^{C}\right]=E\left[\pi_R\left(Q_C\right)\middle|u_C,d_{dis}^{C}\right]+E\left[\pi_M\left(Q_C\right)\middle|u_C,d_{dis}^{C},d_{2nd}^{C}\right]$$
$$=-cQ_C+\left(\left(1-r\right)u_C-\left(s+C_v+qC_e\right)r+ru_C\right)\int_0^{Q_C}x_1 f_1\left(x_1\middle|u_C\right)dx_1$$
$$+\left(\left(1-r\right)u_C-\left(s+C_v+qC_e\right)r+ru_C\right)Q_C\int_{Q_C}^{\infty}f_1\left(x_1\middle|u_C\right)dx_1$$
$$+\left(-h_{r1}+\left(1-d_{dis}^{C}\right)u_C-c_d\right)\int_0^{Q_C}\left(Q_C-x_1\right)f_1\left(x_1\right)dx_1-G\int_{Q_C}^{\infty}\left(x_1-Q_C\right)f_1\left(x_1\middle|u_C\right)dx_1$$
$$+\left(-\left\{-h_{r1}+\left(1-d_{dis}^{C}\right)u_C-c_d\right\}-h_{r2}+\left\{\left(1-d_{2nd}^{C}\right)\left(1-d_{\mathrm{dis}}\right)u_C-m-h_m\right\}\right)$$
$$\times\int_0^{Q_C}\left\{\int_0^{Q_C-x_1}\left(Q_C-x_1-x_2\right)f_2\left(x_2\middle|d_{dis}^{C}\right)dx_2\right\}f_1\left(x_1\middle|u_C\right)dx_1$$
$$+\left(v-\left\{\left(1-d_{2nd}^{C}\right)\left(1-d_{dis}^{C}\right)u_C-m-h_m\right\}\right)\int_0^{Q_C}\int_0^{Q_C-x_1}\int_0^{Q_C-x_1-x_2}\left(Q_C-x_1-x_2-x_3\right)$$
$$\times f_3\left(x_3\middle|d_{2nd}^{C}\right)dx_3 f_2\left(x_2\middle|d_{dis}^{C}\right)dx_2 f_1\left(x_1\middle|u_C\right)dx_1. \quad (4)$$

5. OPTIMAL DECISION PROCEDURES

▪5.1 Decentralized Supply Chain

In decentralized supply chain, the optimal decision is made to maximize the expected profit of each player based on Stackelberg game where a retailer is the Stackelberg leader and a manufacturer is the Stackelberg follower. The optimal product order quantity Q_D^* of the decentralized supply chain is determined so as to maximize the expected profit of the retailer who is the Stackelberg leader under a given retail price u_D and a given discount ratio d_{dis}^D in discount sales market in Equation (1). In order to determine the optimal order quantity Q_D^* in the decentralized supply chain under a given retail price u_D and a given discount ratio d_{dis}^D in discount sales market, first, the feature of the expected profit $E\left[\pi_R(Q_D)\middle|u_D, d_{dis}^D\right]$ in Q_D under given u_D, d_{dis}^D is investigated. Taking the first and second order derivatives with respect to Q_D in $E\left[\pi_R(Q_D)\middle|u_D, d_{dis}^D\right]$ under given u_D, d_{dis}^D, we have the followings:

$$\begin{aligned}\frac{dE[\pi_R(Q_D)|u_D, d_{dis}^D]}{dQ_D} &= -w+(1-r)u_D-(s+C_v+qC_e)r+ru_D+G \\ &+\left\{-(1-r)u_D+(s+C_v+qC_e)r-ru_D+\left(-h_{r1}+\left(1-d_{dis}^D\right)u_D-c_d\right)-G\right\}F_1(Q_D|u_D) \\ &+\left(b-\left(-h_{r1}+\left(1-d_{dis}^D\right)u_1-c_d\right)-h_{r2}\right)\int_0^{Q_D}F_2\left(Q_D-x_1\middle|d_{dis}^D\right)f_1(x_1|u_D)dx_1 \end{aligned} \tag{5}$$

$$\begin{aligned}\frac{d^2E[\pi_R(Q_D)|u_D, d_{dis}^D]}{dQ_D^2} &= \left\{-(1-r)u_D+(s+C_v+qC_e)r-ru_D+\left(-h_{r1}+(1-d)u_D-c_d\right)+G\right\}f_1(Q_D|u_D) \\ &+\left(b-\left(-h_{r1}+\left(1-d_{dis}^D\right)u_D-c_d\right)-h_{r2}\right)\int_0^{Q_D}f_2\left(Q_D-x_1\middle|d_{dis}^C\right)f_1(Q_D|u_D)dx_1 \end{aligned} \tag{6}$$

From Model Assumption 3.1 (2), Equaition (6) <0. We can know that the retailer's expected profit is concave in terms of the order quantity Q_D under given u_D, d_{dis}^D.

Therefore, the optimal product order quantity Q_D^* can be obtained under given u_D, d_{dis}^D as the solution of the following equation by using the adequate numerical calculation:

$$\frac{dE\left[\pi_R(Q_D)\middle|u_D, d_{dis}^D\right]}{dQ_D}=0. \tag{7}$$

Substituting the optimal order quantity Q_D^* determined in equation (7) into equations (1), the expected profit $E\left[\pi_R\left(Q_D^*\right)\middle|u_D, d_{dis}^D\right]$ of the retailer can be maximized.

Next, the optimal discount ratio d_{dis}^{D*} in the clearance sales market in the decentralized supply chain is investigated. Then, the optimal discount ratio d_{dis}^{D*} in the decentralized supply chain should be determined as the discount ratio d_{dis}^D in order to maximize the expected profit

$E\left[\pi_R(d_{dis}^D)\,|\,Q_D^*, d_{2nd}^D, u_D\right]$ of the retailer as the Stackelberg leader under the optimal order quantity Q_D^* of the decentralized supply chain, a given discount ratio d_{2nd}^D and a given retail price u_D. Furthermore, the optimal retailer price u_D^* in the normal sales market in the decentralized supply chain is investigated. Then, the optimal retail price u_D^* in the decentralized supply chain should be determined as the retail price u_D in order to maximize the expected profit $E\left[\pi_R(u_D)\,|\,Q_D^*, d_{dis}^{D*}, d_{2nd}^D\right]$ of the retailer as the Stackelberg leader under the optimal order quantity Q_D^* and the optimal discount ratio d_{dis}^{D*} of the decentralized supply chain and a given discount ratio $d_{2nd}^{D\,*}$. Using the optimal decision procedures provided in this paper, we can determine the optimal order quantity Q_D^*, the optimal discount ratio d_{dis}^{D*} and the optimal retail price u_D^* in the decentralized supply chain, simultaneously. Finally, the optimal discount ratio $d_{2nd}^{D\,*}$ in the secondary sales market in the decentralized supply chain is investigated. Then, the optimal discount ratio $d_{2nd}^{D\,*}$ in the decentralized supply chain should be determined as the discount ratio d_{2nd}^D in order to maximize the expected profit $E\left[\pi_M(d_{2nd}^D)\,|\,Q_D^*, d_{dis}^{D*}, u_D^*\right]$ of the manufacturer as the Stackelberg follower under the optimal order quantity Q_D^*, the optimal discount ratio d_{dis}^{D*} and the optimal retail price u_D^* set by the retailer in the decentralized supply chain.

▪5.2 Centralized Supply Chain

In the centralized supply chain, the optimal decision is made under a situation where a retailer and a manufacturer are integrated as one company. The optimal product order quantity Q_C of the product is determined to maximize the expected profit of the whole system. The optimal product order quantity Q_C^* of the centralized supply chain is determined so as to maximize the whole system's the expected profit under a given retail price u_C, a given discount ratio d_{dis}^C in discount sales market and a given discount ratio d_{2nd}^C in secondary sales market in equation (4).

In order to determine the optimal order quantity Q_C^* in the centralized supply chain under a given retail price u_D, a given discount ratio d_{dis}^D in discount sales market and a given discount ratio d_{2nd}^D in secondary sales market, we investigate the feature of the expected profit $E\left[\pi_S(Q_C)\middle|u_C, d_{dis}^C, d_{2nd}^C\right]$ in Q_C under given u_C, d_{dis}^C and d_{2nd}^C. Taking the first and second order derivatives with respect to Q_C in $E\left[\pi_S(Q_C)\middle|u_C, d_{dis}^C, d_{2nd}^C\right]$ under given u_C, d_{dis}^C and d_{2nd}^C, we have the followings:

$$\frac{dE[\pi_S(Q_C)|u_C,d_{dis}^C,d_{2nd}^C]}{dQ_C}=-c+(1-r)u_C-(s+C_v+qC_e)r+ru_C+G$$
$$+\left\{-(1-r)u_C+(s+C_v+qC_e)r-ru_C+\left(-h_{r1}+(1-d_{dis}^C)u_C-c_d\right)-G\right\}F_1(Q_C|u_C)$$
$$+\left\{\left(-\left(-h_{r1}+(1-d_{dis}^C)u_C-c_d\right)-h_{r2}\right)+\left((1-d_{2nd}^C)(1-d_{dis}^C)u_C-m-h_m\right)\right\}$$
$$\times\int_0^{Q_C}F_2\left(Q_C-x_1|d_{dis}^C\right)f_1(x_1|u_C)dx_1$$
$$+\left\{\left(v-((1-d_{2nd}^C)(1-d_{dis}^C)u_C-m-h_m)\right)\right\}$$
$$\times\int_0^{Q_C}\int_0^{Q_C-x_1}F_3(Q_C-x_1-x_2)f_2\left(x_2|d_{2nd}^C\right)dx_2f_1\left(x_1|d_{dis}^C\right)dx_1 \tag{8}$$

$$\frac{d^2E[\pi_S(Q_C)|u_C,d_{dis}^C,d_{2nd}^C]}{dQ_C^2}=\left\{-(1-r)u_C+(s+C_v+qC_e)r-ru_C+\left(-h_{r1}+(1-d)u_C-c_d\right)-G\right\}$$
$$\times f_1(Q_C|u_C)+\left\{\left(-\left(-h_{r1}+(1-d)u_1-c_d\right)-h_{r2}\right)+(u_3-m_2-h_m)\right\}$$
$$\times\int_0^{Q_C}f_2\left(Q_C-x_1-x_2|d_{dis}^C\right)f_1(x_1|u_C)dx_1+\left\{(v-(u_3-m-h_m))\right\}$$
$$\times\int_0^{Q_C}\int_0^{Q_C-x_1}f_3\left(Q_C-x_1-x_2|d_{2nd}^C\right)f_2\left(x_2|d_{dis}^C\right)dx_2f_1\left(x_{1u_C}\right)dx_1 \tag{9}$$

From Model Assumption 3.1 (2), Equaition (9) <0. We can know that the whole system's expected profit is concave in terms of the order quantity Q_C under given u_C, d_{dis}^C and d_{2nd}^C.

Therefore, the optimal product order quantity Q_C^* can be obtained under given u_C, d_{dis}^C and d_{2nd}^C as the solution of the following equation by using the adequate numerical calculation:

$$\frac{dE\left[\pi_S(Q_C)|u_C,d_{dis}^C,d_{2nd}^C\right]}{dQ_C}=0. \tag{10}$$

Substituting the optimal order quantity Q_C^* determined in equation (10) into equations (4), the expected profit $E\left[\pi_S(Q_C^*)|u_C,d_{dis}^C,d_{2nd}^C\right]$ of the whole system can be maximized.

Next, the optimal discount ratio $d_{2nd}^{C\,*}$ in the secondary sales market in the centralized supply chain is investigated. Then, the optimal discount ratio $d_{2nd}^{C\,*}$ in the centralized supply chain should be determined as the discount ratio d_{2nd}^C in order to maximize the expected profit $E\left[\pi_S(d_{2nd}^C)|Q_C^*,d_{dis}^C,u_C\right]$ of the whole system under the optimal order quantity Q_C^*, a given discount ratio d_{dis}^D and a given retail price u_D. Furthermore, the optimal discount ratio $d_{dis}^{C\,*}$ in the clearance sales market in the centralized supply chain is investigated. Then, the optimal discount ratio $d_{dis}^{C\,*}$ in the centralized supply chain should be determined as the discount ratio d_{dis}^C in order to maximize the expected profit $E\left[\pi_S(d_{dis}^C)|Q_C^*,d_{2nd}^{C\,*},u_C\right]$ of the whole system under the optimal order quantity Q_C^* and the optimal

discount ratio $d_{2nd}^{C\,*}$ of the centralized supply chain and a given retail price u_D. Finally, the optimal retailer price u_D^* in the normal sales market in the centralized supply chain is investigated. Then, the optimal retail price u_D^* in the centralized supply chain should be determined as the retail price u_D in order to maximize the expected profit $E\left[\pi_S(u_C)\,|\,Q_C^*, d_{2nd}^{C\,*}, d_{dis}^{C\,*}\right]$ of the whole system under the optimal order quantity Q_C^*, the optimal discount ratio d_{2nd}^C and the discount ratio $d_{dis}^{C\,*}$ of the decentralized supply chain. Using the optimal decision procedures provided in this paper, we can determine the optimal order quantity Q_C^*, the optimal discount ratios d_{2nd}^C in the secondary sales market and the optimal discount ratio $d_{dis}^{C\,*}$ in the clearance sakes market and the retail price u_D^* in the normal sales market in the centralized supply chain, simultaneously.

6. PROFIT SHARING

In this subsection, profit sharing is discussed as supply chain coordination based on Chauhan & Proth(2005) in order to promote a manufacturer－retailer partnership when a centralized supply chain is taken.

(1) All players' expected profits in the centralized supply chain with profit sharing are higher than those in the decentralized supply chain.

(2) Each players' investment ratio is normalized.

The difference between the maximal expected profit of the whole system for Q_C^* in the centralized supply chain and the expected profit of the whole system for Q_D^* in the decentralized supply chain, ΔE_S, is investigated whether its value is positive or not. Substituting the optimal decisions for the centralized supply chain $\left(Q_C^*, u_C^*, d_{dis}^{C\,*}, d_{2nd}^{C\,*}\right)$ into equation(4) and the optimal decisions for the decentralized supply chain $\left(Q_D^*, u_D^*, d_{dis}^{D\,*}, d_{2nd}^{D\,*}\right)$ into equation(3), ΔE_S is calculated as

$$\Delta E_S = E\left[\pi_S\left(Q_C^*, u_C^*, d_{dis}^{C\,*}, d_{2nd}^{C\,*}\right)\right] - E\left[\pi_S\left(Q_D^*, u_C^*, d_{dis}^{C\,*}, d_{2nd}^{C\,*}\right)\right]. \tag{9}$$

If $\Delta E_S > 0$, an profit sharing approach is applied to determine dividend rates, φ_M and φ_R, of the manufacturer and the retailer. The dividend rate of each player is calculated using the expected investment ratio, which is the ratio of each player's the expected profit to the each player's the expected cost, based on Chauhan & Proth(2005). From equations (1), (2), (3) and (4) for the model with clearance sale, we regard the expected investment amount of the manufacturer and the retailer as the following expected costs for each player:

$$E\left[T_R\left(Q_C^*, u_C^*, d_{dis}^{C\,*}, d_{2nd}^{C\,*}\right)\right] = \left(s + C_v + qC_e\right) r \int_0^{Q_C^*} x_1 f_1\left(x_1 \middle| u_C^*\right) dx_1 + \left(s + C_v + qC_e\right) r Q_C^* \int_{Q_C^*}^{\infty} f_1\left(x_1 \middle| u_C^*\right) dx_1$$
$$+ G \int_{Q_C^*}^{\infty} \left(x_1 - Q_C^*\right) f_1\left(x_1 \middle| u_C^*\right) dx_1 + \left(h_{r1} + c_d\right) \int_0^{Q_C^*} \left(Q_C^* - x_1\right) f_1\left(x_1 \middle| u_C^*\right) dx_1$$

$$+\left(h_{r2}-c_d\right)\times\int_0^{Q_C^*}\left\{\int_0^{Q_C^*-x_1}\left(Q_C^*-x_1-x_2\right)f_2\left(x_2\left|d_{dis}^{C\,*}\right.\right)dx_2\right\}f_1\left(x_1\left|u_C^*\right.\right)dx_1. \tag{10}$$

$$E\left[T_M\left(Q_C^*,u_C^*,d_{dis}^{C\,*},d_{2nd}^{C\,*}\right)\right]=cQ_C^*+(b+m)\int_0^{Q_C^*}\left(\int_0^{Q_C^*-x_1}\left(Q_C^*-x_1-x_2\right)f_2\left(x_2\left|d_{dis}^{C\,*}\right.\right)dx_2\right)f_1\left(x_1\left|u_C^*\right.\right)dx_1$$

$$+(h_m-m)\int_0^{Q_C^*}\int_0^{Q_C^*-x_1}\int_0^{Q_C^*-x_1-x_2}\left(Q_C^*-x_1-x_2-x_3\right)\times f_3\left(x_3\left|d_{2nd}^{C\,*}\right.\right)dx_3 f_2\left(x_2\left|d_{dis}^{C\,*}\right.\right)dx_2 f_1\left(x_1\left|u_C^*\right.\right)dx_1. \tag{11}$$

First, the investment ratios, ρ_M and ρ_R, of the manufacturer and the retailer is calculated as the ratio of each player's the expected profit to the each player's the expected cost

$$\rho_R=\frac{E\left[T_R\left(Q_C^*,u_C^*,d_{dis}^{C\,*},d_{2nd}^{C\,*}\right)\right]}{E\left[\pi_R\left(Q_C^*,u_C^*,d_{dis}^{C\,*},d_{2nd}^{C\,*}\right)\right]}, \tag{12}$$

$$\rho_M=\frac{E\left[T_M\left(Q_C^*,u_C^*,d_{dis}^{C\,*},d_{2nd}^{C\,*}\right)\right]}{E\left[\pi_M\left(Q_C^*,u_C^*,d_{dis}^{C\,*},d_{2nd}^{C\,*}\right)\right]}. \tag{13}$$

Next, we normalize the investment ratios, ρ_M^{nor} and ρ_R^{nor}, of the manufacturer and the retailer as

$$\rho_R^{nor}=\frac{R_R}{R_R+R_M}, \tag{14}$$

$$\rho_M^{nor}=1-R_R^{nor}. \tag{15}$$

Next, we calculate the dividend rate, φ_M and φ_R, of the manufacturer and the retailer as

$$\varphi_R=\Delta E_S\times R_R^{nor}, \tag{16}$$

$$\varphi_M=\Delta E_S\times R_M^{nor}. \tag{17}$$

Finally, the each player's expected profit after profit sharing can be obtained by adding each player's dividend rate as

$$\tilde{E}\left[\pi_R\right]=E\left[\pi_R\left(Q_C^*\right)\left|u_C,d_{dis}^C,d_{2nd}^C\right.\right]+S_R, \tag{18}$$

$$\tilde{E}\left[\pi_M\right]=E\left[\pi_M\left(Q_C^*\right)\left|u_C,d_{dis}^C,d_{2nd}^C\right.\right]+S_M. \tag{19}$$

7. NUMERICAL EXAMPLES

In this section, the effects of retail price and discount sales in both the discount sales market and the secondary sales market on the optimal product order quantity and the expected profits of the retailer, the manufacturer and the whole system are investigated through numerical examples. Concretely, the

results in the decentralized supply chain with return handling without discount sales (base model) are compared with those with both return handling and discount sales (the proposed model). Similarly, in the centralized supply chain, the results in base model are compared with those in the proposed model. The optimal product order quantity without discount sales under both the decentralized and centralized supply chain can be made by removing all terms related to discount sales in equation (1) and (2). Moreover, the effect of profit sharing on expected profits of the retailer and the manufacturer in the centralized supply chain is investigated through numerical examples. The expected profits of both players in the decentralized supply chain are compared with those in the centralized supply chain with profit sharing.

System parameters used in numerical examples are set as follows: The demand x_1 of the product in the normal sales market follows the normal distribution with population mean $\mu_1 = d_{u_i} \times \mu_1^0$ and population standard deviation $\sigma_1 = d_{u_i} \times \sigma_1^0$, where $\mu_1^0 = 1000$ and $\sigma_1^0 = 300$, the increment ratio of product's demand in the normal sales market $d_{u_i} = 1.0 + 2.0\left(u_i^0 - u_i\right)/u_i^0$, $0.0 \le d_{u_i} \le 1.0$, depending on the value of retail price $u_i\left(i = D,C\right)$. The demand x_2 of the product in the discount sales market follows the normal distribution with population mean $\mu_2 = d_{dis}^i \times \mu_2^0$ and population standard deviation $\sigma_2 = d_{dis}^i \times \sigma_2^0$, where $\mu_2^0 = 0.7 \times \mu_1$ and $\sigma_2^0 = 0.7 \times \sigma_1$, depending on the value of discount ratio $d_{dis}^i\left(i = D,C\right)$ in discount sales market of retail price $u_i\left(i = D,C\right)$. The demand x_3 of the product in the secondary sales market follows the normal distribution with population mean $\mu_3 = d_{2nd}^i \times \mu_3^0$ and population standard deviation $\sigma_3 = d_{2nd}^i \times \sigma_3^0$, where $\mu_3^0 = 0.5 \times \mu_1$ and $\sigma_3^0 = 0.5 \times \sigma_1$, depending on the value of discount ratio $d_{2nd}^i\left(i = D,C\right)$ in secondary sales market of retail price $u_i\left(i = D,C\right)$. Rework cost $m = d_{2nd}^i \times m_0$, m_0=0.1, depending on the value of discount ratio $d_{2nd}^i\left(i = D,C\right)$ in secondary sales market. As the system parameters of a manufacturer: c=5.0, $w = 0.6u_i$, $b = 0.5u_i$, h_m=1.0, v=2.5. As the system parameters of a retailer: u_0=14, r=0.2, s=0.5, C_v=1.0, q=0.8, C_e= 2.0, G=10.0, h_{r1}=h_{r2}=2.0, c_d=1.5, $0 < d_{dis}^i \le 1.0$ and $0 < d_{2nd}^i \le 1.0$.

Table 1 shows comparison results of the optimal inventory-sales policy of the base model and the proposed model under the decentralized supply chain. Table 2 shows comparison results of the base model and the proposed model under the centralized supply chain without profit sharing. For discount ratio in discount sales market $d_{dis}^i\left(i = D,C\right)$ and discount ratio in secondary sales market $d_{2nd}^i\left(i = D,C\right)$, '----' indicates no discount sales, $d_{dis}^i = 0.0$ and $d_{2nd}^i = 0.0$, corresponding to the base model. The ranges of $0 < d_{dis}^i \le 1.0$ and $0 < d_{2nd}^i \le 1.0$ indicate the proposed model.

From Tables 1 and 2, the following results can been seen: all the expected profits of the manufacturer, the retailer and the whole system of the proposed model with price-sensitivity and discount-sensitivity under both the decentralized supply chain and the centralized supply chain are higher than those of base model without with price-sensitivity and discount-sensitivity.

In the proposed model, the retail price u^D under the decentralized supply chain is lower than the retail price u^C under the centralized supply chain. This indicates that the increment ratio of product's demand in the normal sales market under the decentralized supply chain is higher than that under the centralized supply chain. Under the decentralized supply chain, the optimal discount ratio in the discount sales market d_{dis}^D can be obtained in the range where $0.2 \le d_{dis}^D < 0.3$. Under the centralized supply chain, the optimal discount ratio in the discount sales market d_{dis}^C can be obtained in the range where $0.3 \le d_{dis}^C < 0.4$. This indicates that the increment ratio of product's demand in the

discount sales market under the centralized supply chain is higher than that under the decentralized supply chain. Under the decentralized supply chain and the centralized supply chain, the optimal discount ratio in the secondary sales market $d_{2nd}^{i}\left(i=D,C\right)$ can be obtained in the range where $0.3 \leq d_{2nd}^{i} < 0.4$. From the comparison results in terms of the price-sensitivity and discount-sensitivity, the expected profit in the normal sales market under the decentralized supply chain is higher than that under centralized supply chain, while the expected profit in the discount sales market under the decentralized supply chain is lower than that under centralized supply chain.

From the effects of price-sensitivity and discount-sensitivity for discount sales in both the discount sales market and the secondary sales market, the result of the optimal order quantity can been seen: from Table 1, the optimal order quantity of the proposed model with under the decen- tralized supply chain is larger than that of the base model without with price-sensitivity and discount-sensitivity. This is the reason why the optimal decision is made so as to maximize the

Table 1. Comparison results of optimal inventory-sales policy and expected profits of base model and proposed model under decentralized supply chain

	Base model	Proposed model
u_D^*	14	13
d_{uD}^*	1.00	1.14
d_{dis}^{D*}	0.0	0.2
d_{2nd}^{D*}	0.0	0.3
Q_D^*	1268	1485
π_R	3515.12	4026.92
π_M	3000.63	3472.32
π_S	6515.76	7499.24
Normal sale market	5740.87	5876.76
Discount sale market	0.00	610.58
Secondary sale market	218.07	598.56
Disposal sale market	556.81	413.34

Table 2. Comparison results of optimal inventory-sales policy and expected profits of base model and proposed model under centralized supply chain

	Base model	Proposed model
u_C^*	14	15
d_{uC}^*	1.00	0.86
d_{dis}^{C*}	0.0	0.3
d_{2nd}^{C*}	0.0	0.3
Q_C^*	1257	1204
π_R	3514.12	3709.05
π_M	3002.85	4212.18
π_S	6516.97	7921.23
Normal sale market	5764.75	5714.31
Discount sale market	0.00	1405.79
Secondary sale market	215.07	550.31
Disposal sale market	537.16	250.82

Table 3. Comparison results of expected profits of proposed model under centralized supply chain without profit sharing and those under centralized supply chain with profit sharing

	Proposed model		
Expected profit	Decentralized supply chain	Centralized supply chain	
		No profit sharing	Profit sharing
Retailer	4026.92	3709.05	4175.70
Manufacturer	3472.32	4212.18	3745.53
Whole system	7499.24	7921.23	7921.23

expected profit of the retailer who is the Stackelberg leader. From Table 2, the optimal order quantity of the proposed model with price-sensitivity and discount-sensitivity under the centralized supply chain is smallest among those of the base model without discount sales and the proposed model under the decentralized supply chain. This is the reason why the optimal decision is made so as to maximize the expected profit of the whole system which integrates the retailer and the manufacturer as one company.

(3) Effect of profit sharing on the expected profit of each player within the supply chain

From Table 2, in the proposed model under the decentralized supply chain, the expected profits of the manufacturer who is the Stackelberg follower and the whole system under the centralized supply chain are higher than those in the decentralized supply chain. However, the expected profit of the retailer in the centralized supply chain is lower than that of the retailer who is the Stackelberg leader in the decentralized supply chain. Table 3 shows the results without/with profit sharing in the centralized supply chain for the proposed model. In Tables 2 and 3, we compare the results of all the expected profits in the centralized supply chain without profit sharing with those with profit sharing. From the results, after the profit sharing, the expected profits of the retailer and the manufacturer under the centralized supply chain are higher than those in the decentralized supply chain. This result shows

that a change from the decentralized supply chain to the centralized supply chain enables to bring more profits to all players within the supply chain.

8. A FRAMEWORK OF DEVELOPMENT OF DECISION SUPPOT FOR INVENTORY-SALES POLICY UNDER SUPPLY CHAIN SYSTEM

A framework of development of decision-support under supply chain system discussed in this study is shown. Figure 2 shows an example of windows application development of decision-support for the optimal inventory-sales policy under supply chain system with supply chain coordination, return handling, price-sensitivity and profit sharing. This application is developed by using combining .Net Framework 3.5 and C# programming under the integrated development environment named Visual Studio 2008.

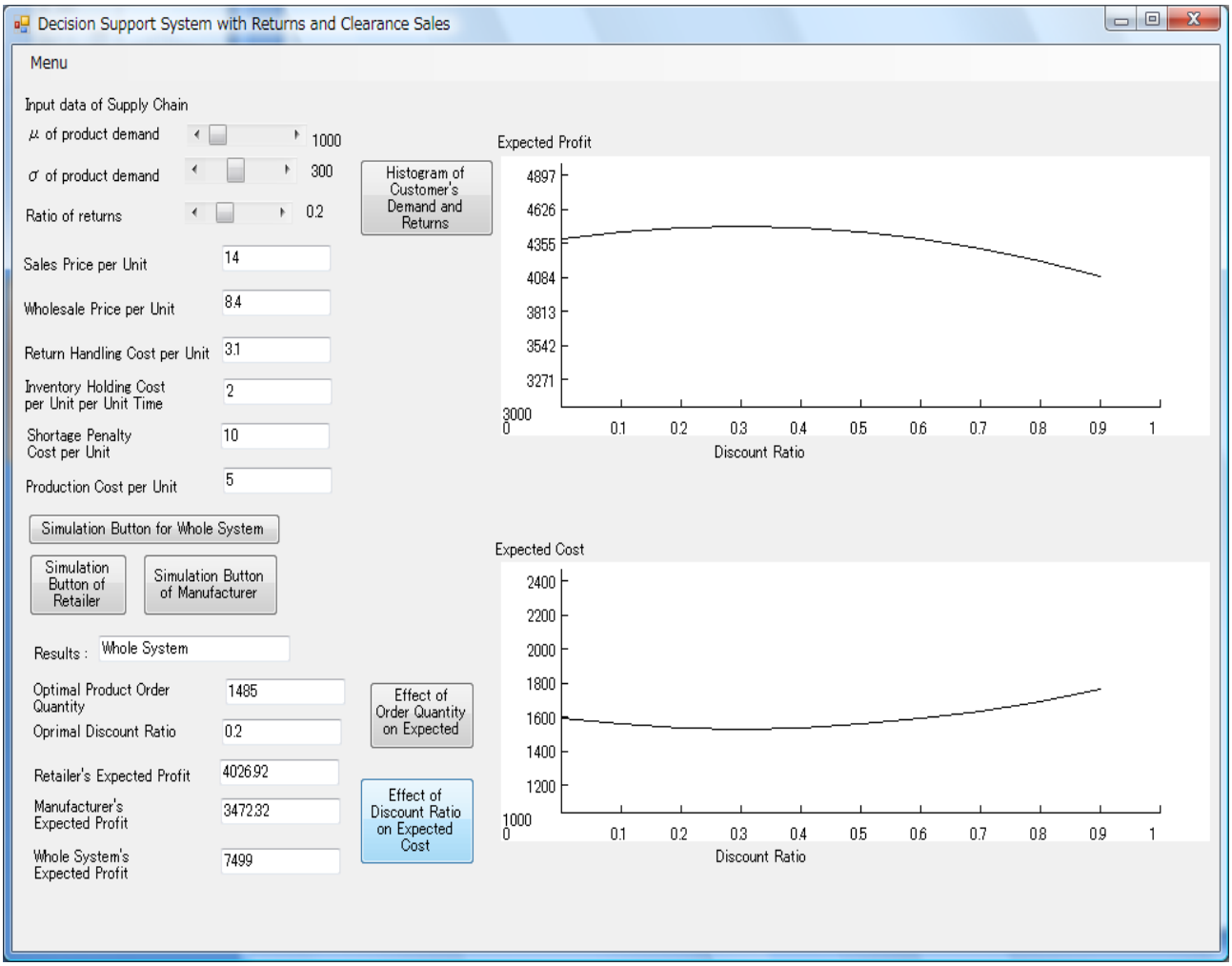

Figure 2. An Example of windows application development of decision-support under for the optimal inventory-sales policy under supply chain system discussed in this study

9. CONCLUSIONS

In this paper, a mathematical model was developed to determine an optimal inventory-sales policy for a supply chain with return handling, price-sensitivity and profit sharing. In this study, a supply chain which consists of a retailer and a manufacturer was addressed. Two types of supply chain are analyzed: (Type I) the decentralized supply chain, (Type II) the centralized supply chain. As the optimal inventory-sales policy, product order quantity, retail price and discount ratio were determined based on Stackelberg game where a retailer was the Stackelberg leader and a manufacturer was Stackelberg follower. In Type I, the optimal decision was made to maximize the expected profit of each player. In Type II, the optimal decisions were made to maximize the expected profit of the whole system as one company. In Type II, profit sharing approach was discussed as supply chain coordination. In numerical examples, the optimal inventory-sales policy and effect of profit sharing are shown. Finally, a framework of development of decision-support for the optimal inventory-sales policy under supply chain system with supply chain coordination, return handling, price-sensitivity and profit sharing was shown.

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Innovation Capability Maturity Model (ICMM): Building Organisational Innovation Processes

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Abstract

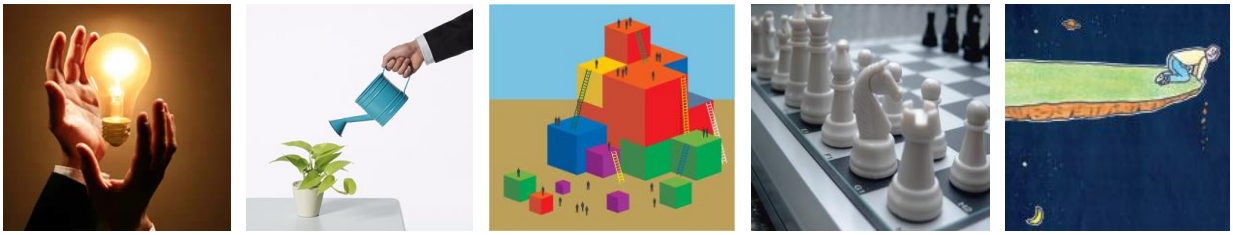
Most innovation attempts end in failure. The paper hypothesises that the main reason for this is that the innovation capabilities of most organisations are ill-matched to the prevailing market needs. Based on the output of a six-year programme of research into organisational innovation capability, the paper has uncovered a number of distinctly different stages and levels of capability. These levels are described and then connected to a maturity model, now being endorsed by some of the most respected academic, industrial and governmental institutions in the world. The primary aim of the model is to help organisations to introduce and utilise the appropriate innovation tools, methods and strategies at the right time and in the right context, thus enabling an opportunity to significantly increase innovation success rate and resource utilisation effectiveness.

The paper is divided into three sections: the first describes the Innovation Capability Maturity Model; the second describes the things that will and will not work should an organisation at a given level attempt to innovate; the third describes the process by which organisations can measure where they are on the Model scale.

Introduction

It's probably no understatement to say that the large majority of organisations on the planet are struggling to make sense of the continuous-innovation world that we currently find ourselves in. Out of the confusion, false-starts and even the occasional success story, a distinct pattern of behaviours seem to be emerging. In line with our desire to uncover discontinuous evolution patterns, the behaviour patterns now seems clear enough that we can construct what we hope will become a new entry in our collection of discontinuous business evolution trends.

Our search for trends has been assisted in this case by the book 'Innovation and the Future Proof Bank' (Reference 1). Probably not the best title in the world given the recent global financial crisis, and indeed for much of its content the author seems to be wildly naïve when it comes to the innovation story. But then banks are not traditionally know as great innovators. Customers in fact tend not to want too much innovation from the guardians of their finances. And there is much evidence to suggest that the GFC was in no small part a result of too much of that naïve innovation in the sector. That criticism of the book aside, what does appear clear from its content is that the building of an innovation capability within an organisation needs to pass through a number of stages. Figure 1 offers our thoughts on what those discontinuously different stages look like, based on our own programme of investigation:



SEEDING CHAMPIONING MANAGING STRATEGISING VENTURING

Figure 1: Organisational Innovation Capability Evolution Trend

Consistent with all of our other trend patterns, this one is drawn in such a way that increasing ideality occurs as organisations evolve from left to right across the pattern. Let's have a more detailed look at each of the stages:

Seeding

Before an organisation has any innovation capability to speak of, the first thing that needs to be done is achieving some early success. Typically, organisations deciding that they need to become 'more innovative' will begin by giving some poor unfortunate soul an innovation related job-title. This is usually a way for the senior management team to demonstrate to their masters that the company is 'doing something'. Typically also it is an opportunity to divest responsibility – few if any executives welcome the disruption and risk that comes with the innovation territory at this stage, so passing the responsibility for success to someone else is a great way to be seen to be doing something while simultaneously guaranteeing that nothing of significance will emerge to disrupt the status quo. At this stage in the innovation capability trajectory, the driving management force appears to the outsider as a 'not on my watch' aim. Few if any senior managers will wish to change or disrupt an organisation that appears to be working well. All in all, the innovator's operating in an organisation at this 'seeding' stage traditionally have little or no chance of success. The poisoned chalice they have been handed, however, doesn't have to be fatal to either career or organisation. The key to success – and therefore an opportunity to reach the next stage in the capability evolution – is to achieve some kind of small scale success. The innovation 'team' (it may be one or two unofficial intrapreneurs) is likely to have to find their own opportunity areas. Mostly likely these will need to be some way away from the company's core activities, and far enough out of the limelight that there are few if any vested interests that will try to kill the innovation attempts. Finding a 'common enemy' is often a good start point – a small but thorny problem that annoys large numbers of people, or would be noticed by large numbers if the problem was fixed. The key is success rather than scale – in other words, it doesn't matter how 'trivial' the success is, the important thing is that it is viewed by people, and especially management, as something that delivers some kind of tangible difference.

A large majority of innovation capability initiatives fail at this first hurdle because the innovators are tempted (or pushed by senior management) to tackle something big and important. Given this kind of experience, a far better strategy involves starting very small, and possibly even with a problem or two that only the innovation team themselves will know about. These invisible successes are useful as a way of building confidence in a team that, as it begins to look for innovation stories outside the organisation, quickly begins to learn that most innovation attempts globally fail. Once there are a few success stories – eventually ones that are noticed by others (for example, in Samsung, one of the very first TRIZ case studies was a 'low-key' manufacturing cost reduction problem that turned out to save $91M (Reference 2)) – then the organisation is ready to advance to the next stage…

Championing

With some 'runs on the board' the innovation team should now be ready to begin spreading the word, building a network of supporters and, most importantly, begin introducing some tools, systems or methods into the infra-structure. The primary aim during this championing stage is to achieve broad acceptance across the organisation that innovation is a key business process rather than an ethereal, high-risk enemy. It is crucial during this second stage that the innovation team is able to begin quantifying the improvements being delivered. Often it is necessary to measure what is simple to measure (number of patent applications is a nice easy track) rather than what is important, but the important feature is that the team is able to demonstrate to senior managers that they are developing a predictable capability that is able to deliver against targets. Solving the measurement credibility problem is perhaps the toughest challenge during this championing phase. It will typically require at least one full-time person to act in the championing/networking/measuring role. It is during this second stage too that innovators and the innovation champion are likely to hit several contradictions, two of which are particularly important and need to be solved before advance to the next evolution stage can occur:

1) In addition to networking to build support, there is a parallel need to keep delivering success stories. This is because the shelf-life of a good idea tends to be fairly short – any good idea once implemented and everyone can see it is a good idea quickly becomes the new common sense…
2) …which in turn leads to perhaps the biggest conflict of all during this second stage – the implemented ideas look 'obvious' which in turn tends to plant the thought 'we didn't need an innovation team to do that' in the minds of many outside the team. Alas, this phenomenon is inherent in any innovation story – if the solution doesn't look 'obvious' it probably isn't good enough. But the conflict does have to be overcome before advance to the next stage is possible:

Managing

The third stage in innovation capability evolution starts when there is a clear innovation process in place and that when goals are set, there is a strong chance that the process will be capable of reliably and repeatably delivering what is says it will deliver. Recognition that failure is 'inevitable' in any innovation process ('if we're not failing we're not pushing hard enough'), a key part of this managing process is convincing the senior management team that risks are capable of being managed by the innovation process. A good example of this kind of demonstration occurs in organisations with a 'fail fast, fail forward' philosophy – where 'failures' are constructed as experiments from which the team will learn and build towards a future bigger success.

Again there are a number of contradictions that the innovation team is going to have to overcome if they want to progress to the next evolution stage:

1) Management of the Hype Cycle (Reference3, Figure 2) – with a series of success stories under their belt, there is a strong temptation for senior managers to come on board to such an extent that the successes are over-played
2) Scaling the capability – because the stream of innovations needs to continue, there is a need to begin bringing larger and larger numbers of people within the organisation into the innovation fold. The inevitable problem here is that the organisation has to simultaneously keep doing the day-to-day business as well as building the innovation capability. Behind this problem is the fact that much of the innovation DNA is polar opposite to the DNA of the traditional business. Think about the destructive

introduction of 6Sigma into 3M (Reference 4) as the poster-child of the size of this contradiction. 3M has traditionally always been a very innovative company (i.e. already at this third evolution stage – if not the 4th), but when 6Sigma was introduced across the whole company it sent out a message that data was more important than ideas and as a consequence largely killed the flow of new ideas. Think too about the difficulties being faced by GE CEO Jeff Immelt as he tries to bring about an innovation transformation after Jack Welch's 6Sigma legacy.

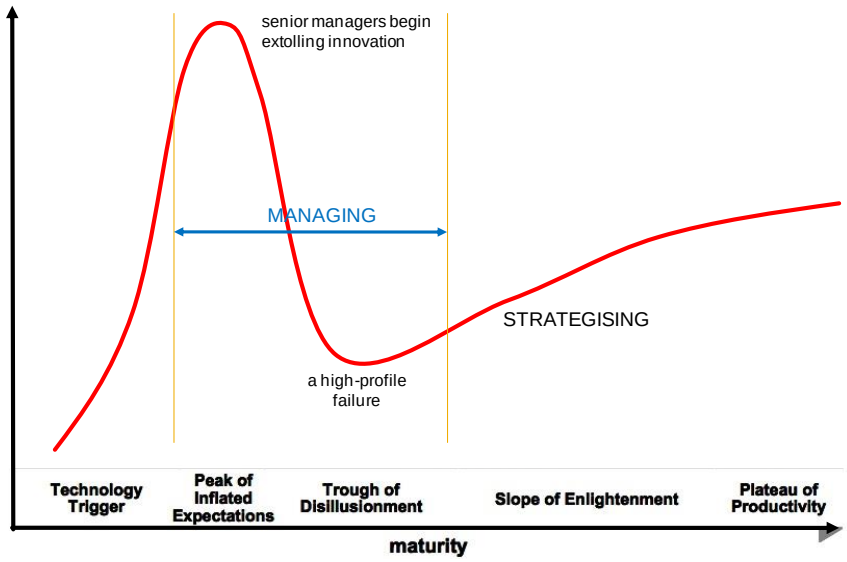


Figure 2: Organisational Innovation Capability Evolution And The 'Hype Cycle'

Strategising

Once the scaling and predictable-process contradictions have been resolved, the innovation team finds itself at the fourth – strategising – stage of evolution. Innovation is now highly visible on the senior management radar screen and, in all probability, there is going to be someone with full-time responsibilities for innovation within that team. Innovation is no longer seen as a poisoned-chalice at this stage in the evolution, and in fact, quite likely, people are beginning to see innovation functions as 'the place to be' for the best chances of career progression. The key objective to achieve, then, during this fourth stage is the transition of innovation from that of a predictable business process to one that is capable of delivering the future success of the business. Innovation at this stage, in other words, takes a leap outside the traditional doors of the business and begins to examine the future position of the business in a wider context.

A key test during this fourth stage is that it becomes possible to show and talk about pictures like the one shown in Figure 3:

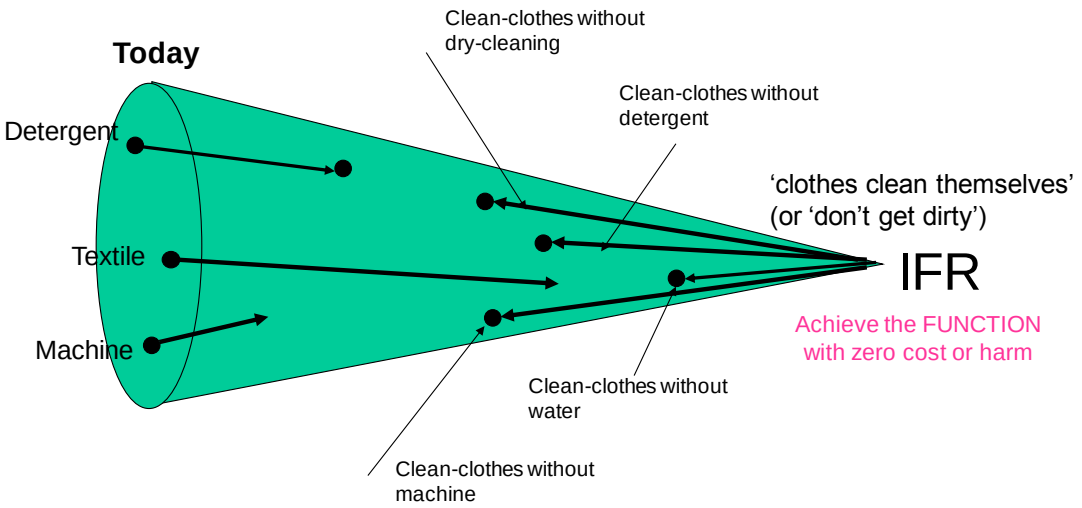


Figure 3: Signifying The Switch From Managing Innovation To Strategic Innovation

For the detergent or washing machine manufacturer, this picture can be a fairly depressing picture, because it fairly clearly paints a story that says neither will exist at some point in the future when textiles are capable of cleaning themselves. It is impossible to meaningfully present this picture to the population within an organisation at the third evolution stage because it says that detergent chemists and washing machine mechanical engineers won't have a place in the future. It *can* be shown to large numbers of people in organisations at the fourth stage of capability evolution because they are open to the bigger world-view and hence the possibility that the threats highlighted by the picture are also potentially opportunities ('what consumable product do we sell to the person with a self-cleaning shirt?').

The key new skills the innovation team needs to develop during this fourth stage, therefore, are scenario-planning, story-telling and managing the internal intangibles. The critical mass point for the 'strategising' stage is that innovation inputs are integral to the strategic planning process of the organisation. This in turn means that the innovators have sufficient authority and respect to authorise practically anything, given sufficient motivation to do so… which usually implies that the key conflict needing to be overcome at this stage is the parallel need to know what we're good at and to be able to break out of our current knowledge silos in order to truly serve the customer's needs.

Venturing

There aren't many organisations that have successfully transcended the fourth stage of evolution to reach this fifth, and thus far 'final' stage (no doubt in the future there will be more stages to come). What is happening at the fifth stage is a general recognition within the business of a number of global phenomena, namely:

a) The evolution of human systems is generally convergent – like a mega-scale version of the cone showed in Figure 3 – and in such a world there clearly isn't room for all of the current players. The fifth stage organisation is able to pro-actively venture outside its core skill areas and into other areas. This might well mean spinning off different businesses, but is highly likely to turn the venturing job into a global scale version of the Rule Of Three (Reference 5). Retailer, Tesco, and Richard Branson's Virgin group are probably two of the best examples of organisations that understand the need to venture into new areas, whilst simultaneously retaining credibility with their existing customer base and employees.

b) The parallel recognition that the world cycles through periods of punctuated equilibrium. In other words, the organisation recognises that there are times when innovation is really important (i.e. now and probably for the next 20 years), and then other times when competition slows down and stability becomes the order of the day, and designs their business accordingly.

So there we have it. Five stages (so far) of organisational innovation capability: Seeding – Championing – Managing – Strategising – Venturing. We think you need to know where your organisation is on the progression. And what are you doing to ensure you successfully make it to the next stage. In the next section, we explore what the Capability Maturity Model indicates as the things that an organisation can and cannot hope to achieve at each of the different stages. In a final section we describe the process by which organisations can assess where they are on the Model scale, and what they need to do to advance to the requisite level for their industry and operational context.

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TRIZ and Yin-Yang Theory: General and Particular

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Abstract

TRIZ and Yin-Yang are common sources. These sources are the laws of nature, the synthesis of previous experience, bottom-up approach, statistics. Sources of Yin-Yang are analysis of the treatment of illness and the relationship between the organs of the body, use of pain medications property (plants, animals, minerals, and so on). Sources of TRIZ are analysis of the awnings and history of the development of technical systems, the use of scientific effects (physics, chemistry, biology, mathematics, and so on).

TRIZ and Yin-Yang have similar objectives. Technique: analyzing tasks, using of instruments, generating solutions, choosing the best solution, productive solutions. The Yin-Yang Theory body consist of Yin-Yang, which once divided into Yin and Yang. Under the TRIZ in any system there are processes of deployment and closure processes. TRIZ can be further developed with the help of Yin-Yang Theory.

Keywords: Contradictions, SuField analysis, TRIZ tools, Yin-Yang theory.

TRIZ 和阴阳学说

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1. 序言

阴阳学说历史悠久，TRIZ 相对来说是比较新的学说。然而这两个理论有很多共同点，并且阴阳学说可以丰富 TRIZ 理论，尤其是在预先分析问题方面。

2. TRIZ 和阴阳学说的哲学基础

中医学理论体系，是包括理、法、方、药在内的整体，是关于中医学的基本概念、基本原理和基本方法的科学知识体系。它是以阴阳、五行学说为哲学基础和思维方法，一肺腑经络及精气为病理学基础，以辨证施治为诊治特点的独特的医学理论体系。

阴阳学说认为：世界是物质性的整体，宇宙间一切事物不仅其内部存在着阴阳的对立统一，而且其发生、发展和变化都是阴阳二气对立统一的结果；TRIZ 认为：矛盾是事物发展的动力，矛盾的不断产生和解决推动了事物的发展和进步。

中医学用阴阳学说阐明生命的起源和本质，人体的生理功能、病理变化，疾病的诊断和防治的根本规律，贯穿于中医的理、法、方、药，长期以来，一直有效地指导着实践。

阴阳的对立、互根、消长、转化，是阴阳学说的基本内容。这些内容不是孤立的，而是互相联系、互相影响、互为因果的。阴阳学说贯穿于中医理论体系的各个方面，用来说明人体的组织结构、生理功能、病理变化、归纳药物的性能并指导临床诊断和治疗。而相应地 TRIZ（1984 年，根里奇·阿奇舒勒）认为：系统是发展的，系统发展是有规律的，系统发展的规律可以被人们所认识，人们可以利用这些规律来促进发展。 并且 TRIZ 中有评价所得解决方案的通用标准—最终理想解。

结论： TRIZ 和阴阳学说的哲学基础非常相似，通过 TRIZ 可以掌握技术系统的进化，通过阴阳学说可以掌握人体组织结构的进化。

3. TRIZ 和阴阳学说的来源

中医学有数千年的历史，是中华民族在长期的生产与生活实践中研究人体生命、维护健康、战胜疾病的宝贵经验总结，是中国传统文化的结晶。中医学在长期的医疗实践中积累了丰富的防治疾病的经验和科学的思维方法，并在此基础上形成了独特的理论体系。

中医学属于自然科学的范畴，但亦具有浓厚的社会科学的特点，同时还受到中国古代哲学思想的深刻影响，是一门以自然科学为主体、多学科知识相交融的医学科学。中医学理论体系吸收了中国古代的天文、历法、气象、数学、生物、地理等多种学科的重要成果，在阴阳五行学说指导下，总结了以前的医疗成就和治疗经验，确定了中医学的理论原则，系统地阐述了生理、病理、经络、解剖、诊断、治疗、预防、保健等问题，建立了独特的理论体系，成为中医学发展的基础和理论源泉。

TRIZ 在系统论、认识论、自然辩证法的指导下对前人发明成果（专利）、技术系统发展史的分析、研究、归纳、总结和相关学科的融合形成了发展想像力产生创新思想的工具；分析解决问题的工具；预测未来的工具等组成的系统的创新方法。

结论： TRIZ 和阴阳学说的来源非常相似。

4. TRIZ 和阴阳学说解决问题的系统方法

中医学和 TRIZ 解决问题的对象虽然不同，一个是针对人、一个是针对产品，但是解决问题的方法和机理是相同的：分析问题、诊断问题、应用工具提出解决方案、选择方案、解决问题。这些都是建立在依据过去经验总结的指导下的，建立在统计学基础上的定性分析的经验学，并不能称为严格意义上科学。例如 TRIZ 和中医学都有系统化的解决问题的工具。TRIZ 中有 40 创新原理、系统化进化法则、效能、76 个标准解、物-场分析等；中医学中有各种疾病的症状、各种中药的药效、中药配方、经络、针灸等。

例如，应用中药人参、足部按摩治疗疾病：可以有效地刺激分泌，达到补气安神的作用。这可以治疗大量疾病，劳伤虚损、食少、倦怠、反胃吐食、大便滑泄、虚咳喘促、自汗暴脱、惊悸、健忘、眩晕头痛、阳痿、尿频、消渴、妇女崩漏、小儿慢惊、久虚不复及一切气血津液不足症状。TRIZ 认为矛盾是事物的本质，矛盾的变化是推动事物发展的动力。

TRIZ 可以解决技术问题、提高产品质量，并可以预测系统发展。

结论： TRIZ 和阴阳学说解决问题的系统方法极其相似。

5. TRIZ 和阴阳学说的相互关系

TRIZ 认为，每个系统都存在矛盾，系统只有在解决存在的矛盾后才能发展。中医学认为：阴阳是事物的本质，阴阳的消长变化是推动事物发展的动力。

中医理论在阴阳学说基础上建立起来的，阴阳五行学说，是中国古代朴素的唯物论和自发的辩证法思想，它认为世界是物质的，物质世界是在阴阳二气作用的推动下孳生、发展和变化；阴阳五行学说，是中国古代朴素的唯物论和自发的辩证法思想，它认为世界是物质的，物质世界是在阴阳二气作用的推动下孳生、发展和变化；并认为木、火、土、金、水五种最基本的物质是构成世界不可缺少的元素。这五种物质相互资生、相互制约，处于不断的运动变化之中。

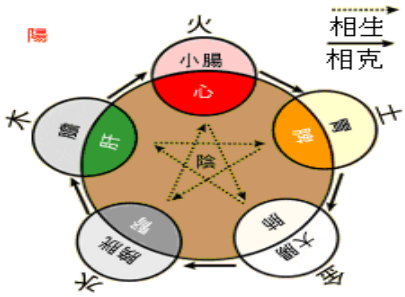

Figure 1. 人体脏腑的五行关系

技术系统也符合相生相克规律，执行机构（工具）作用于产品，改变产品。但只有当工具与产品相协调时，系统作用具有最佳效果，也就是在产品的作用下，工具应当发生变化。协调过程是逐级向系统内部进行的：传输机构和执行机构相协调，动力机构与传动及能源机构相协调。换个角度讲，能源从来源机构经动力机构、传动机构、执行机构传向作用客体，并使其发生变化。

6. 结论

阴阳学说可以应用于解决技术问题，特别是分析和解决复杂问题。

阴阳学说能较快地揭示问题的本质，提出理想的解决方案。这为阴阳学说丰富 TRIZ 提供了可能。

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Automatic Identification of Relevant Technical Trends using Function-Attribute Relationships and Cosine Mapping

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Abstract

Based on the idea that problems of similar class tend to have similar solutions, this research established a problem modeling approach, based on Problem Characteristics Array (PCA), and a solution modeling approach based on TRIZ Trends of technical evolutions to identify stages of relevant trend for problem solving. A set of similarity formula were established to extract relevant trends and stages for solutions from solutions to problems of similar PCA. The PCA of a problem consists primarily of the functions needed to solve the problem and attributes or their changes needed for problem solving. The mathematical model for similarity calculations to match problem characteristics array (PCA) onto corresponding stages of relevant evolutionary trends was codified in Excel-based software for ease of usage. The model can indentify relevant trends quickly and objectively without relying on experienced and subjective human judgments.

The contributions of the research include: 1) Establishing a mathematical model to automatically and quickly identify solution models in relevant trends without relying on expert's knowledge or subjective judgments; 2) Identifying relationship among attributes, states, and functions of an engineering system paving the foundation for function-attribute-based solution identifications using various similarity analyses in the future; 3) Establishing standardized evolution trends tables on function-attribute relations for further relevant studies.

Keywords: TRIZ, Problem Characteristics Array, Function and attribute analysis, Trends of Technical System Evolution, Similarity Rating.

1. Introduction

Originating from the induction of hundreds of thousands of patents, TRIZ can be described as a classification learning (Sheu, 2007). Based on different classification perspectives, it has different problem-solving models including trends of evolution of technical systems, which is one of the powerful problem-solving tools and can serve as an aid to R&D strategy. Its application approach is to identify evolutionary trends relating to the system to be improved and judge the current evolutionary

stage of the system, so that the future evolutionary stages of relevant trends can be a reference to the improvement of the current system. However, the difficulty in applying the trends of evolution of technical systems is how to identify the system to be improved and what trends are involved. It requests human judgment and is highly dependent on expertise.

From the viewpoints of FAA (Function and Attribute Analysis), this article analyzed the attributes and functions involving the system, resolved the problem at the fundamental level, found the core of the problem, significantly reduced problem types to enhance the opportunity to identify similar problems. However, similar functions or attributes in various industries may have their specific ways of expression, which may prevent the application of solutions across different fields. Hence, it is expected to enhance the opportunities of cross-industry and cross-field applications by integration and summary of similar functions or attributes of different fields. This study expected to establish the PCA (problem characteristics array) by using the standardized functions and attributes, conduct relational analysis by computer automation and calculate the similarity of functions and attributes to replace the pairwise matching of stage trends by staffs or experts.

The purpose of this study was to improve the practical application of the above mentioned trends of evolution of technical systems, establish a computerized mathematical reasoning tool to directly help users identify appropriate trends and stages as the trigger solutions to the problems. As a result, it is not dependent on experts and it does not need to go through all trends or stages. Thus, it may substantially reduce the search time.

2. Literature Review

▪2.1 Attribute

The FBS diagram (Function-behavior-state diagram) proposed by Umeda, Takeda, Tomiyama and Yoshikawa (1990) defined attributes as certain qualities that can identify an object. In 2003, Takahara argued that the object had static and dynamic properties. The static properties were attributes and the dynamic properties were properties to change. The broad and narrow definitions of attribute are as follows:

- attribute (general ─including quantity attribute and quality attribute
- attribute (narrow)─a capacity cannot easily be changed

The state refers to the attribute prone to change.

However, this study found that speed was one of the attributes of an object although it belonged to the dynamic properties of the object. Hence, the above definitions were believed as not comprehensive.

In the Directed Variation® CREAX structure proposed by Dewulf (2006), property was used to describe the attribute and dimension of an object as a variable usually expressed by an adjective. In addition, it was also proposed that "A property spectrum depicts the variety, segments or scale in which a property is variable". Sheu pointed out that attribute can be expressed by noun or adjective as it was attached to descriptions of components. To sum up the above literature, attributes represent certain properties of an object.

▪2.2 Function

The definition of function varies from field to field. In literature on mechanical design, Rodenacker (1971) and Kleer (1984) defined function as the conversion of input of mass, energy or information into an action. Roth (1982) indicated that the representation of the main purpose of the object is function. FBS diagram (Function-behavior-state diagram, Umeda et al.) regarded behavior as one or more gradually changing states while the definition of function is "an extracted description of behavior recognized by people for the purpose of using the behavior", in short, it is "to do something".

Rantanen and Domb (2002) argued that function is still a fragmented concept including the following implications: (1) including the interactive operations of action and object, such as the driving of motorcycle; (2) the purpose of action, such as the driving of motorcycle for fun; (3) the result of action, such as the driving of motorcycle producing noise and emissions.

Takahara's definition of function refers to the "positive meaning" of an object on the external environment. When the function satisfies the following three conditions regarding the external environment (see Table 1), it forms the "positive meaning":

Dewulf indicated that function is the object purpose and is a useful action mainly expressed by a verb. To achieve a function, a property or property combination should be changed.

Both Takahara and Dewulf argued that function can create interactive operational relations on attribute and even can change a certain property or property combination. However, some functions are to prevent the object from changing its properties. For example, "hold" is to keep the location attribute of the object unchanged. Hence, this study suggested that function is to change or keep the object attribute or attribute combinations.

▪2.3 Trends of Evolution of Technical Systems

Evolution means the non-continuous development process from one stage to another. The process from one stage to the next was a jump. From the perspective of overall trend, it was the gradual development toward the ideal state of the system that can be logically followed. Laws of development of technical systems proposed by Altshuller (1984) are the ancestor of all the currently available evolution trends systems (renamed as Evolution of Technical Systems in 1997). He classified the evolution laws into three types: (1) statics; (2) kinematics; (3) dynamics. Statics determine the laws

governing the initial existence of a technical system; kinematics describe the development direction of the technical system regardless of the external conditions; dynamics reflect how the system developed under specific conditions. Table 1 shows the 8 laws of evolution by classification:

Table 1 Laws of development of technical systems

Classes	Laws of development of technical systems
Statics	● The law of the completeness of parts of the system ● The law of energy conductivity of a system ● The law of harmonizing the rhythms of parts of the system
Kinematics	● The law of increasing the degree of ideality of the system ● The law of uneven development of parts of a system ● The law of transition to a super-system
Dynamics	● The law of transition from macro to micro level ● The law of increasing the S-Field involvement

▪2.4 Similarity Rating

There are abundant findings in data mining and information retrieval literature regarding the similarity rating, comparison and other related methods. The similarity level can be judged by the distance between two data points through using the simple spatial distance calculation equation. The commonly used distance measurement equation was as follows (Salton, 1989): assume A, B as two non-overlapping sets:

(1) Euclidean relative distance ε(A, B) and Euclid closeness Nε(A, B) :

- Euclidean relative distance

$$\varepsilon(\tilde{A},\tilde{B})=\sqrt{\frac{1}{n}\sum_{i=1}^{n}(\mu_{\tilde{A}}(x_i)-\mu_{\tilde{B}}(x_i))^2}$$

$$\mu_{\tilde{A}}=(x_1,x_2,...,x_i)$$
$$\mu_{\tilde{B}}=(x_1,x_2,...,x_i) \quad i=1,\ 2,\ \dots,I$$

- Euclid closeness

$$N\varepsilon(A,B)=1-\sqrt{\frac{1}{n}\sum_{i=1}^{n}(\mu_{\tilde{A}}(x_i)-\mu_{\tilde{B}}(x_i))^2}$$

$\mu_{\tilde{A}} = (x_1, x_2, ..., x_i)$
$\mu_{\tilde{B}} = (x_1, x_2, ..., x_i)$ $i=1, 2, \ldots, I$

(2) Relative Hamming distance and Hamming closeness

- Relative Hamming distance

$$\delta(\tilde{A}, \tilde{B}) = \frac{1}{n}\sum_{i=1}^{n}\left|\mu_{\tilde{A}}(x_i) - \mu_{\tilde{B}}(x_i)\right|$$

$\mu_{\tilde{A}} = (x_1, x_2, ..., x_i)$
$\mu_{\tilde{B}} = (x_1, x_2, ..., x_i)$ $i=1, 2, \ldots, I$

- Hamming closeness

$$N_{\delta}(A, B) = 1 - \frac{1}{n}\sum_{i=1}^{n}\left|\mu_{\tilde{A}}(x_i) - \mu_{\tilde{B}}(x_i)\right|$$

$\mu_{\tilde{A}} = (x_1, x_2, ..., x_i)$
$\mu_{\tilde{B}} = (x_1, x_2, ..., x_i)$ $i=1, 2, \ldots, I$

Mahalanobis distance proposed by Mahalanobis (1936) can also measure the distance between two sample points in multi-dimensional space. Mahalanobis distance applied the CW to adjust the traditional Euclidean distance. When considering the impact of co-linearity among variables, it can handle multivariate problems by the formula as follows:

$$MD_{ij} = (X_i - X_j)^T C_W^{-1}(X_i - X_j) = \left[X_{i1} - X_{j1}, X_{i2} - X_{j2}, ..., X_{ik} - X_{jk}\right] C_W^{-1} \begin{bmatrix} X_{i1} - X_{j1} \\ X_{i2} - X_{j2} \\ \cdots \\ X_{ik} - X_{jk} \end{bmatrix}$$

X_i: (X_{i1}, X_{i2},… ,X_{ik}) denotes the vector formed by k variables of i-th observation value

X_i^T: the transposed matrix

C_W: the covariance matrix in the joint group

C_W^{-1}: The inverse covariance matrix in the joint group

The most well-known comparison technology at present was the vector space model, which was easy to use by calculating the similarity of two vectors through the introduction of linear algebra theory. Salton listed the commonly used vector similarity equations including the inner product, Dice's coefficient, cosine coefficient, and Jaccard's coefficient. Dice's coefficient and Jaccard's coefficient

were of the set logic viewpoint. A higher overlapping level of the two vectors indicates higher similarity level. The inner product and cosine coefficient compared the bias vector angle, and a smaller angle indicates higher similarity level. By comparison with the inner product technology, the vector should be standardized when using the cosine coefficient for calculation, being relatively unaffected by the dimensions of vector.

3. Research Method

This study established an automatic system to identify the most suitable evolution trends and its stages. The research method consisted of three parts. The first part was to integrate the traditional attributes and engineering parameters, combined with some necessary attributes to create the standardized attribute list; the second part was to encode and modelize the trends of evolution of technical systems according to the attribute list of the first part, the third part was employ the mathematical methods to calculate the similarity between the problem array and the trend stages to find out the most approximate trend and its stages to facilitate the generation of the follow-up problem-solving array.

▪3.1 Standardized Attribute List

First, define attribute, state, and function as follows:

- Attribute: refers to certain properties of a system or component.

This study suggested that attribute can be classified into the following two types:

- original attribute:

It refers to the most fundamental and indivisible properties of a system or component. For example, time, length, shape, etc.

- derived attribute:

It is formed by the combinations of original attributes or derived attributes. For example, distance is the original attribute, time is also an original attribute while velocity and acceleration are derived attributes derived from distance and time. For example, the following cases:

(1) $v = \frac{dY}{dt}$ ◦ For example, Y is distance and t is time. So, $\frac{dY}{dt}$ is speed.

(2) $F = \frac{d}{dt}(m \cdot v)$ ◦ For example, m is mass and v is speed. So, $\frac{d}{dt}(m \cdot v)$ is power.

- State: a set or its value of attributes of concern to any system.

For example, the state of a healthy woman consisted of attributes including height=162 cm, weight=52 kg, heartbeat=72 beats/minute.

- Function: a type of operation that can change or keep the state of some attributes (operation on states), namely, the action presenting the states from point to point.

For systematic analysis, this study classified the attribute changing directions into five basic components including ↑(up), ↓(down), --(maintenance), ⌒⌒(disturbance), □(measurement). Hence, any function can be regarded as the combination of one or more attribute directional changes. In addition, some functions are the combination of cross-attribute changes. For example, hydroelectric power generation was the conversion from location attribute to energy attribute.

Hence, the relationships between attribute, state and function can be defined as follows:

- a set of a group of attributes or their values was state
- change from one state to another or the maintenance of a state was function (thanks to the existence of this function, the state of the system can be changed or prevented)
- function can be represented by itself or changes in attributes

Therefore, all functions can be inferred from the changing or not changing attributes. Hence, all the functions can be determined by the combinations of attributes. As a result, many system problems or situations can be defined by FAA, and thus function and attribute can be regarded as the basis for problem-solving.

Functions of different terms in different fields may have the same significance to changing or not changing attributes by nature and can be solved by similar approach according to the principles of TRIZ. However, many people cannot identify the similarity thanks to different terms and cannot solve the problems by using similar approaches. For example, injection, drinking, capillarity, spraying…despite the differences in terms, they were the movement of liquid from the perspective of function that changed states. Therefore, the methods to solve the problem were mutually applicable. To overcome the obstacles of the cross-field terms, this study analyzed and summarized functions and attributes to integrate the traditional attributes and engineering parameters as well as some necessary but not included properties to get a total of 59 attributes. Combined with the 37 functions of the Creax function database and several functions of the software InnovationSuite, we got a total of 43 functions. We summed up the similar attributes and functions of different fields and classified them more perfectly for standardization as shown in Table 2 for a reference to solving cross-field problems by using the methods previously applied.

Table 2 Attribute List

Attribute	Type	Operation		Elemental Function
1.Mass	Original Attribute	Increase	↑	Heavier , Growth, Grow up, accumulate, deposit, absorb
		Decrease	↓	Weight loss, Thin, Atrophy, Slim, Decompose, Dry
		Maintain	--	Unchanged, Maintain, stabilize, preserve
		Disturb	⌒	Quality change, Changes phase of melts
		Measure	□	Quality Measurement
…	…	…	…	…
53.Loss of substance	Derived attribute	Increase	↑	Material loss, Corrode, Decompose, Erode, Destroy, Break Down
		Decrease	↓	Save material, Protect, Prevent
		Maintain	--	Preserve
		Disturb	⌒	
		Measure	□	Measuring the total weight

▪3.2 Standardized Trends of Evolution of Technical Systems

By using FAA, this study identified the system-related attributes and functions to be improved and determined relevant attributes and functions of various stages of the trends of technology. When the problem and the problem-solving tool were at the fundamental level, we employed the function and attribute for representation by using the function /attribute similarity or other classification technology to identify relevant trends of evolution.

Figure 1 shows the trends of evolution of technical systems. At any stage of the trends of evolution, the relevant state can be represented by the set of attributes and the purpose of the state can be represented by the set of functions. Hence, the attribute segments of any stage can be represented by the set of standardized attributes while the function segments of any stage can be defined by the above definition of functions. The stage function can be jointly represented by the set composing of functions and changes in attributes.

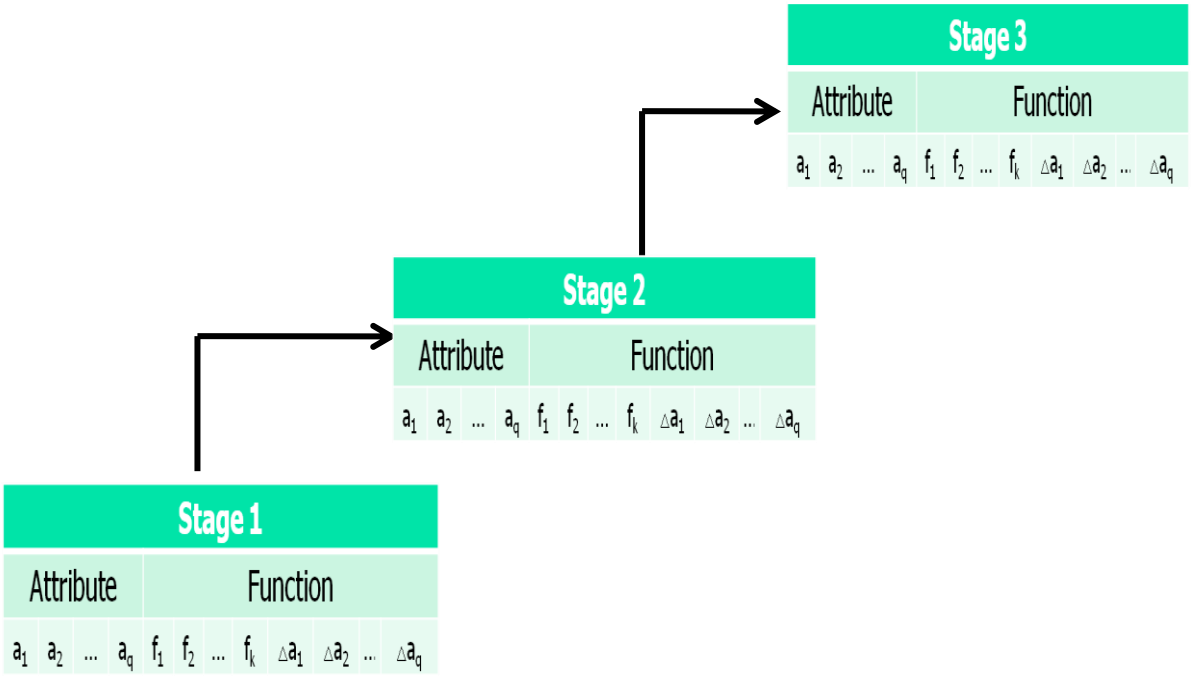

Figure 1 Schematic Diagram of Technology Evolution Trends

According to the attribute list summarized in this study, this study encoded and modelized the trends of evolution of technical systems. Table 3 shows the fifth trend of evolution of technical systems: webs and fibers, using standardized attributes and functions to represent the states and functions of various stages. The rest 30 standardized trends of evolution are listed in detail in Appendix II. Since the purpose of this study was to improve system, this study was not concerned about the functions at the initial stage and overlooked the function segments of the first stage of each evolution trend.

Table 3 Trend of Webs and Fibers

Evolution of Stage	Attribute Section	Function Section
Homogenous sheet structure	2.Weight 6.Thickness 35.Uniformity	
2D regular mesh structure	2.Weight 6.Thickness 36.Surface Finish 42.Porosity	25.Hold 31.Orient 36.Protect 41.Stabilize

		1.Mass(--) 2. Weight (--) 3.Force(--) 4.Amount of Substance(↓) 12.Stress or Press(↑) 14.Shape(⌒) 15.Stability(↑) 16.Strength(↑) 31.Adaptability/Flexibility(↑) 53.Loss of Substance(↓)
3D Fiber alignment according to load conditions	2.Weight 12.Stress 15.Stability 31.Adaptability/Flexibility	36.Protect 41.Stabilize 1.Mass(--) 2. Weight (--) 11.Position(--) 12.Stress or Press (↑) 15.Stability (↑) 16.Strength (↑) 17.Duration of Action by a Object(↑) 18.Reliability(↑)
Addition of active elements	31.Adaptability/Flexibility 38.Homogeneity 49.Aggregateness or Wholeness 52.Versatility	26.Join 49.Aggregateness or Wholeness(↑) 52.Versatility(↑)

▪3.3 Problems and solving mathematical models

Problem Solution Characteristics Array (PSCA) is to determine the core characteristic of the problem. By presenting the problem core characteristic as PCA, the array is composed of two parts: Problem characteristics Array (PCA); (II)Solution Array (SA). The structure is shown in Figure 2:

PCA															SA					
Section 1				Section 2				Section 3				……								

Figure 2 Problem Solution Characteristics Array

In this study, Part (I) is divided into a number of sections. Section 1: Engineering Parameter Contradiction-Based PCA This section describes the problems of parameter contradiction, namely, improvement of some parameters may result in the worsening of some other parameters. The format of this section is as follow:

Case	Problem Characteristics Array											
	Improve Array						Worsen Array					
	1(+)	2 (+)	….	….	….	m (+)	1 (-)	2 (-)	…	…	…	m(-)
i												

Figure 3 Engineering Parameters Contradiction Based PCA

Section 2: Function and Attribute Based PCA. This section was mainly to describe the problem Initial Attribute Array, and what was the Target Attribute Array to improve the problem? Such attribute changes would involve with what functions? Hence, this section was composed of Attribute Array and Function Array. Where, Attribute Array can be further divided into Initial Attribute Array and Target Attribute Array.

	Problem											
Case	Attribute Array				Function Array							
	Initial Attribute Array				Change Attribute				Function			
	a_1	a_2	….	a_p	a_1	a_2	….	a_p	f_1	f_2	…	f_q
i												

Figure 4 Function and Attribute Based PCA

Section 3: Su-Field Based PCA. This section uses the Su-Field relationship to describe the problem. It includes the Su-Field Array and Constraint Array with structure, as shown below:

Case	Problem				
	Su-field Array				Constraint Array
	Substance	Tool	Field	Interaction between substances	
i					

Figure 5 Su-Field Based PCA

Other sections: if there are other classification methods, sections can be added to describe the problem.

Part (II)：Solution Array

The Solution Array is the expression array of the problem trigger solution. The solution tools of TRIZ can be used to present the solution in the following types of expressions:

(1)40 IPs;(2)37 trends; (3)76 standard solutions.

Based on the above PSCA definition, the PCA used in this study uses Section 1: Engineering Parameter Contradiction-Based PCA only; and the Solution Array (SA) uses the IPs only with structure as below:

The solution array is the expression array of the problem trigger solution. The solution tools of TRIZ can be used to present the solution in the following types of expressions:

(1)40 IPs;(2)37 trends; (3)76 standard solutions.

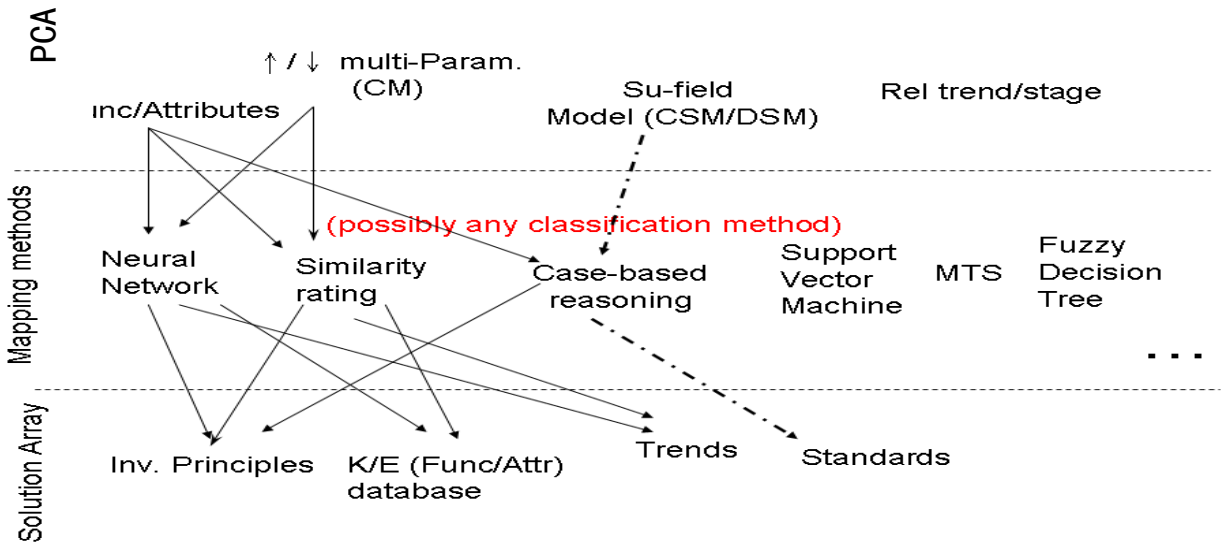

Figure 6 Mapping Method(Sheu,2007)

Due to the introduction of Models (I) and (II), the problem-solving method became a pure mapping problem-solving as illustrated in Figure 6, namely, the mapping from a certain III; PCA mapping to its corresponding SA (Solution Array). The various SA element values denote the various solutions to the problem. The mapping process, in fact, was a classification process (classification), reflecting the "same type solution to same type problem" as stated in the TRIZ principles.

The advantage of the vector space model adopted in this study was easy to use. It employed the linear algebra theory to regard the stages of trends and the PCA of the system to be improved as vectors represented as follows:

$$PCA=\{P_A, P_F\}=\{\{{}_ia_1, {}_ia_2, \ldots, {}_ia_q, \ldots, {}_ia_Q\},\{f_1, f_2, \ldots, f_k, \ldots, f_K, {}_ca_1, {}_ca_2, \ldots, {}_ca_q, \ldots, {}_ca_Q\}\}$$

The vector element a_q denotes the attribute, and there are Q different attributes; element f_k denotes the function, and there are K different functions. The first Q attribute elements ${}_ia_q$ denotes the problem-involving attribute a_q; the latter Q attributes ${}_ca_q$ denotes the attribute a_q to be changed in direction to describe the functions.

Regarding the comparison of the similarity of two vectors, at present, cosine function is the most commonly used one to calculate the similarity by the following equation:

$$sim(P_A,T_A)=\frac{\vec{P}_A\cdot\vec{T}_A}{|\vec{P}_A|\times|\vec{T}_A|}=\frac{\sum_{n=1}^{Q}V_{n,P_A}\times V_{n,T_A}}{\sqrt{\sum_{n=1}^{Q}V_{n,P_A}^2}\times\sqrt{\sum_{n=1}^{Q}V_{n,T_A}^2}} \quad [1]$$

$$sim(P_F,T_F)=\frac{\vec{P}_F\cdot\vec{T}_F}{|\vec{P}_F|\times|\vec{T}_F|}=\frac{\sum_{n=1}^{K+Q}V_{n,P_F}\times V_{n,T_F}}{\sqrt{\sum_{n=1}^{K+Q}V_{n,P_F}^2}\times\sqrt{\sum_{n=1}^{K+Q}V_{n,T_F}^2}} \quad [2]$$

P denotes the PCA (Problem Characteristics Array), T denotes the standard retrieval array consisting of the functions and attributes of each trend, V_n denotes the value of the n-th item of the array at 0 or 1. Q denotes the number of attributes of a total of 59 types. K denotes the number of functions at a total of 43 types. Eq. [1] is to calculate the cosine coefficient value of the vectors of the two attribute segments to identify trend stages of functions necessary for problem-solving.

In geometry, when two vector are close, the intersegments angle θ is smaller. According to the property of the cosine coefficient function, smaller intersegments angle θ will have greater value of cosine coefficient function. Hence, the conclusion can be drawn as follows: when the cosine coefficient function value of the PCA vector and the standardized retrieval array of trends are larger, the intersegments angle of the two vectors is smaller. Hence, the PCA is more similar to the trend stage. On the contrary, the problem is more irrelevant with the trend stage.

Figure 7 shows how PCA and standardized evolution trends conduct similarity matching. The attribute segments of PCA represent the attributes relating to the problems or the system. The function

segments represent the functions to be achieved. The evolution trend attribute segments represent the state of the stage, while the function segments represent the functions of the stage. First, the similarity of attribute segments between the PCA and the standardized evolution trends are compared to identify the problem and the current system stage. The similarity of the two vectors is calculated using the cosine function. If it is smaller than the threshold θ_A, the trend stage is not the initial stage of the problem. The similarity between the next stage function with the function of the system to be achieved is compared. The calculation of the function segments similarity also adopts the cosine function to compare the similarity of the two vectors. When the similarity is greater than the threshold θ_F, the stage can be as the trigger solution of the problem. As shown in Figure 8, the similarity between the relevant attribute and the second stage of the first trend of the problem is greater than threshold θ_A, the problem initial state is similar to the second stage of the first trend. Hence, the desired function can be compared with the third stage of the first trend in terms of similarity. After cosine function calculation, if the value is greater than the threshold θ_F, the third stage of the first trend can be regarded as the trigger solution of the problem.

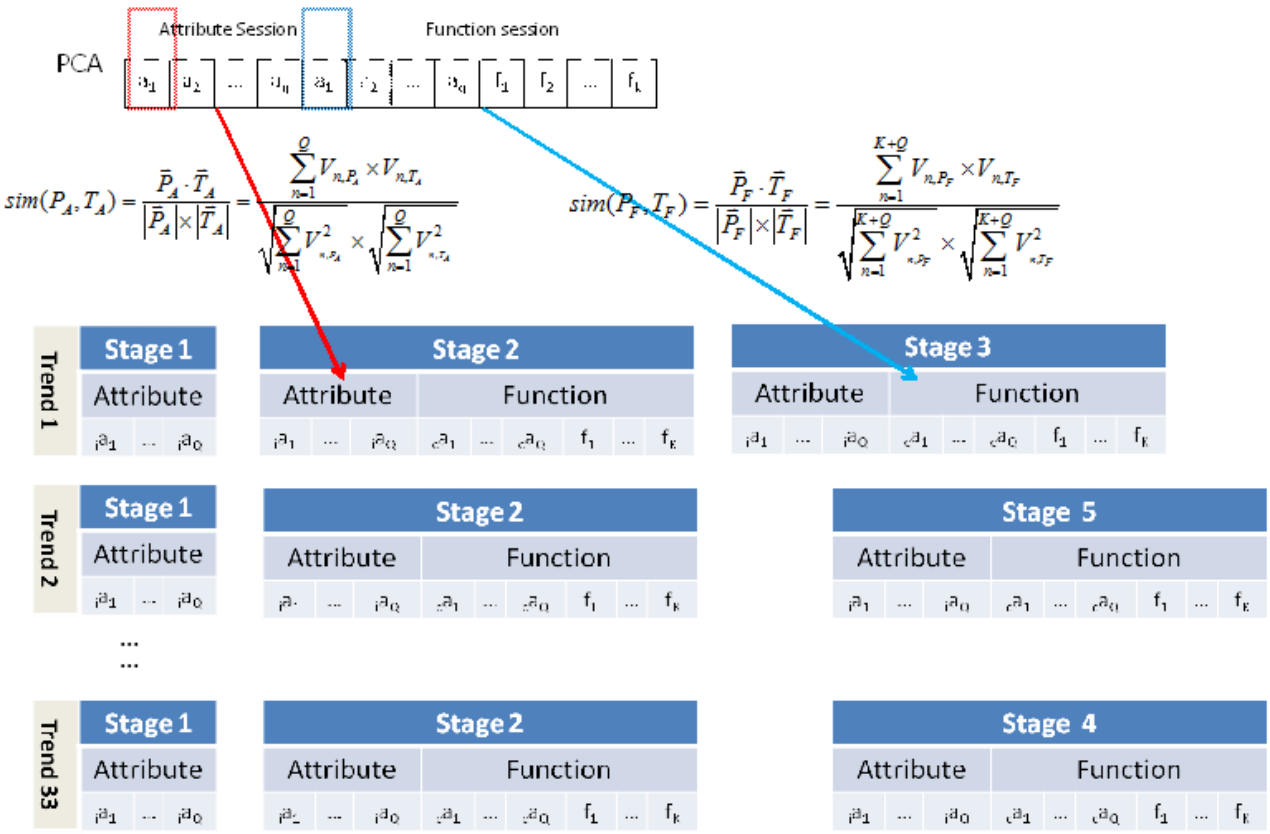

Figure 7 PCA of technology trends over the diagram to find SA

▪3.4 The attribute operational direction similarity calculation correction

Since the function segments of PCA and the standard retrieval array of this study are composed of function array and the array of directions of attribute changes to jointly describe the functions necessary for the problem (or system), namely, the problem DNA's function segments PF={f_1, f_2, …,

f_k, …, f_K, ${}_ca_1$, ${}_ca_2$, …, ${}_ca_q$, …, ${}_ca_Q$}; attribute ${}_ca_q$ denotes the direction of the attribute a_q to describe the function . ${}_ca_q$ cannot be encoded by binary approach and 0 denotes no involvement with the attribute. Characters A, B, C, D and E denote the changes of attribute directions, if any: ↑(up), --(maintenance), ↓(down), ⌒(disturbance), □(measurement).

When comparing the similarity between PCA and the standard retrieval array of the trend jumps, if the PCA attribute ${}_ca_q$ value and the trend stage $T_{i,s}$ attribute ${}_ca_q$ value are not 0, both of them are involved with changes of attribute a_q. In this case, if the attribute ${}_ca_q$ values of the two are different (not 0), the directions of attribute a_q changes are different. As a result, the similarity of the two should be modified.

This study modified the original cosine coefficient function equation for the calculation of the similarity of function segments [2], by dividing it into two parts of calculating the similarity of the subset f_k of function element and the subset ${}_ca_q$ of attribute direction changes. The equation is as follows:

$$sim(P_F,T_F)=\frac{\vec{P}_F\cdot\vec{T}_F}{\left|\vec{P}_F\right|\times\left|\vec{T}_F\right|}=\frac{\sum_{n=1}^{K+Q}V_{n,P_F}\times V_{n,T_F}}{\sqrt{\sum_{n=1}^{K+Q}V_{n,P_F}^2}\times\sqrt{\sum_{n=1}^{K+Q}V_{n,T_F}^2}}$$
$$=\frac{\sum_{n=1}^{K}V_{n,P_F}\times V_{n,T_F}}{\sqrt{\sum_{n=1}^{K}V_{n,P_F}^2}\times\sqrt{\sum_{n=1}^{K}V_{n,T_F}^2}}+\frac{\sum_{n=1}^{Q}V_{n,P_F}\times V_{n,T_F}}{\sqrt{\sum_{n=1}^{Q}V_{n,P_F}^2}\times\sqrt{\sum_{n=1}^{Q}V_{n,T_F}^2}}$$
$$=\frac{\sum_{n=1}^{K}V_{n,P_F}\times V_{n,T_F}}{\sqrt{\sum_{n=1}^{K}V_{n,P_F}^2}\times\sqrt{\sum_{n=1}^{K}V_{n,T_F}^2}}+\frac{\sum_{n=1}^{Q}\alpha_n\times V_{n,P_F}\times V_{n,T_F}}{\sqrt{\sum_{n=1}^{Q}V_{n,P_F}^2}\times\sqrt{\sum_{n=1}^{Q}V_{n,T_F}^2}}$$

[3]

When comparing the similarity of function segments between PCA and the standard retrieval array of various trend stages, the first K items of function segments are the function element f_k valued at V_n of 1 or 0 with 1 representing the function f_k required by the problem. The latter Q items of function segments are ${}_ca_q$ representing the direction of attribute a_q. If it were not involved with attribute a_q, its value V_n was 0. Otherwise, the attribute direction changes are denote by characters including A, B, C, D and E: ↑(up), --(maintenance), ↓(down), ⌒(disturbance), □(measurement). However, the value V_n was 1 and α_n should be applied to adjust the similarity of different directions. The value of α_n is shown in Table 4. In sum, considering the relationships between PCA and the ${}_ca_q$ of the function segments of the various trend stages, if the direction of the attribute a_q of the two were the same, α_n is 1. If the directions were different, the a_q should be adjusted downwardly to weaken the similarity between the two.

Table 4 The correction value of α_n

α_n	Functional Attribute Section(Trend)${}_ca_q$				
	A (↑Attribute)	B(--Attribute)	C(↓Attribute)	D(⌒Attribute)	E(□Attribute)

Functional Attribute Section(PCA) $_ca_q$	A (↑Attribute)	1	0.447	-0.6	-0.447	0.447
	B(--Attribute)	0.447	1	0.447	-1	0.5
	C(↓Attribute)	-0.6	0.447	1	-0.447	0.447
	D(⌒Attribute)	-0.447	-1	-0.447	1	0
	E(□Attribute)	0.447	0.5	0.447	0	1

The setting of α_n is shown in Figure 8. X-axis denotes the direction of change in attribute value, and Y-axis denotes the maintenance of attribute value. When the attribute value changing direction is positive, it is denoted by X=1, if it is negative, it is denoted by X=-1. It the attribute value can be kept unchanged, it is denoted by Y=1. If it is hard to keep attribute value unchanged and its changing direction, then it is denoted by Y=-1. B denotes the maintenance of attributes, hence, it is neutral to the changing direction and can be denoted by (0, 1). As A denotes the positive rise of attribute value, its maintenance of attribute value is weaker than B, and therefore, it can be denoted by (1, 0.5). As C is the opposite of A, it can be denoted as (-1, 0.5). D denotes disturbance, and the changing direction is uncertain. It is hard to maintain the attribute value in this case, hence, D can be denoted by (0, -1). E denotes the measurement of attribute and it may result in slight disturbance of the attribute values in uncertain directions. Hence, it can be denoted by (0, 0.5). After determining the spatial locations of A, B, C, D and E, the cosine coefficient values of the intersection angles of the vectors are calculated to get the table. However, due to the overlapping of vectors B and E on the plane, the cosine coefficient calculation results using other vectors would be the same with that of the Vector E. Hence, according to the relationship between other vectors and vector E, the values of the fifth row and fifth column are slightly adjusted.

The summary of the above descriptions are shown in Figure 9. When comparing the attribute similarity between PCA and the standard retrieval array of various trend stages, $sim(P_A, T_A)$ is applied to calculate cosine coefficient values and the threshold is θ_A. When the similarity is greater than threshold θ_A, the function similarity between the next stage denoted by $sim(P_F, T_F)$ is calculated. The first K items of the function segments are the function element f_k. 1 denotes that the problem requested function f_k, otherwise 0. The comparison of the α_n value of the latter Q $_ca_q$ in the function segments is shown in Table 4. Considering the relationships between the $_ca_q$ item of the function segments of PCA and various trend stages, if the direction of attribute a_q of the two are the same, α_n was 1; if not, α_n should be modified downwardly to weaken the similarity between the two.

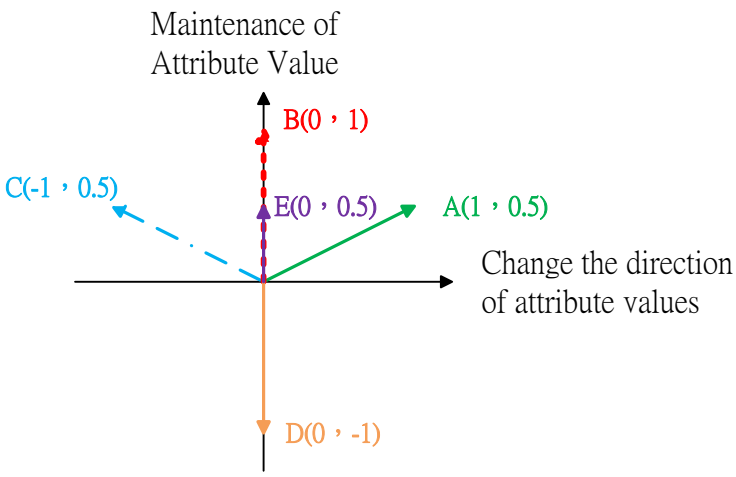

Figure 8 The direction of the relationship between the operation of the attribute

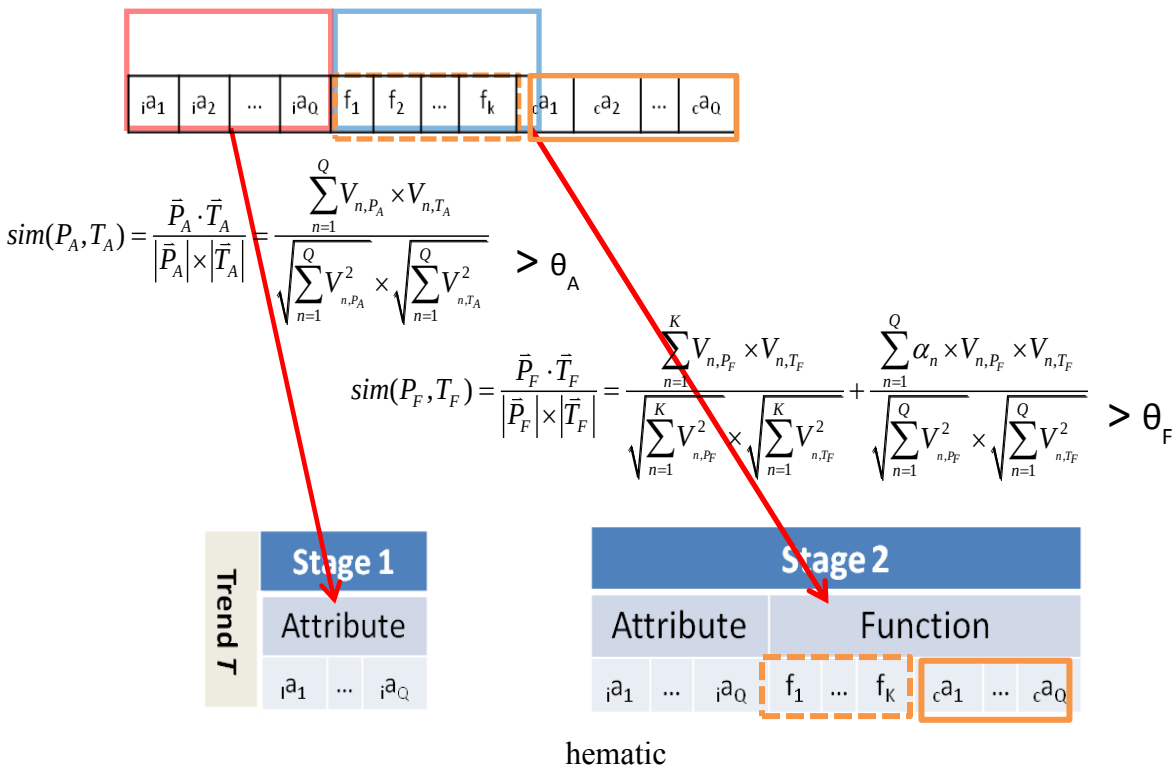

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Figure 9 The PCA of technology trends over the diagram to find SA

▪3.5 Threshold selection

Since it is difficult to collect evolution trend cases, this study only employed the cases of various evolution trends contained in the “Hands-On Systematic Innovation” as the source of training data. This study selected 50 cases and slightly adjusted the standard retrieval array of the various trend stages of the 50 training data, as shown in Table 5. The initial stage and destination stage of the 50 data samples are known and the evolution process of various cases are shown in Table 3. The initial stage cosine coefficients of the attribute segments and the cosine coefficients of the destination stage

function segments are calculated. Due to different number of attributes and functions corresponding to various trend stages, the coefficient values of the destination stage function segments vary considerably. For easy identification of the evolution trends similar to the testing cases in the future, the first quartile (Q1) is selected as the first stage and second stage threshold θ_A and θ_F. The first quartile of cosine coefficient value of the attribute segments is 0.2236068, and the first quartile of the cosine coefficient value of the function segments is 0.1781742. After being rounded respectively, the threshold θ_A and θ_F are respectively 0.22 and 0.18.

Table 5 The training cases of attribute and functions

No.	Trend	Initial Stage	Attribute similarity coefficient	Final Stage	Function similarity coefficient
1	smart material	1	0.2390457	4	0.4902903
2	smart material	2	0.2236068	4	0.2672612
3	space segmentation	1	0.4803845	5	0.2020305
4	space segmentation	1	0.46291	3	0.2390457
5	surface segmentation	1	0.3015113	2	0.1781742
6	surface segmentation	1	0.3015113	3	0.1290994
7	surface segmentation	1	0	2	0.2842676
8	object segmentation	1	0.421637	8	0.3244428
9	object segmentation	1	0.1259882	5	0.201008
10	webs and fibers	2	0.1666667	4	0.1740777
11	webs and fibers	1	0.3086067	3	0.4136185
12	macro to naro scale	1	0.3535534	2	0.421637
13	macro to naro scale	1	0.3333333	2	0.1259882
14	macro to naro scale	1	0.1507557	2	0.3015113
15	decreasing density	1	0.5050763	2	0.4353624
16	increasing asymmetry	1	0.3779645	3	0.4472136
17	increasing asymmetry	1	0.3015113	3	0.2581989
18	boundary breakdown	1	0.3015113	3	0.244949
19	boundary breakdown	1	0.3535534	3	0.3162277
20	geometric evolution (linear)	1	0.40824829	4	0.1443376
21	geometric evolution (linear)	2	0.522233	4	0.1230915
22	geometric evolution (volumetric)	2	0.3922323	4	0.1360828
23	geometric evolution (volumetric)	2	0.3162278	3	0.0912871
24	nesting (down)	1	0.1507557	4	0.2401922
25	nesting (down)	1	0.2182179	4	0.3508232
26	dynamization	1	0	4	0.1118034
27	dynamization	1	0.4082483	4	0.2236068
28	action coordination	2	0.3333333	4	0.4564355
29	action coordination	1	0.3015113	4	0.381385

30	rhythm coordination	1	0	2	0.1230915
31	non-linearities	1	0.3162278	3	0.1336306
32	mono-bi-poly(similar)	1	0.3333333	4	0.1543033
33	mono-bi-poly(similar)	1	0.3015113	4	0.2721655
34	mono-bi-poly(similar)	1	0.3333333	4	0.1543033
35	mono-bi-poly	1	0.3481553	4	0.3198011
36	mono-bi-poly (various)	1	0.2519763	4	0.4419417
37	mono-bi-poly (increasing difference)	1	0.3779645	3	0.3779645
38	nesting (up)	1	0.3535534	3	0.3872983
39	decreasing dumping	2	0.4724556	3	0.8819171
40	increasing use of senses	1	0.6708204	4	0.5
41	increasing use of color	2	0.4472136	4	0.2236068
42	increasing transparency	1	0	3	0.1825742
43	design point	1	0.140028	3	0.4193139
44	degree of freedom	2	0.6324555	6	0.5656854
45	trimming	1	0.4045199	4	0.4008919
46	controllability	2	0.3922323	4	0.3535534
47	reducing human involvement	1	0	6	0.4472146
48	reducing human involvement	1	0.1924501	6	0.2696799
49	design methodology	1	0.2886751	6	0.421637
50	reduce number of energy conversions	1	0.4714045	4	0.5039526

▪3.6 Problem-solving process

(1)Definition of problem array

Problem Characteristics Array $=\{P_A, P_F\}$PCA included the attribute segments and the function segments; $P_A=\{{}_ia_1, {}_ia_2, \ldots, {}_ia_q, \ldots, {}_ia_Q\}$, $P_F=\{f_1, f_2, \ldots, f_k, \ldots, f_K, {}_ca_1, {}_ca_2, \ldots, {}_ca_q, \ldots, {}_ca_Q\}$, therefore, $PCA=\{P_A, P_F\}=\{\{{}_ia_1, {}_ia_2, \ldots, {}_ia_q, \ldots, {}_ia_Q\},\{f_1, f_2, \ldots, f_k, \ldots, f_K, {}_ca_1, {}_ca_2, \ldots, {}_ca_q, \ldots, {}_ca_Q\}\}$. The vector element a_q denotes the attributes in a total number of Q attributes; element f_k denotes K number of functions. The first Q attributes' element ${}_ia_q$ is 1 or 0 as representing involvement with attribute a_q, otherwise it is 0; K number of function's f_k element is 1 or 0 as 1 denotes involvement with function f_k, otherwise 0, the latter Q number of attributes' ${}_ca_q$ denotes the direction of the attribute a_q to describe functions with 0 representing no involvement with the attribute, and the changes of attribute were: ↑(up), --(maintenance), ↓(down), ⌒(disturbance), □(measurement), denoted respectively by A, B, C, D and E.

(2) Calculation of similarity of trends closest to the current problem and its trends

The similarity between the attribute segments of the problem array and various stage trends is calculated using the principles of cosine coefficient. Assume the similarity threshold between the PCA

attribute segments and trend stage was θ_A, and the SIM (P_A, $T^A_{i,s}$)>θ_A trend stage is obtained. A denotes attribute, P_A denotes attribute array, and $T_{i,s}$ denotes the s-th stage of i-th trend. When $T^A_{i,s}$ satisfies the conditions, the function segments of next stage (namely, $T_{i,s+1}$) can be calculated (namely, $T^F_{i,s+1}$) as whether it is close to function segments of the problem array.

(3) Similarity calculation of trend stage closest to the requested function

The similarity between the function segments of the problem array and various stage trends is calculated using the principles of cosine coefficient. Assume the similarity threshold between the PCA attribute segments and trend stage is θ_F, and the SIM (P_F, $T^F_{i,s}$)>θ_F stage is obtained. F denotes attributes, P_F denotes the function, $T^F_{i,s}$ denotes the function segments of s-th stage of i-th trend. When $T^F_{i,s}$ satisfies the conditions, $T_{i,s}$ can be a possible solution to the problem.

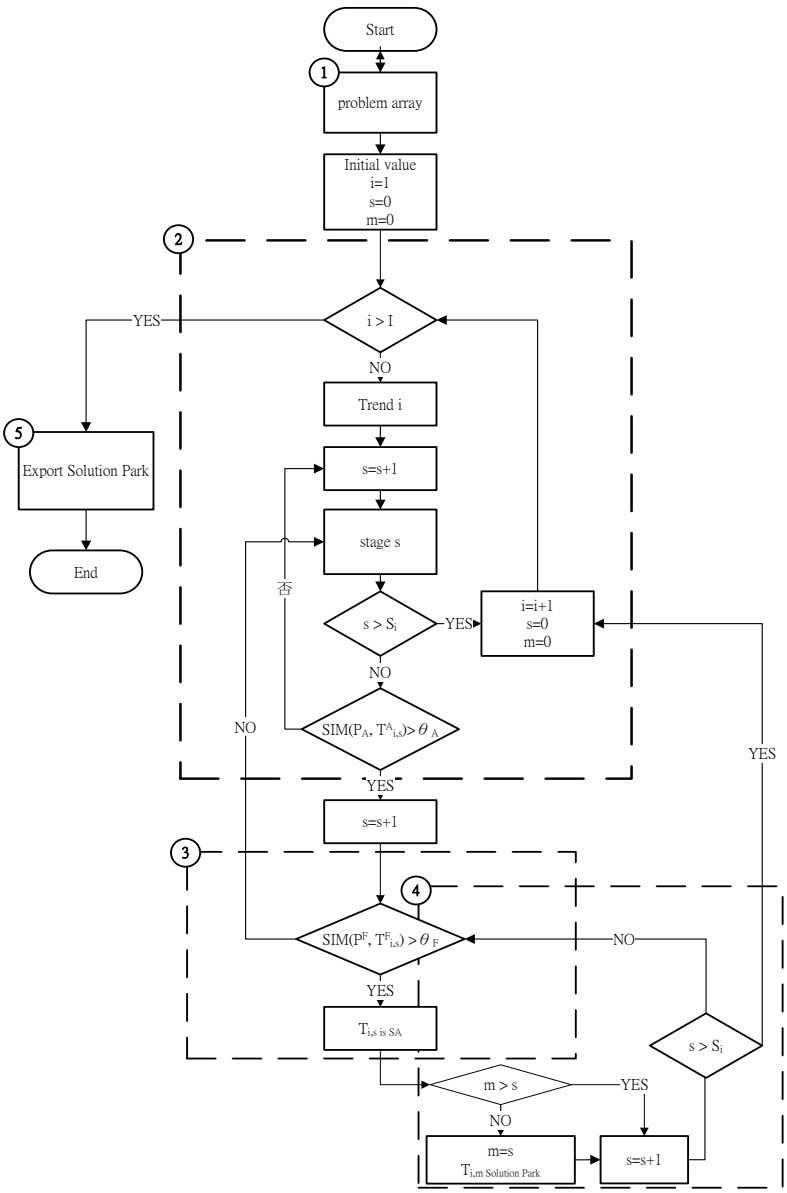

Figure 10 Solving Process

(4) Looking for the highest level trigger solution under the trend

To find more ground-breaking solutions, this study attempted to get the trigger solution of the highest level under the evolution trend. In order to obtain the more progressive solution to the problem, the cycle can be compared the similarity with the next stage of the solution array. The similarity between ${}_{T}F_{i,s+1}$ and the original problem. If the two are similar, it can possibly be a more ground-breaking solution. Hence, the similarity between ${}_{T}F_{i,s+1}$ and the original problem array is compared. If the similarity is smaller than the threshold, the current solution array is the ideal destination solution. Otherwise, the current stage solution is not the most ground-breaking solution. The problem-solving process may move onto the next stage until it is smaller than the threshold value or the last stage of trend i is reached.

(5) Output of all solution array

Output all solutions in the buffer area and these solutions might be the possible trigger solutions of the problem.

4. Validation Research

▪4.1 Model validation performance indicators

he research model has two performance indicators as follows:

- # of relevant trend identified: number of trigger solutions after the similarity comparison
- # of identified trend verified: number of trigger solutions generated by similarity comparison that can be converted into specific solutions

To judge the percentage of effective solutions of this model, the two indicators of more than 10 cases should be added up and divided by the following equation:

$$\frac{\sum_{i=0}^{10} \text{\# of relevant trend identified of Case}_i}{\sum_{i=0}^{10} \text{\# of identified trend verified of Case}_i}$$

▪4.2 Illustration of validation cases

This study collected from journals and academic papers cases relating to the problem-solving by applying trends of evolution of technical systems as the data source of the model validation of this study. Some cases were proved by the U.S. patents as shown in Table 6:

Table 6 Test Cases List

No	Short Title	Title of source Paper	Source	Remark
1	Self-aligning Roller Bearing	Better technology forecasting using systematic innovation methods	Technological Forecasting & Social Change 70 (2003) 779–795	US patent 6,296,395
2	Air Cooled Umbrella	Relating properties and functions from patents to TRIZ trends	CIRP Journal of Manufacturing Science and Technology 1 (2009) 126–130	US patent 5,349,975
3	Flow Control Arrangement in a Circulation Lubrication System	Application of systematic innovation trend prediction tools to the design of future bearing and lubrication systems	The TRIZ Journal, March 2002	US patent 6,217,004 B1
4	Gas turbine fan	Fan Technology: Evolutionary Potential and Evolutionary Limits	The TRIZ Journal, December 2004, Article 4.	
5	Data Storage Disc Drive Apparatus with Integral Forced Air Cooling Capability	Fan Technology: Evolutionary Potential and Evolutionary Limits	The TRIZ Journal, December 2004, Article 4.	US patent 6,359,856
6	Forced Air Cooling Fan having pivotal fan blades for unidirectional air flow	Fan Technology: Evolutionary Potential and Evolutionary Limits	The TRIZ Journal, December 2004, Article 4.	US patent 6,669,013
7	Packaging Design	Case Studies from a Breakthrough Innovation Product Design Program for Local Industries	The TRIZ Journal, September 2006, Article 1.	
8	Reduce defects in paper bags	Case Studies from a Breakthrough Innovation Product Design Program for Local Industries	The TRIZ Journal, September 2006, Article 1.	
9	Flushing Go	Case Studies in TRIZ: Flush'n'Go	The TRIZ Journal, June 2005, Article 2.	
10	karaoke audio/video product	Results Of A Multi-Company Scale TRIZ Deployment In Hong Kong	The TRIZ Journal, December 2005, Article 2.	

▪4.3 Validation results

The validation results of 10 cases are summarized, as shown in Table 7. Each case can have more than one trigger solution and have specific solutions, indicating that the research model of this study can provide effective evolution trends as the trigger solutions to the problem. Meanwhile, 65.28% of the identified evolution trends are effective solutions, and it can considerably reduce the time and energy to compare trends manually.

Table 7 The validation results of 10 cases

No	Relevant Trend Identified	# of relevant trend identified	Solution Trend Verified	# of solution trend verified
1	$T_{3,2}$、$T_{5,3}$、$T_{7,2}$、$T_{10,3}$、$T_{11,3}$、$T_{12,4}$、$T_{13,5}$、$T_{14,4}$、$T_{16,3}$	9	$T_{3,2}$、$T_{5,3}$、$T_{10,3}$、$T_{11,3}$、$T_{16,3}$	5
2	$T_{2,5}$、$T_{9,3}$、$T_{13,6}$、$T_{17,4}$、$T_{18,4}$、$T_{19,4}$、$T_{30,4}$	7	$T_{2,5}$、$T_{13,6}$、$T_{18,4}$、$T_{30,4}$	4
3	$T_{1,4}$、$T_{3,4}$、$T_{4,6}$、$T_{14,4}$、$T_{28,6}$、$T_{30,4}$	6	$T_{28,6}$、$T_{30,4}$	2
4	$T_{2,4}$、$T_{4,6}$、$T_{5,3}$、$T_{7,2}$、$T_{10,3}$、$T_{11,3}$、$T_{12,4}$、$T_{13,6}$、$T_{16,3}$、$T_{27,4}$	10	$T_{2,4}$、$T_{5,3}$、$T_{7,2}$、$T_{10,3}$、$T_{11,3}$、$T_{13,6}$、$T_{16,3}$、$T_{27,4}$	8
5	$T_{3,4}$、$T_{11,3}$、$T_{13,3}$、$T_{17,4}$、$T_{18,4}$、$T_{19,4}$、$T_{20,3}$	7	$T_{11,3}$、$T_{17,4}$、$T_{18,4}$、$T_{20,3}$	4
6	$T_{3,3}$、$T_{4,8}$、$T_{13,3}$、$T_{14,4}$、$T_{20,3}$、$T_{27,4}$	6	$T_{4,8}$、$T_{13,3}$、$T_{14,4}$、$T_{27,4}$	4
7	$T_{1,4}$、$T_{2,4}$、$T_{3,3}$、$T_{4,4}$、$T_{7,2}$、$T_{8,3}$、$T_{13,5}$、$T_{14,4}$、$T_{17,4}$、$T_{18,4}$、$T_{19,4}$、$T_{21,4}$、$T_{29,4}$	13	$T_{1,4}$、$T_{2,4}$、$T_{3,3}$、$T_{4,4}$、$T_{7,2}$、$T_{13,5}$、$T_{14,4}$、$T_{17,4}$、$T_{21,4}$	9
8	$T_{3,2}$、$T_{4,5}$、$T_{9,3}$、$T_{10,4}$、$T_{11,3}$	5	$T_{3,2}$、$T_{9,3}$、$T_{10,4}$	3
9	$T_{3,4}$、$T_{8,3}$、$T_{16,3}$、$T_{29,4}$、$T_{30,3}$	5	$T_{3,4}$、$T_{8,3}$、$T_{16,3}$、$T_{30,3}$	4
10	$T_{18,4}$、$T_{20,3}$、$T_{22,5}$、$T_{29,4}$	4	$T_{18,4}$、$T_{20,3}$、$T_{22,5}$、$T_{29,4}$	4
Success Rate				65.28%

5. Conclusions and Suggestions

▪5.1 Conclusions

By using the PCA based on attribute and function, this study employed the mathematical model constructed by the cosine function to compare the similarity between the standardized evolution trends of attribute and function in order to provide trigger solutions to the problem. The main contributions of this paper are summarized as follows:

(1)The trigger solution identification success rate of using the mathematical model constructed by the relationship between function and attribute to identify evolution trends and stages relating to problem-solving was as high as 100%. 65.28% of the identified evolution trends were effective solutions. The identification of a few possible solutions among a large number of trends can considerably reduce the time and energy of comparing the trends manually.

(2)The standardized relationship table of attributes and functions is established to prevent users of different fields from being unable to identify the similarity between functions due to wording differences.

(3)The standardized evolution trends are established on the basis of attributes and functions.

▪5.2 Suggestions

By using the PCA based on the attribute and function, this study employed the similarity comparison mechanism established by the cosine function to identify the relevant evolution trends and provide problem trigger solutions. The energy and time for manual identification of evolution trends can be considerably reduced. However, there is still room for improvement. The unsatisfactory effects may be caused by the weakening of the cosine coefficient function calculation sensitivity due to excessive unimportant attributes or negative functions. In addition, 50 training data are too few to result in poor adjustment results of the standard retrieval array of the evolution trends to lower the model effects.

The following suggestions are proposed for future research directions:

(1)Other mathematical models, such as the neural data mining, MTS or other similarity rating methods, such as the relative Euclidean distance and Jaccard's coefficient, can be used as the mathematical model for problem property matrix mapping to solution array based on evolution trends to improve the trigger solution effectiveness.

(2)More cases can be included to modify the standard retrieval array of evolution trends, or train the standard retrieval array by neural network or MTS to improve accuracy. ,.

(3)When modelizing the evolution trends, high, medium and low weights can be used to represent the correlation level of the evolution trend with the attributes and functions, rather than using 1 or 0 to represent "have" or "have not" of the attribute and function elements.

Other statistical methods may be used to determine similarity threshold values.

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The 12 Chinese zodiac management system and business TRIZ

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ABSTRACT :
Recently, a book on 12 Chinese Zordiac management system was published. Mr. Sun Wook is the author who was the TRIZ champion in Samsung. This book is the result of his long time role as the top R&D manager at Samsung. The 12 Chinese animals of the Zodiac system, mouse, cow, tiger, rabbit, dragon, snake, horse, lamb, monkey, chicken, dog, pig epitomize the essence of modern management practices. Moreover, the order of the animals has special meaning and is also easy to memorize. As we find that this idea is a new and innovative management system which can be applied easily to a company, in this paper we tried to explain this system in terms of TRIZ. Main ingredients of the management system are matching well with the basics of business TRIZ and the coherent explanation is introduced.
Keywords : New management system, Business TRIZ, 12 Chinese zodiac

Introduction

People resort to accumulated wisdom of humankind to find practical methodology to establish systematic innovation. The deductive systems, such as TRIZ, try to present universal wisdom from data to information and knowledge through transformation.[1,2] Established algorithms of systematic innovation should provide universality and a small, manageable entity to be useful. The basics should be at least could be remembered and used easily. Currently the nature is one of the largest repositories of such wisdom revealing evolution results over the eons and biomimetics research have been active accordingly.[3]

Here we are presenting another eminent example which is considered as an essence of East Asian historical wisdom. Although Western culture has similar system, namely horoscope zodiac, it is much different from East Asian system.

Recently, Mr. Sun Wook from Korea gave new insight to the Asian 12 animal zodiac by correlating with modern management system.[4] In this paper, new 12 Asian zodiac

management principles are introduced and the implication to systematic innovation in terms of business TRIZ is discussed.

Mr. Sun Wook is a professor at AICT (Advanced Institutes of Convergence Technology) of Seoul National University. Before he came to SNU, he had spent many years at industries. He spent most of his careers at Samsung. He was the president of SAIT (Samsung Advanced Institute of Technology) and SDI. He is famous as the TRIZ Champion because he introduced and supported TRIZ into Samsung group. After Samsung careers and before SNU, he worked as the president of Nongsim Group which is a big company on food industry. His book is the creative combination of Chinese 12 zodiac system and the epitome of his top management career at Samsung.

1. The 12 Chinese zodiac management system

The authors personally have been always curious how the order of 12 animals in the zodiac system developed. One old story tells that this is the order of passing the finish line after running. The cow (or bull) was fastest but a mouse sat on the head of the cow and jumped down in front of the cow when the cow approached the finish line. There was no more explanation on the order except this.

Here is an exquisite expression of essence of modern management system in terms of the characteristics of Chinese 12 animals. The 12 animals are grouped in 3 steps. The first is for thinking, the second for innovation and the third for win-win system. The first group consists of mouse, cow, tiger and rabbit. Actually 2011 is the year of rabbit. The second consists of dragon, snake, horse, lamb, monkey and hen. The third consists of dog and pig.

Here is a brief review of each animal's implication on modern management as described in the book.

A. Thinking skill – Understanding the crisis.

1. Mouse (子) : A mouse is a small and weak animal. But it has a great capability of for premonition. Mouse is the first one who sees a problem in a vessel. Mouse gives lesson as 'Know your current situation'.
   Cases : Gary Kildal, Britannica Encyclopedia, KT method.
2. Cow (丑) : Continue chewing the problem.
   A cow has 4 stomachs and it implies fundamental understanding of the problem and continuous efforts to solve which are very important in modern management. He approaches the problem tenaciously and thoroughly.
   Cases : Barings bank, TRIZ

3. Tiger (寅) : Run to the goal decisively.

   A tiger doesn't step back in front of a prey. Tiger is the king of animal world with courage and decision. He does his best even when he tries to capture a rabbit.

   Cases : Opportunity cost, Johnson & Johnson Tylenol 1982, CDMA, Aron Ralston, PI at Samsung SDI, Thick face black mind, AHP (Analytic Hierarchy Process)

4. Rabbit (卯) : Be prepared for potential problems.

   A rabbit is very weak. He is very cautious on every detail to protect from stronger enemies. A clever rabbit always make 3 warrens. (狡兎三窟) We should consider all latent and hidden problems without looking away.

   Cases : Contingency plan, General Yi Sun-sin of Korea(李舜臣 將軍), King Sejong of Korea (世宗 of 朝鮮), TPM, Toyota, Chrysler, FMEA

B. Innovation skill – Overcoming the crisis

5. Dragon (辰) : Prepare core competence for transformation

   Dragon is an imaginary animal which is a combination of images of 9 animals. Dragon is capable of leading transformation and should have great role in such a digital, cyber world. But dragon has a royal wrath (逆鱗). The dragon's royal wrath for a company is the customer value.

   Cases : Model T of Ford company, GM, FAST SECOND, DRAM of Samsung Electronics, TPI (Total Productivity Innovation), CTQ (Critical to Quality), PLC ABC (Product Life Cycle ABC), 着眼大局 着手小局

6. Snake (巳) : Pursue transformation till success

   A snake will die without sloughing its skin. It is same for a company, or any organization. A burnt child dreads the fire. Human kind and any organization have tendency to go back. Innovation can be successful when the change is on level of DNA.

   Cases : GE, From how to do to who to do. TPS (Toyota Productivity System : 三現主義 : 現物, 現地, 現實), IPS (Ideal Production System) of TDK

7. Horse (午) : Future of a company is on fostering competent employee

   A horse runs fast and aggressive. Essence of the management of a company is finding, hiring and fostering competent people. A fine horse (千里馬) cannot show his capability without feeding and opportunity.

   Cases : Ringelmann effect, CLO (Chief Learning Officer)

8. Lamb (未) : Build a human network.

   A lamb is a symbol of obedience, endurance and peace. Every letter of goodness, such as a virtue (善), beauty (美), righteousness (義), auspiciousness (祥), has the character of a lamb in it. (羊) A lamb is used for an offering to God. Lambs live as a flock. It is same in a company. Communication is essential for successful organization.

Cases : Workout of Jack Welch, 5S of Canon, Anatomy of the word, Hearing in Chinese (聽), KI (Knowledge Intensive of Staff Innovation Plan), PERT/CPM

9. Monkey (申) : Follow the best company.

A monkey has remarkable ability to imitate and create. Japan is a good example. The 6 sigma system of American response revitalized American competency.

Cases : Management revolution according to Tom Peters, VI (Value Innovation)

10. Hen (酉) : Set up rules and processes.

Hens always keep punctuality. And also it is said the screams of hens at dawn expel demons. This suggests much to companies that they should have concrete rules and processes. Latent abilities explode through rules and processes.

Cases : Autobahn, No process no work, IE (Industrial Engineering), VE (Value Engineering), QC (Quality Control),

C. Win-win skill – Beyond a company

11. Dog (戌) : Keep unchanging core values.

A dog is loyal. Also a company should keep receiving trust by protecting values of the customers and the society.

Cases : Security hole, Open door system, Fair process

12. Pig (亥) : Dream about more contributions.

Last animal in the zodiac system is a pig. A pig is giving all for food. It is not dangerous. A company should be like a pig in giving and sharing wealth. The answer for the question 'Why do we run a company ?' is to contribute more.

Cases : From Give & Take to Give & Give, Sustainable growth, Value shift, Noblesse oblige, John Wanamaker, 盡人事待天命, Goodbye Jack Welch, CSR (Corporate Social Responsibility)

3. Context into business TRIZ

One of the complaints from TRIZ novices is the complexity of the contents and excessiveness of tools to use. Usually they cannot use right tools properly in adequate manner. Methodology should be carved in memory and muscles and ready to be used immediately. In this sense, the 12 system is well memorized in almost of all East Asians. The names and order of 12 animals are remembered and easy to recall and apply to current problems. TRIZ as one of the major systematic innovation tools provides rich connection with this system. At first, the12 animal system is divided into 3 categories of the tools, for thinking, for innovation and for win-win, respectively. Those 3 categories are the essence of the business TRIZ. Even though Mr. Sun explicitly designate TRIZ as one of

essential tools on the section of a cow, the systems of basic concepts lying under the TRIZ has much resemblance. The comparison of the 12 zodiac management system and business TRIZ is in the Fig. 1.[1)]

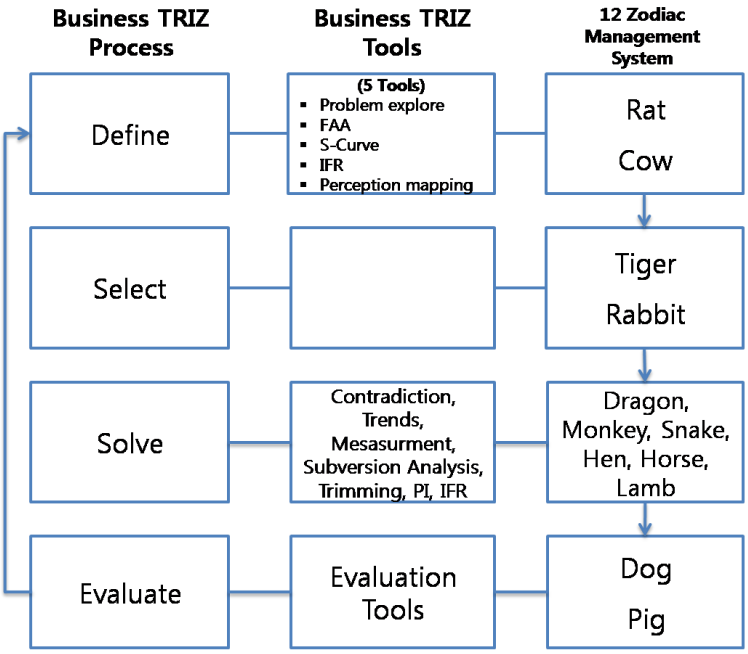

Figure 1. The comparison between business TRIZ and 12 zodiac management system

When we compare these 2 systems, following observations can be made.

1. The 2 systems provide tools and processes for innovation in same order.
2. The 12 zodiac management system provides tools vacant in business TRIZ for selection process.
3. The 12 zodiac system has benefit to follow and applied easily.

Conclusion

A new interpretation of modern management system is proposed by Sun Wook and explained. The connection and implications with business TRIZ is also investigated. The 12 Chinese zodiac management system has merits over business TRIZ in the sense of easiness to remember and be used. And it provides more complete system of tools for each step of innovation process.

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Development of an improved stapless stapler – A case study of the capstone course in the department of mechanical engineering

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Abstract

Current practice of mechanical design is applied to the stapless stapler. The problem of innovative design of a paper fastener is identified as a typical USIT problem and solved by USIT methodology. The design issue is on the improved version of a stapless stapler. After the problem is defined, closed world method and particles method are used to bring out ideal solutions. Temporal and spatial uniqueness were examined. The ideas were evaluated to give the optimized solution. All of these processes were done as a capstone project for a team of 4 senior students in one semester.

Keywords : Capstone design, Engineering design, Stapler, TRIZ, USIT, New product development

Introduction

Creativity is one of the key issues in engineering education, especially on design activity. A systematic approach should be transferred to the average students in the program. The CAI (Computer Aided Innovation) and SI (Systematic Innovation) are used in this context. In this paper, we applied one of popular approaches based on TRIZ is used to develop a new stapless stapler. This paper consists of 2 parts. The first part describes how the course is running and the way students learn and practice. The second part explains the process and result which are outcome from one semester of a capstone design course. It was applied to find a new type of paper fastner and the process leads to a new improved type of stapless stapler

1. Capstone design course

Korean engineering schools are to be certified by ABEEK (Accreditation Board for Engineering Education of Korea). Design education is very much emphasized in ABEEK

system. Our Ajou University reformed design curricula several times and the current system is as follows. Creative problems solving project (3 credits) for freshmen. Creative engineering design project (3 credits) for juniors. New product design (3 credits) for 1st semester of seniors. Capstone design (3 credits) for 2nd semester of seniors. The students should take at least 18 credits for engineering design courses. Usually 4 students make a team and perform a project during the one semester course. The capstone project is the final concluding course to sum up all the activities related with design. Some practical subjects are selected and the final results are evaluated by the panel of professors and industry practitioners. One day fair of exhibition is offered and students also evaluated other team's project results. Many teams successfully applied for IP's, such as patents or utility models after the course. Students confess they get practical senses of whole processes of design. In this paper, an example of performing capstone design project finished during the second semester of 2010 school year. One of the textbooks is the 'Creativity of Design Engineer' by Prof. Yoo which describes how creativity can play important role in design course and how to use TRIZ.[1)]

2. Stapless stapler design

One team, who are the authors, chose to develop a new type of paper fastner. The topic was drawn from their experiences and investigation of IFR (Ideal Final Results) on paper fastening. The ideal fastner should be able to keep papers without using energy, devices, and with no waste. The history of paper fastening has been studied and it drew a suggestion. The first simple way to keep several pieces of paper is to fold. As simple folding cannot keep fastening, we may tear the folded parts of the papers. Simple devices appeared to have patents as pins, clips, etc. The American patent for a bent-wire by Matthew Schooley dated back to 1898.[2)] More complex devices come as staplers and push type holders. They are far from ideality as they use staples and holders and they are lost most times as wastes. This notion brings to a concept of a stapless stapler. This conclusion has been derived from long investigation, but already it is now selling in stores unfortunately. The stapler and the operation are shown in Figure 1.

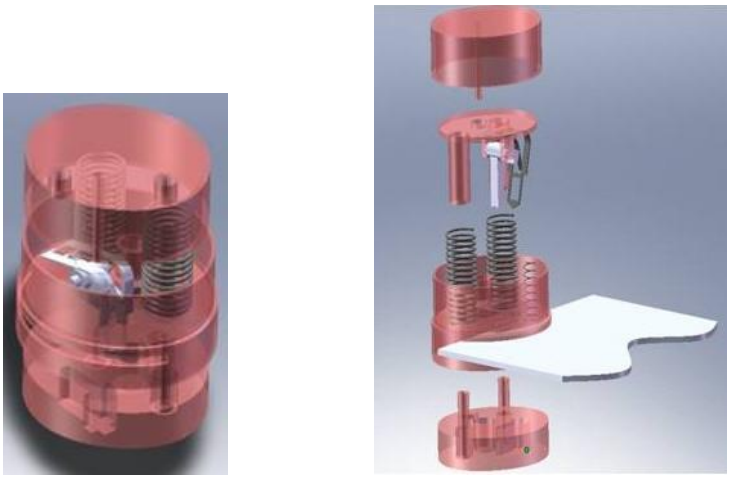


Figure 1. Currently selling stapless stapler and the operation

When the students suggested this subject, the author as their advisor should have shown them the sample which was bought at MOMA (The Museum of Modern Arts) at New York, USA a few years ago. But it turned out that it is selling very well in many internet shopping mall at very low price. Consequently, the object of the project should have been changed to making improvement of the stapler. Then it turned to be a good way to fulfill the course requirement by followng a good paper which covered the issue of improving a different type of paper fastner.[3)] They used USIT as the tool to attain their goal. The team studied USIT and followed whole steps to improve current version of the stapless stapler. The USIT approach consists of 6 steps, problem definition, closed world method, particles method, uniqueness, solution procedures and evaluation, respectively.

1. Problem definition.

The problem can be well defined by root cause analysis. The process is analyzed and the main cause is disclosed. The operation of the stapless stapler is shown in Fig. 1 and the process can be divided into following steps.

1. Insert the papers into the groove.
2. Push down the stapler.
3. The inside spring is compressed.
4. The papers are penetrated.
5. Parts of the papers downed are elevated by the catcher.
6. Elevated parts are fixed.
7. Pull the papers.
8. The problem is identified as follows.

a. The number of papers is limited.

b. The fixed parts are not neat.

Next is the step of setting of problem.

◆ Setting Target & Criterion

1. WANT Condition : possible number of papers : as many as possible
2. WANT Condition : result of cutting : as accurate as possible

◆ Setting Assumption - Restricted condition

1. Set of numbers of Papers : 4 sheets (Want : 10 sheets or more)
2. Cut places : As clean as possible.

Next is the root cause analysis and the process is summarized in the Fig. 2.

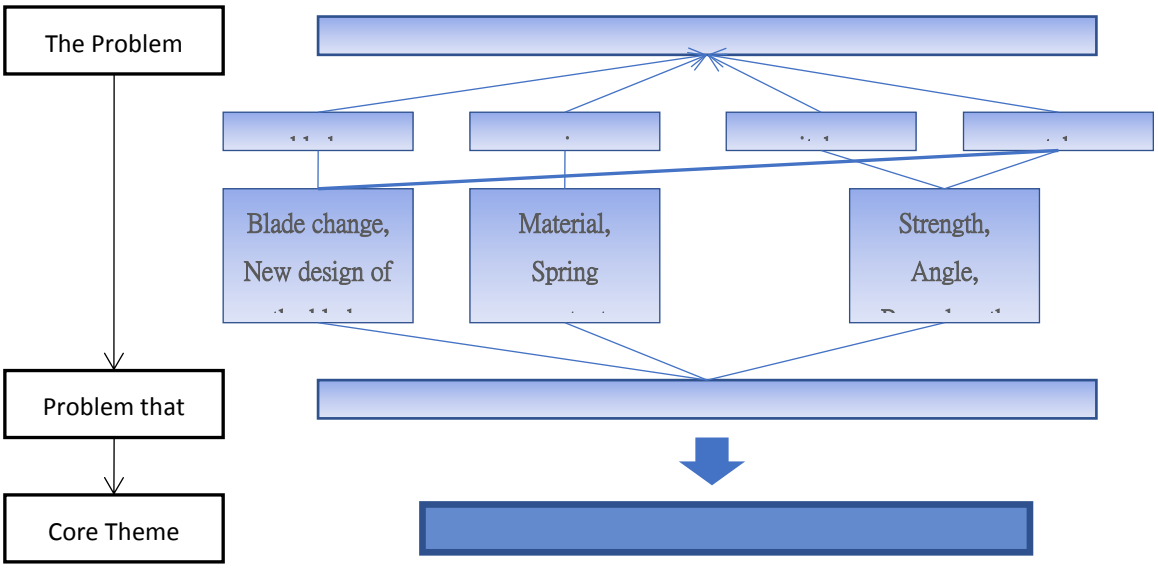


Fig. 2 The process of the root cause analysis of the stapler

A minimum set of objects are extracted and it becomes the target of new design.

2. Closed world method.

The closed world diagram is drawn to identify the most crucial parts by constructing OA matrix. The attributes of all parts of the object is compared with each other. The shape of the catcher is turned out most crucial.

3. Particles method

Sketches of the problem situation and the solution ideas are drawn. The concept of

the smart little people is used and the action and property diagram is obtained.

4. Next is to check the uniqueness.

Current and ideal model is compared with in terms of the functions and attributes of the design.

5. Solution procedures.

Solutions are generated by the standard USIT operators. Object pluralization method, attribute dimensionality method and function distribution method are applied in the direction of elimination-unification, increase-introduction, division - distribution, generalization-substitution. Each generated ideas are compared with in the sense of each applied method. The concepts are drawn in Fig. 3.

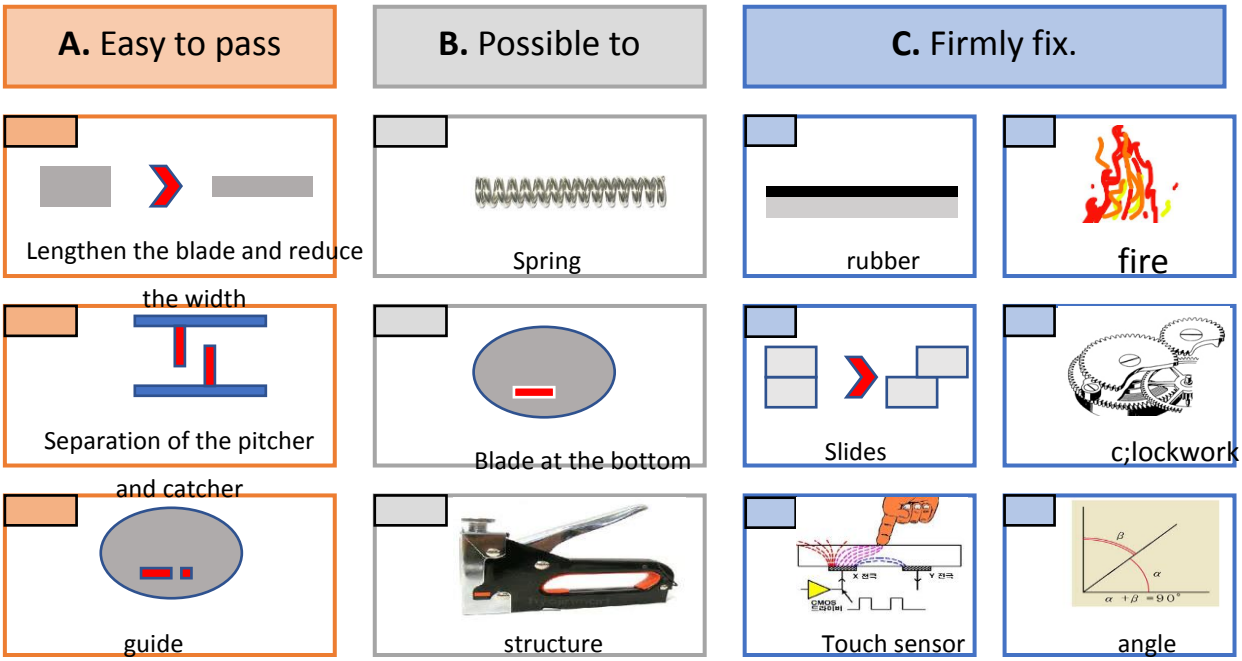


Fig. 3 The solution concepts according to the attributes

The above was the primary step and the secondary steps are done for generating each practical solution. One of the generated solution is idea 3 obtained by combining ideas as shown in Fig. 4.

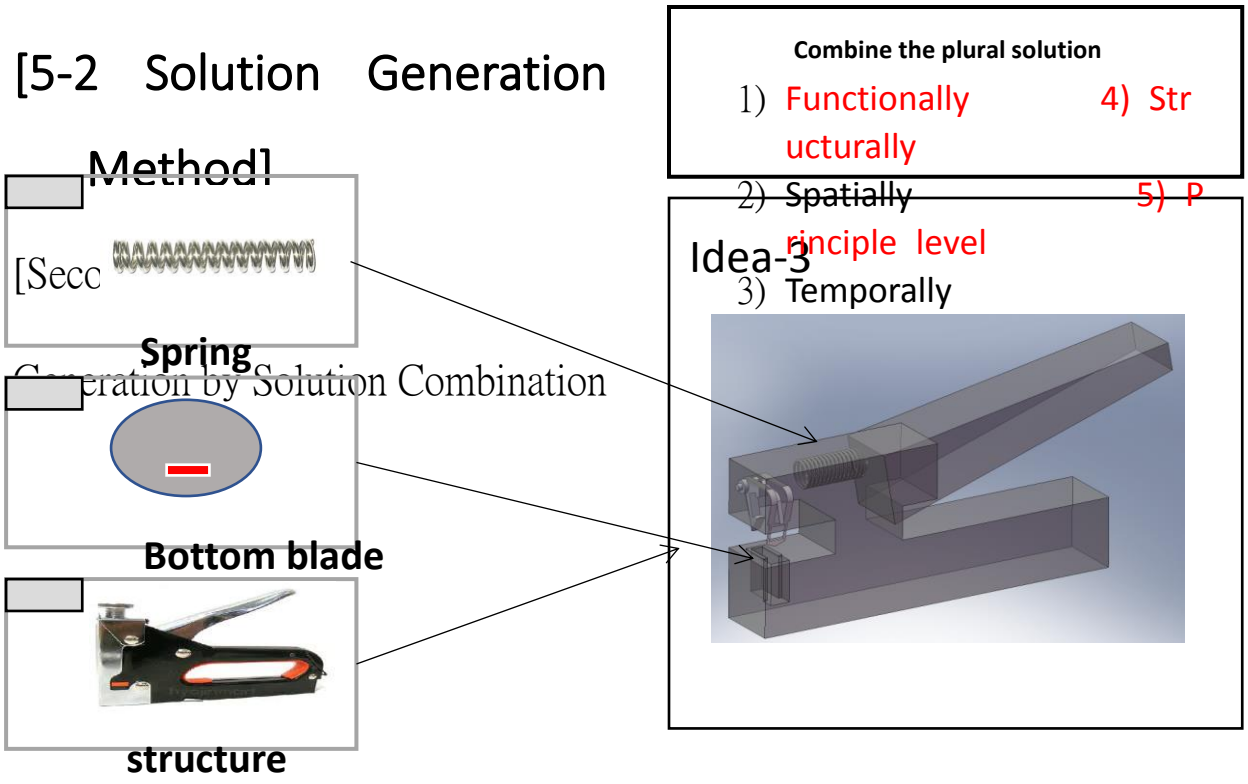
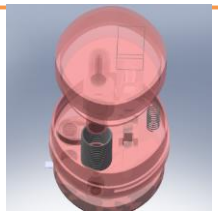
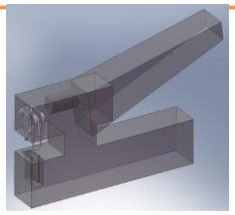


Fig. 4 One of the solution generated

6. Idea estimation

The generated ideas are compared with each other and get scores in terms of the attributes as shown in Fig. 5. The idea shown in Fig. 4 had got best score and it was the final design. The prototype was made and checked the validity of the idea.

Idea-1	Idea-2	Idea-3	Idea-4
			

Evaluation item	Idea 1	Idea 2	Idea 3	Idea 4
1. Replacement time : as faster as possible	1	2	2	1
2. Consideration to easiness to arrange	2	3	4	3
3. Flexibility to thickness: The Min 2mm thickness. (Want:5mm)	1	2	4	2
4. Basic function as a paper fastener (pressing firmly)	1	3	3	3
5. Easiness of Pitcher, Catcher to pass	2	3	3	3
Overall Evaluation	7	13	**16**	12

Fig. 5 The estimation table of the generated ideas

Conclusion

The idea of development of a new ideal stapless stapler reached a proposal to design a new system. Currently selling stapless stapler forced the team to change the objective of the project to designing an improved system. The USIT approach guided the team to follow the process to find the root cause, concentrate on the crucial part, make several ideas to check. The solutions are evaluated to obtain the final suggestion. The completion of the project by a team of 4 senior students in one semester was impossible without help of the tools of systematic innovation such as USIT. As the final result was so impressed, they got a silver medal at the capstone project fair. It can be a good example of how the systematic innovation can contribute to the modernization of engineering design course.

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The Interface Between Industry and Universities, With Specific Focus on Problems that Exist at the Interface: A Review

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Abstract

The focus of this review paper is the problems existing at the interface between universities and industry. According to the surveyed articles, these problems have been categorized into 4 groups: intellectual property problems, culture problems, knowledge problems and environment that influence the collaboration of university and industry, among which, intellectual property problems have been subdivided into 3 categories: patenting in knowledge transfer, IPR through contract research and university's IP policies. This paper is the start part of my research which aims to acquire problems, solutions to problems, and then create 40 principles in area of knowledge chain between universities and industry. This paper contributes to smooth knowledge transfer, knowledge sharing, knowledge creation and systematic innovation system of universities and industry.

Keywords: intellectual property, knowledge transfer, problems, university-industry interface

1. Introduction

Many authors have written on aspects of university-industry collaboration. Some key examples are as follows: major categories of university-industry interactions (Wu, 2000), potential risks of university-industry partnership (Wu, 2000), formal and informal university-industry interaction channels (Christian, 2009), the government and programmatic policies on university-industry collaboration (Park and Leydesdorff, 2010), university IP policy and knowledge transfer (Welsh et al., 2008), University-Industry collaboration models (Philbin, 2008), factors for effective partnering (Kleyn et al., 2007), the broader reasons for partnering (Manley et al., 2007), the social capital perspective of university-industry cooperation (Thune, 2007), and culture difference (Manley et al., 2007). This review paper focuses on the problems that have been identified which may exist at the interface between university and industry. Some examples of key words which have been used individually or in combination to research this area includes: academic-industrial collaboration, university-industry barrier, knowledge

transfer office, spin out, spin off. After reading all the surveyed articles carefully, categories are thus developed.

2. Type

From the literature, there is a general view that Intellectual property is a key problem that universities and industry face when partnering. Hall (Hall, 2001) comments that Intellectual property is time-consuming and the biggest problem in the negotiations between universities and firms nowadays. Generally, the intellectual property problem between university and industry include three categories: patenting in knowledge transfer, contract research and IP policy.

2.1 Intellectual Property problems

(1)Patenting in knowledge transfer

Knowledge transfer start from the point that the universities own the patent rights and the industry want to commercialize the academic ideas and bring the results forward to marketplace in the form of new products (Gils et al., 2009). Therefore, license of university intellectual property is one mechanism through which the knowledge and expertise possessed and developed by universities can flow directly to industry (Verspagen, 2006). If property rights are weak and the knowledge is tacit, the researchers don't want to transfer the knowledge. However, if the intellectual property right is strong, the researchers are willing to transfer the knowledge, but at the same time, there is another rising issue, that is, royalty payments. Brunnel (Brunnel et al., 2010) and his colleagues illustrate that royalty payment from patents or other intellectual rights and concerns about confidentiality are potential conflicts. The university need to negotiate with the firm about technology transfer instruments (e.g. an exclusive and non-exclusive license or option, material transfer etc.) and the compensation on the agreement (e.g. royalties, equity and barter) (Goldfarb and Henrekson, 2003).The surveyed papers show that it needs much time to get the agreement on the royalty payment, for example, the amount of money need to be paid, the ways to pay. In many cases, the negotiation fails due to the disagreement in this area.

(2) IPR through contract research

If the universities do not have existing patent rights, and firms fund academics to create new ideas, transform new ideas into innovation and so IP is developed during the collaboration, the issue of intellectual property is more complicated. Based on the qualitative, exploratory study, Gils (Gils et al., 2009) noted that, “It is increasing difficult to agree on IPR part of a contract, though all firms have a general interest in working with universities”. For one thing, If the inventions belong to a firm, the university gets a pre-bargained fee. Otherwise, the university owns the property rights; the university gets a profit through a licensing fee. In short, the negotiation depends on the benefit expectation of the inventions (Aghion and Tirole, 1994). Because of the higher and higher revenues from licensing, the universities try to get hold of IP (Colyvasm et al., 2002). IPR has been identified as a new financial resource since the

government funding to universities is being reduced (Geuna and Nesta, 2006). The universities' intent to capture the commercial benefit has caused significant distributional conflicts (Florida, 1999). What's more, the universities' overvaluation of IP has led to the accentuated conflicts (Clarysse et al., 2007). However, firms want to keep the ownership of all results and patents, if they expect the results to be commercially applicable. Even though commercial application is not expected, the firms still keep their specific knowledge from leaking into society. As a result, who has the ownership of IPR is controversial. In general, it is better to make strict agreement on IPR and secrecy before starting the collaboration.

(3)University's IP Policies

Universities build administrative office such as Patents and Technology Licensing Office, Technology Transfer Office and Technology License Office to undertake knowledge transfer and technology transfer (Rahm and Hansen, 1999). In order to encourage and promote technology transfer, polices and regulations need to be created. However different university's IP policies give rise to the conflicts between the university and industry, for example, if the university's IP is complicated, then there is a transaction conflict; If the university has a incentive IP regime , researchers are willing to give the right to university and transfer the knowledge (Crespia et al., 2010). There is a survey which shows that 71% inventions need researcher's further involvement during the successful commercialization (Crespia et al., 2010, Jensen and Thursby, 2001). Therefore, if the university's IP policy is not effective and suitable, there must be conflicts while transferring the knowledge. Furthermore, if the university's IP policy pay much more attention to the patent rights, many conflicts will be produced during the negotiation.

2.2 Culture problems

Besides the organizational cultures, cultures here still refer to mission, objectives, research orientation, research interests and communication. It is widely accepted that university and industry have a different orientation because of different internal systems, e.g. incentive system, academic reward system. Goldfarb and Henrekson (Goldfarb and Henrekson, 2003) noted that "there is little reason to believe that the goal of producing useful inputs into the research of other academics is congruent with the goal of producing commercially valuable knowledge. Hence, effort directed at the production of commercially valuable knowledge will most likely come at the expense of the production of reputation-enhancing academic knowledge". Similarly, Bogler (Bogler, 1994) suggested that universities need to publish articles and disseminate knowledge, but industry must deliver products. As a result, when the university is industry-funded, there is no freedom for them to publish articles, attend academic conference, and communicate with others, even within the academic circles (Ronit, 1994, Wu, 2000, Welsh et al., 2008). However, advancement of social knowledge is one of the university's main function, so academics are willing to create "leaky knowledge". Researchers are stimulated to distribute the knowledge to get the acknowledgment by their peers. In others words, the researchers want to produce the knowledge which can be used in other academics' research, which is the criterion for the researchers to make effort and get the high income and

prestige (Goldfarb and Henrekson, 2003). Nelson (Nelson, 2004) argued that "university researchers are also likely to choose research topics that are perceived by their peers to be interesting and valuable". At the same time, firms want the knowledge to be "sticky", then they can control exclusive resources, gain competitive advantage, create new innovative products, acquire the market share and get the high profits (Brown and Duguid, 2000) and they like to choose the research topics which can be valuable for the development of new products and services (Nelson, 2004). In addition, the researchers are used to doing their research in a slow pace and wish everything is perfect, for example, they care about practical use, they want theories to be more complete as well. They don't want to be disturbed and work over hasty. In contrast, companies need suitable and valuable products and service, that is, applicability, not perfection. They have very strong time concept, so that they can meet the requirement of markets (Welsh et al., 2008, Brunnel et al., 2010). Some characteristics of firms' culture always leads to conflict, for example, organizational culture which promotes the results but not the sharing, little commitment of managers in knowledge sharing process, lack of motivation from superiors for knowledge sharing and intolerance toward mistakes or the need for help. As to the communication, there are many failed cases because of the unsmooth communication between the university and industry (Rivera-Vazquez et al., 2009), for example, the university and industry have different communication language which include different type of language (e.g. English, Chinese, Japanese) and different exclusive inter-academic or inter-firm language. Due to the different cultures, there are many conflicts between university and industry.

2.3 Knowledge Problems

If the sort of knowledge such as data, information, experience can be successfully transformed into what the enterprise want, the knowledge creation will take place (Rivera-Vazquez et al., 2009). When the enterprise try to extract the knowledge from the university, the most important point is the enterprise' ability of acquiring, assimilating, adapting and applying the new knowledge (Hauke, 2006). Therefore, any above aspect fails, the knowledge transfer fails. For example, the low knowledge absorptive ability and low knowledge learning ability of enterprise will set back the knowledge transfer (Wu, 2000, Quan, 2010). In most cases, information lose quality and even be useless while transferring (Quan, 2010). Quan noted that it is very difficult to access to tacit knowledge. The researchers are asked to share the tacit knowledge and involve in the later projects, but if the IPR is not strong and the compensation is not enough, they are not willing to transfer such knowledge. In such case, the enterprise will be passive. Under some circumstance, the content of knowledge will be the conflict origin. In other words, there is a gap between the theoretical knowledge and practical knowledge (Quan, 2010). The knowledge form the university is always theoretical and there is still far way from practical knowledge. The transition sometimes leads to failure.

2.4 Environment that influence the collaboration of university and industry

Out of the university and industry, there are always existing policies and cultures that contribute to the conflicts between university and industry indirectly. Because attribution of indirection, they are put into the environment group. In order to promote the technology transfer, government creates many policies. The starting point of the policies is to catch the super-optimum policy solution (Rahm and Hansen, 1999). After the early 1980s, the United States acquired such super-optimum policy through economic impetus (Rahm and Hansen, 1999, Nelson, 1989). The Bayh-Dole Act of 1980 is main case of such policies. It stimulates universities to own the intellectual property which result from their research funded by federal money (Crespia et al., 2010, Rahm and Hansen, 1999). However, Before Bayh-Dole Act, the ownership of such patent belong to the federal government (Rahm and Hansen, 1999). In 1992, $ 172 million dollars were earned from the royalties and licenses which is 30% higher than the amount earned in 1991. Because of the rising importance of such revenue, the university are promoted to try to get the intellectual property rights (Rahm and Hansen, 1999). This motivation leads to further intellectual property dispute and more time consumption. In contrast, it is not same in European country. Some European countries traditionally give the IPR to the inventions because of the professor privilege. However, these countries changed their law and gave the ownership to the university. Gradually, the university ownership has been the legal default, but due to the weakness of enforcement, who own the patent has become a controversy and caused conflicts (Crespia et al., 2010). Sohn (Sohn, 2009) illustrated that "Korean case is a successful example of government leading industrialization…, Korean universities ,traditionally, have been loosely connected with industry…, Moreover, most Korean companies have depended on foreign technology visa reverse engineering …" After 1990s, through all kinds of policies, the university is promoted to link with industry in Korea. From this point, we can see policy has effect on collaboration of university and industry and at some degree, also influence on conflicts.

2.5 Conclusion

The problems identified in this paper are the main problems existing at interface between universities and industry. These problems lead to ineffective and unsmooth collaboration of universities and industry. In order to create an effective innovation system of universities and industry, these problems must be removed. The first stage is to identify all kinds of existing problems. The future research is to find the solutions, create 40 principles and how to set up an effective innovation system.

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Developing Podcasts to Introduce TRIZ

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Abstract

The development of simple, widely accessible training material to enable people to start using TRIZ is generally speaking, not readily available. With the advent of podcasts and developments such as iTunesU (university material available on smart phones), the situation is changing. This paper reports the development of three podcasts. Case studies developed by peers of one of the authors, when based at INSA, Strasburg, are used as an approachable vehicle to illustrate the material. Feedback from TRIZ professionals and students not yet exposed to TRIZ will be discussed, alongside lessons learnt from using this technology.

Keywords: Podcasts, learning TRIZ, introducing TRIZ, educational material.

1. Introduction

Podcasting is an area, at present, seeing a lot of focus in higher education. Lonn and Teasley (2009) define podcasts as 'any digital media file, or series of files, distributed over the Internet for playback on portable media players and personal computers'. In fact with Apple's introduction of iTunes University, (McKinney et al. 2009), the pressure is now on academics to provide this service, which can help non traditional entrants, and with flexible delivery. To gain an overview, it is worth starting with the review paper of Heilesen (2010), in which he looks at the recent scholarly papers and concludes that 'podcasting does seem to have a generally positive impact on the academic environment'. Other authors seem to be even more positive from the results of their research (Copley 2007, Fernandez et al. 2009, Parson et al 2009, Sutton-Brady et al 2009). Fernandez et al. (2009) say that 'the findings, discussed within the framework of principles for good practice in higher education, suggest some interesting issues in distance courses, such as: (1) podcasting is a powerful tool as a complement to the traditional resources on a course, but not a substitute for them; (2) the characteristics of podcasting increase the impression of permanent contact between students and

teachers, increasing students' motivation; (3) the use of podcasting allows for a diverse range of student skills and learning methods.' This is amplifed by other authors (Parson et al 2009) who suggest that podcasting is a 'beneficial addition resource for learning, particularly when used in conjunction with lecturers' slides and as a tool for revision/assessment' and Lohn & Teasley (2009) 'students use podcast materials largely for reviewing concepts and issues raised in lectures that they have previously attended'. The clear message is that Podcasts do not replace the lecture but are a useful support. With this in mind, it seemed appropriate to invesitgate introducing the concepts of TRIZ using this media, not least because of the reported ability to easily review ideas and concepts, which, in the authors experience is most necessary with TRIZ.

2. The Market

An early decision was made, that the way one introduced TRIZ, depended enormously on the audience (learner). The "market" defined in this series of podcasts was defined as engineering students, but also far more importantly, engineering lecturers not exposed to TRIZ. Note that a series was developed because it was realised that people would find small 'developmental' chunks easier to assimilate/ be less threatening. To appeal to lecturers it was realised, one needed practical examples of innovative work that other students had developed (and ideally many examples to trigger interest). Also to grab the interest of academics, utilising some perceived challenging theory or complex software, is a bonus (which is what INSA has done). The 'complexity' is introduced here with low prominence, as the author believes that TRIZ needs to be understood initially without software/ complex theory, to gain the basic principles i.e., tools, approach etc.

3. The Development Media

The podcasts were developed with software called Camtasia (E.g., TechSmith 2011). Basically any electronic media can be stepped through and then a voice track added synchronously or later. Viewers can see for example a software package being run in real time and see the mouse movements, selections etc. For these podcasts, we focused on a pre developed PowerPoint which was played in real time and subsequently spoken over (see Griffin et al 2009). Videos of CAD package screens were also incorporated between PowerPoint slides. It should be noted that specialist software is not necessarily needed (Copley 2007).

4. Podcast Series Development

A series of three podcasts were developed with an educational developmental theme. The first podcast introduces the TRIZ Principles by looking at three innovative designs developed by INSA students. For each design, two or three Principles are highlighted and related directly to the design. An example of one Principle is shown in detail and suggestions were made as to how it can be used to trigger innovative ideas.

The second podcast is based around a different INSA student design: the crutch. It focuses on developing contradictions, solving them using the Matrix and showing how the identified Principles lead to improvements in crutch design. To ascertain the contradiction pairs: functional definitions, the Multi-screen (9 Windows) tool, and the identification of key parameters, are all introduced briefly. This follows the INSA problem solving model:-

1) Key function definition
2) Multi-screen analysis
3) Evolution laws
4) Hypothesis merging
5) Parameters and contradictions
6) Links between parameters and contradictions
7) Most important contradictions
8) Contradictions solving by using matrix
9) Evaluation and integration of concepts into a new design

In the third podcast the same crutch design is analysed using the INSA model, but the focus is on using the INSA developed software (TRIZAcquisition 2011) which runs calculations to identify the most important contradictions. Whereas podcast 2 focused on steps 1, 2, 5, 7, 8, & 9 of the INSA problem solving model, the third podcast takes the viewer through all nine steps.

5. Lessons Learnt

The first lesson that was learnt was to develop and write a script. It takes many attempts to get a dialogue flowing well. You can hear the difference between one author's unrehearsed dialog and that of the second author, who lived and breathed the podcast development for three months. Secondly, it adds variety to have two people speaking and the French accent adds colour; though at times some lack of clarity. This is offset by the ease of replaying a fragment or all of the podcast. The third lesson is that a clear developmental theme is needed with conclusions summarising the content and then leading into the next podcast. The introduction of the subsequent podcast needs to link back to the previous podcast. This is of course good practice.

6. Conclusion

The key conclusion is that you need a huge amount of time to develop a series of podcasts properly, but the benefits are worth it; to get TRIZ understood and appreciated. Feedback and interest level has yet to be realistically analysed. The podcasts have been used by a very small group of students (10) with positive feedback. Also the podcasts have been introduced to a TRIZ meeting of about 25 TRIZ practitioners where the feedback was 'get these out on the internet' i.e., very positive! The real test will be whether other university lecturers will take the bait and come asking for TRIZ! This is to be investigated over the next few months.

Developing TRIZ podcasts for the general public or specific target groups will be a major and different challenge to that reported here. Again the use of good relevant examples applicable to the specific target domain, will in the authors' opinion, have to be identified and utilised appropriately.

▪Acknowledgement

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An Origami-TRIZ-Synthesis for Systematic Innovation

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Abstract

This contribution is about folds, pressure and artery blockage. What seems to be a negative scenario, actually is the trigger for a whole host of positive effects: focused creativity, systematic invention and the use of a traditional art for innovatively solving (not only) technical problems. For the first time, the art of paper folding is linked to TRIZ, to highlight the inventive potential for today's technical product development and innovation. The shown analogies between Origami and TRIZ recommend Origami as a new, nonetheless unusual approach to understand and apply selected TRIZ tools more easily. Industrial applications are demonstrated, as well as the positive effects, the knowledge about Origami can produce in mathematics, production technology, product development and methodical innovation.

Keywords: Analogy, Invention-on.-demand, TRIZ, Origami

1. Invention-on-demand with TRIZ – and Origami?

Technological development is as old as humankind itself. Innovations are the engines for this development. Even if many innovations brought humankind forward, such as the wheel, the automobile, the telephone, antibiotics or the computer, most of these innovations resulted from coincidence and over a long period of time. Coincidence and a long period of time between the first idea and the successful application are increasingly considered inefficient in today's world of product development. The demand for systematic methodical innovation in a shorter period of time increases to the same degree as society or a company aims for competitiveness. Technological competitiveness is thereby driven by inventions and new ideas in product development.

Every new technical product, be it a device or a process, pursues an idea and a concept that has to be elaborated at the beginning of the actual developing process. Effects given by nature have here to be combined with personal or social demands to useful functional lines. If this combination has never been there before, you can call it an invention. This invention uses therefore existent knowledge

of natural scientific effects and special skills to realize a new problem solution. Only the transformation in a product that is successful on the market is an innovation.

In the process of product development firstly the need for a problem solution is to be identified and denominated. This need is to be expressed as a technical problem and converted into a product concept. Product design takes a look at several alternative solutions under given circumstances and implies to choose the best out of several possibilities. The actual product concept emerges from this evaluation process, being therefore the interface for all successive divisions (Hentschel, C. 2006). Initially the product is realised as a prototype and can later be produced as often as wished. The conception phase actually doesn't get as much methodical support as the other development phases, and developers could here benefit from TRIZ very much.

TRIZ is the abbreviation for "Theory of inventive problem solving" in Russian. It is less focused on theory than on the practical approach to focus the innovative process in an early stage on promising ideas and nonetheless accept new approaches (Hentschel, 2006, Hentschel 2010) . The systematic method can be traced back to Genrich S. Altshuller (1929 – 1998) and consists of a multitude of instruments to create goal-oriented creativity through uncompromising, contradiction overcoming and structured approaches that help to solve mainly technical problems in an innovative way. (Altschuller, 1998, 2004, Gimpel et al., 2000). This kit's charm lays in the fact, that Altshuller's logic revolutionises the problem solving approach and therefore resolution methods emerge that hadn't be thought of before (Hentschel, 2007). These methods are globally acknowledged and used successfully in many development processes mainly in big companies in different technical disciplines (Schweizer, 2008, Hentschel, 2004).

The scope of application has hardly been exhausted yet. This may be because of the complexity of the method on the one hand, with its number of instruments: TRIZ requires technical interest, considerable previous knowledge, a profound comprehension of the underlying way of thinking, practical application and the willingness to make detours that seem to get you far away from the original aim. On the other hand the imparting of TRIZ is yet to be improved: teaching TRIZ has to be more orientated on the learner's needs than on the teacher's skills (URL1). To follow the learner's interest and to strengthen the future application, technologies should be used with which the learner can identify at the best. At the same time, the technology should offer a big inventive potential.

The inventive potential of a technology is considered here as the possibility to create new innovative products or solve the problems that lay within it, based on its knowledge. Thus, the developer needs to acquire knowledge beyond his field and apply it in his field. Origami not only is able to help overcome contradictory requirements of the product. It also strengthens the comprehension for TRIZ methods of people who aren't ostensibly interested in technical contexts, but rather have an artistic or practical background.

The approach of this contribution is:

- Which analogies are there between Origami and the systematic innovation with TRIZ?
- How can Origami be implemented to make specific aspects of TRIZ easier to comprehend?

- If Origami in terms of TRIZ is to be understood as an expression of learnable creativity and technical problem solving, which industrial applications are imaginable?
- And if nothing else: Can the reader himself imagine another application of Origami and/or TRIZ?

2. State-of-the-art: Origami

Derived from the Japanese words "ori" (fold) and "kami" (paper), the term Origami has for a long time been a synonym for folding animals, figures and other objects from a square piece of paper. The art of folding paper has a long tradition, not only in Asia, where paper was invented 2000 years ago and was folded 600 years later for religious rituals in the first place, later also for profane purposes. Regardless of that, there are theories indicating that also Europeans, like the German pedagogue Friedrich Fröbel (1782-1852) brought the art of folding paper from Europe to Japan. In general, folding paper is an art that plays an important role in every culture of the world, and that is why designers and objects from many countries of the world can be found today (Lang, 2003, LaFosse, 2005).

Recently, the American engineer and former NASA scientist Dr. Robert J. Lang attracted attention with a lecture on the TED Conference in Monterey, California, on the potentials and possible areas of application of the Origami technique (URL2). With his presentation the experienced Origami designer managed to show that this sometimes as children's toy or craft mocked art has enormous potentials for technical application, when combined with knowledge from mathematics and engineering. As the author of many books, one of it being a standard work (Lang, 2003), he developed techniques and software that uses Origami as a method of technical problem solving. Dr. Lang is Origami consultant and supports the automotive industry developing folding patterns for smallest possible packed airbags, as well as astronomers designing unfoldable giant lenses for space telescopes and promotional film makers with the use of animated paper figures (URL2).

In the traditional art of Origami, folding is always done with a square sheet of paper, straight folding edges and without scissors or glue. The achievable diversity of forms is astonishing. For instance, it is possible to fold a rattlesnake, a spider or an elk out of one square sheet of paper (figure 1).

Figure 1: Selected objects in the art of classic paperfolding by R.J. Lang (URL3)

The rattlesnake, folded in a process of several hours of about 1000 folds, is only one of many breathtaking animal examples in the Origami world. Other examples originate from the flora or fauna or the world of insects, picture mathematical structures, mythical creatures, or even humans, houses or technical objects (URL2, Kawasaki, 2005, Lang 1995, Montroll, 1996). However, only few persons are able to realize natural examples like these into folded paper. The amount of Origami experts that leave the surface or – like Dr. Lang – commit themselves only to the art of Origami might be just little over a handful worldwide. Still there are many objects published under the name of the respective author – or let's say the respective artist – but only few information on the background of how these objects came into existing are available.

This is possibly due to the fact, that it is much easier to fold paper following a known instruction than to develop the instruction after a desired paper form. A folding instruction does not describe in any way how it got developed. This corresponds with a routeing or a technical drawing, that might reveal to an expert how to produce the device, but does not reveal how the device was developed or which idea let to it.

But whereas technical drawings and workplans enthuse mainly domain experts, more people respond to the special aesthetics and the mathematical structure of Origami figures. That is why a link to the easier employability of complex coherences, e.g. in mathematics and geometry, in product engineering or technical product innovations can be assumed. TRIZ as a definitely beneficial method

is still considered - also by experts - as a method that is difficult to teach and can therefore benefit from Origami in a way that it clarifies some tools and aspects in product development, independent from a favoured technical discipline.

3. TRIZ in a nutshell

Altshuller postulated three fundamental realizations after having analyzed many patents, which were confirmed also after continuing to analyze the newest patents (Mann et al., 2008):

1. A contradiction or conflict that is thought to be insuperable forms the basis of every inventive task. Only the elimination of this contradiction, not the compromise solution, leads to really innovative solutions.
2. The same principles of problem solutions form the basis of many inventions that can be used repeatedly in situations of conflicts or contradictions to increase the probability to find a successful solution more quickly.
3. The evolution of technical systems follows certain recurring patterns that can be used progressively.

From these realizations, Altshuller developed tools as procedure models to create innovative solutions systematically.

One thinking model that became a TRIZ tool is the Ideal Final Solution (IFS). A final solution is ideal when it fulfils the function without even existing. This is obviously utopia, but still development of technical systems follows this direction. Developers try either to minimize harmful parts or increase positive functions or both. In retrospect, often exactly the inventions that did not come from the area of expertise were used.

Nonetheless, inventions are not automatically useful, they only increase the customer's benefit in the ideal case. Customer needs are rarely innovative as well, usually they are based on contradictory and conflicting requirements: A product should be big and small at the same time, its steadiness high and weight low. In the conflict matrix, another TRIZ-tool, technical parameters face each other, reflecting the current patent literature by displaying the most frequent innovative solutions in an abstract form. Hence this tool stimulated to use solutions also from patents outside the field without tagging along all the details of the patented solution and without wasting time.

The lion's share of the TRIZ examples in literature consists of technical problems, as the analysis bases on patents. This is why in particular non-engineers are deterred from tackling the thinking models (URL1). Origami can be understood as an ideal field in which non-engineers, artists and engineers can communicate. The center of attention is not only to formulate new problems and solutions, but to mediate the spectrum of TRIZ methods and to easier memorize single parts of them with the help of

analogies. While collecting folding examples and discovering folding rules and techniques, parallels between Origami and TRIZ emerged, that are addressed herewith for the first time.

4. Origami and TRIZ

▪4.1 General analogies in the approach

Problem solving with TRIZ occurs with the help of the tools, following a structured, rule-based approach that firstly formulates the problem abstractly. This abstraction frees the thinking from entrenched categories and leads from subject based established solutions to new approaches and impulses. The new basic solutions have to be adjusted and elaborated to the original problem. Although the developer makes a detour this way, he avoids thinking about details that would have to be sorted out later on for not being promising. Therewith TRIZ accelerates the innovation process. Already concerning this approach, Origami and TRIZ show an obvious analogy (Figure 2).

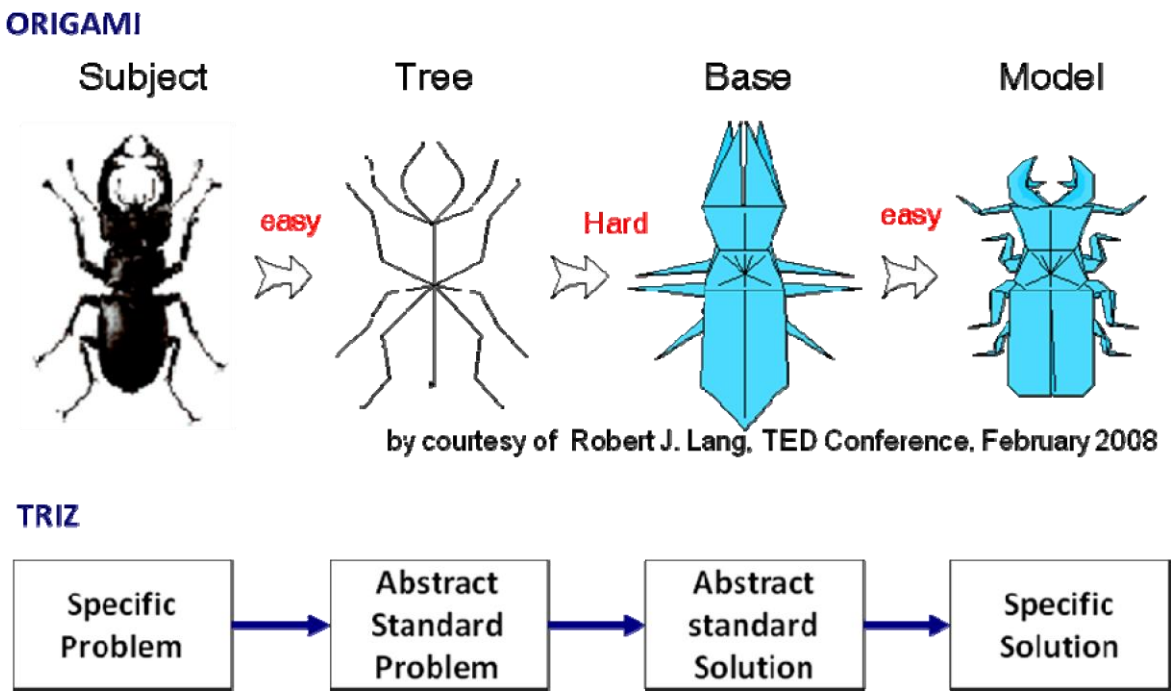


Figure 2: process of transforming the desired form given by nature into a folding pattern (URL2) and analogy to the TRIZ approach.

In the art of Origami, based on a desired form, e.g. an animal, firstly the form is abstracted. A tree structure, as an abstract image of the original, describes the amount and length of the needed flaps. These flaps are separated by adequate folding at an early stage and function later on as a leg or feeler. The tree structure is transformed in a base model that can be detailed and elaborated later on.

Both in the art of Origami and in TRIZ the first and the last step seem to be rather easy. The step in-between however, the transformation of the abstract problem into an abstract solution statement, is

only solvable by a layperson with the respective support. Both for TRIZ and Origami, experts are recommended as facilitators. They can guide the application of the existing tools in an optimal way. As TRIZ consists of a lot of tools that can be used beneficially individually, it is rather easy to work modularly when teaching and learning the method.

Within TRIZ and Origami, it is considered inefficient trying to solve a specific problem only by trial and error and therefore risk accepting a suboptimal solution. TRIZ puts up with making a detour parting from a concrete problem to an abstraction in order to be able to utilise knowledge of patents. A problem does therefore not seem to be unique and only known in one specific field of application, but has appeared more often. Therefore there is a high probability that it has been solved in an innovative way in the past and/or in another field of application. In order to be able to acquire these external solutions, more field specific barriers have to be overcome than solutions be reinvented completely.

To find this solution quickly, it is desirable not to use all details of the other analogical problem, but to extract only the relevant information for the original problem. TRIZ and Origami both suggest an approach that uses a detour and many rules in order to get the solution more quickly and more focused.

▪4.2 Selected TRIZ tools and Origami techniques in comparison

(1) Resources checklist and Origami axioms

Before changing a system, the first question to be answered during a TRIZ project is what resources exist. At the best they are to be used to improve the system, before new parts are introduced and therefore might complicate the system unnecessarily. Origami uses only one square sheet of paper as a resource as well as - usually manual - folding energy using strength and contact pressure. Two different creases can be created: valley folds and mountain folds. A mountain fold results by folding the upper part of a sheet backwards, a valley fold results by folding the upper part of the sheet forwards onto the lower part of the sheet. The folding planning coordinates the arrangement and the order of the folds with the objective of realising a given figure. In the folding planning, virtual points and/or lines are generated and/or positioned to each other in a specific way. The result is two- or three-dimensional forms with new characteristics, e.g. regarding surface or volume. Similar to TRIZ, where there is a list with all available resources in the form of 6 groups, Origami uses 7 axioms altogether to describe all basic folding operations completely (Figure 3).

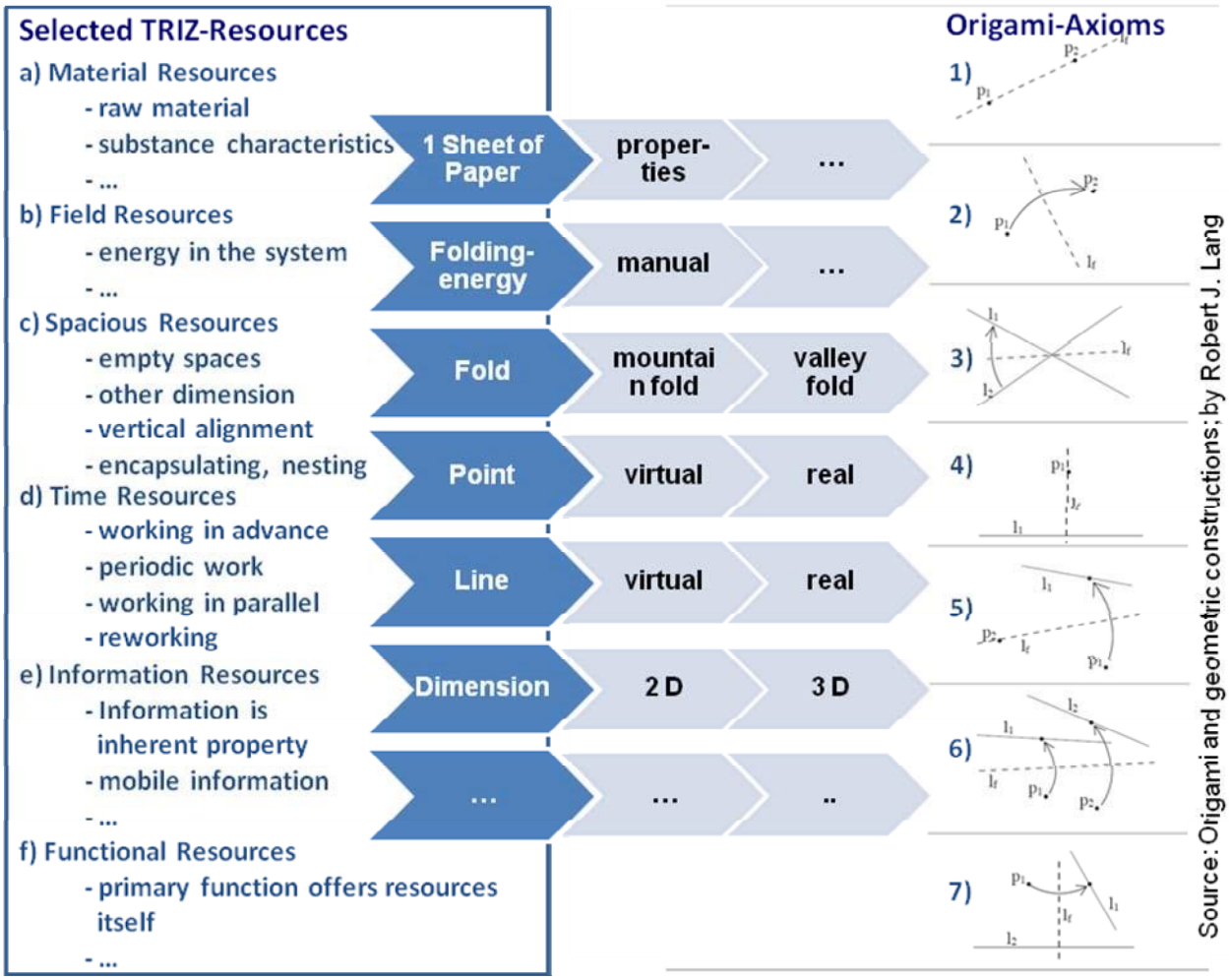


Figure 3: Select TRIZ resources in comparison with basic Origami folding resources (Altshuller, 2004, Lang, 2003)

The first six Origami folding ground rules, the so called 6 Huzita's axioms, describe the connection of predetermined points and lines by folds (Lang, 2003):

1. Connecting two points on the sheet the shortest way possible by one same folding line,
2. Overlapping two predetermined points on one sheet of paper by folding and therefore laying it on top of the other at these points,
3. Laying two lines on top of the other by one folding,
4. Creating a folding line that is at the same time vertical to a predetermined line and going through a predetermined point,
5. Creating a folding line that at the same time goes through a predetermined point and lays another predetermined point on a predetermined line, as well as
6. Creating a folding edge that connects two predetermined points and two predetermined lines in a way that in each case one point lays on one line.

The seventh ground rule, the so called Hatori axiom, describes the

7. Creation of a vertical folding line to a predetermined line by folding a predetermined point on another predetermined line.

Each of the predetermined lines expresses possible points or folding lines that can be connected with other points or lines or laid on top of each other. These axioms demonstrate the basic operations of every Origami folding and are the mathematical backbone of every available folding instruction including Origami software. Along the lines of the resources in TRIZ they support the thinking process and the structured use of the existing system elements.

(2) Ideality and operator Size-Time-Cost when folding paper

TRIZ plans to subject every development task to a critical system analysis and to express the fixed notion or objective, the ideal final solution IFS (or: Ideal End Result). Inventions use knowledge and aim for increasing the system's ideality. Mostly the way to an ideal solution is blocked by an insuperable contradiction. Ideality has therefore limitations in reality that TRIZ tries to postpone with an inventive solution.

This aspect of ideality can be made clearer in a folding experiment. Imagine how thick a folded sheet of paper would get, if it was folded 50 times in a half. An outspread sheet of paper characterises the initial situation. The ideal end result would be of paper layers that were composed of the same sheet, folded 50 times.

In reality it is basically impossible to fold a normal A4 sheet of paper more than six times. This real limitation leads to another TRIZ tool, the Operator Size-Time-Cost. This method confronts the developer with hypothetical extreme situations, as much material/dimension, time or money as wanted or nothing at all. Similar to the zero-base-budgeting in business management this extreme way of thinking enforces and negates existing limitations and this can lead to ideas and stimulations that weren't taken into account beforehand.

Transferring this theoretical experiment to paper folding, the paper size could be – at least theoretically - as big as wanted and/or the thickness of the paper could be reduced to zero. In this constellation it is much easier to accept that in practice many more folds could be possible (Figure 4).

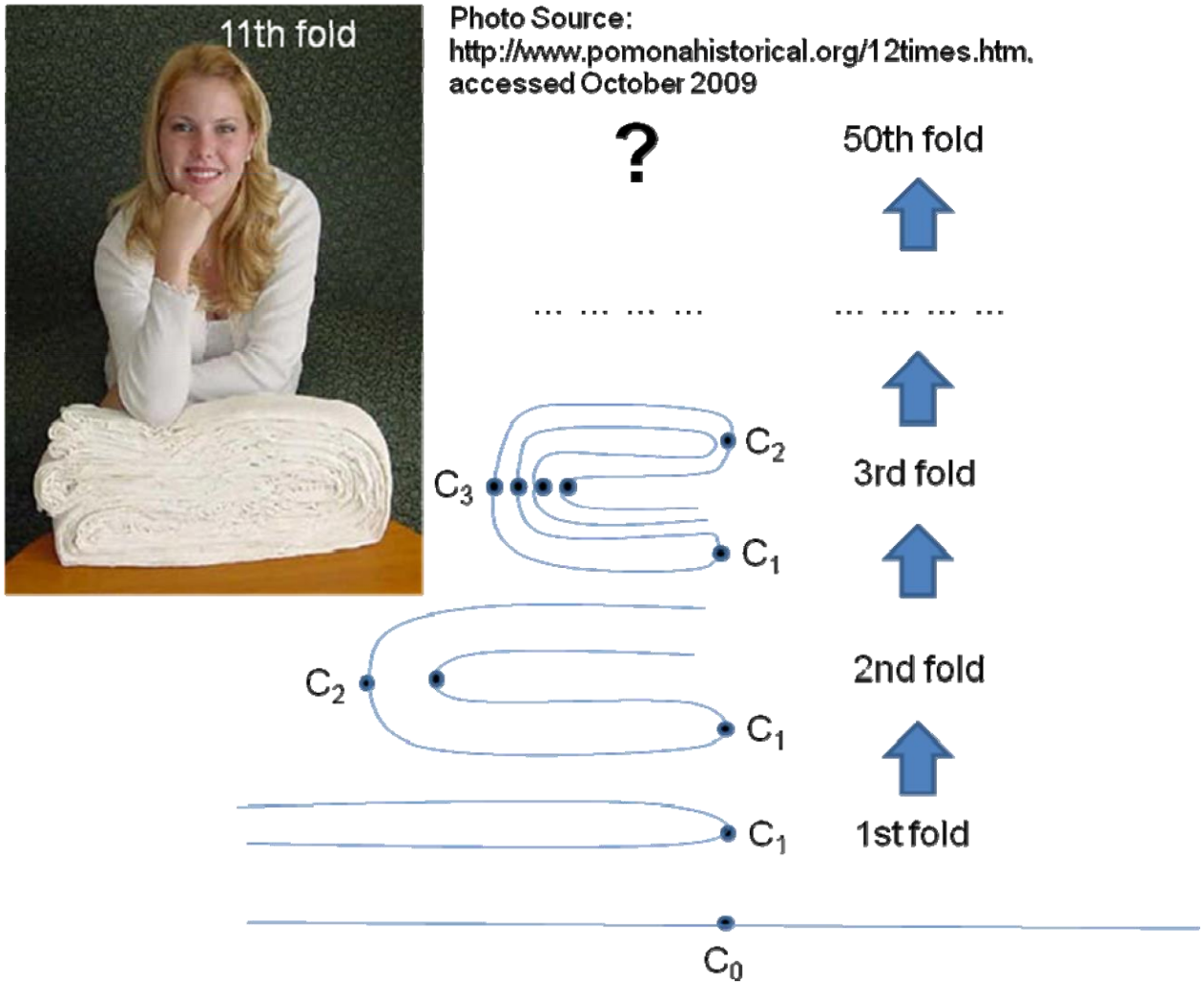


Figure 4: Theoretical paper folding experiment and real test; c = crease

A correspondingly big sheet of paper has currently only been folded 11 times into half. Both in practice and notional or with the aid of verbal descriptions one strikes against limits, just as the concept of ideal systems strikes against real limits. Only with the aid of mathematical description methods the IER can be described: to calculate the height of the paper deck, 250 foldings have to be multiplied by the paper's thickness. Executing this with paper 0,01 cm thick, the arising paper deck would reach two thirds of the distance between the earth and the sun, which is clearly beyond imagination.

In the same way that mathematics can be used here as the method to solve the original problem, the model of the ideality and the Operator STC in TRIZ can make sure to create the ideal solution that can lead to the further problem handling, even if the ideal solution cannot be realised. In the same way that mathematics are able to solve the problem of paper folding under real conditions, TRIZ can be understood as the mathematics of inventions. TRIZ identifies the direction that ideally should be taken and accelerates therefore the developing process.

(3) Anticipatory Failure Determination AFD and Reverse Origami

Another TRIZ tool, the Anticipatory Failure Determination (AFD) is used to find innovative solutions for a problem by generating the problem consciously and intentionally or even increasing it. This leads to new strategies for avoiding the problem in the first place. Within AFD the question is posed, how to lead the system to collapse, to destroy itself consciously or to run backwards. The solutions found hereby liberate a big amount of creativity to dissolve the problem contrariwise.

Following this principle also the art of Origami asks which knowledge and application arise when folding backwards, that is to say unfold the paper. Some experiments have shown that doing this is so much easier when one controls the folding process. Unfolding is therefore not a self-explanatory process, when a certain complexity of the object is achieved and the foldings are unknown.

If any object is unfolded, a look on the crease patterns show that Origami follows only few rules (URL2):

1. If one interprets every single folding line on the paper as a boundary line of a field that is bordered by the line, the fields of every folding pattern are to be coloured with only two colours in a way that never two fields with the same colour share a boundary line.
2. Look at the directions of the folds at any given vertex: the number of mountain folds and the number of valley folds always differ by two.
3. If one numbers the angles around a vertex, alternate angles, all even numbered angles add up to a straight line, and all odd numbered angles add up to a straight line (a 180° angle)
4. Look how the layers stack: a sheet can never penetrate a fold.

Reverse Origami has been looked at only recently, but in return it is the headstone for the specific generation of foldings in order to be able to create desired objects in an efficient way. Dr. Lang has created an algorithm based on these four rules that you can use to transform every desired form using mathematical calculation into a folding pattern (figure 5).

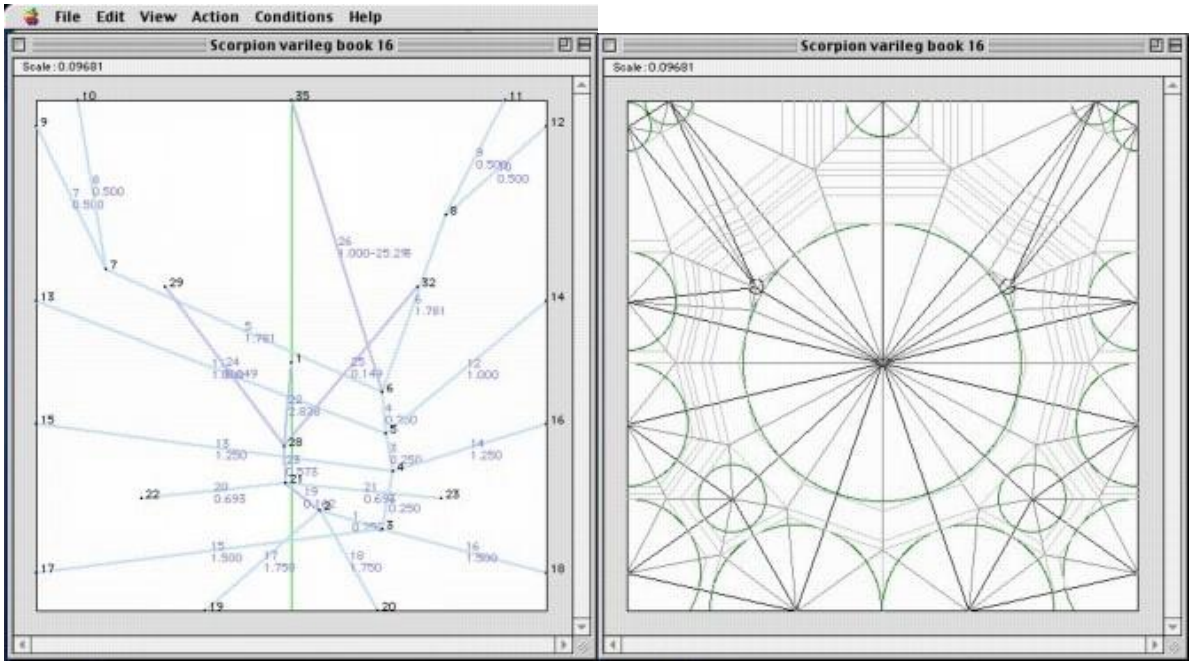


Figure 5: Software realisations to plan foldings: tree structure and transformation into a folding pattern through the use of circles using the example of a scorpion (URL3)

In technical software realisation the transformation from the original form into a folding pattern through a tree structure corresponds to an arrangement of circles and segments of circles on the paper. Every segment of a circle is therefore available to a future flap in the right length. Every circle, every segment of a circle allows the creation of a flap that later on will be a detail or a characteristic of the Origami figure. The remaining part of the sheet can be used for other parts of the object. The array of circles on an area or in a space is a mathematical problem that keeps mathematicians busy since Johannes Kepler (1571 - 1630). The results of that have been used in this Origami software. The pattern found with the help of the software can be detailed and adjusted, but the amount of flaps can't be changed in this stadium, it can only be detailed.

This is exactly how the solution found with TRIZ works as a basic model for further elaboration and adjustment on the specific problem. The solution space has been narrowed, but with this focus every trial-and-error can be stopped and directed into promising ways. The elaboration of the solution corresponds to the detailing of the flaps of an Origami figure.

The software is available for download on Dr. Lang's homepage and runs on prevalent operating systems (URL3). That means wider diffusion for technical product development is possible. But still it is to be expected that analogically to the TRIZ software, it is nearly impossible to use the knowledge quickly without the help of experts. Origami experts like Dr. Lang and TRIZ moderators are available to accompany the process.

(4) Contradictions and conflicts in the folding art of Origami

(a) Technical contradiction parameters and Origami analogies

In general, TRIZ supports thinking in analogies and overcomes habits and thinking in specific disciplines. A basic concept of analogy instruments in TRIZ is thinking in contradictions. A physical contradiction is, whenever one task requires two contradictory system parameters. A technical contradiction is when by improving one parameter the other one worsens. Analysing Origami models optical, production-oriented, mathematical, scientific and artistic analogies become apparent.

Every Origami folding can easily show physical contradictions and express ambiguity of the same system parameter. Beginning with the declaration that a two-dimensional object, the sheet, becomes three-dimensional by folding it, complete different objects can be folded with one sheet of paper (Figure 1 and 6).

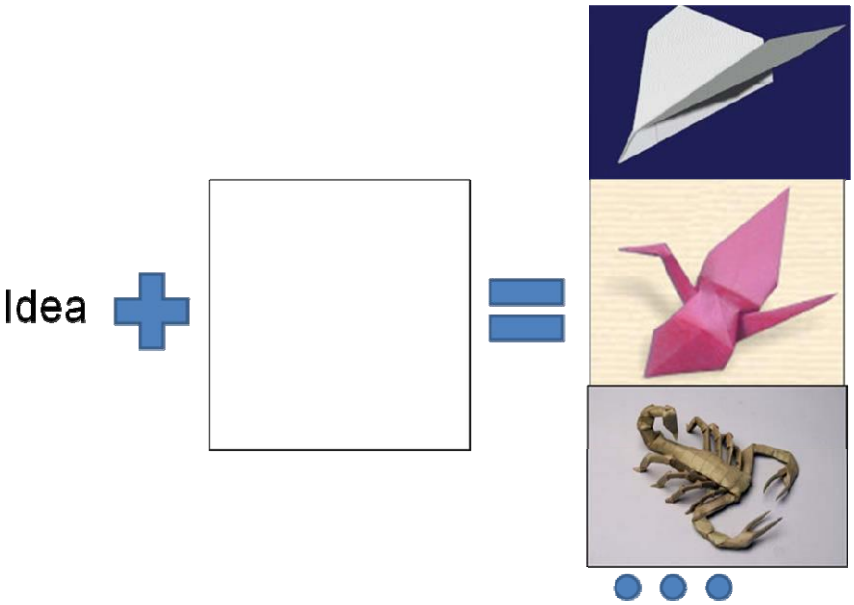


Figure 6: A square sheet of paper is a plane, is a crane is a scorpion (scorpion by R. J. Lang)

Folding paper allows to experience, that paper has a wide square dimension and at the same time a little one, it is square and by folding it round, or it can be thin while it is outspread, but folded it is thick. Depending on how you look at it, it is either a plane, which is familiar, or the crane, which is rather not familiar, or it becomes a scorpion that is totally unknown, although they are all made of the same sheet of paper. This example shows clearly the conflict of perception that prevents innovative solutions in real life.

In industry many innovative applications are known whose development needs to be oriented on exactly this ambiguity. Wherever it is required that small structures become big in terms of volume at

a special time, parallels to Origami can be found. There are medical systems that need to perambulate the whole human body in a small shape before “unfolding” themselves (Figure 7).

Figure 7: Stent in medical engineering (Courtesy K. Kuribayashi, Z. You, University of Oxford)

So-called stents in medical engineering are folded devices that are introduced in blood vessels in order to get rid of deposits in the arteries. The shown object, made of stainless steel, is 12 mm small at the beginning and unfolds itself to the size of 23 mm in the blood vessel.

In automotive engineering this ambiguity can be of big use. Airbag foldings and other security systems like crash structures made of metal or parts of the car body made of membrane already use or might use simple Origami techniques. Beginning with furniture one could mention fashion, architecture or telescope lenses, but also dough making in food industry, protein folding in chemistry or genetics as well as folding of time and space in astrophysics – they all show application of Origami folding.

Generally the connection between a special Origami technique and the characteristics of the future solution has to be analysed. For example structures could be evaluated in terms of how low the generated stress on the paper is or how to avoid the paper to rupture in a point where folds cross. Furthermore, Origami could be used in special problems as a low cost method of prototyping. It could

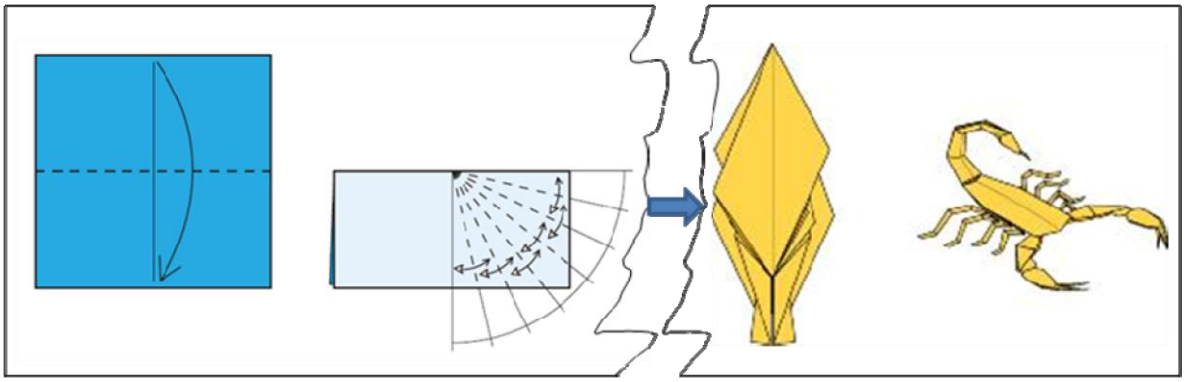
be analysed under which circumstances extremely long, short, flat, reduced in terms of surface or volume, easily unfoldable, movable or stable, firm or bendable, streamlined or flexible forms could be designed.

In these terms some technical parameters that build the lines and columns of the TRIZ contradiction matrix are reflected. Recent sources show, that the patent literature results from contradictions that consist of 2 of 48 updated parameters at the most (Mann, 2008). This list of 48 parameters is worth being analysed regarding its analogies to paper folding. Both technical parameters and the innovative principles of TRIZ can be understood as abstract tools; they can fall back on formulated problems as well as their solutions and knowledge without even knowing the details of where this knowledge has been applied so far. The approach in the (not only) computer aided Origami folding art uses mathematical rules as abstract descriptions of desired parameters, similar to Altshuller's approach to file the knowledge found out in patents in the list of technical parameters and the contradiction matrix.

(b) Basic innovative principles and basic Origami forms

In the cells of the contradiction matrix, build of 39, recently 48 technical parameters (Mann et al., 2008), the 40 innovative principles are to be found that have been used successfully in a given conflict situation in patent literature most frequently. Not only is it noticeable that the parameters in conflict repeat themselves, but also their solutions.

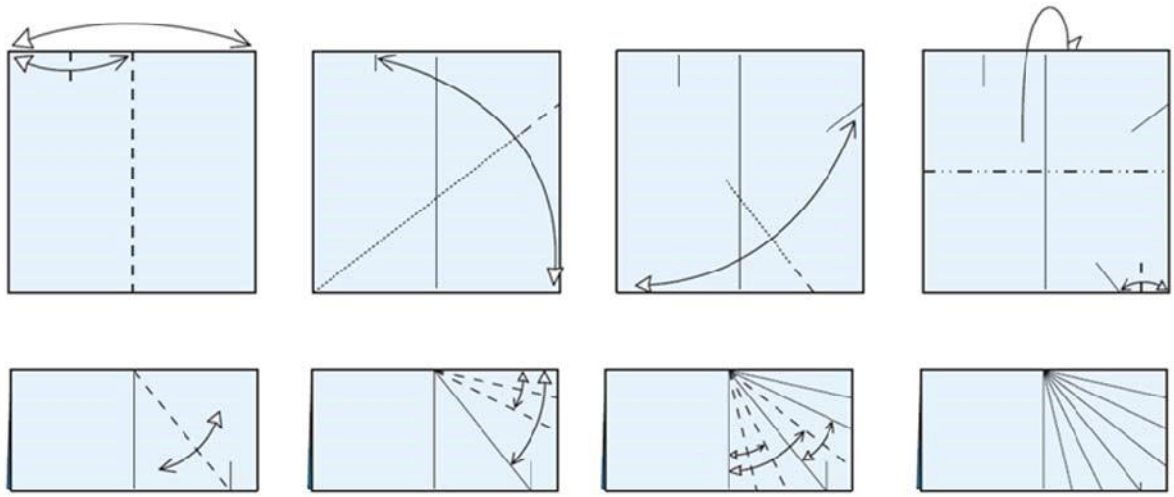
Also, in the art of Origami already knowing some recurrent basic forms can be useful in order to be able to decide how a desired form is realisable later on. When folding an Origami object, the first question is, if the sheet should be folded diagonally or straight (Figure 8).



Source: Origami and geometric constructions; by Robert J. Lang

Figure 8: The first two steps when folding the scorpion (URL4)

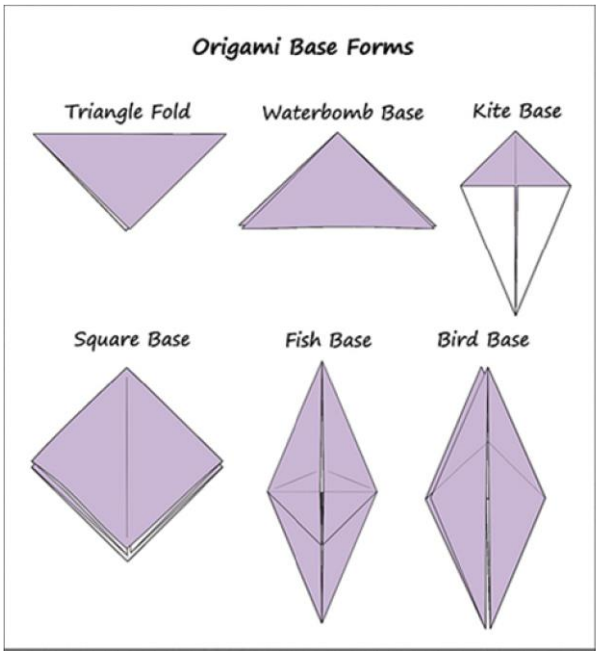
In this procedural method of folding a scorpion, the basic operation at the beginning is halving the sheet by a straight line. In the next step the folding sequence follows the basic geometrical possibility to divide a square angle into seven equal parts (Figure 9).



Source: Origami and geometric constructions; by Robert J. Lang

Figure 9: Basic folding sequence, dividing a straight angle in seven equal parts using triangles (URL4)

The basic forms resulting from the first folding steps, e.g. the triangle fold, the waterbomb base or the kite base, already show rules that can be fallen back upon later in order to have the right amount of material on the right location to design the details (Figure 10).



Source:
http://www.flickr.com/photos/origamis/3194374168/

Figure 10: Selected Origami base forms and the most relevant of the 40 inventive TRIZ principles

Knowing these simple basic forms already enables a wide range of middle and end forms or certain effects, such as stiffness, flexibility or flatness of the object. Even if that alone does not necessarily be the objective, it gives the possibility to choose from them, depending on the desired effect. Knowing the folding instruction or the tricks for getting certain effects, by exercising one gets the ability to create own forms and define own tricks to create certain effects.

In the Origami art this knowledge basically consists of mathematical correlations that describe a selected variety of forms. The same folding creates in a modified way and/or length completely new objects. Similar to the recurrence of a comparatively small amount of solution principles in TRIZ, Origami also shows a comparatively small amount of basic folding and mathematical rules, upon which every folding instruction recurs. It is not even necessary to know the purpose of a certain folding in former Origami models, because in this case as well, the objective is to create a desired form, independent from the knowledge in which other forms it already had its influence in.

Without analysing every innovative principle en detail in view of Origami in this paper, still the first 20 seem to be especially relevant for the Origami analogy. The first principle, segmentation, can already be confirmed in view of the above mentioned correlation: Origami disassembles the paper not physically – that would be contrary to the basic rule – but still notional in individual circles and segments of circles that later on is available for the flaps.

Asymmetry, nesting or counterweight, principles 4, 7 or 8 are also obvious when folding. Prior action, principle no. 10, is often used in more complex Origami objects: Certain folds are done at the beginning of the process and reversed in order to use them later on in the process. In the several hours' process of folding the scorpion shown earlier, some creases can't be done because of the limited accessibility in their full performance without bringing some process steps forward. For this aim the paper is folded and unfolded during the first 45 minutes in order to prepare the paper by prior action for future folds. In such a way many TRIZ principles can be transformed or at least recognized in a great amount and allow increasing the appreciation for systematic creativity.

(5) Substance Field Analysis SFA and Origami Optimization

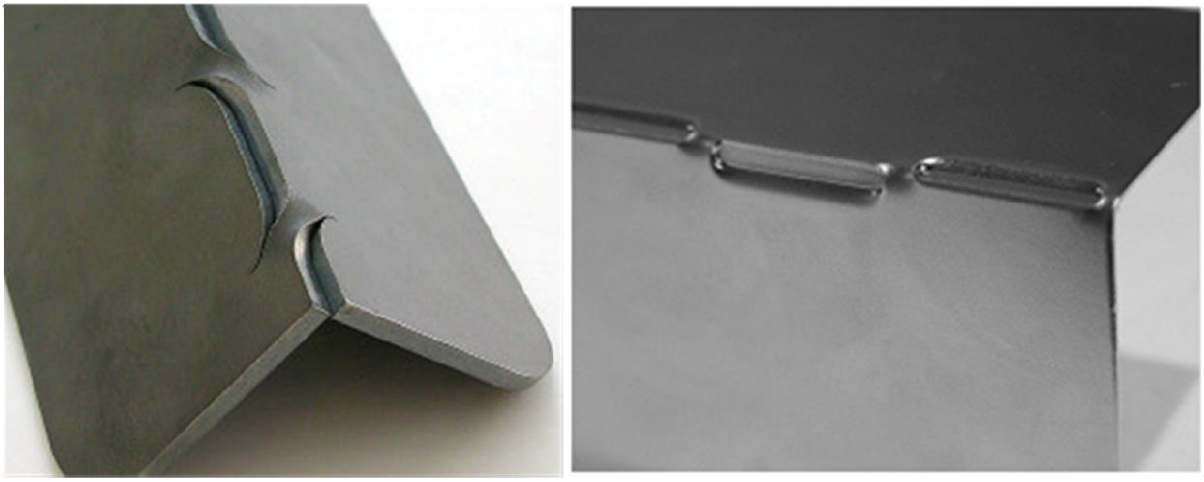
Not every technical problem has its root in a fundamental physical contradiction or a technical conflict. If the focus lies on improving a technical system regarding its ideality, making it more efficient, letting it work better in some parameters or less harmful, the TRIZ model of Substance Field Analysis SFA comes into consideration.

Every functioning system consists of at least two basic elements that correlate through a mediator, e.g. a field or an energy source. If one of these two elements gets removed, the system breaks down and it doesn't work any more. If one wants to optimize this system, it must be looked at more precisely and modelled as a triad of substances and field. Similar to the allowed operations when modifying

triangles in geometry, TRIZ knows 76 standard solutions for the improvement and completion of these effect triads. These standard solutions work with an analogical way of thinking. If one succeeds to model a problem in one of these triangles the standard solutions can provoke ideas.

In geometry the allowed mathematical operations consist of sums of angles or the Pythagoras' theorem of the proportion of the legs of a triangle. The correlation to Origami becomes apparent as by folding paper not only triangles become visible but also fundamental geometrical rules.

In engineering mainly other material than paper is used. In the Substance Field model instead of paper for example a metallic material like plate would be used. This also changes the folding technique (Figure 11).



Quelle: http://www.industrialorigami.com, Januar 2009

Figure 11: So-called Smiles in sheet metal forming, alternatingly done with a high speed LASER in order to create creases (URL5).

In order to fold sheet metal plates analogically to paper, so-called smiles are stamped with a high speed LASER, creating a load-bearing edge-to-face overlap that alternates from smile to smile. Another example highlighting the analogy between sheet metal and paper is the often insufficient stiffness of paper folds. In sheet metal forming, vault structures and surface curvatures have proven successful. Those could be applied to paper, too. Indeed, Origami knows rules to generate certain structures and textures to surfaces.

To continue the analogy thought, one could ask to what extent material in general can be defined as a function of its distance to paper. Depending on the material, its behaviour, could be expressed as a distance to the material paper, supplemented by specific parameters such as flowability and reversibility of a form change. By applying these rules on paper, these connections can be experienced and comprehended much easier, as this sometimes is the case with sheet metal.

Also in paper folding, the accurateness of the edges coins the later appearance of the object. This is the reason why also in Origami, more and more tools are applied that produce certain properties of the creases. Also regarding the choice of paper, one can get advice from the experts. The so-called "Zander's Elefantenhaut" a special paper trademark, is considered as optimum when sharp creases are to be obtained. Recycled paper, however, is inappropriate for this purpose, due to its small fibre length. It is historically that paper was often produced of elephants' manure that due to its high cellular portion and long fibres was very durable. The very same requirement is often to be fulfilled by Origami models, so that artistic models are made of sheet metal or bronze. Also paper models are preserved by synthetic resin coating or materials are used that harden after the folding process.

Three-dimensional objects always being the objective, some flat models can be inflated to three-dimensional shape of be filled another way, what matches the introduction of another substance in the method Substance-Field-Analysis SFA in TRIZ. This is not only recognized by packaging industry. Also the unfolding of an automobile's airbag founds on a gas stream as additional substance.

The TRIZ tool Substance-Field-Analysis SFA was developed further in the course of time. Not only the list of the technical parameters was enlarged to 48, but also the SFA was adapted for practical reasons and conditions by the Tool-Field-Function Model (TIP-Model) (Altshuller, 2004). To the extend classical TRIZ tools are developed further, one can also record a turn for industrial requirements for the art of Origami.

(6) S-curve, patterns of evolution and Dynamic Origami

The patterns of evolution offered by TRIZ show how inventions change over time and progress. Altshuller extracted 8 basic patterns of evolution following this order:

1. Every system develops along a life cycle stepwise from birth, childhood, adolescence andmaturity to death.
2. Development goes in a direction of increasing ideality.
3. Non-uniform development of system elements that lead to new problems or shows oldproblems more clearly.
4. Evolution toward increased dynamism and controllability.
5. Increased complexity than simplification.
6. Evolution with matching and mismatching elements.
7. Evolution toward Micro-level and increased use of fields.
8. Evolution toward decreased human involvement.

Similar to the TRIZ statement of a directed evolution, also Origami has developed from an only intuitive trial-and-error method to a directed playing to a systematic folding technique in the last 50 years. Younger Origami folding, for example, creates structures that are flexible and move (Lang,

1997). The flexibility is not only triggered by an exterior force, but the figure links the flaps such that the movement of another, often hidden connection in the interior of the object. Depending on the material used, Origami partly offers the same possibilities and effects as technical components. Here, more investigation has to be done, in how far Origami structures of alternative materials would be able to transmit or produce tensions, forces or fields.

Currently even more significant is the arrangement of the folds in the way of the so-called Miura-Ori pattern: it makes the folding area draw aside when gentle pressure is produced in order to let the folds yield to create a flexible hinge (Figure 12).

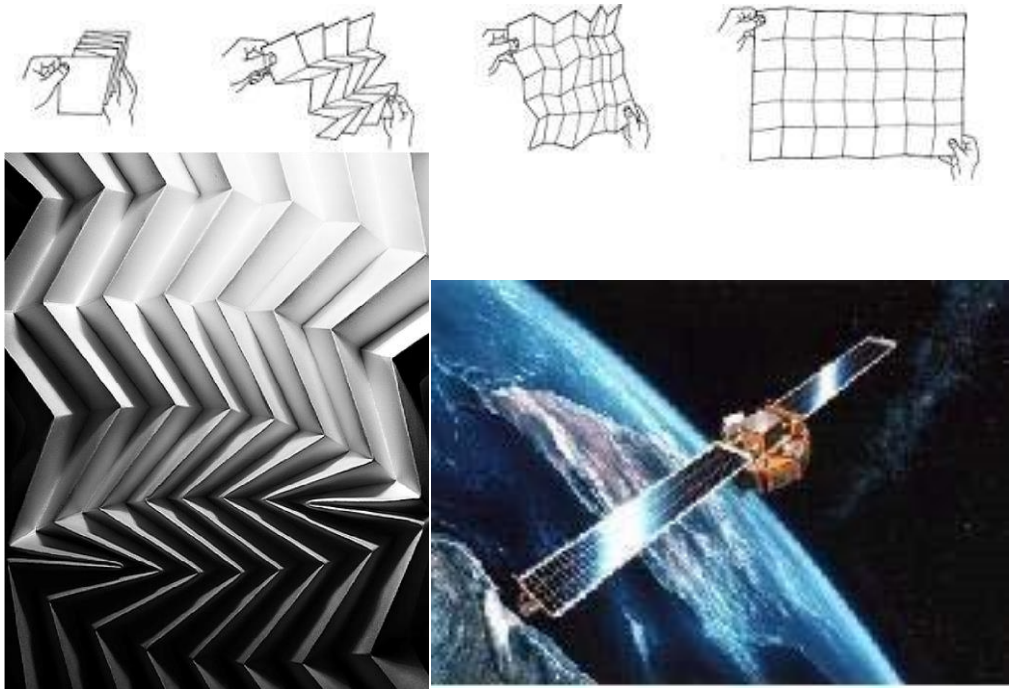


Figure 12: flexible stable Miura-Ori-Pattern and application as solar canvas in space

This patent-registered folding pattern is called after its inventor Prof. Koryo Miura, a Japanese physicist and director of the Tokyo University lnstitute of Space and Aeronautical Science. The Miura-Ori-Pattern's distinctiveness is that the folding goes back to its original status without damaging the paper or even stress it mechanically (URL6,7). This pattern solves in the same time effectively and aesthetically the conflict between mobility and stability and overcomes the physical contradiction between a small and big surface area of the material. The Miura-Ori-Pattern was the inspiration for the development of a huge solar canvas used in space.

Other Origami structures are capable of making noises by moving them. Also generating initial tension by narrow packing density can be imitated with paper. The process of coating paper or selected parts of the Origami structure with foil or colours, the soaking of cellulose in rosin (beforehand or afterwards) or in general folding with different material than paper allows combinations of fluids or

gases, as well as applications in more aggressive environmental conditions and therefore leads to new operational areas.

Another Origami optimization strategy is to work with curved and smooth folds in order to create even more free form lines and areas, as well as stable structures. For the purpose of a technical application the edges should not be sharp, because that weakens the material in this area and the object gets less stable in a toppled level. Development goes to the point where objects don't have sharp folding edges any more. Disordered position and smooth contours of folds, similar to a crumpled sheet of paper, show new possibilities for creating forms or protecting them.

Further on, figures are put together off three-dimensional structures (Mitchell, 2005), an approach forbidden by classical Origami. Although some of these forms could traditionally be folded off one sheet of paper without additives, still the combination of folded objects enables a new level of form attainment and allows at the same time to keep the complexity of the folding in an appropriate scope.

The maceration of the classical Origami rules is observable at the most where scissors and glue are used and/or the paper is ruptured. Foldings can penetrate themselves there. This technique is called Kirigami (URL8). The amount of possible structures increases hereby (Hangar-7, 2005).

In comparison to these lines of development, the miniaturisation of Origami structures almost is a tradition. Under the keyword Nano-Origami paper works are manually produced out of a piece of paper with only one square centimetre of area or even smaller. The resulting models are only to be looked at through a magnifying glass and have to be prevented from draft.

In industrial engineering the producibility or reproducibility of a form or a technical effect is more important than an artistic or aesthetically sophisticated art of folding for its own sake; so it seems technical applications are much easier to fold as the complex instructions suggest, as they require for example imitating a nature-given object off a sheet of paper following the classical Origami rules. Still, Origami can be understood as a creativity technique in order to understand selected TRIZ tools more easily and as a form of art that systematically generates creativity. To the point of evolution pattern Origami itself is to be understood as a technology that is applicable in technological application, as well as TRIZ supports inventive problem solving on the meta-level of inventing.

5. Conclusion of the Origami-TRIZ-Synthesis

Origami "unfolds" its industrial usefulness exactly where reducing parts, reducing manufacturing and assembly operations, stock or transportation expenses by reducing volume or weight or increasing accuracy and rapidness in prototyping or product development is desired. The usefulness of Origami as a method of Rapid Prototyping on the other hand competes against alternative techniques as clay modelling, selective laser sintering or stereo lithography.

Origami uses paper, which is a rather cost-saving material. But still, also paper can be arbitrarily expensive, if one only put the requirements high enough. But it can still be used as an ideal simulation material in order to comprehend some manufacturing correlations. At the same time paper models are capable of transmitting basic ways of thinking of TRIZ, a fact that has been proven successfully by the author in her lectures. On this note Origami prepares the ground for a better understanding of targeted creativity, not only with TRIZ tools. Origami exercises systematic thinking by connecting scientific rules and mathematical basics of theory of numbers, geometry, trigonometry, linear algebra and binary numbers. Even positive effects on health and well-being are reported, as Origami trains concentration, fine motor skills and dexterity, but also spatial sense and it connects sense of achievement and fun. That is also the reason, why Origami is more and more used in learning therapy and when teaching kids (Baicker, 2004, Joosten, 2007, URL9,10). In this application area TRIZ has definitely a backlog demand; the potential is there, first approaches are to be met (Sidorchuk et al., 2006).

The shown width in which both Origami and TRIZ knowledge can be used in engineering is by far not exhausted. From the knowledge of the art of Origami and the methods of TRIZ more and more innovative problem solutions can be deduced than it could be assumed. More investigative work on the activation of the innovative potential of Origami for technical and industrial applications is to be done. In the same way that TRIZ can be used as an objectifiable method of planning inventions, Origami can support solving future problems not only in engineering.

Note of thanks

For the author, the shining example in first trial-and-error, and then more and more fluent and purposeful folding of a square sheet of paper is her now 13year-old, elder son **Moritz Wilksch**. The author's initial reservation about Origami and its mere decorative character was not shared by him. Only **Dr. Robert J. Lang**'s presentation on the TED Conference, his willingness to share information as well as a meeting during the Annual Conference of Origami Artists 2009 near Berlin has convinced the author, that artistic approaches can also be of high industrial value, but this being often neglected. In reverse, also the beauty of a method like TRIZ can be highlighted by Origami in a particularly appealing way. I express my thanks to **Prof. Dr.-Ing. Alexander Czinki**, University of Applied Sciences FH Aschaffenburg, for the lively exchange of ideas and his understanding for the potential addiction that the subject radiates. I also thank **Iris Kuhlmann** for translating big parts of the German text into English.

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Effective Method to Create High-Value-Added Product based on Inventive Thinking Power –Utilization of Two Types of Redesigned Contradiction Matrices-

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Abstract

It was found from my previous survey that majority of Japanese manufactures still (mainly export-driven manufacturers) continue "kaizen activities" like QC and VE based on "Catch-up Strategies", even comeback by developing countries like "BRICs" in 2000's. Fixed on same strategies without an ingenious attempt, they might face severe challenges to keep industrial competitiveness. Therefore, eliminating the mismatch phenomenon like this, they have to make an effort to practice "Innovation Activities" as one of "Front runner Strategies". To that end, it's required to gain an understanding of the inventive thinking power to create "High-Value-Added Product (HVAP)". Here, I think TRIZ has chance to show off. Because the result of our study about an analysis of "Recent Big Hits (RBH) =HVAP" clearly shows that "Realization of Latent Required Functions (RLRF)" and "Solution of Product Contradictions (SPC)" are some of essential conditions for HVAP. Therefore, we would like to introduce effective method to create HVAP based on inventive thinking power, developing two types of "Redesigned Contradiction Matrices (RCM)", which are understandable and practical techniques for TRIZ practitioners, especially TRIZ beginners. Two types of RCM are redesigned based on "Altshuller's Contradiction Matrix (ACM) as one of effective techniques for HVAP.

Keywords: High-Value-Added Product, inventive thinking power, two types of "Redesigned Contradiction Matrices" ,TRIZ beginners

1. Introduction

What the survey conducted in 2006 made clear is that most of Japanese companies have a lot of challenges about "Structure of New Product Planning Stages "and "Innovation Power", commonly-used MOT techniques at production activities are still limited to QC and VE and only focus on Brainstorming technique (BS) at idea generation stage (Sawaguchi, 2006). That is to say, TRIZ is still an underutilized technique in creative activities at the companies. QC and VE are still keeping the position of mainly utilized techniques. It is because QC has been contributing to the improvement of "Product Quality" through "QC Circle" and "Kaizen Activities (KA)" since 1960's (high-growth

period) and the competing power based on cost performance has been enhanced by VE since 1973 oil shock. However, if they only chase 'Catch-up Strategy" like above-mentioned improvement activities, it will be difficult to arrive in the challenges regarding the upstream stage of "Product Development Activities (PDA)". This is fair statement. Consequently, I suggest that they actively use TRIZ methodology against the challenges regarding R&D and Engineering divisions (Structure of New Product Planning Stages) on "Top down Management". Because the effectiveness of TRIZ is becoming clear from some presented papers and examples of the application at the international conference focusing on Innovation like ETRIA, ICSI and so on. We can say with fair certainty that this suggestion is one of right directions for utilizing TRIZ. However, to be frank, a majority of companies but some big hesitate to introduce TRIZ in real field (Sawaguchi, 2006). Because compared to both QC and VE, TRIZ leaves the impression of complicated and profound method. Seeing the present situation firsthand, recently, I think that it might be effective to practice proposed method "Mihara et al.(2010)", which is called two types of "Redesigned Contradiction Matrices (RCM)", based on the "Middle-up Approach", instead of "Top down Management". Because "Middle-up Approach" usually deals with the possibility of PDA". Therefore, we want to extend TRIZ thinking about "Contradiction Solution (CS)" from field site(at upstream stage) to top management site by "Middle-up Approach" focusing on PDA. To be specific, if we are able to prepare "TRIZ story" to use easily and effectively like QC story, which once known for effective tools at the manufactures during the years of steep economic growth in Japan, we might draw a right direction to facilitate inventive thinking power. With that, we prepared not only "two types of RCM" but also "Contradiction Definition Template (CDT)" by each RCM and "Flowchart for utilization of RCM", instead of "TRIZ story". Two types of RCM are understandable and practical techniques for TRIZ practitioners, even beginners and are redesigned based on benchmark activities focusing on original "Contradiction Matrix (CM)" developed by Altshuller, which is a typical technique in TRIZ field(Kaplan,1996). Therefore, in the first half of this paper, we would like to explain the basic concept of two types of RCM and introduce the effectiveness of proposed methods for creating "High-Value-Added Product (HVAP)" through case examples in latter half.

2. Necessity of Two Types of Redesigned Contradiction Matrices (RCM)

In order to facilitate inventive thinking power to create HVAP, understanding and practicing whole TRIZ methodology is an ideal way. But it sounds like unrealistic demand because of limited time in real field. On the other hand, the result of our study about an analysis of "Recent Big Hits (RBH) =HVAP" clearly shows that "Realization of Latent Required Functions (RLRF)" and "Solution of Product Contradictions (SPC)" are essential conditions for realizing HVAP. (Sawaguchi, 2010) Because of these factors, it is clear that grasping and solving product contradictions systematically are needed in real field under limited management resources. Therefore, we want to introduce two types of RCM as one of effective methods to realize above-mentioned purpose.

▪2.1Product Development Activities (PDA) and Each Level about Technical Contradiction

Through PDA, first of all, grasping "Voice Of Customers (VOC)", we have to define "Required Functions (RF)". After that, we must consider the mechanism to achieve RF. As the result of a series of activities, we usually get to the basic concept. At this stage, we can imagine whole shape of an object. At the next stage, we have to decide detail of mechanisms like considering length, area and volume of each component and finally get to the design of the product. Figure1 shows "Demand Characteristics for Three Stages of PDA". Therefore, we prepared two types of RCM to deal with demand characteristics for three stages (at least, two) of PDA (See Figure2).

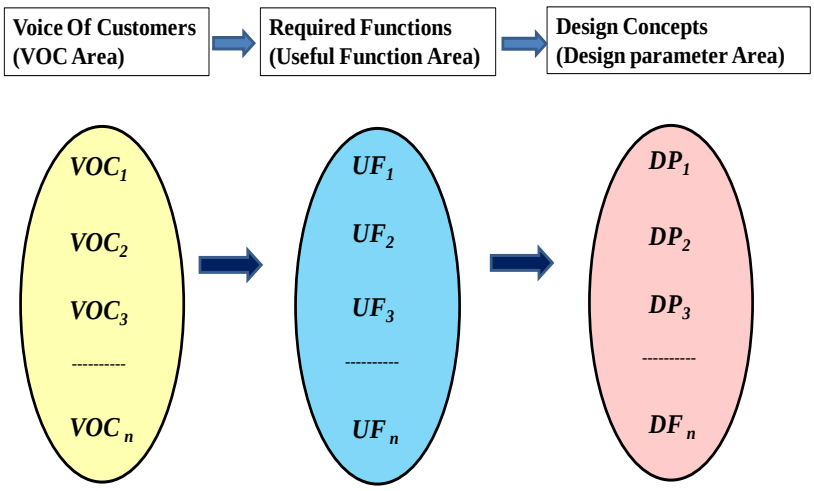

Figure 1. Demand Characteristics for three stages of PDA

To be specific, we want to utilize two type of RCM as usage in the real field, which exist technical contradictions (including physical contradictions) corresponding to demand characteristics for three stages. That is why we prepared two types of RCM.

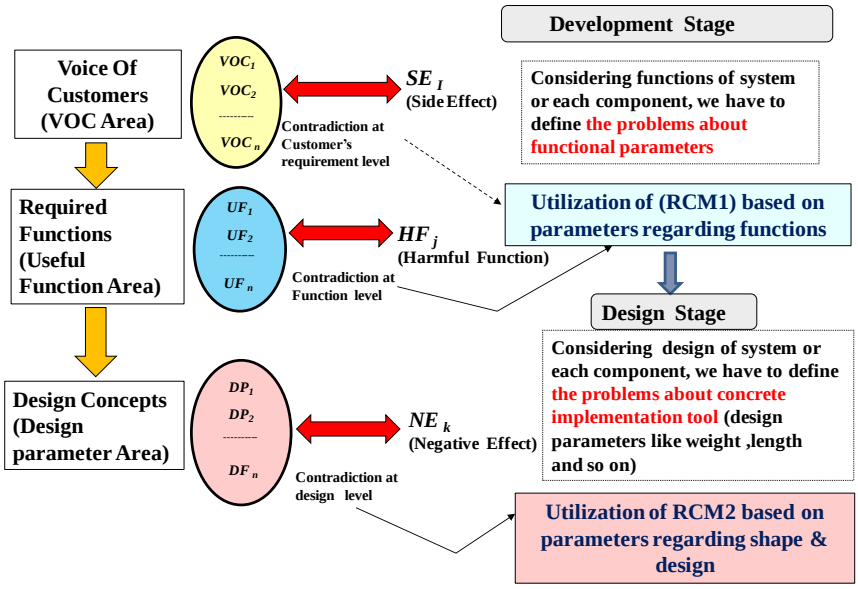

Figure 2. Demand Characteristics for three stages and Two Types of RCM

2.2 First Contradiction Matrix (RCM1) Focusing on Parameter Regarding Function.

Taking RF of system or its components into account at upstream stage of product development, first contradiction matrix (we want to call as RCM1) focuses on parameters regarding function and is for fuzzy front end of product process. Because engineers have to define and solve a series of challenges to realize RF through PDA. As just described, RCM1 is developed for the utilization in" RF Area (Useful Function Area)". Therefore, we select 22 parameters from 39 on "original CM (Altshuller version)" as parameters about function and organize 13 parameters from 22 because some of parameters are kindred (See Figure 3).

Parameter of RCM 1				Parameter of original version (Altshuller version)
Performance	Reliability /Accuracy	Reliability	F1	27 Reliability
		Accuracy	F2	28 **Accuracy** of measurement
				29 **Accuracy** of measurement
	Harmful effect	Hramful effect	F3	30 **Harmful factors** acting on object
				31 **Harmful side effects**
	Operability /Durability	Operability	F4	33 **Convenience** of use
				38 Level of **automation**
		Complexity of device	F5	37 Complexity of device
		Maintenance/Repairbility	F6	34 **Repairability**
				36 **Complexity** of device
		Adaptability/Elasticity	F7	35 Adaptability
		Durability	F8	15 **Durability** of moving object
				16 **Durability** of immobile object
	Manufacturability	Manufacturability/ Productivity	F9	32 **Manufacturability**
				39 **Productivity**
	Loss	Amount of substance /Waste	F10	26 Amount of substance
				23 Waste of substance
		Amount of information/Loss	F11	24 Loss of information
		Amount of time/Loss	F12	25 Waste of time
Energy			F13	19 **Energy** spent by moving object
				20 **Energy** spent by immobile object
				22 Waste of **energy**
			13	22 Parameter

Figure 3. 13 Parameters Regarding Function on RCM1

It's possible to utilize RCM1 not only in "RF Area" but also in "VOC Area", even fuzzy front end, if we predict "Technical Contradictions" coming in near future.

2.3 Second Contradiction Matrix (RCM2) Focusing on Parameter Regarding Shape and Design.

Solving the challenges related to implementation tools after progress of basic design or for improvement of existing product in the market, second contradiction matrix (we want to call as RCM2) focusing on parameter regarding shape & design is prepared. For these reasons, we select 17 parameters from 39 as parameters about shape &design and organize 11 from 17 because some of parameters are kindred (See Figure4). In particular, deciding that we don't need to distinguish between "moving" and" immobile" constitutes a major cause of organizing 11parameters.

Parameter of RCM2		Parameter of original version (Altshuller version)
Weight of object	D1	1 Weight of moving object
		2 Weight of immobile object
Length of object	D2	3 Length of moving object
		4 Length of immobile object
Area of object	D3	5 Area of moving object
		6 Area of immobile object
Volume of object	D4	7 Volume of moving object
		8 Volume of immobile object
Speed	D5	9 Speed
Power	D6	10 Force
		21 Power
Tension,Pressure	D7	11 Tension,Pressure
Shape	D8	12 Shape
		13 Stability of object
Strength	D9	14 Strength
Temperature	D10	17 Temperature
Brightness	D11	18 Brightness
	11	17 Parameter

Figure 4. 11 Parameters Regarding Shape and Design on RCM2

2.4 From 40 Inventive Principles to 25 Inventive Principles for Two Types of RCM

We tried to consider the meaning of each inventive principle in order to consolidate from a series of inventive principles (it's called 40 inventive principles) to smaller numbers like making 39 parameters smaller numbers for two types of RCM(See Figure3 and 4). Expected outcome of proposed CM (two types of RCM) compared with original CM is to utilize easier for not only TRIZ experienced practitioners but also TRIZ beginners. Because proposed CM is simplified and systematical. In order to consolidate 40 inventive principles, we utilized affinity diagram.

	New Inventive Principle		Original Inventive Principle
Taking out/segmentation combination/combinig	1	Taking out/Segmentation	1 Segmentation
			2 Taking Out
	5	Merging	5 Merging
	7	Nested Doll	7 "Nested Doll"
	26	Copying/Substitution	6 Universality
			26 Copying
			28 Mechanics Substitution
			29 Pneumatics And hydraulics
change of shape	4	Asymmetry	4 Asymmetry
	14	Curvature	14 Curvature
	17	Another Dimension	17 Another Dimension
change of thinking or viewing location	10	Preliminary Action	9 Preliminary Anti-Action
			10 Preliminary Action
			11 Beforehand Cushioning
	13	The Other Way Around	13 The Other Way Around
	16	partial Or Excessive Actions	16 Partial Or Excissive Actions
	23	Feedback	23 Feedback
	25	Self-Service	25 Self-Service
	27	Cheap Short-Living Objects	27 Cheap Short-Living Objects
	22	Blessing In Disguise	22 Blessing In Disguise"
	34	Discarding And Recovering	34 Discarding And Recovering
change of materials	3	Local Quality	3 Local Quality
			32 Colour Changes
	31	Porous Materials	31 Porous Materials
	40	Composite Materials	40 Composite Materials
	30	Flexible Shells And Thin Films	30 Flexible Shells And Thin Films
	33	Homogeneity	33 Homogeneity
Change of supplying method of energy	12	Equipotentiality	8 Anti-Weight
			12 Equipotentialitychange
	15	Dynamization	15 Dynamization
			18 Mechanical Vibration
			19 Periodic Action
	20	Continuity Of Useful Action	20 Continuity Of Useful Action
			21 Skipping
change of situation or characteristic features	35	Parameter Changes	35 Parameter Changes
			36 Phase Transitions
			37 Thermal Expansion
	24	Intermediary	24 Intermediary
			38 Strong Oxidants
			39 1 nert Atmosphere
25 Inventive Principles			40 Inventive Principles

Figure 5. New 25 Inventive Principles for Two types of RCM

As shown in Figure 5, we pay regard to each number for each inventive principle on original CM. Now, we are going to show you complete pictures for two types of RCM (See Figure6, 7).

Worsening Feature / Improving Feature			Performance												Energy
			Reliability /Accuracy		Harmful effect	Operability /Durability					Manufacturability	Loss			
			Reliability	Accuracy	Harmful effect	Operability	Complexity of device	Maintenance/Repairbility	Adaptability/Elasticity	Durability	Manufacturability/Productivity	Amount of substance /Waste	Amount of information/Loss	Amount of time/Loss	
			F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13
Performance	Reliability /Accuracy	Reliability F1	B1,B2, B3,B4	3,10, 23,1	27,35,1, 40,26	27,17,40, 10,13	27,40,26	1,10,13,35	13,35, 12,24	1,35,3,25, 34,27,26,40	1,35,26,24	20,26,40,3, 10,35,24	10,26	10,30,4	20,10,27,15 35,23,
		Accuracy F2	5,10,1, 23,3	B1,B2, B3,B4	26,24,22, 10,35,3,33, 4,17,34	1,13,17,34, 3,23,26, 10,34,15	26,24, 3,	1,3,13,10, 25,27,35, 34,26,15	13,35,1	26,3, 27,40,10, 24	26,35,25,15, 1,13,17,34, 3,23	1,26,3,30, 10,16,31, 35,24	13,10,2,3: 4,7,24,25, 37	24,34,26, 3,15	3,26, 1,13,
	Harmful effect	Harmful effect F3	27,24, 1,40,	26,33,23, 3,10,15, 4,17,34	B1,B2, B3,B4	1,25,26,24, 33,3,34	22,15,26, 40,1,20, 27,	35,10,1,22, 15,26,40, 31	35,10, 22,31	22,35,33,26 31,17,1,40, 20,24,16	24,35,1,22, 13,15,	35,33,26,31, 3,24,1,22, 15,40,10	22,10,1, 20,26,	35,15,34, 1,22	1,24,26,27, 35,10,22, 15,22,
	Operability /Durability	Operability F4	17,27,12, 40,10,3,	25,13,1,34, 3,35,23, 26,10,15	1,25,26, 24,33	B1,B2, B3,B4	34,27,25	12,26,1,3, 25,17,35,13 24,10	34,1, 16,27,4, 35	26,3,12, 25,1,16, 10	1,5,12, 26,13, 35,	12,35,26,3, 1,24,13,10, 15,5	4,10,27, 22,35,33	4,26,10, 34,24,35, 30	1,13,24,15, 3,23,26
		Complexity of device F5	27,40, 26,12	26,24,3	22,15,26, 1,20	1,5,34,20	B1,B2, B3,B4	12,26,35, 10,	1,35	15,26,25, 24,35	5,26,10, 35,15	3,27,26,15, 1,10,24	35,33,27, 22	15,26, 3,10	35,24,15, 16,3
		Maintenance/ Repairbility F6	10,1, 26,13,35	10,2,13,1, 26,34,25, 24,3	35,10,1, 16,22,15, 26,40,	1,12,26, 27,10,24, 34,35,	35,10, 26	B1,B2, B3,B4	7,1,4,16, 26,35,	10,26, 27,4, 35,1	1,35,10, 27,26,13,3, 12,17,	2,26,10,25, 13,3,27,35, 34,	3,9,13,26, 1	3,1,10, 25,26,	1,26,16, 27,3,15, 10,35,13
		Adaptability/ Elasticity F7	35,13, 12,24	35,5,1,10	35,10, 3,31	34,1,16, 27,35	1	1,16,7,4, 35,26,	B1,B2, B3,B4	13,1, 35,16	1,13,31, 35,26,	3,35,10, 1,13	7,3,10,26, 37	35,26	15,35,26, 13,1
		Durability F8	10,1,13, 34,27, 26,40	3,10,26,24, 27,16,40	22,35,33, 26,17,1,40, 20,24,16	12,27,1, 26,10	15,26,24, 35,25,34,	26,10,27, 1,4,35	1,35, 13,	B1,B2, B3,B4	27,1,4,35, 10,17,14,15, 20,16,24	3,35,10,40, 31,26,27,15, 16,24	10	20,10,26, 15,16	26,35,15
	Manufacturability	Manufacturability /Productivity F9	1,35, 10,24	1,35,12,15, 10,34,26,3	24,1,22, 35,13	5,13,16, 1,26,7,10, 12,35,	26,10, 1,35,15, 27,	35,1,10, 3,25,27,26, 12,17,24	13,1, 35,26,	27,1,4,35, 16,10,15, 20,24	B1,B2, B3,B4	35,23,1,24, 34,33, 26,10	3,24,15, 16,13,35, 23	35,26, 34,4	26,27,1, 4,15,35, 10,24,
	Loss	Amount of substance /Waste F10	15,3,26, 40,10, 24,35	3,1,26,33, 30,16,34,31 35,10,24	35,33,26,31 3,40,24, 30,10,1,34,	35,26,10, 25,12,3, 1,24,15	3,27,26, 15,35, 10,13	1,3,10,25, 13,27,35, 34,26,24	35,3,26, 10,1	3,35,10,40, 31,26,27,15 16,24	26,1,35,27, 13,3,34, 33,10,23	B1,B2, B3,B4	24,26,35	35,24,15, 16,10	34,26,16,15 3,35,31,7,25 24,5,27, 12,31,1
		Amount of information/Loss F11	10,26,23	25,17,37,1, 4,32,10	22,10,1, 20	27,22,35	35,33	2,10,17,13,	24,5,25,9	10	3,13, 23,35	24,26,35,	B1,B2, B3,B4	24,26, 3	15,10
		Amount of time/Loss F12	10,30,4	24,34,26, 3,15	35,15,34, 22,24	4,26,10,34, 24,35,30	15,26, 3,10	3,1,10, 26,	35,26	20,10,26, 15,16	35,26,34,4	35,24,15, 16,10,	24,26, 3	B1,B2, B3,B4	35,24,15, 1,10,5,3
Energy			F13	15,20,10, 27,35,23,	3,1,	1,35,26,27, 10,22, 15,20	15,35,3, 1,22,	35,24,15, 16,25,3, 23	1,35,17,15, 26,27,7,23	35,17, 13,16	26,35, 15	1,4,26	34,23,16,15, 3,35,31,7,25 24,5,26,27,1	15,10	35,24, 15,10, 3,7	B1,B2, B3,B4

Figure 6. RCM1 Focusing on Function

Worsening Feature / Improving Feature		Weight of object	Length of object	Area of object	Volume of object	Speed	Power	Tension, Pressure	Shape	Strength	Temperature	Brightness
		D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11
Weight of object	D1	B1,B2, B3,B4	15, 12, 26,34, 10, 1,35	26,17,24, 34,35, 30,13, 1	26, 1,40, 5,35,14	1,12, 15,24	12,10, 15,35,	10,35,40 13,26,15	10,14,35, 40,13, 26,14	26,27, 15,40, 1,10	26,20, 4, 24,15 3,22	15, 1, 3,35
Length of object	D2	12,15,26, 34,35,40	B1,B2, B3,B4	15,17, 4, 7, 10,40	7,17, 4, 35,12, 1,14	13, 4, 12	17,10, 4,26,	1,12, 35,14	1,12,10, 26,13,14, 15, 7	12,35, 26,34, 15,14	10,15, 3, 35,24,	3,25
Area of object	D3	1,17,26, 4,30, 14,15	14,15, 4, 26, 7, 10,24	B1,B2, B3,B4	7,14, 17, 4	26,30, 4,34	15,30, 35 ,1,	10,15, 35,26,	5,34, 26, 4	3,31, 40,14	1,15,16, 35,24	15, 3, 13
Volume of object	D4	1,26,40, 35,10, 15,14	1, 7, 4, 35,15, 14, 12,	1, 7, 4,17	B1,B2, B3,B4	26, 4, 24,34	15,35, 1,	26,35, 24	1,15,26, 4, 7, 35	10,14,15, 7,17	34,24,10, 15,35, 26, 4	1,13, 10
Speed	D5	1,26, 13,24	13,14, 12	26,30, 34	7,26, 34	B1,B2, B3,B4	13,26, 15,	26,15, 24,40	35,15,34	12, 3, 26,14	26,30, 35, 1	10,13, 15
Power	D6	12, 1,35, 15,13,26	17,15,10, 35,26,	15,10, 1,35	15,10, 12,35,1	13,26, 15,12	B1,B2, B3,B4	15,20, 10	10,35, 40,34	35,10, 14,27	35,10, 20	
Tension, Pressure	D7	10,35,40, 13,26,15	35,10, 1, 14,16	10,15, 35,25,	26,35, 10,24	26,35,	35,20	B1,B2, B3,B4	35, 4, 15,10	10,15, 3,40	35,24, 15, 1	
Shape	D8	12,10, 26,40, 15, 3	26,34, 5, 4,13,14, 10, 7	5,34, 4,10	14, 4,15, 22, 7, 1,35	35,15, 34,	35,10, 40	34,15, 10,14	B1,B2, B3,B4	30,14, 10,40	22,14, 15, 3	13,15, 3
Strength	D9	1, 12,40, 15,26,27,	1,15,12, 35,14,26	3,34,40, 26,10,	10,15,14, 7,17	12,13, 26,14	10,15, 3,14	10, 3, 15,40	10,30, 35,40	B1,B2, B3,B4	30,10, 40	35,15
Temperature	D10	35,22, 26,24, 3	15, 10	3,35, 24,15,	34,24, 40,15, 35,26,4	1,26, 35,30	35,10, 3,20	35,24, 15, 1	14,22, 15, 3	10,30, 22,40	B1,B2, B3,B4	3,30, 20,16
Brightness	D11	15, 1, 3,35	15, 3, 16	15, 3, 26	1,13, 10	10,13, 15	26,15,		3,30	35,15	3,35,15,	B1,B2, B3,B4

Figure 7. RCM2 Focusing on Shape and Design

3. Flowchart for Utilization of Two Types of RCM and Preparation of Contradiction Definition Template (CDT)

As explained in previous chapter, proposed CM is expected to utilize easier for not only TRIZ experienced practitioners but also TRIZ beginners. Therefore, in order to enhance the convenience of this method, we developed "Flowchart for utilization of proposed CM (See Figure8)" and "Contradiction Definition Template (CDT)"by each CM (See Figure9). If you use them appropriately, proposed CM leads TRIZ practitioners the way to get the good ideas for realization of HVAP. In addition, it is expected to improve their "inventive thinking power" to be necessary for realization of HVAP.

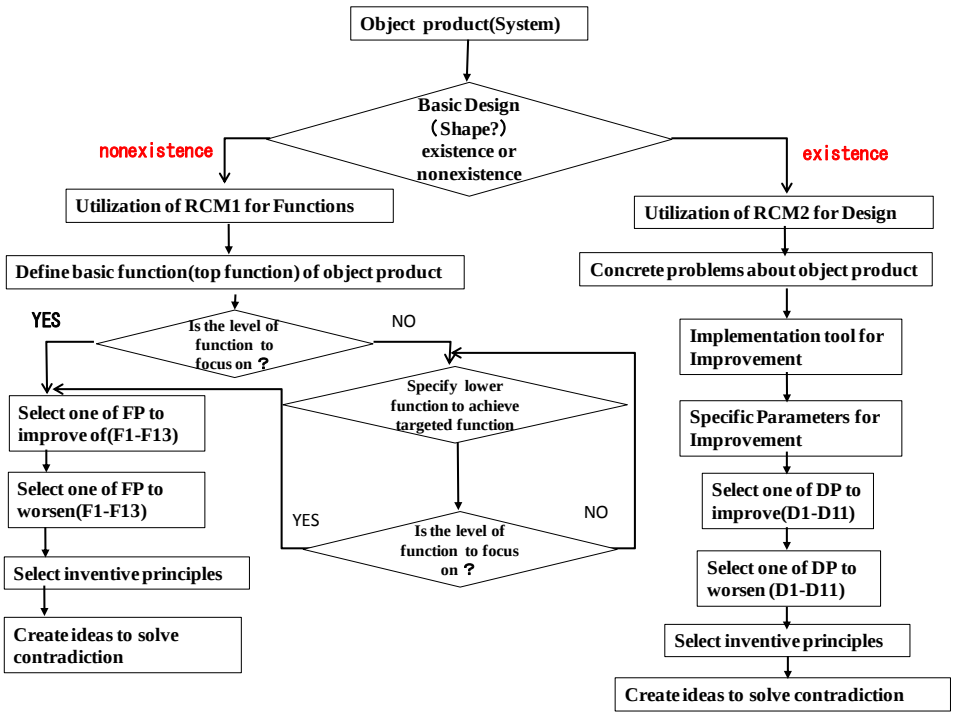

Figure 8. Flowchart for utilization of Two Types of CM

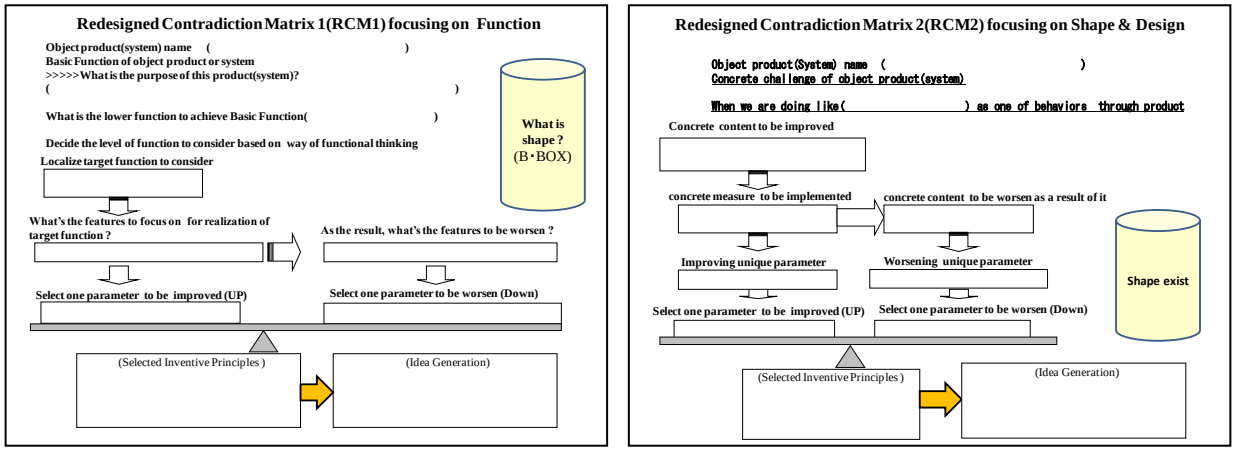

Figure . 9 Contradiction Definition Template (CDT)"by each CM

4. Comparison of Characteristics Between Existing CM and Two Types of RCM

We tried to organize the features in a small compass about original CM (Altshuller version) and Matrix 2003"Mann et al.(2003)" as the existing CM. As is clear from comparison table (See Table.1), the usability of Matrix 2003 is better than original CM. To be specific, Matrix 2003 has 48 parameters for defining a technical contradiction easily compared with original CM because of wide range of parameters to localize a huge variety of technical contradictions. Moreover, All cells ($_{48}P_{47}$=48×47") have inventive principles on Matrix 2003. On the other hand, 234 of all cells (a_{ij}: "$_{39}P_2$=39×38") don't have any inventive principles on original CM. It means that rate of effectiveness about cells on 2003 Matrix is 100% and original CM is approximately 84.2% .

Table 1. Comparison Table about Characteristics between Original and 2003 Matrix

	Original CM(Contradiction Matrix) (Altshuller Version in 1971)	Matrix2003
Manner of Basic Utilization	We define a technical contradiction on the matrix by localizing "improving feature =i th row" and "worsening feature=j th column " and pick up appropriate inventive principles from an appointed cell.	We define a technical contradiction based on same manner of original CM But, localizing it, we define a technical contradiction based on matrix consisting of two phases about parameters.
About Parameter	"improving feature (row)"="worsening feature(column) "="39 parameters"	"improving feature (row)"="worsening feature(column) "="48 parameters" But, Matrix 2003 consists of two phases like 6 large classification and 48 parameters.
About Inventive Principles	Each cell on the matrix but diagonal basically has several inventive principles from 40 inventive principles	Each cell on the matrix but diagonal has several inventive principles from 40 inventive principles
Features about CM	*234 of all cells (a_{ij}: "$_{39}P_2$=39×38") don't have any inventive principles. *Rate of effectiveness about cells on the matrix is approximately 84.2% (No good)	*All cells (b_{ij}:"$_{48}P_{47}$=48×47") have inventive principles. *Rate of effectiveness about cells on the matrix is 100% (Good)
	the number of inventive principles on each cell is zero to four. It means range in width. (No good)	the number of inventive principles on each cell is four to five. It means uniformly numbered. (Good)
	(a_{ii}):each cell on diagonal is blank space (-)	(b_{ii}):each cell on diagonal is blank space (-)

From the result of this feature analysis about existing CM, it is clear that 2003 Matrix is improved to be effective for TRIZ practitioners in real field. But we don't know if existing CM is suitable for TRIZ beginners. So we decided to redesign original CM to be suitable for TRIZ beginners. Now, we want to show the result of features analysis about proposed CM (See Table2.) in a small compass like existing CM (See Table1.). One of the most important features is to prepare two types of RCM to deal with demand characteristics for three stages (at least, two) of PDA (See Figure2) as previously explained. Briefly speaking, usability of proposed CM is improved. All cells (c_{ij}:"$_{13}P_{12}$=13×12") on RCM1 have inventive principles. Rate of effectiveness about cells on the matrix is 100% (Good). It sounds like "Good".

On the other hand, Only 3 of all cells (d_{ij}: "$_{11}P_{10}$=11×10") on RCM2 don't have any inventive principles. Rate of effectiveness about cells is approximately 97.3%. It sounds like "Not so bad" compared with original CM. Moreover, each cell on diagonal on two types of RCM has separation principles to solve physical contradiction. This is a one of useful characteristics from a standpoint of

problem solvers in real field. Because they sometimes notice that the essential problem they want to solve is a physical contradiction, on the way to the solutions about a technical contradiction. That's why we need CM like proposed CM with separation principles on each cell on diagonal.

Table 2. Comparison Table about Characteristics About Two Type of RCM

	Proposed Method (Two Types of Redesign Contradiction Matrix)	
Manner of Basic Utilization	RCM1 (base on 13 Parameters Regarding Function)	RCM2(based on 11 Parameters Regarding Shape &Design)
	We define a technical contradiction regarding function on RCM1 by localizing "improving feature =i th row" and "worsening feature=j th column " and pick up appropriate inventive principles from an appointed cell.	We define a technical contradiction regarding shape &design on RCM2 by localizing "improving feature =i th row" and "worsening feature=j th column " and pick up appropriate inventive principles from an appointed cell.
About Parameter	"improving feature (row)"="worsening feature(column) "="13 parameters focusing on function" But, RCM1consists of three phases like 2 large , 3 middle classification and 13 parameters.	"improving feature (row)"="worsening feature(column) "="11 parameters focusing on shape &design"
About Inventive Principles	All cells of not only RCM1 (c_{ij}: "$_{13}P_{12}$=13 × 12") but also RCM2 (d_{ij}: "$_{11}P_{10}$=11 × 10") have some from "New 25 inventive principles". *Rate of effectiveness about cells on the matrix is 100% (Good)	
Features about CM	*All cells (c_{ij}:"$_{13}P_{12}$=13 × 12") have inventive principles. *Rate of effectiveness about cells on the matrix is 100% (Good)	*Only 3 of all cells (d_{ij}: "$_{11}P_{10}$=11 × 10") don't have any inventive principles. *Rate of effectiveness about cells on the matrix is approximately 97.3% (No bad)
	The number of inventive principles on each cell is one to fourteen. It means range in very width. (No good)	The number of inventive principles on each cell is two to eight. . It means range in very width. (No good)
	(c_{ii}):each cell on diagonal has separation principles (good)	(d_{ii}):each cell on diagonal has separation principles (good)

5. A Case Example - Portable Toilet for Elderly

In this chapter, we would like to introduce "Portable Toilet" as a home appliance for elderly developed by one of Japanese chemical industries, S-company. S-company created this HVAP by utilizing both VE and TRIZ (focusing on original CM) in 2002 (Sawaguchi, 2002). In particular, I want to focus on highly-valued "Elbow Rest Unit" developed by utilizing original CM as a real case example in this paper. In addition, I tried to apply proposed CM based on "Reverse Engineering Approach" to prove the effectiveness of proposed CM. At first, "Elbow Rest Unit" was stationary type in developmental process. After that, giving heed to the convenience for users (mostly elderly), S-company thought of the function to adjust the height of elbow rest unit (See Figure.10).

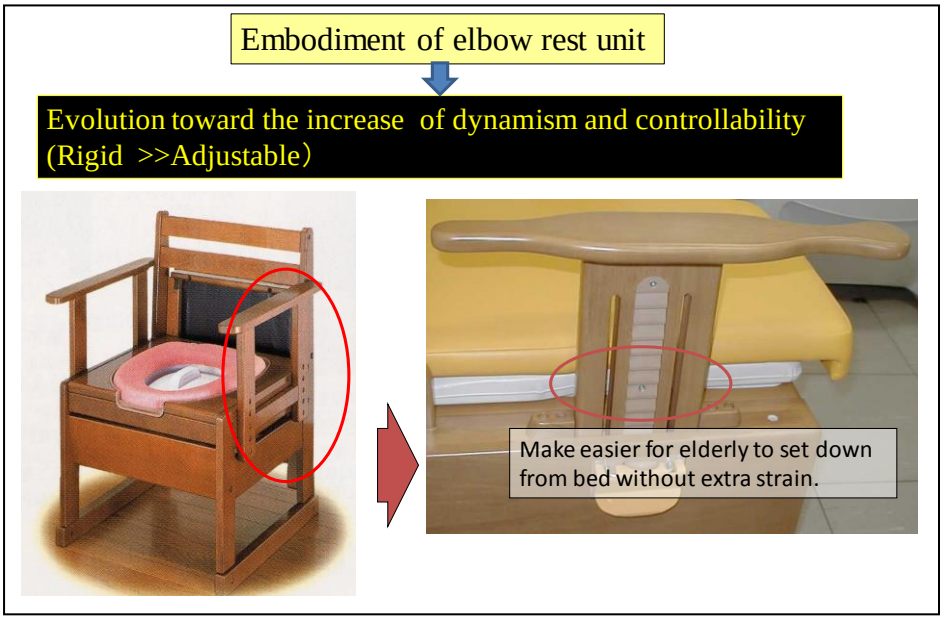

Figure. 10 One of Direction to Improve "Elbow Rest Unit (Stationary to Adjustable) "

In order to fix "Elbow Rest Unit" after adjusting the height of it, S-company adopted "Lock system" shown in Figure 10. However, considering detailed mechanism of "Lock system", they noticed that being improved handleability, "Lock System" will be heavier than expected weight. This is a technical contradiction. That's why they tried to solve this technical contradiction and created "W Lock System" shown inFigure11.

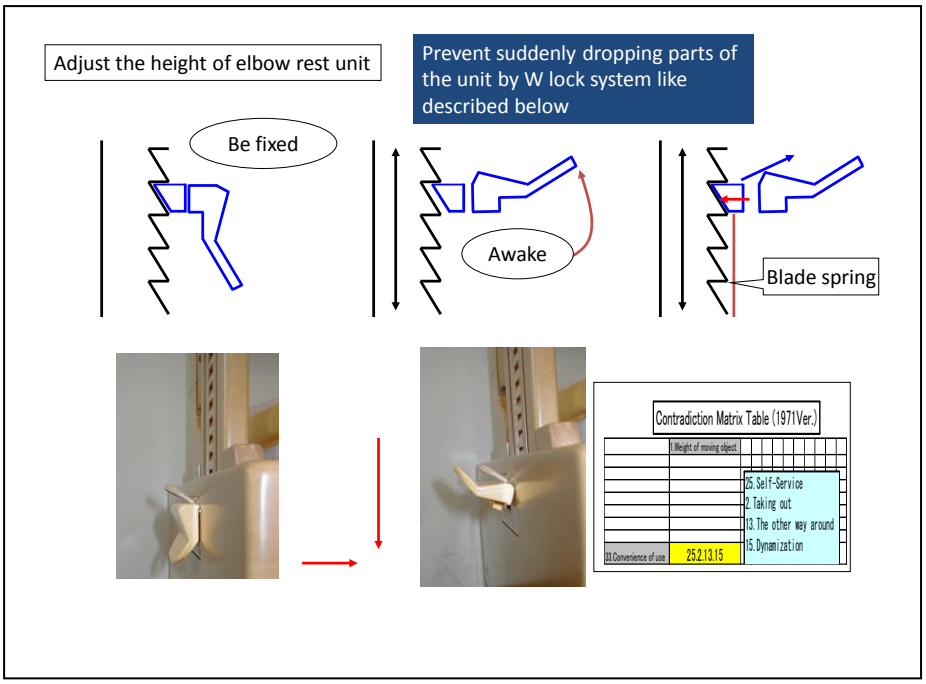

Figure. 11 Definition of a Technical Contradiction about Lock System and its Solution

"W Lock System" is one of real case examples. Moreover, we want to apply proposed CM (Two type s of RCM) to verify the effectiveness of "Blade Spring" to prevent dropping parts of W Lock System" and to think of possibility of other systems but "W Lock System". First of all, we would like to

introduce a case example about "RCM2 Focusing on Shape & Design". We confirmed that "Blade Spring" is one of highly-valued parts by utilizing RCM2 shown in Figure 12. To put it another way, we could create "Blade Spring" as one of effective implementation tools rationally according to CDT for RCM2.

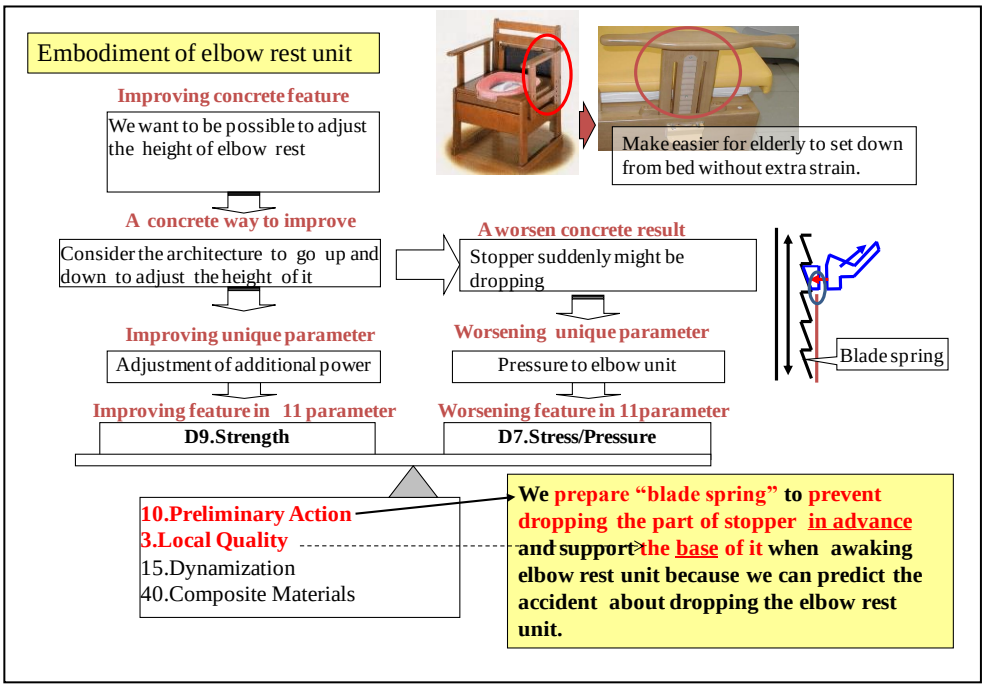

Figure. 12 Validation of W Lock System by RCM2 Focusing On Shape & Design

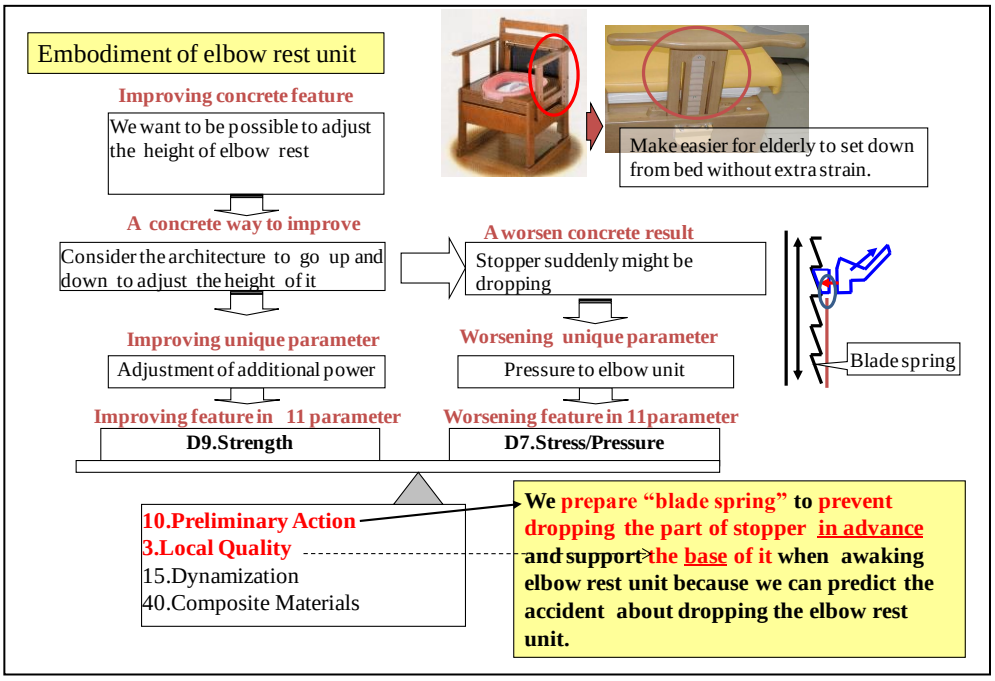

Figure. 13 Possibility of Another Implementation Tool Instead of W Lock System by RCM1 Focusing On Function

Secondly, we would like to introduce a case example about "RCM1 Focusing on Function. We tried to create the other implementation tools instead of "W Lock System" to adjust the height of it. If we apply RCM1, we don't need to consider existing shape and have to focus on functions. As shown in Figure 13, we could create another highly-valued system like shock absorber as a single step form.

6. Summary

We introduced proposed CM (Two types of RCM) compared with existing CM(original CM and Matrix 2003) and referred the convenience of both "Flowchart for Utilization" and "Contradiction Definition Template (CDT)" for not only TRIZ experienced practitioners but also TRIZ beginners. In addition, we tried to apply proposed CM in a real case example based on reverse engineering approach. As a result of these attempts, it was clear that proposed CM is very effective and useful to create highly-valued ideas connected with HVAP systematically. And if TRIZ practitioner, even TRIZ beginners, get accustomed to use proposed CM including Flowchart and CDT in real projects, their inventive thinking power will be improved effectively. We want to continue experimental study to verify the effectiveness of proposed method compared with existing CM. if we find out some disadvantages about proposed CM through experimental study, we want to refine this method to be valuable for TRIZ practitioners ,especially for TRIZ beginners.

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Using Equipotentiality Principle and Resource to Develop Stock Strategy of Low Nominal Value Stock

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Abstract

This paper aims to formulate a contrarian stock strategy for the laymen with minimum of NTD 500,000. No prerequisite or special tools are required to implement the stock strategy. The strategy is composed three rules for choosing a promising stock and three rules for selling the stock. The strategy is derived from the philosophy from TRIZ equipotentiality and resource principle. The verification of the strategy is contrary to the previous approach, a retro-perspective way, but a perspective way. Previous verification used past data to verify the performance of presented strategy. Our verification use future data to verify the proposed strategy. That is, the real stock exchange is executed by one of the author in Taiwan exchange stock market with the proposed stock strategy for one year and four months period. This verification method makes the result more realistic. Nine transactions are completed and each of them earns a rate of return over 10%. The total rate of return is 25.56%.

Keywords: Contrarian stock strategy, Equipotentiality, Perspective verification, Resource.

1. Introduction

It is well known that financial performance is associated with risk and stock return (Schadler and Eakins, 2001). An investor must be careful in his selection of a stock to be sure that the stock has a level of risk which fits his risk tolerance. MorningStar risk index can serve its purpose. Some people prefer to choose a high risk stock because they believe that it will render high stock return. However, ex-post data shows that it is not necessary the case. As for the stock return, there are many financial ratios can be used to measure various aspects of the stock company's performance. For example, current ratio and cash flow ratio can measure the liquidity, and assets turnover rate and operating profit per employee can measure the operating efficiency, etc.

In additions, researchers also investigate the momentum investing and contrarian strategy and its effect on the stock investment (Li, Qiu and Wu, 2010 and Naughton, Truong and Veeraraghavan 2008, Kadoya, S., Kuroko, T. and Namatame, T. 2010). Each strategy has its own strength. Various scholars

hold preference on their own strategy according to the empirical result they found on different region in different time period and based on different theory (See the references cited therein Li etal, Naughton etal and Kadoyo etal). As for the school of momentum investing, it is believed that investments that have performed relatively well continues to perform relatively well and vice versa, thus it encourages buying hot stocks. Whereas the contrarian strategy encourages stock players buy value stock and sell hot stocks. Still some researchers focus on the forecast of the stock price based on some kind of tools such as neural network, statistical regression, fuzzy set, time series, etc (Horng ,Z.C. 2009 and Beaver, W., Cornell, B., Landsman, W.R., and Stubben, S.R. 2008).

Although different aspects are addressed on the stock prices, they all have something in common. First, all the data they used to verify the proposed methods or strategy are based on previous records, thus a retro-perspective approach. Second, all the techniques involve moderate and heavy mathematical computation, a skill demands specialty and profound knowledge. However, the question we would like to propose here is "Who will involve in stock exchange? Are they all skillful in mathematical computation?" The answer is obvious. Most people in Taiwan involve in stock exchange and the majority of them are laymen in terms of the financial knowledge. Moreover, most of them lack of skill in performing complex computation. According to the Taiwan Stock Exchange there are over fifteen million stock accounts up to the end of the 2009. Based on such a large population in stock market and the majority of them has little financial knowledge and minimum tool for complex computation, an interesting and challenging question arise in us: is it possible to develop a free, user friendly and useful stock strategy for those people? And that strategy should help the stock investors earn a rate of return better than the long term deposit interest rate in the bank. Thus this draws attention to us to develop such strategy so that it is free and easy to use and most important it works. The verification of its performance should be tested based on the future data, not the historical records, to make this strategy more realistic.

2. Development of the Strategy

Before we set out to find a strategy, the objective of the investment strategy should be defined clearly. It is clear that different objective has its unique strategy. The objective of the strategy is to help investors earn a rate of return over 10% given a minimum of NTD 500,000. The way the objective is defined is because the average long term deposit interest rate in Taiwan for the last ten years is about 1~5%. The bank of Taiwan issues a trend of one year deposit interest rate for the last 10 years shows that the variation of interest rate in Table 1. If the rate of return from the strategy is higher than the interest rate, then the strategy can be considered as a good performance strategy. Since this is the first launch of the strategy project, a conservative rate of return with 10% is set. After important issue is the lump sum money we should endorse. There are many high schools and college departments use the funny money to train the students how to learn the investment strategy.

Usually a funny money of 10 millions NTD is assigned to each student and they can play with that in software that uses the real time stock price information for one month. After one month they will know how much they gain or lose. That approach is not what we choose. Because in real life, there are not many people have so much money to spend in sock market. However, to have a NTD 500,000 to begin the stock investment is not that difficult. In addition, spending funny money does not cause stress on players whereas people are usually more cautious in the expenditure of his/her money. For this reason, NTD 500,000 is chosen as the investment amount and player who uses the strategy should invest that amount of money in the Taiwan exchange stock market.

Table 1. Trend of one year deposit interest rate from 2001 to 2010.

After setting up the objective of investment, the derivation of strategy is followed. As it is mentioned in the first paragraph, the evaluation of a company's performance is a complex matter. Many indicators have to be considered, specific information has to be retrieved from all sort of resources and professional knowledge has to be applied. For an ordinary investor, it is a tremendous task to tackle. There is substantial threshold needs to be climbed over. In TRIZ difficult problem in the here and now situation can be solved by tapping the resource from the super-system or sub-system. Or the problem can be solved before or after the current time span. This is the 9-window tool in solving an inventive problem. In the current problem, two tools from TRIZ can help solving the difficulty. One is the equipotentiality in the 40 inventive principles (Altshuller 1997) and the other is tapping the resource from the super-system, an application of 9-window tool (Mann 2007). All the complex financial knowledge can be distilled down into two simple rules. In the stock market, all the knowledge is aimed to determine: 1. to buy a stock which can make profit, and 2. to buy that stock with a relative low price. There are many indices to serve the purpose of profit making, EPS, gross profit margin, operating

profit margin and Moving Average Convergence/Divergence (MACD), to name a few (Fernandez-Blanco, P., etal 2008). Ones choose the gross profit margin, operating profit margin, pre-tax profit margin and after-tax profit margin in the most recent season financial report as the profit making indicators of a stock. Two reasons of choosing them as indicators are: 1. they are easy to understand, and 2. they can be freely assessed in the internet service. To solve the problem of choosing a low price stock, a contrarian strategy is implemented with the 72 consecutive closing prices of the stock. Note that this information is also freely assessed in the internet. If the stock closing price decreases in the recent five days and the current closing price falls within the bottom 20% of the price range of its 72 consecutive closing prices, then one considers the stock price is below the stock intrinsic value. Under the contrarian strategy, that kind of stock is worthy to buy and has great potential in making good profit in the future. No theoretical justification can be provided for this proposition. However, retro-perspective analysis shows the proposition is reasonable and will be elucidated in different paper.

With those views in mind, three rules for choosing the quality stock are listed: 1. the current stock price must be in the bottom 20% in the price range of closing prices in the recent 72 transaction days, 2. the gross profit margin, operating profit margin, pre-tax profit margin and after-tax profit margin in the current season financial report must all be positive, 3. the stock holding rate by board of directors must be greater than 5.5%. The last rule is added to make sure that the managerial level of the stock company hold accountable for their performance. The value of 5.5% is recommended by the monetary authority in Taiwan. If the stock holding rate of the board directors is too low, then they can escape away from their poor performance in managing the stock company. However, if the stock holding rate is too high, it will do no good for the circulation of the stock. The fluctuation of the stock price will not be much which will render a low turn over rate of the stock exchange. But this issue will not be pursued here in this paper. All the rules can be implemented using the free internet service from the bank of Taiwan. The detail operation will be shown step by step in the paragraph below. Thus the implementation of three rules covers the equipotentiality and resource in TRIZ. For the resource from super-system, the required information in the rules is retrieved from the free internet service of bank of Taiwan. Everything is free. As for the equipotentiality, people do not need to study too much in finance and stock investment, the rules are intuitively appealing. They are self-explained. There is no barrier to climb over in order to use this strategy. The implementation of the three rules fit the core values of equipotentiality. After completing the rules for choosing a stock, the rules for selling a stock are discussed.

There are three situations to sell a stock: one is for profit reaping, the second for stopping bleeding (i.e. keep losing money), and the last one is the poor updated financial report. As ones mentioned before a good situation to sell the stock is when its rate of return is over 10%. This is the good situation we all expect to happen, but real life does not always go this way. Thus a precaution umbrella is needed for the rainy days. How about the stock price keeps going down? When should we sell the stock to stop bleeding and save the money for the next stock candidate? Ones use 30% loss as the threshold. If the purchase price of a stock is NTD 10,000 and the closing price of the last transaction date is lower

than NTD 7,0000 (the 30% loss occurs), then the stock should be sold out. Regarding the last situation in selling a stock, the reason is trivial. When the updated financial report contains negative gross profit margin, operating profit margin, pre-tax profit margin or after-tax profit margin, the stock should be sold out. This stock does not make profit any longer for the stock holders. Although three rules for selling a stock are outlined, only the first rule is implemented in the following experiment. The last two rules are never used.

The last question in the strategy is how do I find those stocks which have the higher probability of meeting the requirements of our quality stocks? Of course, we cannot find and test the stock one by one until the promising one appears. It will be very time consuming and not practical. Fortunately, the bank of Taiwan provides a useful table which shows the first 30 drawdown in the recent 5 transaction days. Starting from the table we can easily find the stock we want to buy. A sample table is listed in Appendix.

3. Experiment

An experiment is performed to test the validity of this strategy. One of the authors uses a lump sum of NDT 50,000 to implement the strategy from 2009/10 to 2011/02. Nine stocks have been purchased and sold with each ROR more than 10%. Two out of nine transactions share identical stock. Among them, the shortest investment period is eight days, whereas the longest period is about three months. The total ROR for the investment is 25.56% which is very promising. The eight unique stocks are 信昌電(6173), 國產(2504), 國建(2501), 新建(2516), 新建(2516), 美吾華(1731), 方士昶(6265), 蔚華科(3055), 立基(8111). Among them 新建(2516) is purchased and sold twice. In addition, in the time being there are two stocks in hand waiting for prime opportunity to sell. Their transaction records are listed in Table 2.

Here stock 6173 is used to demonstrate the purchase and sell mechanism. Figure 1 shows the price histogram for the stock 6173 on date 2009-10-20. On that chart there are 72 transaction prices are sorted in the ascending order with abscissa representing the transaction amount for the corresponding closing prices. The last transaction date closing price is 18.2 which is marked in aqua and circled in red. The transaction amount is about 300 shares. The closing price in the first date of the 72 transactions is 21.05, which is marked in green. Its transaction amount is about 3100 shares. The closing price ranges from 18.0 to 23.1. It is clearly that closing price of 18.2 falls within the bottom 20% of the price range. Then one checks the profitability of the stock 6173 by looking the season financial report as shown in Figure 2. The third season, which is the season we are in at the moment, shows that the gross profit margin (19.79%), operating profit margin (11.46%), pre-tax profit margin (13.11%) and after-tax profit margin (10.67%) are all positive. Lastly the stock holding rate by the board of directors is checked as shown in Figure 3. The holding rate is 45.18% much higher than the required threshold 5.5%.

Table 2. Nine stock transactions from 2009/10 to 2011/02.

	信昌電 6173	國產 2504	國建 2501	新建 2516	新建 2516	美吾華 1731	方士昶 6265	蔚華科 3055	立基 8111
Purchase time	2009-10-20	2009-11-10	2009-12-15	2009-12-22	2010-01-27	2010-01-27	2010-01-27	2010-05-21	2010-07-28
Sell time	2009-12-04	2010-10-25	2010-01-08	2009-12-30	2010-02-22	2010-03-29	2010-05-17	2010-07-08	2010-10-21
Holding (days)	45	334	24	8	26	61	110	48	85
Purchase price	18.65	14.6	13	7	7	14.8	13	22.2	23.15
Selling price	20.65	16.15	14.4	8.1	7.8	16.55	14.5	24.5	25.6
Profit (NTD)	1980	1553	1380	1080	780	1730	1480	2280	2430
Rate of Return	10.6%	10.4%	10.6%	15.38 %	11.11 %	11.67 %	11.37 %	10.26 %	10.49 %

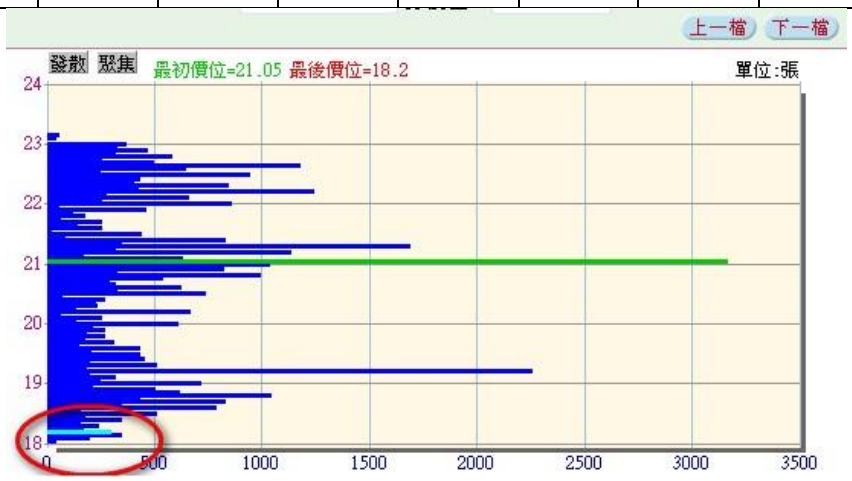

Figure 1. Price histogram for stock 6173.

· 98年度

季別	毛利率	營益率	稅前盈利率	稅後盈利率
四	17.44%	7.33%	15.26%	12.09%
三	19.79%	11.46%	13.11%	10.67%
二	16.18%	5.92%	5.26%	4.55%
一	5.22%	-6.48%	-6.19%	-4.85%

· 97年度

Figure 2. Profitability index for stock 6173.

日期:10/20

	張數	佔股本比例
董監持股	73,838	45.18%
外資持股	286	0.17%
投信持股	11,226	6.87%
自營商持股	1,227	0.75%
法人合計	12,739	7.80%
融資餘額	7,535	4.61%
融券餘額	332	0.20%
集保庫存	163,182	99.86%
六日均量	725	0.44%

(6173)主力進出

最後更新日: 10/20

買超				賣超			
買超券商	買進(張)	賣出(張)	買超(張)	賣超券商	買進(張)	賣出(張)	賣超(張)
富邦證券	74	8	66	國泰證券	0	167	167
統一證券	71	9	62	群益證券	43	160	117
華南永昌證券	63	32	31	兆豐證券	23	75	52
元大證券	126	95	31	第一金證券	6	21	15
日盛證券	37	11	26	凱基證券	46	59	13
聯邦商銀	30	10	20	台証證券	22	26	4
大華證券	20	3	17	大昌證券	2	5	3
金鼎證券	25	10	15	合庫	0	3	3

Figure 3. Stock holding rate by board of director for stock 6173.

In order to show have a helicopter view of the Taiwan stock exchange market in the duration of our study, a market index of Taiwan stock exchange is provided. It is superimposed with the timing of the nine transactions and is shown in Figure 4. It serves the purpose that the timing of purchase and selling a stock has nothing to with the fluctuation of the market index. The red one is the purchase transactions whereas the green one is the sale transaction. The purchase time of stock is not always in the declining mode and the sale time of stock is not always in the rise mode.

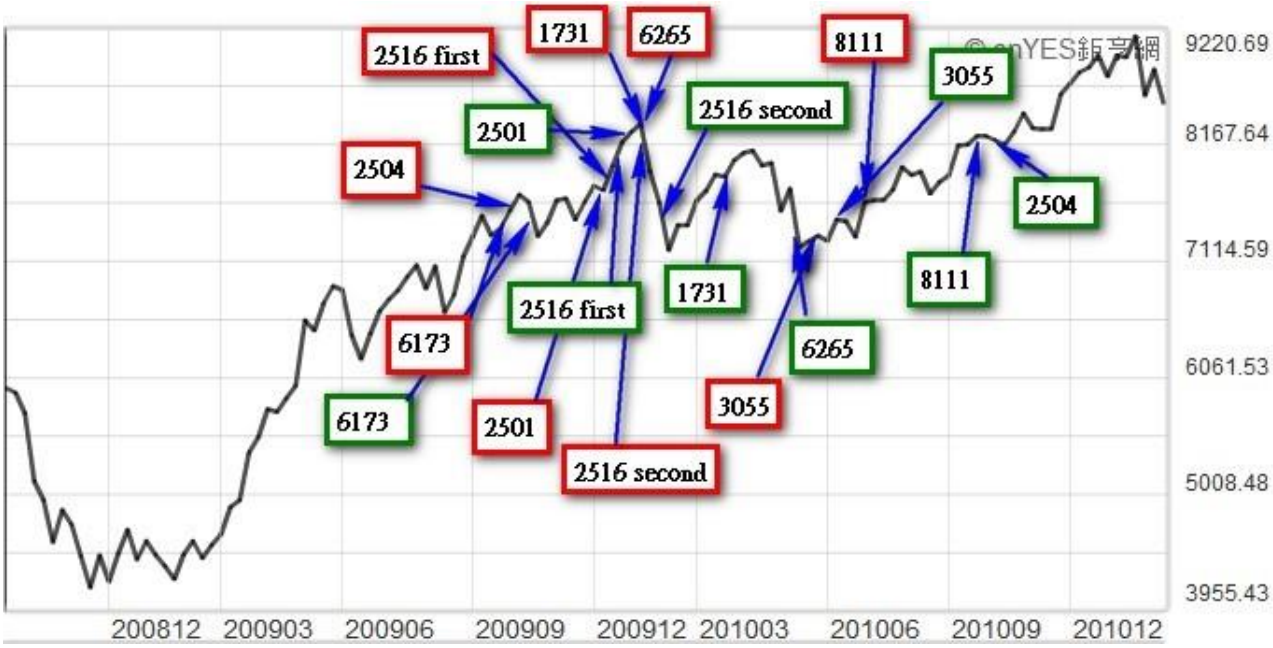

Figure 4. Market index of Taiwan stock exchange market.

4. Conclusions

People have psychology inertia in insisting that good solution in engineering or managerial problems always involve highly mathematical tools and profound knowledge. However according to the TRIZ ideality things should happen by themselves. The best solution should always tap the resource from the super-system to solve the problem in the proposed system. This research uses the equipotentiality and resource in TRIZ to tackle a strategy problem in stock investment. The aim is to find a strategy such that people with minimum knowledge in finance and stock investment can do the stock investment without paying extra money. Usually the majority laymen in stock investment pay the money to join some club in order to buy some good stock information. However the information does not guarantee the stock will make profit. Still others buy some sophisticated software and interpret the result with their own knowledge to make the investment judgment. All those required resource from the system. In our case, the investors need to pay for the purchase of information. Contrary to all the above methods, our proposed method is free and easy to use.

Three rules for choosing the quality stock are listed: 1. the current stock price must be in the bottom 20% in the price range of closing prices in the recent 72 transaction days, 2. the gross profit margin, operating profit margin, pre-tax profit margin and after-tax profit margin in the season financial report must all be positive, 3. the stock holding rate by board of directors must be greater than 5.5%. In additions, there are three situations to sell a stock: one is for profit reaping, the second for stopping bleeding (i.e. keep losing money), and the last one is the poor updated financial report. A good situation to sell the stock is when its rate of return is over 10%. This is the good situation we all expect to happen, but real life does not always go this way. Thus a precaution umbrella is needed for the rainy days. Ones use 30% loss as the threshold when the stock price keeps going down. Lastly, when the updated financial report contains negative gross profit margin, operating profit margin, pre-tax profit margin or after-tax profit margin, the stock should be sold out.

A perspective experiment is implemented by one of the author from 2009/10 to 2011/02 with NTD 500,000 as the lump sum capital. Nine stocks have been purchased and sold with each ROR more than 10%. Two out of nine transactions share identical stocks. Among them, the shortest investment period is eight days, whereas the longest period is about three months. The total ROR for the investment is 25.56% which is very promising.

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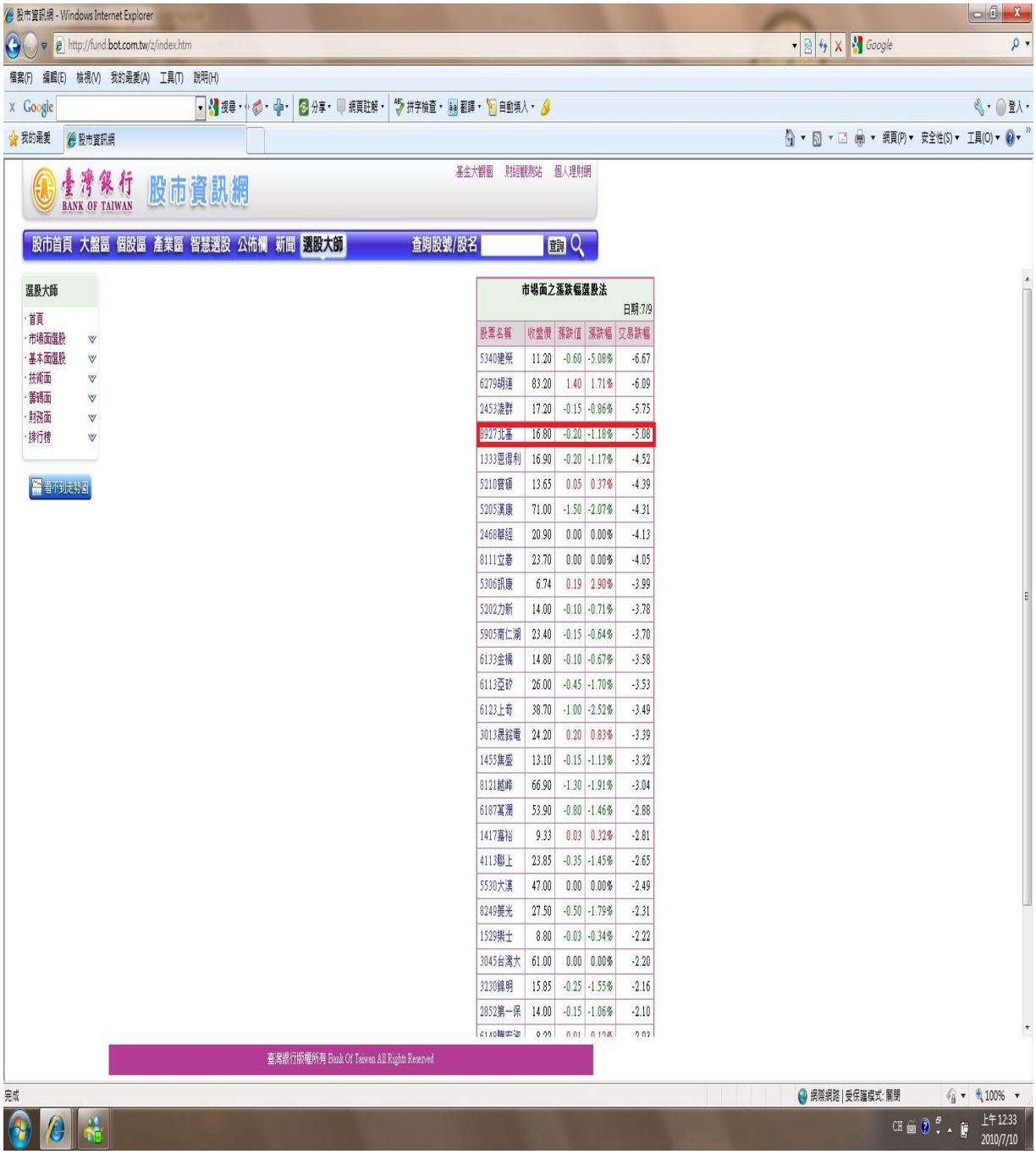
▪Appendix

We use the sorting table of the first 30 drawdown stock to demonstrate the entry point of choosing the possible stock candidates. The date is 2010-07-10. The maximum drawdown stock is stock 5340 with the drawdown rate of -6.67%. The fourth drawdown stock, which is circled in red rectangle, is stock 8927 with the drawdown rate of -5.08%. It is in stock 8927 we find the promising stock to buy after trying out the first three stocks.

Table A1. First 30 drawdown stocks in 2010/07-10.



市場面之漲跌幅選股法

日期:7/9

股票名稱	收盤價	漲跌值	漲跌幅	交易跌幅
5340建榮	11.20	-0.60	-5.08%	-6.67
6279胡連	83.20	1.40	1.71%	-6.09
2453凌群	17.20	-0.15	-0.86%	-5.75
8927北基	16.80	-0.20	-1.18%	-5.08
1333恩得利	16.90	-0.20	-1.17%	-4.52
5210寶碩	13.65	0.05	0.37%	-4.39
5205漢康	71.00	-1.50	-2.07%	-4.31
2468華經	20.90	0.00	0.00%	-4.13
8111立端	23.70	0.00	0.00%	-4.05
5306訊康	6.74	0.19	2.90%	-3.99
5202力新	14.00	-0.10	-0.71%	-3.78
5905南仁湖	23.40	-0.15	-0.64%	-3.70
6133金橋	14.80	-0.10	-0.67%	-3.58
6113亞砂	26.00	-0.45	-1.70%	-3.53
6123上奇	38.70	-1.00	-2.52%	-3.49
3013晟銘電	24.20	0.20	0.83%	-3.39
1455集盛	13.10	-0.15	-1.13%	-3.32
8121越峰	66.90	-1.30	-1.91%	-3.04
6187萬潤	53.90	-0.80	-1.46%	-2.88
1417嘉裕	9.33	0.03	0.32%	-2.81
4113聯上	23.85	-0.35	-1.45%	-2.65
5530大漢	47.00	0.00	0.00%	-2.49
8249菱光	27.50	-0.50	-1.79%	-2.31
1529樂士	8.80	-0.03	-0.34%	-2.22
3045台灣大	61.00	0.00	0.00%	-2.20
3230錦明	15.85	-0.25	-1.55%	-2.16
2852第一保	14.00	-0.15	-1.06%	-2.10

Paper ID: 265

Application of Bionical creativity engineering for improving wings of robofly

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Abstract:
Bionical Creativity Engineering have the fundamental role in researches and developments in all sciences . Bionical Creativity Engineering is inspiration and modeling of evolution nature principles , and opening a new and modern approaches for problem solving , management , research & development , Business and soon .
In generally , inspiration of nature (principles , scale , shape and …) called Bionical Creativity Engineering , that in this paper described Bionical Creativity Engineering and applications of this for Aerospace Industry.
Keywords: Bionics , Research and Development , Bionical Creativity Engineering, Aerospace Industry.

1-Introduction

Creativity and Innovation playing essential and important role in progress and grows science. one barrier in improvement and progress of research and development is lake of creativity and innovation that with use of evolution nature principles could achieved creative solving of technical problems(1) .

Nature, with its great variety of efficient structures, it suitable as a source for the stimulation of possible ecologically and ergonomic solutions to problems and opportunities . Examples in nature can become a creative element within the process of producing solution to problem. Bionical Creativity engineering have the fundamental role in researches and developments in all sciences especially Aerospace Industry . Bionical Creativity engineering is inspiration and modeling of evolution nature principles , and opening a new and modern approaches for problem solving , management , research & development , Business and soon . In generally , inspiration of nature (principles , scale , shape and …) called Bionical engineering, Bionics and Biomimetic , that in this paper described Bionical Creativity engineering and applications of this for Aerospace Industry (2) .

Bionical Creativity Engineering is inspiration and modeling process of nature for creation of new innovations and ideas. Bionics are new techniques that helped engineers. Bionics and related fields, learning to engineering that how nature design systems .

Object of this science, produced complex materials and machines with modeling of nature . nature without population , have creative process and design that better function than process and design traditionally developed by engineers(2) .

This Paper described the important role of Bionical Creativity Engineering In Aerospace Industry.

2-Bionics

Design and function in plants and animals have been optimized under evolutionary pressures over millions of years.

Time scales may be different but design constraints and objectives are very similar : functionality, optimization and cost effectiveness. Therefore, it is not surprising that engineering has always admired biological structures and often been inspired by them, therefor we can appreciate their aesthetical attributes as well as their engineering and design content(3).

Bionics as a scientific discipline deals with the technical transformation and application of structures, procedures and developmental principles of biological systems.

Originally, the word Bionics derives from the terms bio and technic. Nowadays, the word is more generally used for a young and interdisciplinary research field which combines biology with the sciences of engineering, architecture, and mathematics(3).

Examples in nature can become a creative element within the process of producing a solution to a problem. The rules of biological evolution can be used both for determining the aims and the principles of functions of structures and organizations as well as providing a model for determining solutions. The Bionic approach is seen as reducing the gap between the man made world and nature (4).

During million of years of evolution , plants and animals have perfected ingenious design, that are the best model for Research and Development in industrial countries .

Principles of nature are the abundant source of inspiration for products and materials (4).

Bionical Creativity Engineering is innovative modeling or learning of nature .this science is a principle of design that looks suitable solution for human problems and problems of R&D Management. using of nature principles , permits engineers that creation materials , design , process and soon .

Many of older inventions based on study of natural mechanisms and many of them are now . structures in nature important in micro and macro levels and both levels use for modeling and inspiration .

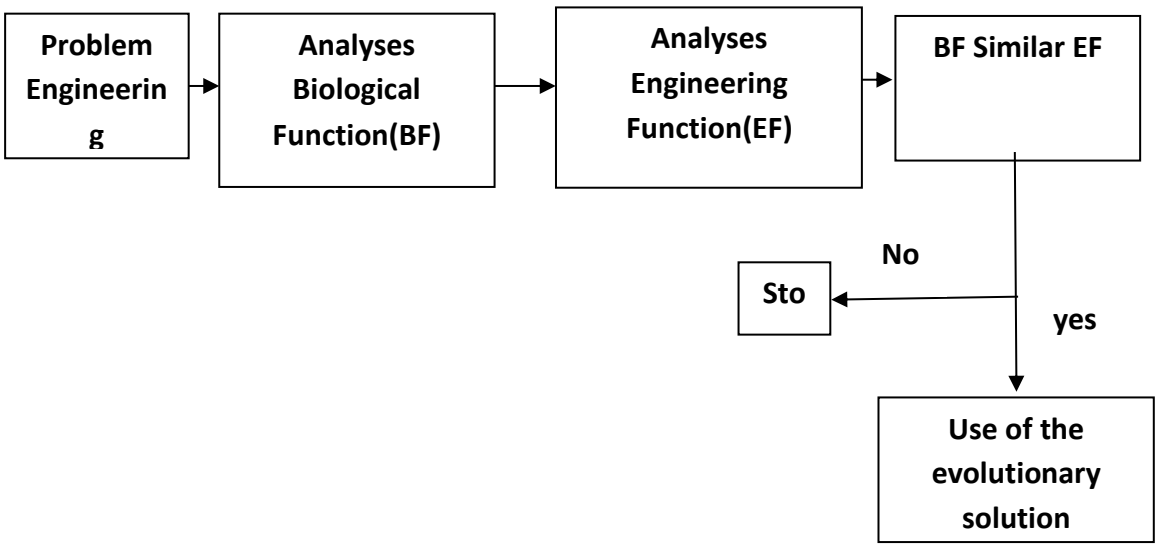
Bionical Creativity Engineering is important issue at all disciplines of Science and Engineering and its play strategic roles in development of researches and innovations. its very powerful tools for Creative Problem Solving, Innovation, Invention, Quality

Development, Research and Development, Productivity and ... in all industrials , that with them achieved their goals(3).

Investment in Bionical Creativity Engineering, and establishment of creative problem solving groups and Bionical Creativity Engineering groups in R&D units in developing countries and increasing their problem solving skills are the key factors of knowledge base economic development, this is the reason the developed countries in this decade is mostly emphasizing on skills of creative problem solving techniques.

Bionical engineering for creative problem solving in R&D units in industries could accelerate technology transfer cycle as well as technology development period(5).

However, care must be taken when natural principles perform a variety of functions, as they may not be optimized for the problem studied in R & D units. There is no strict procedure available to ensure the correct abstraction is made or that the organism mimicked is the most suitable. This means that there is a need for a methodology to formalized the process of Bionical Creativity Engineering (6).



Bionical engineering could help to:
Increasing the creation of new ideas;
Increasing the creative thinking
Increasing the ability for forecast the future of technology and Science
increasing the progress and development in technology and strategies(7).

3-Application of Bionical Creativity Engineering for Researchers and Designers in Aerospace Industry

Application of Bionical engineering for Researchers and Designers in Aerospace Industries are very large but in this paper a lot of them described. Some of them are:

- One of the simplest of cases is Inspiration of Beehive and use for the knowledge Aviation (Aeronautical)(6).
- Inspiration of Mechanical receptors (near the antennae) in insects led to optimized sensory systems. Very little information about the organs on the insect cuticles are available, but with further study in this area and they can used for aerospace composite materials (11).
-Researchers of Air Force Special Research (AFOSR) works great on infrared detectors and sensors of snakes and beetles to create an infrared detector (5).

Bill Clegg at Cambridge University inspired of nacre(pearl) to strengthen the blades of the jet structure. Inner layer of nacre in many mollusk made of 95 percent gypsum that is 3000 times harder than ordinary gypsum . composite structure is hardly the result most of the aragonite. (9).

- heat detectors allow animals attack, their prey sure to trap the missile can be guided towards their target. Samar Plan Maple in the design of new kind of ballet helicopter is used. Ignazio and Igo Etrich first glider style building with a copy of gymnosperms seeds made by the wind that moves.

-Radar Development Principles inspired of bat. Here, the fighter aircraft to provide a monitoring system, improvement or part of an intelligent control and feedback system is used. - the aerodynamic flying insects, especially flies chicken key patent that makes researchers hopeful. Biologists and engineers at Berkeley University of Technology last four years made a small insect or mechanical Flying Insect like flies will be flying. Pentagon's Defense Advanced

Research Agency beside major investment projects to monitor the deals to sever them. These are all natural inspirations to engineers and managers will induce and cause managers to promote research to improve quality and efficiency are (4).

Figure 1: Micro Robot made in Berkeley

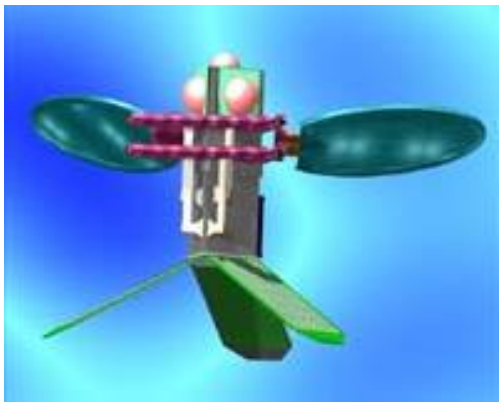


Figure 2: Flying Robot

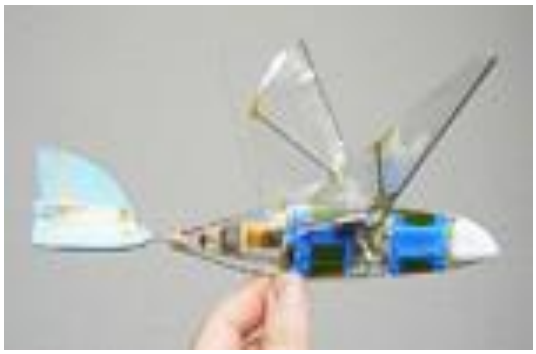


Figure 3: Micro Flying Robot

Figure 4: Mentor: Micro Flying Robot

4 - Some suggestions for improving wing flying robot system

Here are four suggested to improve the robot wings

1-4 - inspiration of butterflies and birds, making smaller and smaller proportion wings and fuselage robot

Always Engenderers make smaller cars, parts and else , that interesting work has been honored. With smaller devices able to carry them easily in any small space and gives them instead in places that require little equipment to use. science such as nanotechnology was formed. One of today's human tool use by the sky and space around the aircraft is. Thereby minimizing the aircraft , one of the goals. smaller aircraft could be hidden from the eyes and not be seen easily.

Aircraft normal force required to produce that aircraft engine power forward does produce speed air flow over aircraft. Force for creating Lift depends on aircraft wings Reynolds number.

$$\mathrm{Re} = \frac{DVD}{\mu}$$

Equation of Reynolds number

D is the characteristic diameter of the crater wing, shrink the aircraft with wing spans are shrinking. Also being small plane aircraft speed decreased and Reynolds will be reduced. Reynolds number in their calculation of force showed reduced levels of speed and wing reduce lift air .

$$L = \frac{1}{2} PSCLV^2$$

When this figure furthers reveal that wants to build insects .

The subjects to be described because for the minimizing of a conventional fixed wing aircraft and the Propulsion forward ¬ not be used. One of the solution , use of methods such birds have wings mechanism. Flap the wing is a method that can compensates the reduced Reynolds

number. With the smaller wing surface should increase air speed. the speed of air that passes over the wing to produce much lift, and even also can fly in difficult conditions such as low density air. this theory was that the ability to fly wing formed on Mars and Ehtompter different models were built.

Robofly designed with a wing span cm 110, body length cm40and weight is g450. Reynolds number is appropriate for these Robofly, robofly with the same dimensions can fly with the constant wings . the smaller robofly can specific capabilities similar to these birds (7).

we can be designed to target robofly with wing span 20 cm. wing span of selective robofly has a direct relationship with the weight . In other words, more freedom to select whatever pieces but we will need to be smaller tools and parts with lower weight, more used. Figure show relationship between weight and size.

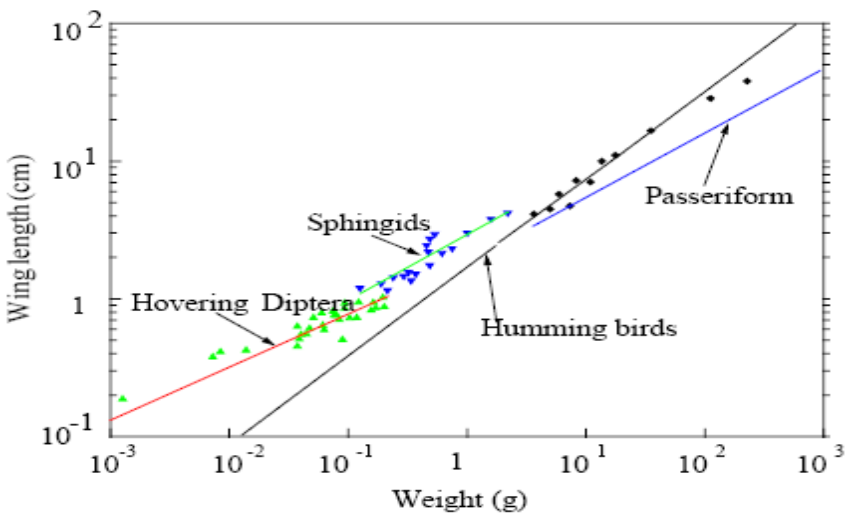


Figure5: Relationship between weight and size

This figure means that if the wing length is about cm20 , weight would be about g70 (8). Another important design feature wing surface is plane. With a wing area and wing span can obtain the total wing. Under the terms of this guideline does determined weight Robofly. It is statistical charts based on information available to other birds are derived.

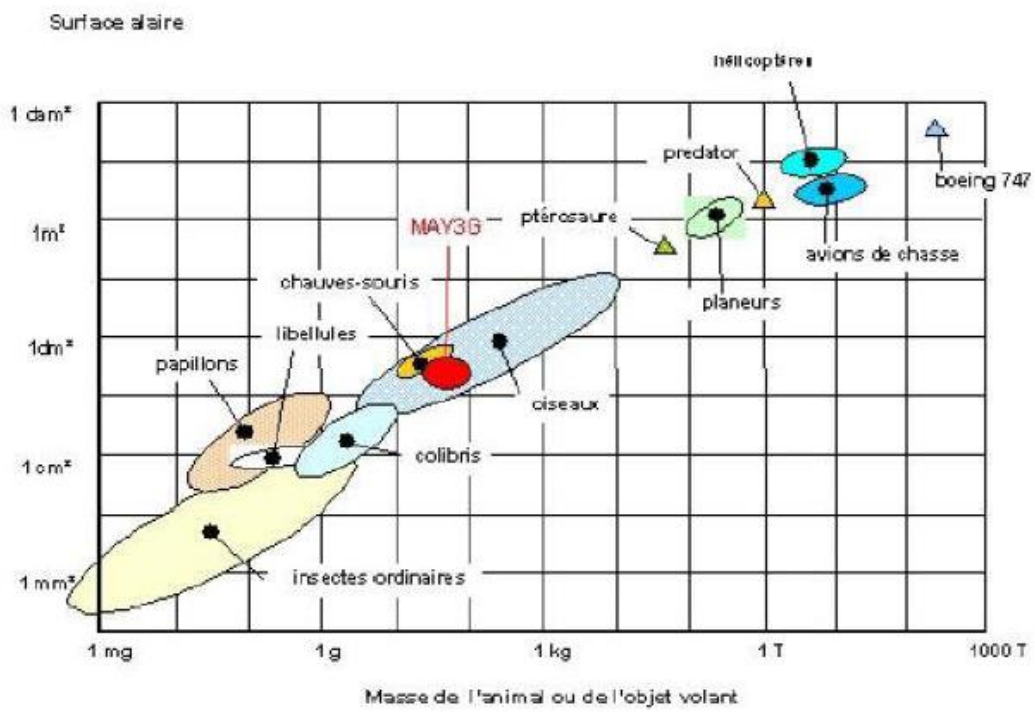


Figure6: wing surface vs weight for different flying vehicles

For example, weighing around 70g comes wing surface gain of about 0.3 dm^2 .

Flight speed:

Other feature of Robofly flight can be speed of flying robofly, a direct relationship with engine power. This structure is associated with weight.

This characteristic of the relationship is calculated below.

$$U = 4.77m^{\frac{1}{6}}$$

Flight speed 9.6 m / s can be achieved With a weight of about 70g.

Frequency of flap the wing:

Honeybees for hover have the frequency around 200 Hz . wings are flapping 200 times per second, their wings up and down. We arrive at this point is that whatever wing wings of robofly is smaller, its frequency should be higher. Any bigger robofly need to be a less frequency. in the nature , this problem is evident in large birds like eagles wing are low frequency and often even without flapping and with less energy expenditure continued to fly . in contrast Honeybees are flying to be high-frequency (11).

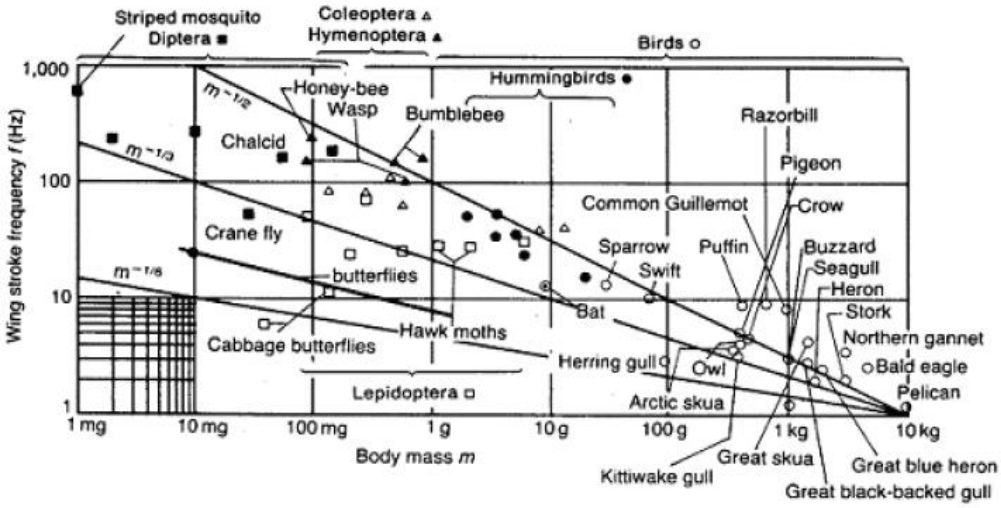


Figure7: Comparison of frequency against the wings in different organisms

Frequencies around 20 Hz are obtained with Weight 70g. To obtain accurate frequency wings important parameter in selecting the type , engine power , speed , the size of the gearbox and the material used for the gear , because the high frequencies can be caused corrosion gears .(9) However, an approximate frequency obtained for the model with a 70g weight. The best material for building material such as gears and large force arrived on the wings are not the problem a corrosion gear is not considered. A type of brush less of electric motor used. Engine power must be something around 20 W and is recommended AXI engines used (8). Depending on construction conditions are different mechanisms , can be used for transmission.

2-4 - Moving wings in different degrees of freedom

¬ Robofly must move wing in different degrees. These movements should be able to create a positive lift. These movements are as follows:

1 – flap the wing

The scope of flapping that shown with ℓ .

2 - Wing Rotation

that shown with α

Move out of the page

3 - Deviation from the wings page with θ be determined.

Each of these movements should be done. Above all angles in the following figure is indicated(10).

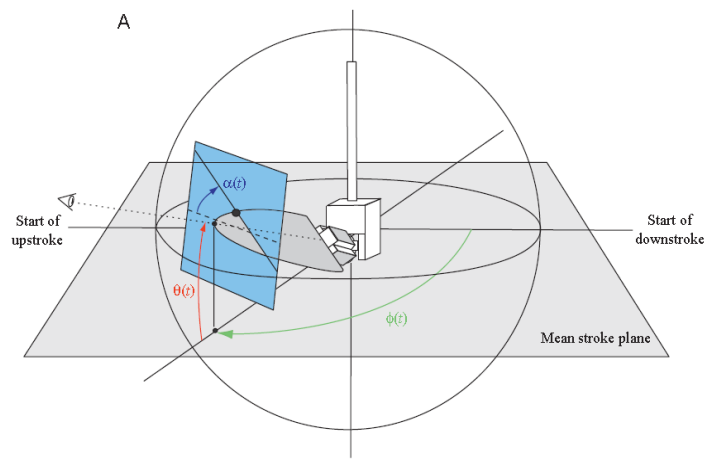


Figure8: wings angles

The three mechanisms of different birds create aerodynamic flow and cause bird can give different maneuvers.

These three mechanisms are:

- ✓ Rotational Circulation lift : Current rotation that produced a lot of lift
- ✓ Wake Capture Mechanism
- ✓ Delayed Stull

The three mechanisms for producing aerodynamic flow should be very careful. two main moves:

1) Upstroke: moving toward the top that φ and θ change , but α is nearly constant.

2) Down stroke: moving down that φ, θ and α change

And two lateral motion:

1) Flip : the wing rotation At the end of Down stroke

2) Rotation of the wing at the end Upstroke

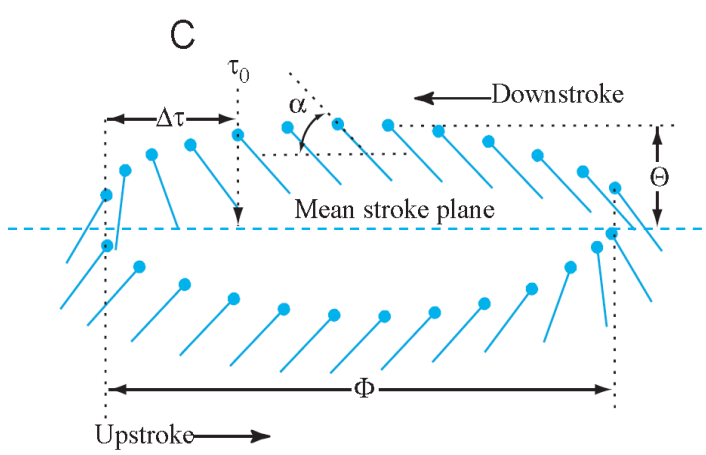


Figure9: Motion mechanisms

Another moves:
1 - the Oval move.

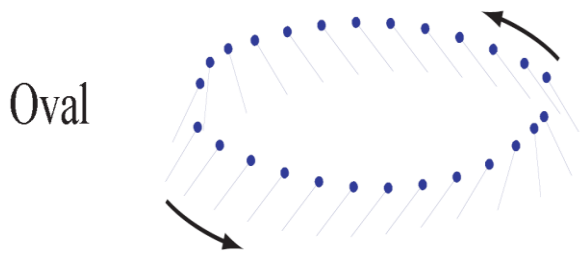


Figure10: Oval move

2 – Figure of eight :

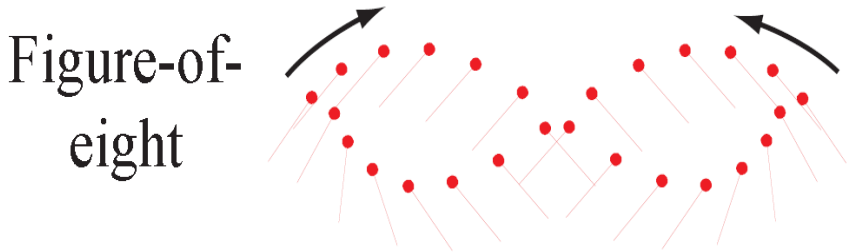


Figure: Figure of eight

designed Mechanism should do all these movements and the complete coordination with each other to be able to create lift force. Hummingbird eater flies with the same motion and hover mode.

5 - Conclusion

Plants and animals are such successful machines. The goal of this work was to lay a framework to understand the manner in which the common Robofly achieves this locomotion same Birdes , with the broad vision of providing insights into potential design solutions for future robotic vehicles.

The biological example has several key variations in the flapping technique adopted in air. Aside from the variations in flapping kinematics, the key mechanism used by the common

Robofly, , is the retraction of the wing reducing the overall wing plan form area and moment arm about which the wing is flapped.
Empirically determined values associated with inspiration of Nature for design Robofly and determined decreasing drag for locomotion.

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TRIZ activities in Korea by 2011 with some success stories

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Abstract

Korea is the most active country on TRIZ application field. This paper explains the success factors at big companies and Universities in Korea through TRIZ activities from early stage in 1996 to 2011. Specially, author explains TRIZ promotion team, TRIZ training program for big success stories at companies and Universities. He describes the developmental direction of Korea TRIZ activities to TRIZ education at University and schools, business and social conflict management in future.

Keywords: TRIZ application, Success factor, Korea TRIZ, TRIZ promotion team

1. Introduction

TRIZ applications with practical case studies in Korea are the most active in the world. TRIZ experts in the world like Russia and China are curious on "What is strong point of Korea TRIZ activities?" This paper describes the success factors through the TRIZ activities from early stage in 1996 to 2011.

2. Summary of Success factors of TRIZ activities in Korea

1) TRIZ has made the important role for compensating defects in idea generation in "Improve" stage of 6 Sigma process that is most popular during past 15 years

2) Korea TRIZ champion, former CEO Sun Wook's strong support at initial stage of Samsung Advanced Institute of Tech and then, the foundation of KATA (Korea Academic TRIZ Association) in 2010.

3) Direct introduction from Russia (about 10 Russian TRIZ specialists not through U.S.A, Europe and Japan) to biggest companies

4) Strategic Approach of TRIZ team at Samsung Electronics;

- Sharing big results at company-inside annual event with top executive managers & many Engineers.
- Special TRIZ introduction to all executive directors in R & D field and organizing the STA (Samsung TRIZ Association) that the related Samsung branch companies using TRIZ to empower the TRIZ activity inside Samsung Group and all TRIZniks in Korea.

5) About 70 TRIZ Korean translations and books and specially, "Online TRIZ" education courses to public domain in Korea

6) Currently, effective tool for "Creative management" at Samsung and "Creative Environment" by Government administrations

7) Almost Engineering Schools at many Universities have opened "Creative Engineering Design" official and mandatory subject for ABEEK (Accreditation Board for Engineering Education of Korea) like ABET (America Board for Eng. Education) certificates these days

8) Many TRIZ application education programs with seminar & consulting

9) Korean super dynamic nationality to like new issues and methods for innovation (such as TRIZ, six sigma and blue ocean strategy) is more active and faster than other countries

10) The 1st (in 2010) and 2nd (in 2011) Global TRIZ Conference in Korea had been successfully (with success stories at companies) held by the KATA (Korea Academic TRIZ Association) since 2010. (see www.KoreaTRIZCON.kr)

The news had been spread as big reports by 5th big newspaper, "Korea Economic Daily (韓國經濟新聞)" several times.

3. Characteristics of TRIZ in Korea Companies and University

1) Independent TRIZ promotion team & activities

The independent TRIZ promotion teams have made the big success stories with some customerized TRIZ training programs under innovation-related organization inside big companies.

For instance, Samsung Electronics has about 15 TRIZ enigineers with Russian TRIZ under the innovation related division, "VIP (Value Inovation Program) Center". POSCO (Pohang Steel Company) has about 10 TRIZ related engineers with some outside TRIZ consultants under "Productivity Research Center". Samsung Corning Precision Glass, Samsung SDI, Samsung Electro-Mechanics, SMD (Sunsung Mobile Display) as member companies of STA (Samsung TRIZ Association) have similar organization with some Russian TRIZ experts. The "DFSS (Design for Six Sigma) team" at Namyang Research Center of

Hyundai Motors, TRIZ team at "Production Technolgoy Center" of LG Electronics and TRIZ teams at Research Center and Production Division at Hynix Semiconductor are making the good results using TRIZ at each big companies.

The TRIZ teams at big companies are leading the TRIZ activities comparing to academic field and Korean TRIZ consultants in Korea.

Some Univerisities such as Korea Polytechnic University and Ajou University have introduced some good educational results. However, the portion is still small among over 100 Universities. Since several years ago many engineering Universities have opened the «Creative Design» course with 16 weeks and 3 credits as required subject for ABEEK (Accreditation Board for Engineering Education of Korea) centificate with TRIZ and other methods. The evalution for most professors at main engineering Univesity in Korea is mostly depend on the numbers of SCI (Science Cited Index) academic Journal. By the way there is no academic journal with SCI including TRIZ practices yet. So most Korean professors have not researched TRIZ in more depth and publish papers more and do not know well how to teach TRIZ at creative design course with not sufficient teaching materials. Sometimes they have disappionted the exaggerated TRIZ effects by TRIZ related salesman with expensive TRIZ softwares and the contradiction matrix.

2) TRIZ training programs

At initial stage in Korea, the TRIZ training programs had been imported from Russian TRIZ experts and Korean edition of English TRIZ books. These days Korea TRIZ experts have custormized the contents and problem solving process with other problem analyzing methods such as Function Analysis, Root Cause Analysis, Conflict Diagram in TOC (Theory of Constraints), Matrix between required functions and main design parameters in Axiomatic Design etc. The TRIZ problem solving processes based on ARIZ 85C process like Six Sigma such as DMAIC (Define–Measure-Analyze- Improve- Control) has been made in template form with some examples such as DAGEV (Define-Analyze-Generate-Evalute-Verify) at Samsung, LG and the similar process names at POSCO and other TRIZ and six sigma consulting companies.

Specially, some simplified processes called by "Quick TRIZ", "Practical TRIZ", "Easy TRIZ" have introduced for creative design education at Universities, invention education for young students at middle and high schools, engineers working for small and medium sized companies and workers at business and managing divisons at some government supported institutes.

3) Projects for big success at companies

The problems with some contradiction or called-by dilemma, paradox and conflict are effective for TRIZ application. Specially, projects suggested by TOP and not solving problems (for instance by six sigma) inside companies for long time are very effective to expand the

power of TRIZ if they are solved by support of TRIZ. Unfortunately many success stories have not opened to public domain because of secret policy of companies. However, some results have published and presented at www.TRIZ-journal.com, some international TRIZ conferences and specially, at the Global TRIZ Conference every spring held in Korea (See the abstracts and printed materials in www.KoreaTRIZCON.kr). Some approaches with case studies have introduced by Korea TRIZ engineer, consultants and professors in the world.

4. Perspective of Korea TRIZ activities

In author's viewpoint and experience, many general persons in Korea have started to know the name of TRIZ at least. The increasing interest on creativity atmosphere boomed up specially by "Apple", "Smart Phone", "Steeve Jobs" will make more general persons to have interested in TRIZ application in Korea. Korea Government and big companies such Samsung, LG, POSCO are driving the "Creative Management (創造 經營)" or "Smart Management society" as good environment for the growth of TRIZ activity. To be the TRIZ as bigger role in Korea, the balance between company, academia and consulting fields is important. The relatively weak effort at Universities has to be improved more and more with more many TRIZ class to educate talented persons with creativity, deep research on TRIZ itself and the related knowledge sharing not like the decreasing Six Sigma activities in Korea that had focused mostly on the consulting business for companies without much academic research at Universities.

The KATA (Korea Academic TRIZ Association, www.KoreaTRIZCON.kr) was organized with TRIZ teams at big companies, some professors and TRIZ consultants to organize the Global TRIZ Conference every spring since 2010 first. Basically it focuses practical aspects of TRIZ with sharing TRIZ news, TRIZ knowledge, publishing the domestic academic journal and communication with TRIZ communities in other countries in open mind.

The applied fields by TRIZ are hoped to be expanded to resolve the social conflict and managing conflict in business strategy. However, many persons have still complained the difficulty to understand and learn with difficult terminology and so many versions according to each TRIZ experts with not unified well-organized TRIZ knowledge. The examples and knowledge are mostly on problem solving in manufacturing such as mechanical engineering even though the TRIZ is introduced by the "creative thinking way". The forecasting by TRIZ is to show just mega trend of technology and product and not concrete and give a few clue for new business.

Korean TRIZ experts and users will expand the knowledge and approach in conventional TRIZ to business, social things and forecasting field for finding new and competitive business, product and technology combining other methods as more concrete concept generating method.

5. Conclusions

This paper explains the success factors at big companies and Universities in Korea through TRIZ activities from early stage in 1996 to 2011 according to author's personal experience. However, the issues mentioned in this paper with experience in Korea will be helpful to all TRIZniks in the world including China and Taiwan. Some practical case stories at Samsung and LG Electronics has been published in Chinese language at one Chinese home appliance monthly journal (see www.bmicn.com).

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Construction of Three Components -Function Model Based on Technical State Diagram of Subsystem

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Abstract

Three components-function model which developed from the Su-field model presented by Altshuller is a Systematic tool for analyzing problems. It can be more easily to identify the engineering problems with the model. The mostly used method to construct the model now is analyzing the actions and harmful effects between components one by one, which is inefficiency and difficult to ensure the accuracy of the model unless analyze it repeately. This paper presents a method of building three components-function model based on technical state diagram of subsystem. With this method, not only the process of modeling is clarity but also improve the efficiency and accuracy of modeling.

Keywords: functional decomposition, three components-function model, technical state of subsystem, sub-function,

1. Introduction

Three components-Function model is a Subject – Action– Object model. Subject – Action– Object models which derived from the Su-field modeling method of classical TRIZ presented by Altshuller are based on specific physical components of a system and the explicit effects they exert on other components of the system. Altshuller's students Zinovy Royzen developed the Su-field model and proposed Tool-Object-Product (TOP) Analysis method in 1989. In TOP model, the field of Su-field model is replaced by the action between the tool and object. This is the early three components -function model. Ives De Saeger divided action types between components into useful-harmful, insufficient-excessive, missing-effective when applying the functional thinking method to build three components -function model (Ives De Saeger named it functional analysis according to TRIZ (...) model). Joe Miller constructed the time dependence Subject - Action-Object models. DL Mann developed the model by establishing a time and attributes based function model (FAA model) and introducing the harmful reasons in the model through applying cause-effect method.

Although the structure of three components-function model is improved continuously, the methods of establishment mentioned in the existing references are relatively little. Tan used the reverse fishbone diagram method in building three components-function model[1] , which

Simplifies the process of defining components of complex product system. TechOptimizer software provided the computer-aided system of modeling, which can make the operation process of constructing more convenient to some extent. DL Mann built the model with the relationship matrix method which made the analysis of relations between components more organized[2]. With the foundation of previous research knowledge, this paper proposed a method of constructing three components-function model based on technical state diagram of subsystem, which makes the process of identifying harmful actions more organized and efficiency. The comparison between traditional steps of modeling and the one proposed in this paper is shown in table 1.

Table 1. The comparison between traditional steps and the one based on technical state diagram of subsystem

traditional method steps	**Steps based on technical state diagram of subsystem method**	Remarks
	1. Build technical state diagram of subsystem to identify the region existing problems.	
1.Identify system components	2. Identify system components	reference to [1]
2.Identify relationships between components	3. Identify relationships between components	reference to [2]
3.Identify harmful actions by analyzing the relations between all components one by one	**4. Analyze the problem region and map the problems to the harmful actions between components.**	
4.Link the components with actions to build the model	5.Link the components with actions to build the model	

As shown in table1, about the first two steps of traditional method，Tan and Mann have proposed methods([1]&[2]) to improve them. The differences of the method compared with traditional one are the first and final steps. The first step of the method proposed in the paper is that identify all problems in the system and problem regions through constructing technical state diagram of subsystem. By doing this, in the final step, it only need to find the harmful effects between the components in the problem regions, thus simplifying the cumbersome process with traditional method which need to analyze the actions between all components one by one. In addition, it is easy to lost some hidden problems when identify the harmful effects with traditional method. But for the method based on technical state diagram of subsystem, the final step is actually the process of mapping the problems have been identified to the harmful actions between components. It ensure that there is a problem in the system there are corresponding harmful actions in the model. In this way, the accuracy is improved.

2. Build the three components-Function model

2.1 Building the technique state diagram of subsystems

Technical state diagram of subsystem is a diagram that can express the state disparity between system features of each sub-function and the design requirements. i.e. through the

diagram it would be clear to know that which sub-function meet the design requirements and which not. The purpose of building the technology state diagram of sub-system is to find all the system problems and identify problem areas. For the sub-function which has met or exceeded the design requirements, it is considered that there is no technical problem in it's corresponding technical subsystem. But it is likely to cost more when exceeded the design requirements,which is a waste of resources. For the sub-function which can not meet the design requirements ,there must be some problems to be solved in its corresponding technical subsystem.Technical state diagram of subsystem is a qualitative diagram.We can get it through system functional decomposition,sub-function technology systems analysis and then compared with design requirements. According to design requirements, sometimes performance status is also necessary as a technical subsystem to analysis.

For example, a product,through functional decomposition and analysis ,its technical state diagram of subsystem is as shown in Figure 1. Assuming functional technology system E is composed of 4 sub-function systems, E={E1，E2，E3，E4 }. The shadow region represents the technical performance states of every sub-function and the dashed line represents the design requirements.

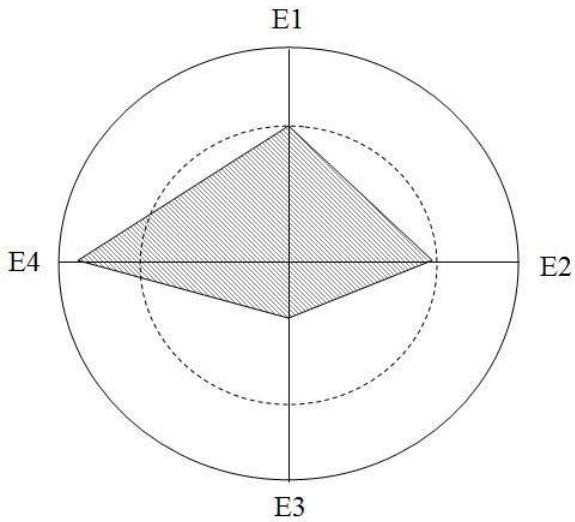

Figure 1. Technical states of subsystem

As shown, functions of E1 and E2 have met the design requirements and function of E4 has exceeded the design requirements. Function of E3 can not meet the design requirements which implies that system problems exist in E3 corresponding subsystems. The specific way of how to build the technical state diagram of subsystem will be illustrate in the case study.

2.2 Determining the super-systems, product and components

Chao-system is the system which not the one we study. Chao-systems are considered only when they have effects on the system we study. The output of the system are the products which are the purpose of the system. Components are the elements of the design system.

2.3 Building relationship table

This step integrates the third and fourth step in the table1. Integrate the information from above steps and relationshipes between components into table. It is only need to consider the E3 sub-system when analyze of the harmful effects between components. Map problems to the harmful,insufficient or excessive actions between components. Get the table similar to table 2. The specific process will be illustrate in the case study.

Table 2.System function relationship table

Subject	Action	Object	Action type	Function	Function type
Component1	Action1	Pruduct	useful	E1	Main function
Component2	Action2	Component1	useful	E2	Main function
Component1	Action3	Component3	useful		
Component3	**Action4**	**Component4**	**harmful**	**E3**	**Auxiliary function**
Component4	**Action5**	**Component5**	**insufficient**		
Component5	Action6	Component6	useful	E4	Auxiliary function
supersystem	Action7	Component5	useful		

2.4 Establishing three components-function model

Connect the components in table 2 with the actions between them. Establish the three components-functional model shown in Figure 2. In the model, the dashed up area is the E3 corresponding region where exist problems. Its problems have been mapped to harmful action4 and insufficient action5.In this way all the system problems are shown in the model.

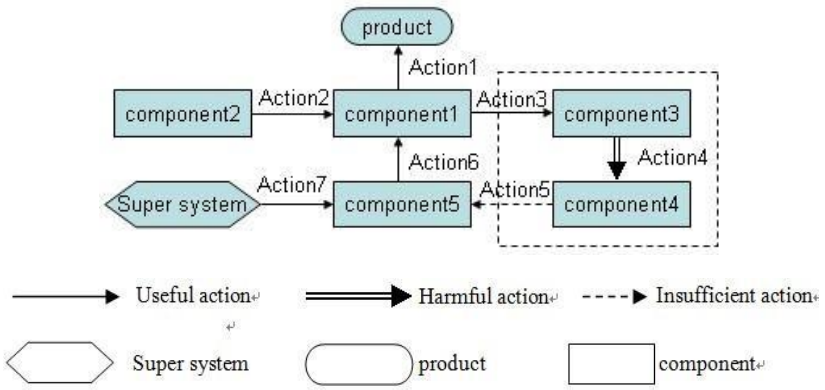

Figure 2. three components-function model

3. Case study: hot-warm straight water dispenser

Base on the market requirements we suppose the design demands: the water is clean and sanitary, meet the water supplying function,device safe and reliable,no secondary pollution. We take the most common type of hot-warm straight water dispenser in the market as an example to study.

3.1 Building the technique state diagram of water dispenser's subsystems

Firstly, take functional decomposition.The function of the water dispenser is decomposed into water supplying,water storage,heating,dust proof,shell protection, human computer interaction,overcurrent protection sub-functions and each sub-function corresponds to a technical subsystem. According to the design requirements, analyze each subsystem and the results are shown in Table 3.

Table 3. technical state of functional sub-system analysis of water dispenser

Sub-function	Sub-function's corresponding technical state of subsystem
Water supplying	Meet the design requirements
Water storage	Meet the design requirements
Heating	The dispenser would repeate heating the boiled water and produce furring when heat water, which are harmful to health. The water can not be heated to boiling because it will generate a lot of steam difficult to discharge. The sub-function can not meet the demand.
dust proof	The dust can get in through the Ventilated device. It can not meet the demand
Shell protection	Meet the design requirements
Human Computer Interaction	Meet the design requirements
Overcurrent protection	Meet the design requirements
Insulation	Insulation performance of sponge is insufficient. Can not meet the demand.

Technical state diagram of subsystem can be drawn as Figure 3 according to the table 2. From this we can clear that the problem areas of the water dispenser system are the the heating, dust proof and insulation sub-function corresponding subsystems.

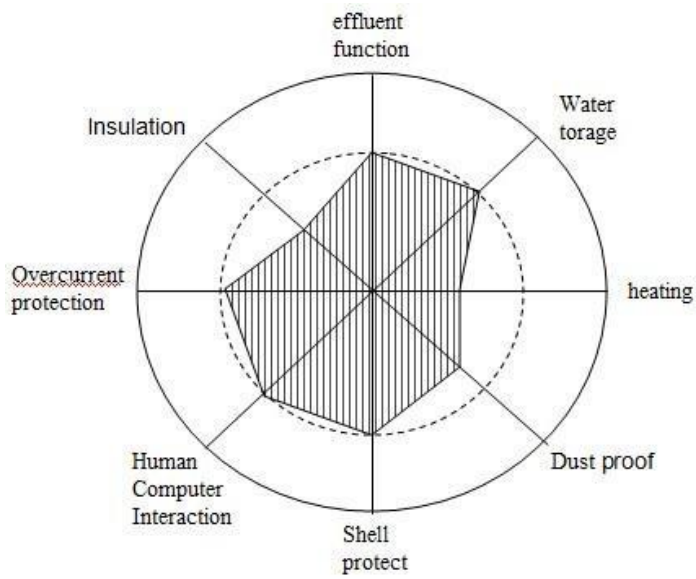

Figure 3. water dispenser's technical state of functional sub-system

3.2 Determining the super-systems, product and components of the Water dispenser system and functional relationship table

This step integrates the second ,third and fourth steps in the table1. Because the first two steps are not the main content of the paper，they will not be discussed here in detail. Considering the external environment which has impact on the dispenser system, we identify the dust as a super-system. Water dispenser is used to provide drinking water to people. So the products of the system are water and hot water. Then defined the system components (the steps not be discussed here) .Refer to Figure 3, the sub-functions of water supplying, water storage, shell protection, human-computer interaction, overcurrent protection have met the design demand, so there is no problem exist in the sense of design. We only need to further analyze of problem regions which are reflected in Figure 3 and map the problems to harmful actions between components. According to table 3, for the sub-function heating, the problem of repeated heating the boiled water is mapped to the harmful action of boiling between heater and water. The problem of producing furring is mapped to the harmful actions of producing furring and the furring pollutes the hot tank. The problem of water can not be heated to boiling is mapped to the harmful action of water produces steam when heating it. The problem in the dust proof region is that the dust can get into the inside of water dispenser through the ventilated device,which can be mapped to the incefficient action of obstruction between dust and ventilated device and the harmful action pollution between ventilated device and water. The problem in the insulation region can be mapped to the incefficient action of insulation between sponge and hot tank and the harmful action of reheating between heater and water. Integrate all the information above, then we can get the water dispenser system function relationship table as table 4.

Table 4. Water dispenser system function relationship table

Subject	Action	Object	Action type	Function	type
PC barrel	store	water	useful	water storage	Main function
water	flow to	water Storage tank	useful		
water Storage tank	contain	water	useful	Water supplying	Main function
	Stream	outlet pipe	useful		
	Stream	hot tank	useful		
outlet pipe	flow to	water valve	useful		
hot outlet pipe	flow to	hot water valve	useful		
water valve	control	water	useful		
hot water valve	control	hot water	useful		
ventilated device	hold pressure	water storage tank	useful		
	exhaust	steam	useful		
exhaust pipe	into	ventilate device	useful		
Sponge	Insulating	hot tank	**insufficient**	**Insulation**	Auxiliary
hot tank	contain	water	useful	**Heating**	Main function
	contain	Heater	useful		

heater	heat	water	useful		
	reheat	water	**harmful**		
water	produce	Furring	**harmful**		
	produce	Steam	**harmful**		
steam	into	Exhaust pipe	useful		
furring	pollute	hot tank	**harmful**		
The thermostat	thermometry	water	useful		
	Control	Power	useful		
power	Provide energy	Heater	useful		
	Provide energy	The thermostat	useful		
	Provide energy	fuse	useful	Overcurrent protection	Auxiliary function
fuse	control	Power	useful		
power	Provide energy	pilot lamp	useful	Human Computer Interaction	Auxiliary function
pilot lamp	Provide signal	user	useful		
user	Control	Switch	useful		
switch	Control	Power	useful		
intelligent drainer	obstruct	dirt	useful	**Dust proof**	Auxiliary function
	hold	PC barrel	useful		
	Stream	water	useful		
ventilated device	obstruct	dirt	**insufficient**		
dirt	Pollute	Ventilated device	**harmful**		
shell	fix	Intelligent drainer	useful	Shell protection	Auxiliary function
	protect	water Storage tank	useful		

3.3 Establishing three components-function model of Water dispenser

According to Table 4, three components-function model can be built by linking the components with actions between them, as Figure 4. In the Figure，the dashed up area are the sub-functions of dust proof, heating and insulation corresponding regions where exist problems. In this model, all the problems need to be solved in the system have been mapped to the three components-function model.

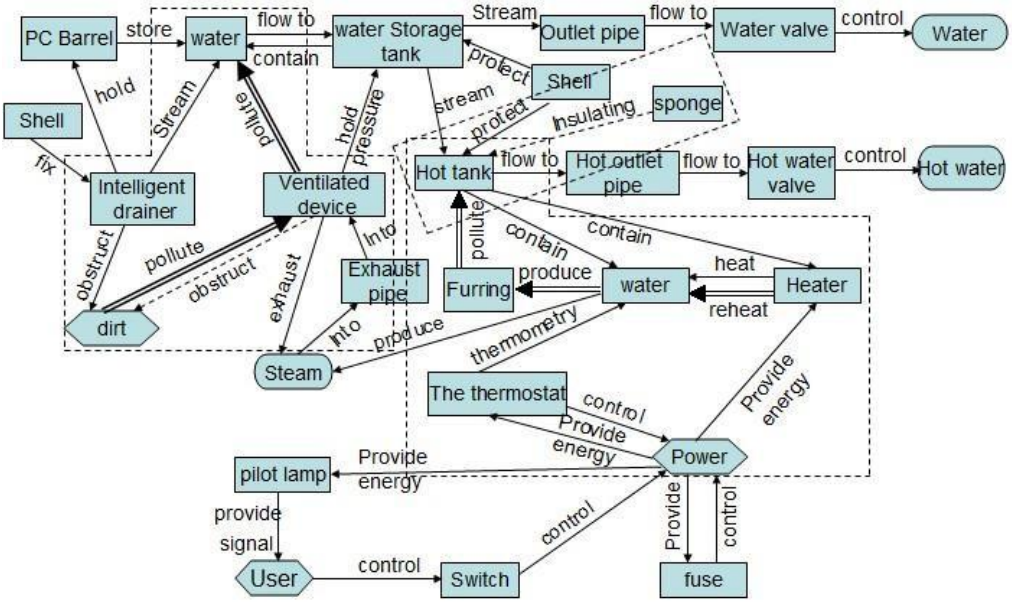

Figure 4. The three components -function model of water dispenser

4. Conclusion

The application of technology state diagram of subsystem not only makes the process of modeling more organized, but also improves the establishing efficiency and accuracy. In addition, the design requirements are the measurement standard of judging whether there are problems. So, if the problems expressed in the three components -function model are solved, the resulting product will meet the design requirements.

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A Successful Case to Create Innovative Idea for Power Transformer Overhaul

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Abstract— **A lot of people think innovative ideas are random and have to come from genius or otherwise 'trial and error'. There is also a myth that Asian people are strong in 'copying' but not 'creating'.**

Systematic Innovation is a structured way of creating innovative ideas to solve engineering, service and management problems. It is a forced thinking method to create ideas in a fast and directed way. It has different tools which could allow 'nongenius' people to develop ideas for product development, process development, etc. The tools are not just theories, they were developed based on deep analysis of many past patents around the world. The author will demonstrate how to use the Contradiction tool of Systematic Innovation to create ideas for a power plant transformer overhaul problem.

Keywords- Systematic Innovation; Contradiction; TRIZ

I. Introduction

Science and technologies have been changing rapidly in the last fifty years. In this era of rapidly changing and highly competitive environment, innovation is a vital source of competitive advantage. As quoted by the HKSAR government, Innovation and Technology Commission (ITC): "Innovation and technology add value to products and services, and enhance competitiveness of our industries". It was also highly supported by Professor Xu Kuangdi, President of The Chinese Academy of Engineering during his luncheon presentation to the Hong Kong Institution of Engineers on March 17,2010 that innovation is a must for industries to grow and survive.

There is a myth that innovation is relied on the genius in the industries. They are born to be innovation experts thus other people who do not have this genius can only follow instead of innovate. This myth has been proved to be wrong. In fact, most people have hidden genius. People can be trained to equip with some techniques to become innovative. Systematic Innovation (SI) is a guided approach to train engineers, managers to become creative idea generators.

In this paper, the author will present a successful case from CLP Power Hong Kong Limited of using Systematic Innovation tool to create innovative ideas for large power transformer overhaul.

II. Systematic Innovation

Unlike brainstorming type of innovation activities which are often ad-hoc and highly dependent on luck, Systematic Innovation (SI) is regarded as a systematic development of innovative problem solving and opportunity identification (Fig 1).

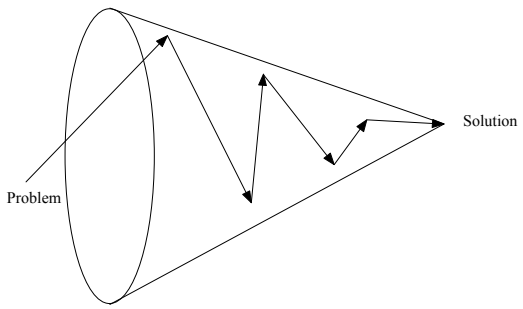

Fig 1: Systematic Innovation concept

There are many techniques inside SI, to name a few: TRIZ, SCAMPER, Six Thinking Hats, DeBono random words, etc. Among them, TRIZ is one of the most powerful concepts. Using TRIZ, one can generate better ideas faster. The ideas can solve the problem effectively and form a basis for further improvements.

TRIZ, introduced by Genrich Altshuller (1950), is a systematic and creative approach to reach innovative results by using 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 patent inventors' problem solving knowledge to enhance practitioner's domain knowledge and inventing problem solving skills.

There are five key concepts which make TRIZ very valuable for innovative problem solving.

1. Functionality- which helps to focus on the fundamental function and inspires us to create simple design.
2. Contradiction- the underlying factor that blocks human advancement is contradiction. Innovation is to solve at least one contradiction in the system.
3. Resources- which inspires us to use existing resources and to turn the harmful factors to benefits.

4. Ideality- which defines the goodness of the product and system. It is the measure of how close the system is to the ideal final result.
5. Space/time/interface- which facilitates us to see problems from various space/time/interface and allow us to solve problems easier and more innovatively.

III. Case Study of Large Power Transofrmer Overhaul

This case is from the Power Transformer Services Team of Technical Services Department, Power Systems Business Group, CLP Power Hong Kong Limited regarding overhauling of large power transformer. They demonstrate how to use Systematic Innovation tool- TRIZ to create innovative idea to improve the process. It leads to improving of efficiency, saving of costs and capital investments.

The life of a large power transformer will shorten from year to year due to the deterioration of the insulation performance. The deterioration is mainly due to the degrading performance of the insulation material (usually paper) because of moisture absorption in years. Therefore the drying process of the insulation material becomes the most important step of the overhaul.

Conventional method of drying-out a large power transformer is to submerge the transformer in a controlled environmental chamber (Fig 2). The chamber is filled with hot oil which would heat up the moisture and act as a carrier to carry the moisture away during the circulation. This method has the limitation that the moisture absorbed deeply inside the insulation material is not able to be removed. It is because the temperature of the hot oil would be greatly reduced when passing through the insulation material.

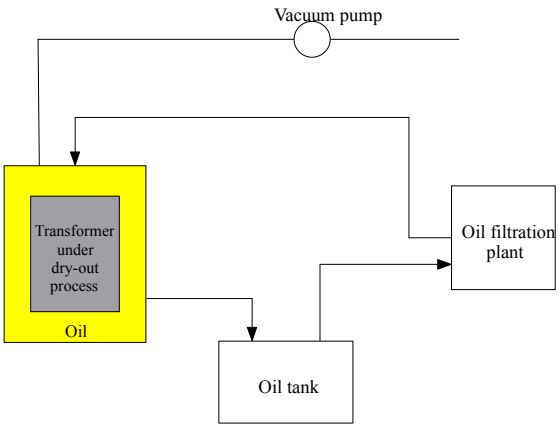

Fig 2: Conventional Dry-out Process by Hot Oil Circulation & Vacuum Extraction

This dry-out process is a long process depending on the moisture level inside the insulation material. For moisture percentage of 3~4 %, the duration of this dry-out process could be as long as 15 days. The goal of the Power Transformer Services Team is to improve the efficiency of this overhauling process by shortening the duration of the dry-out process with the condition that the investment of the new process has to be justified.

IV. Systematic Innovation Tool Application

The team used traditional thinking to identify a solution to this problem but in vain. Finally they selected to use TRIZ as the systematic innovation concept to create solution.

There are different tools inside TRIZ: Ideal Final Result, Trend of Revolution, Contradiction Matrix, Function Analysis, Trimming, S-Fields, ARIZ, etc. The team chose to use Contradiction Matrix because they could easily identify many technical contradictions in the system.

There are two types of contradictions, technical and physical contradiction. Technical contradiction is a situation in which an attempt to improve one parameter lead to the worsening of other parameter. Physical contradiction is two opposite requirements placed upon a single physical parameter.

Contradiction Matrix which contains forty inventive principles is used to solve the contradictions. The parameters of the contradiction were used as the two inputs of the vertical and horizontal axis to identify the suggested Principles at the intersection box of the Matrix.

The team found that there are at least two technical contradictions in the dry-out processing system. They can shorten the dry-out process by increasing the <u>temperature</u> of the oil so that the moisture could be carried out faster; however the insulation material would be damaged leads to <u>poor reliability</u> of the transformer. When this technical contradiction is identified, the team used the Contradiction Matrix to look for inventive principles. From the Matrix, there are four inventive principles which could solve this technical contradiction, they are Principle 10- Preliminary Action; Principle 29-Pneumatics and Hydraulics; Principle 35Parameter Changes and Principle 39-Inert Atmosphere.

1. On the other hand, if they <u>reduce the temperature</u> of the process to reduce the damage, the <u>productivity</u> of the process would be lowered. From the Contradiction Matrix again, there are another three suggested inventive principles. They are Principle 15-Dynamics; Principle 28Mechanics Substitution; and Principle 35-Parameter Changes.

From the above Contradiction exercises, Principle 35 – Parameter Changes is a common recommended principle which is a strong signal that this principle could be applicable for the solution. Other recommended principles are also

considered based the expertise of the team. These inventive principles triggered the team to identify creative solutions in combination with the team's expertise.

V. THE INVENTIVE OVERHAUL PROCESS

The Power Transformer Services Team took the suggested principles of Parameter Changes to change the parameter of the oil from liquid state to vapor state for trial. They did experiments to use vaporized hot oil instead of liquid oil for the dehydrating process. Eventually they came up with the idea of spraying very hot oil on the surface of the transformer. The high temperature of the hot oil could dehydrate the moisture of the insulation material much faster. The vaporized hot oil droplets could reach deeper inside the insulation material. Since it is a spray, the hot oil would not stay contact with the material long hence there is minimal damage to the insulation material. The oil spray moves faster inside the chamber because of the light weight of the oil droplets, eventually the whole de-moisturing process could be speeded up. The new hot oil spray process just uses the existing chamber by installing some oil spraying nozzles at the top of the chamber (Fig 3) thus the investment on changing the set up of the new process is low.

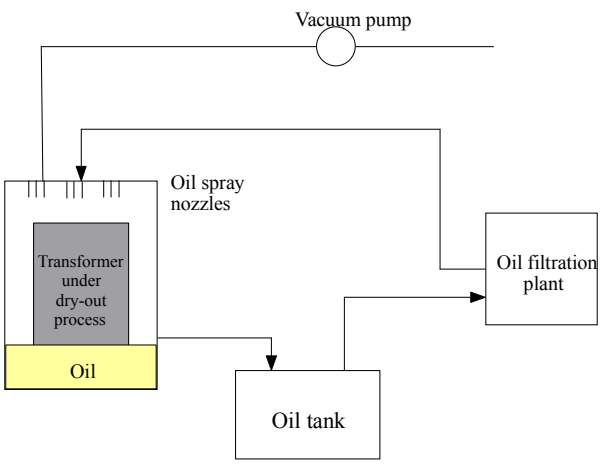

Fig 3: New Hot Spray Dry-out Process

VI. CONCULUSION

This innovative process was developed based on the inventive principles of the TRIZ Contradiction Matrix. The advantage of using Systematic Innovation tool to identify innovative solution is direct and fast. It could identify solutions faster than the traditional brainstorming type techniques; since it is a force thinking tool, it could create innovative ideas in a more focused way.

From the application of this case study, the duration of the new process of the transformer overhaul is only half of the old process. It saves the time of the operation, material (i.e, the oil) and labor cost. It also doubles up the capacity which leads to less future capital investment.

In today's operation, innovation becomes a must in order to enhance competition. Innovation is not a random process as most of the people think. To provide technical solution to product and process development, innovation can be a systematic process that can be learned and trained. TRIZ is one of the systematic innovation concepts that has already been employed by many famous international companies to solve problems, develop new products and processes. It is not guesswork moreover it is also not a magic formula. It triggers the thinking of the people of the organization and directs them to approach a practical creative solution. Along the thinking process, the knowledge of the people contributes to the final solution. This thinking process could become an asset of the company and eventually further enhance future innovative ideas.

The author, Dr Michael YH Li is the President of Institute of Systematic Innovation in Hong Kong and Managing Director of Top Talent Consultants Ltd. He is a MATRIZ Professional of the International TRIZ Association. He is a trainer of TRIZ for CLP Power Hong Kong Limited. Dr Michael YH Li appreciates CLP Power to allow him to use this case for writing up this article.

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DESIGNING A UTENSILS SET FOR VISUALLY DISABLED PERSONS BASED ON TRIZ SYSTEMATIC INNOVATION METHOD

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Abstract

In this research, the principles of TRIZ are applied to design a dining utensils set for blind persons. From the Method of 9-window, the following three ideas were developed: (1) Ease of Recycling: Use different colors for different materials so that it will be easy to recycle. (2) Energy Saving: Use solar rechargeable batteries. (3) Stability: Use magnetic devices, suckers or even fillisters on the dining table to stabilize the utensils set. From the Method of Substance-field Analysis, another designing idea was found: (4) Scald Proof: Temperature sensors and warning devices can be integrated into the utensils set so that the visually impaired users will not be injured by high temperature.
Keywords: dining utensils set for blind people, 9 windows, Substance-Field Analysis

1. Introduction

1.1 Motivation of the Research

Tableware and kitchenware are necessary in our daily life. The usage rate and the demand of the market are quite substantial. The blind can't see anything so they spend a lot of time to take the tableware. In addition, it makes regret that they are easily to overturn the food, scald by hot soup, break the bowls and plates, even cut by the broken tableware. Therefore, the research of the tableware for the blind is significant.

The design of conventional tableware and kitchenware is devised by traditional products or imitated others' products. The tableware and kitchenware are seldom to be developed and designed by innovative method of systematization, so they take much more time to renew the product and the design is limited as well. Therefore, the research implements the innovative design of the tableware for the blind by TRIZ systematization.

1.2 purpose of the Research

The purpose of the research is to accomplish the innovative design of the tableware for the blind and popularize it by systematical and innovative method that contains 9-window and the Substance-Field Analysis.

2. Literature Review

Systematical innovation is the knowledge to improve technology and society. Its purpose is using the systematical method to help people solve problems by systematically and creatively. The idea originated from predecessor and the natural method and theory of innovation. It tries to utilize the theory and the method systematically and innovative to solve problems. In accordance with a certain kind of systematic methods and procedures, the whole space of solution can be seen, and the answer will be shown instantly by analysis. It also can gain the best answer by observing integrality. Systematic innovation unlike traditional brainstorming stressed that invention or innovation depends on the certain procedures and steps but not just random or abstract mental stimulation. Systematic innovation follows the tracks of the thinking of predecessors and extracts the principles of the invention previously. Finally, it induces the general principle to be the direction of thinking when solving problems (Clausing, 2001;Mann, 2003). Some of the theories and methods of systemic innovation are introduced as the following.

2.1 9-window

9-window corresponds with the particularized way of the super system, system and subsystem (the surrounding environment, the system itself, the system elements) to force to ponder any kind of problems and solutions by the past, present and future. 9-window deliberates the useful thing (resource) in the surrounding by the way of logical system. It can employ the useless resource to solve problems for breaking the psychological inertia. It can be divided into two kinds of tables: (1) the life cycle (The products from every stage of materials acquisition, production, usage, maintenance and disposal); (2) the trend (products of different generations)

Table 1 9-window

Time / System	Past	Present	Future
Super System			
System			
Sub-System			

2.2 Substance-Field Analysis

Substance-Field Analysis is a basic concept used on technology deconstruction and innovative invention. Scientists and engineers can segment a bigger problem into a lot of small problems. These problems can be specifically described by indications and symbols and use each rule of transformation to solve problems. Altshuller, the master of TRIZ, proposes a theory called Substance-Field Analysis (Su-Field) to apply to the system of the classification, innovation and operator. Substance-Field Analysis includes

a field and two substances. Field is the needed energy to enable the interaction between two substances. One substance is tool (the strength) and the other is the objective to use the tool (by forced strength). The Figure 1 shows the basic substance, field triangular model (Terninko, 2000;Xiaoming, Xueqing and Simaan, 2007).

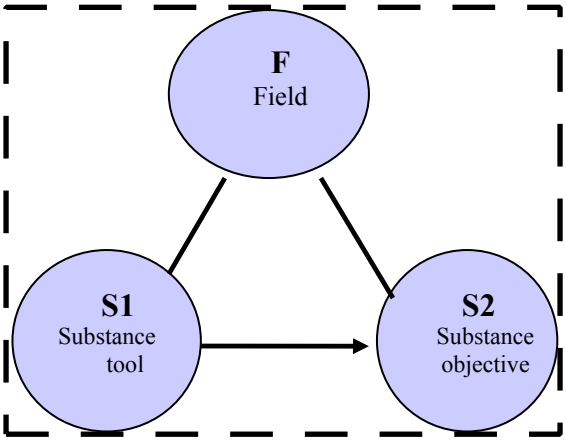

Figure 1 Basic Substances-Field Triangle Model

3. Innovative Design of the Tableware for the Blind

3.1 The Concept of Design

The concept of design is a design for the blind to use the tableware more conveniently. The blind have rights to enjoy the food comfortably and the researchers hope to let the blind feel been concerned. There are spoons, chopsticks, bowls, plates and cups for the main tableware.

3.2 9-window

1. The Table of the Life Cycle for 9-window

Table 2 shows the life cycle of 9-window for the tableware for the blind.

Table 2 The Life Cycle of 9-window for the Tableware for the Blind

Time / System	Past	Present	Future
Super System	Display, Sales, Construction	Kitchen, People, Dining	Recycling (Decoration), Garbage
System	Design, Select Material,	Table*c	Classification
	Store display, Warehouse Inventory	spoons, chopsticks, bowls*c, plates*c, cups*c	Scrap Recycling*a, Disposal, Maintenance of Second-Hand Stuffs
Subsystem	Production	Plastic, Glass	Recycling

2. The Table of the Trend for 9-window

Table 3 shows the trend for 9-window for the tableware for the blind.

Table 3 Trend for 9-window for the Tableware for the Blind

Time Past / System		Present	Future
Super System	Ground and Stone for Table	Kitchen, People, Dining Table*c	Intellectual Feeding, Robot guidance
System	Take Food by Hand, Leafage	spoons, chopsticks,	Intellectual Tableware
Subsystem	Load food	bowls*c, plates*c, cups*c	Intellectual Material, Complex Material
	Leafage, Trees	Plastic, Glass	

3. Creative New Ideas

The followings are the creative new ideas:

a. Using different colors to recycle the materials of different parts and utilize these again.

b. Designing solar power energy for electrifying the rechargeable battery to reduce the usage of electricity.

c. Dinner plate and dining table are designed for holder (groove), and magnet sucker so that bowls, plates, and cups are not easily knocked over.

3.3 Su-Field Analysis

The blind are easily scalded by hot soup. The procedure for solve this problem is as follow:

3.3.1 Problem model

a. Tool substance: Hot soup

b. Objective substance: The blind

c. Field: Temperature (high temperature)

d. Damaging effects: burn

3.3.2 Function Analysis

Conducting function analysis can clearly identify problems. The system brings the related components about a problem shown in Figure 2 in the foregoing problems. When the blind are scalded by hot soup, there will have tabletop to sustain the bowl and then the bowl can hold hot soup, the blind are scalded by hot soup.

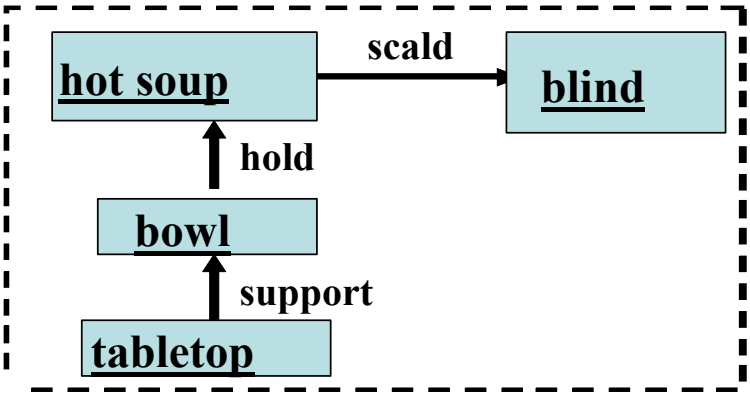

Figure 2 Function Analysis for the Blind Scalded by Hot Soup

3.3.3 The algorithm for standard inventive solutions

Apply the six steps of the algorithm for standard inventive solutions into the field analysis to resolve the problem as it described below.

1. Describe the key problems

Figure 2 shows the problem for the blind scalded by hot soup.

2. List all related interactive components

From the description of the key problem, all related problems of substance and field are listed. The key problem is the blind scalded by hot soup; therefore, hot soup and the blind are the substances and the temperature is the field.

3. Create a Su-Field model of the engineering problem

In the research, hot soup is the tool substance S1, the blind are the objective substance S2, and the blind are scalded by hot soup. Hot soup S1 is damaging (T, Temperature Field), the blind S2, the model of the problem is shown in Figure 3.

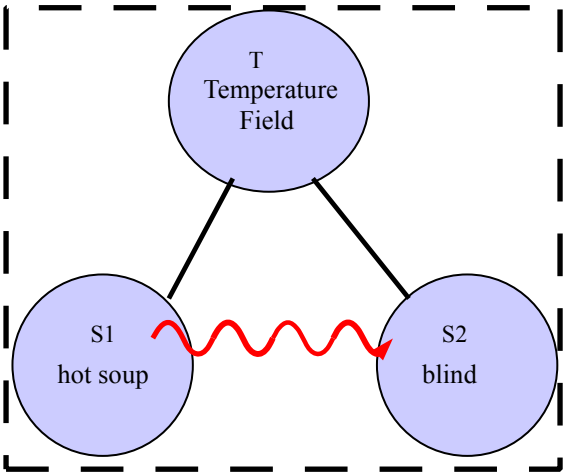

Figure 3: Su-Field model of the problem for the blind are scalded by hot soup.

4. List the corresponding standard inventive solution

The problem corresponds with the standard of solutions is the 1.2,. eliminate the harmful effects.

5. Create a new Su-Field model of the engineering problem

Use the standard inventive solution 1.2 to establish a new Su-Field model. Introduce the useful substance S3 between S1 and S2 to avoid damaging function, and it is able to detect high temperature so that the blind is aware of it.

6. Find the solution to solve the problem

Introduce sensors S3 between S1 and S2 to detect high temperature and then alarm. That can avoid hot soup scald the blind. The model of the solution is shown in Figure 4.

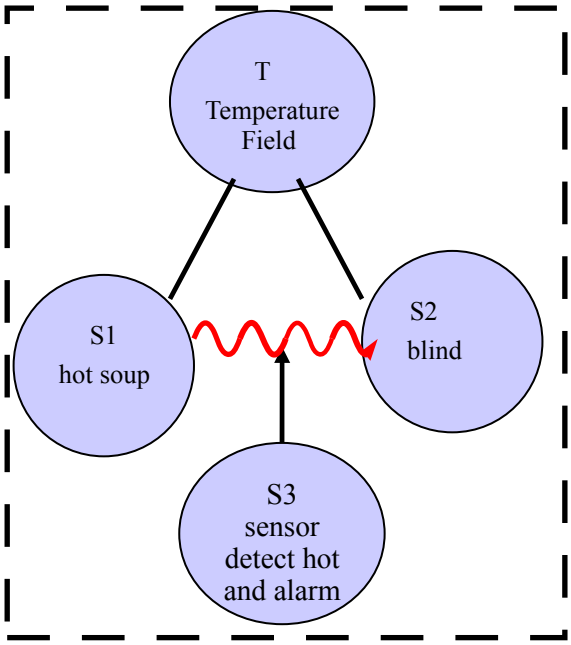

Figure4: Su-Field model the solution for the blind are scalded by hot soup.

3.3.4 Creative New Ideas

A spoon and chopsticks can be designed with a thermometer. If the temperature is too high, it will alarm to notice the blind avoid to be scalded.

4. Conclusion and Suggestion

The research concludes the following:

1. The blind can't see anything so that they are easily to overturn the food, be scalded by hot soup, break the bowls and plates, and even be cut by the broken tableware. Therefore, the research of the tableware for the blind is significant. This research is applied to design a dining utensils set for blind persons.
2. From the Method of 9-window, several new ideas were developed in this research:

a. Ease of Recycling: Use different colors for different materials so that it will be easy to recycle. b. Energy Saving: Use solar rechargeable batteries. c. Stability: Use magnetic devices, suckers or even fillisters on the dining table to stabilize the utensils set.

3. From the Method of Substance-field Analysis, other new designing ideas were found for Scald Proof: Temperature sensors and warning devices can be integrated into the utensils set so that the visually impaired users will not be injured by high temperature.

4. The method in the research integrates 9-window and the Substance-Field analysis on the design of innovation for the blind tableware. In accordance with the same principle, the suggestion is to design more tableware for the blind so that can benefit them for dining.

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Experiences with the creation of CETA - Center of Excellence in Advanced Technologies in Brazil

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Abstract

This paper describes experiences obtained with the creation of CETA – an applied research center for innovation created in Brazil within the scope of an German-Brazilian international cooperation. CETA follows the Fraunhofer applied research model and aims to be an innovation driver for local industry in Southern Brazil. For that purpose, a process acquisition and selection process based on a balanced-score card methodology was developed and strategic partnerships with international research center was established. Among these a collaboration with IMS-Center and Prof. Jay Lee's dominant design approach was established. The paper describes some relevant industrial case studies developed by CETA.

Keywords: applied research, innovation, industrial case studies

1. Introduction

Market demands for innovative, high quality products, aggressive competition at a global scale, increasing productivity through highly optimized production processes, and environmental/societal pressures are some of the challenges faced by industry. In particular for Brazil, one of the BRICS countries (with Russia, India, China, and – more recently added to this group– South Africa), which is facing a considerably economic development over the last decades, the development of innovative products, equipment and services with added-value content becomes of uttermost importance. Several initiative are being undertaken in Brazil in order to develop a good ambient to the creation and growth of competitive, innovative and globalized Brazilian companies. Among these initiatives, the Center of Excellence on Advanced Technologies (or CETA – Centro de Excelencia em Tecnologias Avançadas), an applied Research Center focused on innovation and aiming to make companies, academy and government to work together (following the triple helix concept [ref]) was created in late 90s in Porto Alegre, the capital of the southern Brazilian state - Rio Grande do Sul. CETA was conceived inspired on the German Fraunhofer Model of applied research, within the scope of a German-Brazilian collaborative project. Similar to the German Fraunhofer Institutes (and currently there are more than 72 those institutes in Germany [ref]), CETA is a non-profit applied

research organization that has as mission to promote technological innovation and to contribute to the technological and social development of the sate of Rio Grande do Sul and Brazil.

The paper is divided as follows: Section 2 presents a brief historical perspective of CETA creation. Section 3 discusses CETA operations, focusing on the defined project acquisition and selection process. In section 4 an overview on some selected innovative projects are described. Finally in section 5 some lessons learned and future directions are discussed.

2. Brief Historical Perspective

CETA was created in the late 90's by the State Ministry of Science and Technology and by the Federation of Industry (FIERGS) both from the state of Rio Grande do Sul in Southern Brazil to develop innovative applied research projects in collaboration with academia and industry. CETA's creation was developed within the scope of an international collaboration with the German Ministry of Research and Education (BMBF) and was considered as a prioritary project by Bilateral Commission (Brazil-Germany) of Scientific and Technological Cooperation in 1999 and 2004

Since its foundation CETA was established to cause a paradigm shift in the management of applied research to industry, by focus on technological innovation and added-value products, processes, and services. Main motivation for CETA's creation was the clear identification of a gap in the interaction of universities/research centers and industry (see Fig.1). Despite the fact that some of the top universities in Brazil and Latin America are located in Rio Grande do Sul industry usually considered that research results were too abstract and without direct application to their technological demands and with this a gap existed in their interaction with academia (Fig. 1a). CETA was created to fill this gap (Fig. 1b) aiming to combine academic excellence and high innovation content with industrial relevance and market impact.

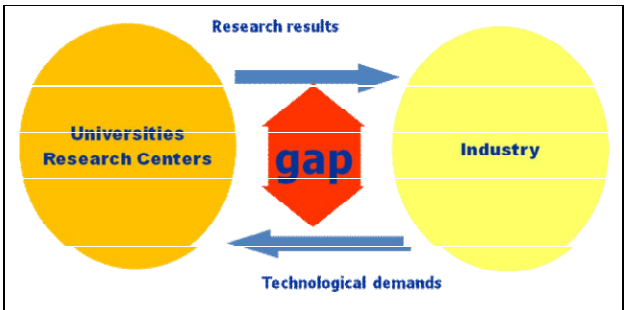

Fig. Existing gap between industry - academy

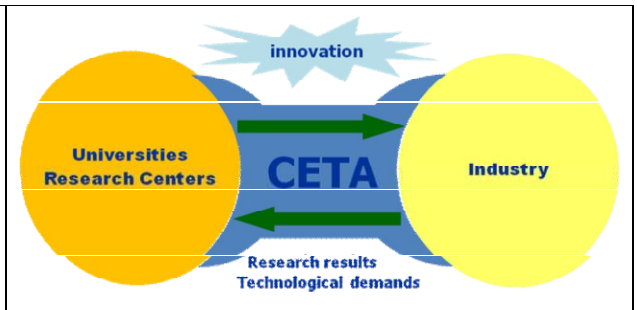

Fig. 1a – CETA as a bridging the gap concept

CETA's creation was planned into 3 distinct phases: the first one (late 90's) included a feasibility study, with the mapping of existing competencies and industrial demands and a business plant was defined. In the second phase some pilot projects, most of them with a strong financial support from Brazilian government, were developed. Those projects were selected on their impact and innovation content, but also trying to avoid very risky projects, since it was important to present some succesfull

results in the initial phase. In its third phase, which started around 2005, CETA should become a self-sustainable entity. In this phase CETA was institutionalized as an operational unit of SENAI, which is the largest Brazilian institution devoted to professional education and training, technological support, technological information, and applied research for the industrial field. Also in this phase it fully assumed the Fraunhofer model in administration, having as Technical Director an university professor and as General Director a SENAI's employee.

CETA's research areas include Information & Communication Technology (ICT) as well as Product & Production Development, developing conceptual solutions, realizing pilot and prototype solutions, feasibility studies, system design, and support in product and process development. CETA's projects are built upon own competencies and in partnership with national and international R&D organizations and technologies centers. CETA has successfully developed projects in area such as Optimization of the production processes (coating, welding, logistics, supply-chain), new product development, Factory Planning, Industrial Benchmarking, Product Lifecycle Management, Intelligent Maintenance Systems, Hygienic Design (Food Industry), and cleaner technologies. Examples of ICT projects are tele-medicine projects (some of them developed with support from the European Community in the Framework Programs), Intelligent Maintenance (in collaboration with the IMS-Center from USA), Power-Line Communication for digital inclusion, innovative medical instruments (such as a Non invasive Glicosimeter), Industrial network protocols (wired and wireless), Supply-chain optimization / management, Virtual Reality and Mixed Reality Applications.

3. CETA Operations Overview – Project acquisition and selection

In order to ensure that developed projects necessarily include innovation and present market relevance, a CETA's projects acquisition and selection process based on a balance-scored card methodology was developed. As can be seen in Fig. 2, all project proposals are assessed in terms of different metrics such as innovation contents, social/economic impact of results, etc. Those metrics are then visualized in a radar chart and categorized. Additionally, a standardized project life cycle workflow was defined (Fig. 3). This methodology has been successfully applied to several research projects (some of them will be summarized on section 4). In the development of one the phase 3 projects, in a collaboration with IMS-Center of the University of Cincinnati, a more close contact witg Prof. Dr. Jay Lee was established. With that, an increasing interest for the incorporation of the dominant design approach [ref] to CETA's process arose. With the organization of two dominant design seminars at FIERGS held by Prof. Jay Lee to an audience with the participation of several key representative (CTOs and R&D directors) of local companies, the first steps towards this goal were undertaken.

Avaliação de Projetos CETA (FINEP)

Projeto: Cliente: **Empresa X**
Data Avaliação: Avaliador:

			CRITERIOS	ATRIBUTOS 1 a 2	3	4 a 5	Escore Projeto	Ideal
MAXIMIZAR	CETA	1	Conteúdo de pesquisa aplicada	Baixo	Médio	Alto	3	5
		2	Difusão de resultados (para outros clientes)	Remoto	Possível	Imediato	4	5
		3	Desenvolvimento de competências (P&D)	Pouco	Moderado	Intensivo	4	5
		4	Perspectiva de longo prazo do projeto	Pequeno	Limitado	Grande	4,5	5
		5	Transferência de conhecimento de gestão para o CETA	Pequena	Média	Alta	4	5
		6	Impacto sócio-econômico	Pequeno	Limitado	Grande	3,5	5
	FINEP/ EMPRESAS	7	Substituição de importações	Pequena	Limitada	Intensiva	3	5
		8	Inovação e geração de patentes	Pequena	Média	Grande	2	5
		9	Modernização sistema produtivo	Insignificante	Razoável	Significativa	4,5	5
		10	Aumento capacidade e escala produtiva	Pequeno	Médio	Grande	4,5	5
		11	Incremento de exportações	Pequeno	Médio	Grande	4,8	5
		12	Financiamento	Difícil	Médio	Fácil	3,5	5
MINIMIZAR	RISCO	13	Complexidade (minimizar)	Alta	Média	Baixa	4	5
		14	Risco (minimizar)	Alto	Médio	Baixo	4,5	5
TOTAL							53,8	70

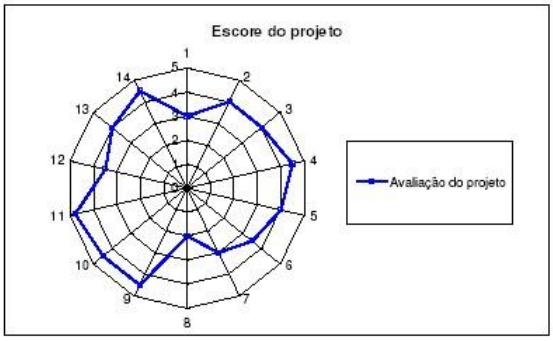

Fig. 2– Project acquisition and selection process

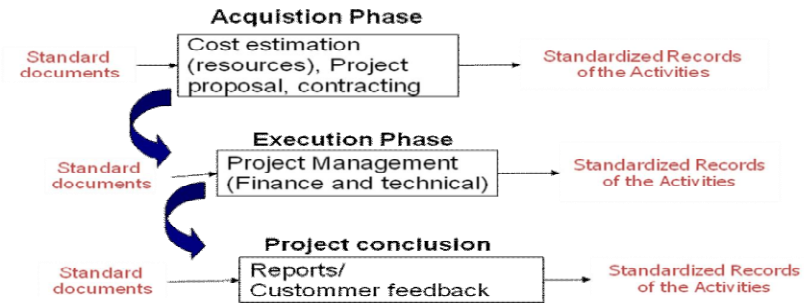

Fig. 3– CETA Project's Life Cycle Workflow

4. Overview on selected innovative projects

This section aims to give an overview on some relevant applied R&D projects developed by CETA. One of the first project developed by CETA – as one of the "pilot project" in phase 2 dealt with the Inbound Logistics Computational Simulation of the Storage and Packaging Area of a Furniture Factory (Torres et al. 2005). It involved the use of Computer Simulation (Digital Factory) in the modeling and study of the internal logistics of the company's storage area, and the simulation of different scenarios for handling methods and working policies. The observed results raised

important aspects regarding to the storage layout and the way of accomplishing the separation and feeding of the packing lines. Company employees believed that a pre-picking in an earlier shift of work would optimize the separation and feeding activities. However, the simulation results demonstrated that this practice would actually decrease the productivity. The company decided to implement all the significant results, even those with high investments. New equipment was suggested which reduced the storage area in seventy percent related to the studied area. This suggestion was implemented in the new plant and kept the same area reserved to the storage looking forward to increasing the production forecasted. The packaging area productivity improved about twenty percent after the implementation of the new picking techniques. The improvement reached that number few months after project end, and was a clear example of the benefits in using a computational model to test real situation before any physical modification. It is important to mention that all those results were accomplished without any reduction in labor force, so nobody was fired during the project and after that, the changes are based on a rationalization of the working tasks. Figure 4 shows the simulation environment model in the software eM-Plant Simple++®.

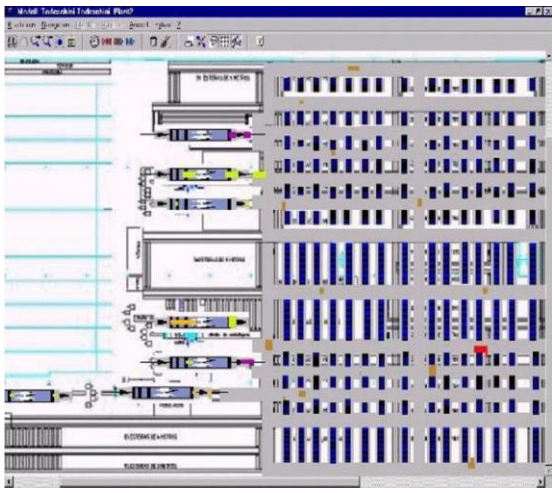

Figure 4 : Computational model in eM-Plant Simple++®.

` CETA has also developed very succesfull projects in the area of Telemedicine. It started with the Telemed project ("*Telemedicine for remote and rural underserved regions in Latin America using e-health platforms"* – see (Binotto et al. 2007, Binotto et al. 2005) a Consortium involving 13 institutions funded by the 6th Framework Program of the European Community - @LIS Call. This project was approved among more than 990 proposals submitted. In the project final evaluation, the activities and results achieved in Brazil were highly appreciated. Following this project, CETA has been selected to develop the T@*his* – *Telemedicine in the Amazonian region, a project funded by the European Space Agency – ESA* (Sachpazidi et al. 2007), with partners as HISPA-SAT, ALCATEL ALENIA Space, Fraunhofer IGD, and the Hospital Santa Casa de Misericórdia de Porto Alegre.

Based on the knowledge from those projects, CETA leaded the *PO@-Saude* project (Binotto et al. 2008, Binotto et al. 2009, Pereira et al. 2008), a collaborative research project among the following brazilian institutions: Federal University of Rio Grande do Sul (UFRGS), CETA,

PROCEMPA - the ICT Company from the City of Porto Alegre, and CEEE - the State Electrical Energy Company), which combines Tele-Medicine and Power Line Communication Technologies in order to improve medical services delivered to low income families in public healthcare units located in Porto Alegre suburbs. The results obtained within the scope of the project were very encouraging: absenteeism has dropped from more than 12% down to less than 3% and waiting time for ultrasound exams was reduced from 4 months to less than 4 weeks. The PO@-Saude project started within the scope of a PLC trial project developed by the project partners, which focused on performance evaluation of power line communication for transmitting different media (video, voice, ultrasound data, etc). The evaluation site was located in the area named as "Restinga", one of the largest and poorest suburbs of Porto Alegre – capital of the Southern State in Brazil – Rio Grande do Sul, located about 30 km from Porto Alegre downtown and with a population of more than 100,000 people.One of the goals of the Po@-Saude project was to make ultrasound tests available to a larger number of pregnant women who live in Restinga as well as to reduce the high rate of absenteeism for medical tests scheduled for pregnant in healthcare facilities located in the central region of Porto Alegre. The situation was particularly worse for pregnant women with other children. Many of them could not take any obstetric ultrasound testing during their pregnancy. Since Restinga has a twice higher birth rate than the rest of the city, this situation leads to many adverse consequences, such as a higher rate of mother and child deaths or bad formation, and a higher number of hospitals beds occupied in the public hospitals.

Currentluy, CETA is involved in the MEDNet – Latin American Health Care Network (www.e-mednet.com). The Project will connect insulated regions in Amazon (Brazil and Peru), by means of DVB/RCS-based satellite (AmerHis) communication system. Consortium: Fraunhofer IGD, Thales Alenia Space Spaña, Geopac, VicomTech, MedCom GmbH, National Technical University of Athens, ESSALUD, Gobierno Regional de Junin, CETA SENAI, Santa Casa de Misericórdia de Porto Alegre. Call: EC FP7–ICT-2007-1, topic 5.2: Advance ICT for risk assessment and patient safety.

Motivated by the success achieved by the IMS Center of the University of Cincinnati, the Federal University of Rio Grande do Sul (UFRGS), one of the top universities in Brazil and CETA have established a collaboration with IMS Center – Cincinnati in order to create an IMS Satellite Center in Brazil. UFRGS and CETA got a project grant from SENAI in Brazil to establish the Brazilian IMS satellite center and SENAI-RS became an official member of IMS Center. Over the last years the center has carried on some successful industrial case studies with Brazilian companies, applying Watchdog agent algorithms developed by IMS Center USA (Lee et al. 2004m Lee 2005) as well as new physics-based modeling for industrial applications in the areas of electrical valve actuators, welding robots, gas compressors and assembly robots. The IMS satellite center in Brazil has a close cooperation with Brazilian industry and has identified new application opportunities in areas such as electrical motors used in steel production, UPS systems, oil transfer and storage, etc. Among the most relevant results obtained so far are (i) the development of a FPGA-based embedded implementation of a Self-Organizing Map (SOM); (ii) the development of an intelligent maintenance

system for electric valve actuators; iii) oil storage and transfer applications (Transpetro project); iv) model driven algorithm for electric motors.

Another area on which innovative projects are being developed by CETA is on the use of virtual and augmented reality techniques to industrial applications (Binotto et ali, 2006). Motivated by the very positive results in the factory design project for a furniture manufacturer in Brazil (previously described in this paper), several projects dealing with the use of advanced ICT tools for optimizing product design, production process, as well in the development of added value services are developed. Within the scope of such projects a low cost optimal tracking system developed by a CETA's spin off company named MaMs in collaboration with Fraunhofer IGD was developed (Santos et al. 2007). BraTrack is a marker-based optical tracking system for augmented and virtual reality applications, varying from generic multiple objects tracking to motion tracking, appropriate for mockups and for engineering, ergonomics, and medical simulations and training. The solution is available as a two-camera stereo configuration with PC-based image processing software. The solution uses epipolar geometry to extract complete pose information – exact position and orientation – from sets of retro-reflective markers (artifacts) seen by both cameras. The expectation is that Bratrack would improve the cost effectiveness of virtual/augmented reality applications in the Brazilian market. The use of virtual reality for maintenance applications is also being investigated (Espindola et al. 2009, Espindola et al. 2010).

As another project in this area, CETA was also involved in the development of a mixed-reality system for automation and control engineering education: the system in collaboration with the Universities of Bremen and Berlin in Germany and with the Federal University of Rio Grande do Sul (UFRGS) and installed in SENAI Mechatronics Center for technology and vocational education (Schaf et al. 2006, Schaf et al. 2007, Bruns et al. 2007).

5. Lessons Learned and Future Perspectives

The results obtained by CETA so far are very positive, having a very positive impact to several local industry. The fact that Brazil experimented a significant economical growth over the last years has surely positively influenced such results, but CETA has achieved a good reputation by local industry as a valuable partner in the development of innovative projects.

Industry has to innovate in order to remain competitive in a very competitive market. It is known that "a bountiful flow of creative ideas is worthless without business processes to assess them, put them into action, and motivate risk taking and other behaviors that drive execution" (France, Mott and Wagner 2011). In collaboration with IEL/RS and with the Council for Innovation and Competitiveness, CETA has started some initiatives on investigating innovation processes that would help in establishing a sustainable innovation engine. One of these initiatives was to establish a collaboration with Prof. Jay Lee and having some seminars on the dominant design methodology in Brazil as well as other training seminars for high-level executives on topics such as TRIZ, QFD, 6-Sigma, Innovation Leadership, etc.

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Improvement of Student's Creativity through Participation in Problem- Solving with Parents

(Improvement of Swimming Goggles using TRIZ)

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Abstract

This thesis suggests the collaboration between elementary school students and problem-solving experts helps develop the students' potential creativity. Based on a case study, this paper also proposes an approach parents(experts) can adopt. To ensure a problem-solving process and scope appropriate for the students, the swimming goggles, a familiar item, was chosen for the study. During the brainstorming session to prevent the swimming goggles from fogging up, elementary school students came up with more ideas and showed more creative imagination than the adults. This may result from the changed environment where, along with adults, children can receive a lot of information via films, TV, and the Internet. In addition, the familiarity of the swimming goggles had two sides. It helped the students come up with various ideas, but the fence of familiarity(paradigm) undermined adults' motivation to generate different ideas. Employed methodologies and principles include the axiom that expressing intangible ideas into the tangibles boosts communication and structuralization leads to easier problem solution, brainstorming for rich idea generation, and TRIZ for problem-solving.

Keywords : Creativity, Expert, Intuition, Positive participation, Listen, Question, System, TRIZ

1. Introduction

Invention techniques are useful in developing ideas so that invention is a sustainable activity, not an accidental or one-time event. This paper introduces a process in which an intangible concept of creativity is delivered as something tangible and comprehensible to elementary school students. The process is based on the idea that the efficiency of a group of people depends more on how well the roles of the members are defined than how much knowledge they have. This thesis uses a systematic approach where each member shares one's ideas which are organized by an adult participant to find solutions to a problem. To take a systematic approach, each member had to stick to basics and ensured the applied problem modeling and different invention techniques were related to each other.

Creativity is one of the most commonly mentioned words when it comes to education. It is said that high creativity needs rich imagination. Academics have tried to give an answer to the question, "What is creativity?" Many of them suggested creativity is a capability to provide various, unique and practical ideas to solve a given problem. However, it is difficult to make children understand the definition. For elementary school students, it is hard to come up with a variety of solutions in a given situation. Even if many ideas are proposed, picking out unique ones is another challenge. It is not appropriate to select an idea simply because it is different from others. Evaluating the practicality of an idea is a time-consuming process that tends to adopt subjective, rather than objective, criteria. Therefore, this paper uses an adjusted definition of creativity more suitable to children: Creativity is the capability to identify inconvenience in daily life and solve the problem. Coming up with a new idea is a tough, exhausting work regardless of one's knowledge or age. Laymen who have not learned problem-solving techniques usually produce ideas based on their intuition. As formulas and laws are used in mathematics and science to solve problems, there are also a variety of techniques and principles for invention. This paper, however, suggests that viable solutions can be produced when the roles of the members are well-defined in a system even if they are intellectually equal. The brainstorming results between elementary school students and an adult are compared, and the problem-solving process and its outcome are analyzed.

2. Roles of the Members

As my daughter grows up, she needs more self-learning ability. At the same time, she has to allot more time for studying which somehow lessens the chance for him to involve in family conversations at home. My family needed an opportunity to improve the student's learning capability and communication through creative problem-solving process. Although there are various factors that affect the development of children's creativity, one of the main, invisible elements is adults' coaching to wait for the children to express their ideas. Creativity is fostered by providing an environment where a child can develop a variety of ideas and think outside the box to solve given problems. In other words, it is a shift from "studying hard" to "thinking hard". The ability to read context, to think outside the box, and to imagine are essentials in creating such a unique value. To help their children in the process, parents can play following roles : (1) Motivating the children to think (2) Providing atmosphere and time to facilitate idea development (3) Helping the children express their ideas and visualize them (4) Engaging in discussions, questions, and careful listening.

I took on the role of a guide by organizing and visualizing ideas to help them use thinking tools. This process placed focus on the three key words: idea, thinking, and imagination.

a. Idea is a picture in the mind.
b. Thinking is the activity of using your brain by creating an idea.
c. Imagination is the power to make pictures in the mind.

To help the children understand the process and freely share their ideas, key concepts were translated into easier expressions: Problem Situation -> What is inconvenient?, Component Modeling -> What is it made up of?, Desired Outcome -> What do you want?, IFR -> If we live without it, what would be convenient and inconvenient?, Voice of Customer -> What do other people want?, Benchmarking -> Are there any other kinds?

3. Creative Problem-solving Process

The problem-solving process is simplified into three steps to help the elementary school students understand the direction.

Step 1: Identifying inconvenience in daily life
Step 2: How can we improve it?
Step 3: How can we help many people use it?

4. Identifying Inconvenience

As the first step, an inconvenience was identified in swimming goggles. We wear swimming goggles to see and to protect our eyes while underwater. The goggles work well at first, but over time, it fogs up that the user sees through it unclearly. This was chosen as the problem to be addressed and solve. [Figure 1].

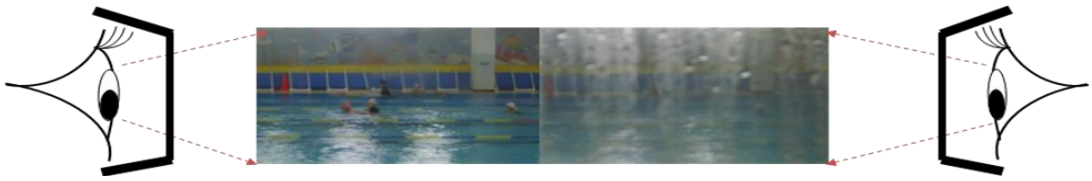
Step 1 : Identifying Inconvenience

Action 1 : In swimming pool -> swimming goggles -> get fog

Figure 1, I can't see through the swimming goggles clearly.

5. How can we improve it?

There are a variety of techniques for coming up with new ideas: looking from different angles, eliminating stereotypes, rearranging, purpose change, merging, etc. These are methods similar to the 40 invention techniques. Rather than rushing into solutions, a systematic approach was used by



offering one thinking tool at a time to the children so that they could easily express their ideas.

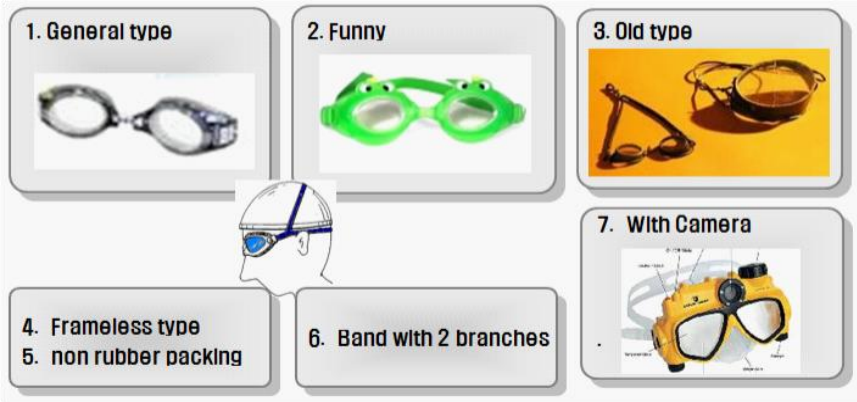
Step 2 : How can we improve it?

Action 2: Unclear View -> Clear View

5.1 Brain Storming (Elementary School Student)

- Replace the goggle with a new one. (It takes additional cost)
- Wash the goggle with the water of the pool. (We have to wash it repeatedly)
- Wait until the water on the goggle dries. (Until when?)
- Apply anti-fog liquid again. (The liquid will contaminate the water of the pool)
- Set the inside and outside temperatures at the same level. (How?)
- Take out the lenses. (The goggles cannot block the water coming in.)
- Blow cool wind into the goggles. (How?)
- Replace the google with a new one and have good maintenance. (It's difficult to practice.)

The ideas proposed by adult participants were: applying anti-fog material on the lenses, making



a hole on the goggle to let out moisture, designing the goggle with materials like Gore-Tex which lets out moisture as well as blocks water from seeping in, dipping the goggle into the water to lower the temperature, circulating liquid inside the lenses, attaching wipers or hot wire to the goggles, putting dry ice inside, etc. However, concerns about side-effects such as additional cost, unsustainable effectiveness held back the problem-solving process.

5.2 Swimming Goggles I want in the Future :

- No fog on the lenses
- Contact lens type .
- Comfortable to wear
- Nice design
- Prescription Goggles

5.3 Convenience of Swimming without Goggles ?

- No fog on the goggles
- Nothing weighing down the face
- No cost for the goggles
- Nothing to wear on the face

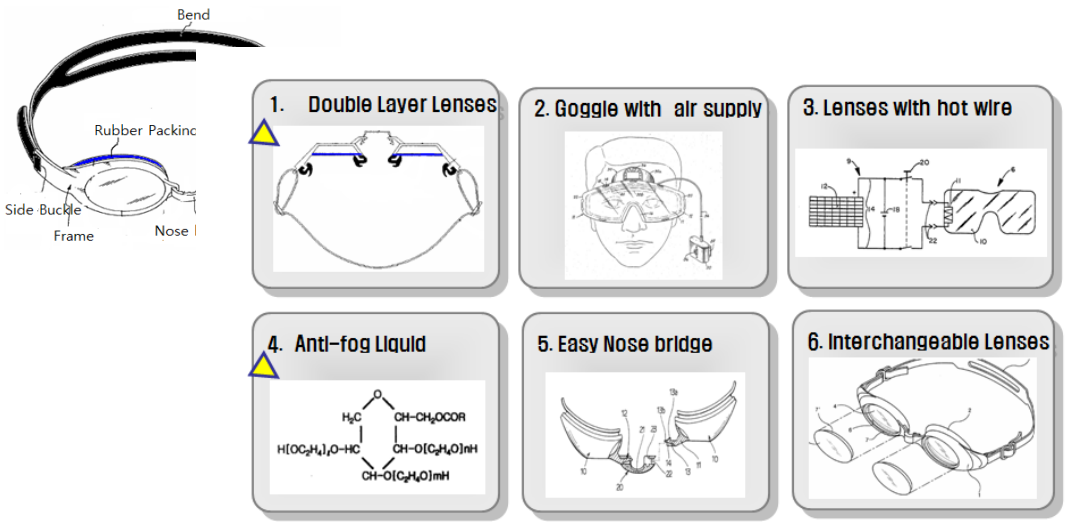
5.4 Inconvenience of Swimming without Goggles ?

- Need to close the eyes under water .
- Lose control of direction, possible collision .
- Not able to swim in the deep water
- Not able to open eyes when diving

To identify an ideal swimming goggles, the following questions were asked: What kind of swimming goggles do you want in the future? What is the convenience of swimming without goggles? What is the inconvenience of swimming without goggles? Three major features of the ideal swimming goggles are it has a clear view, it is easy to use, and it has a nice design. Other desired features included no fog on the lenses, prescription lenses, no scratch, quick dry, lower price, mp3 player, camera.

5.5 What kind of other swimming goggles are there?

Figure 2, Various Swimming Goggles



5.6 Patent Research

Figure 3, Patents Related to Swimming Goggles

Figure 3 is a benchmarking result from the reseach using portal websites. There are a variety of patented swimming goggle features such as double layer lenses, anti-fog liquid, interchangeable lenses, goggles with air supply, lenses with hot wire. In addition to the document research in 5.5 and 5.6, interwiews with professional swimmers were conducted to find differeces between their swimming goggles and the ones ordinary people use. Professional swimmers use head-first entry while ordinary people use feet-first entry in a slowy way. Due to the different entry style, they tend to use goggles with slimer frame.

5.7 What are the swimming goggles made up of?

Swimming goggles are made up of the Frame, Lenses, Bend, Side Buckle, Nose bridge, Rubber Packing, and Anti-fog liquid. [Figure 4]

Figure 4, Structure of swimming goggles

5.8 Why is the view through the swimming goggles blurry?

Water drops cause refraction of light, which blurs the vision. [Figure5]

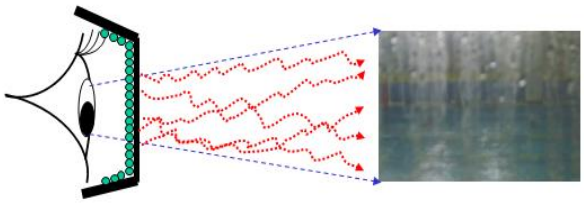


Figure 5, Refraction of Light

5.9 Why do the water drops appear?

Why is the view through the swimming goggles blurry? It is because of the Refraction of Light [Figure 7]. Other causes include: the lenses of the goggles, the temperature difference between inside and outside the goggles, constant supply of heat inside / loss of heat outside [Figure 6], surface tension between the lenses and water drops, the sizes of the water drops, and no ventilation.

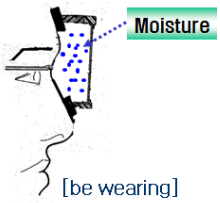


Figure 6, Difference of Temperature

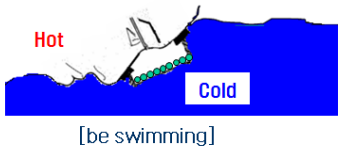


Figure 7, Water inside the Goggles

5.10 What is the Function of Each Component of the Goggles?

A function is an action that directly changes or maintains at least one controllable or measurable parameter of a object. Appropriate action word : move, hold, block, remove, inform, rotate, burn, weld, count, deposit, carry, conduct, etc.

Components of Swimming Goggles	Important Role (Main Function)	Less important roles (Additional Function)		
Frame	Hold	Hold	Water blocking	Heat transfer
Lenses	Light transmitting	Water blocking	Ultraviolet Blocking	Heat transfer
Anti-fog liquid	Visible	Water Pollution		
Side Buckle	Hold			
Nose Buckle	Hold			
Rubber packing	Cushion	Wearing	Water blocking	Heat transfer
Nose bridge	Frame Hold			
Band	Tension	Wearing		

Figure 8, Functions of Each Component

5.11 When Do the Water drops Appear?

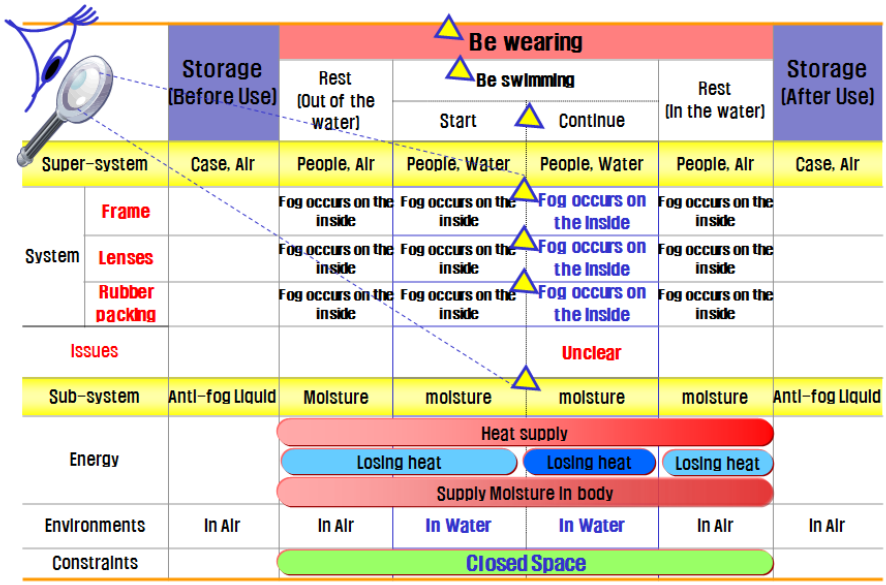


Figure 9, Multi-Screen Thinking of Swimming Goggles

5.12 What Do the Components Do each other?

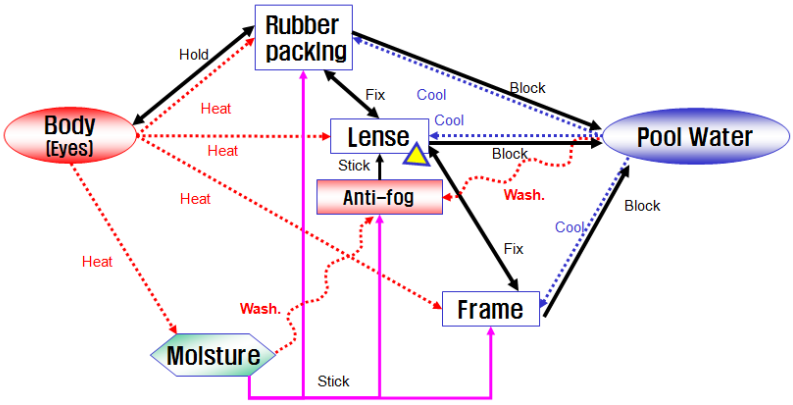


Figure 10, Function Modeling of Water Goggles

Functions of the goggles and multi-screens were used for detailed classification of the functions and resources. [Figure 8, 9,10] Location and timing of water drop appearance could be identified more accurately by looking at the relationships among the human eyes, lenses, water drops, the frame, lenses, and rubber packing.

5.13 Nonsense Situation?

A nonsense situation is a contradiction that holds the clue to the solution. Contradictions related to anti-fog liquid, lenses, moisture inside the goggles are:

a. The anti-fog liquid is necessary for a better view, but the liquid is washed away when cleaning the lenses.

b. The lenses are necessary to prevent water from coming into the goggles, but the lenses get fog.

c. The moisture inside the googles are neccesary for convenient use. But, there must be no moisture to prevent fog on the lenses.

The Separation principle (time, space, condition) were used to come up with the following conceptual ideas. Sustaining the supply of anti-fog liquid, wash-resistant coating on the lenses, a structure for easy replacement of lenses, using lenses with high insulation, using dual lenses.

5.14 Developing Conceptual Ideas through Common Points

Rather than seeking solution directly, merely expressing the current knowledge about the inconvenient situation, we observed common points emerge as follows. Following problems could be expressed more in detail. ‘As new swimming goggles lose their anti-fog capability after 2~3 weeks of use, users have inconvenience of having to apply anti-fog liquid repeatedly.’ ‘Users experience inconvenience of taking care of the goggles to keep the liquid from being washed away.

Common points at each step indicated clues to solutions.

Common Point 1 : The problems stem from the lenses

Common Point 2 : The problems occur during swimming

The two common points showed two directions for solution.

Direction 1 : Find ways to prevent the lenses from getting fog.

Direction 2 : Find ways to prevent fog during swimming.

5.15 Creating Conceptual Solutions

Solution 1. Prevent the Lenses from Getting Fog

We wanted water drops on the lenses to appear in other parts of the goggles. Metallic material which increases the temperature difference was put on the frame where water drops sit. This method can prevent fog without using anti-fog liquid which is harmful to the environment. [Figure 11,12]

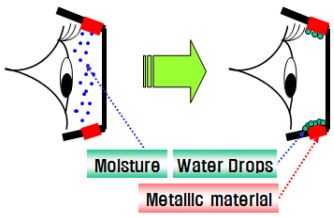


Figure 11, Conceptual Solution1

Figure 12, Making of Prototype1

Solution 2. Refill the Anti-fog Liquid

Based on an idea of constant supply of anti-fog liquid, plastic material is inserted between the lenses and the liquid. Anti-fog liquid can be replaced like Post-it when it is running out [Figure 13]

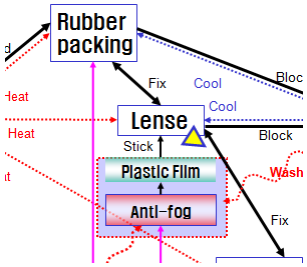


Figure 13, Function Modeling of Water Goggles and Improved

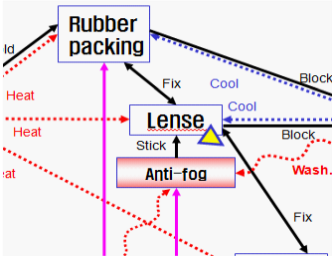


Figure 14, Conceptual Solution2

Figure 15, Making of Prototype2

How Can We Help Many People Use the Idea?

To share the outcome, the idea has been patented. (Anti-fogging swimming goggles, 200451516, Inventor : Park Jeehyun)

Step 3 : How can we help many people use the idea?

Action 3: Document the Idea → Patent the Idea → Apply for a Patent

6. Conclusion

Systematically defined roles of the members and functions of the items facilitated generation and organization of ideas and showed the direction for solving the problem. The final two solutions are the results of ten months of work. It was a time-consuming, care-demanding job to provide an environment where children could generate a variety of ideas within ten minutes, and help them focus on developing them. The three steps were indicators of how much progress the children had been making. As the children didn't have knowledge on various problem-solving techniques, each step was offered as an explanation about the problem to reduce the emotional burden. Idea frameworks were also provided for the young students to express their ideas in an easier way.

Step 1 : Identifying inconvenience in daily life

Action 1 : In the swimming pool → swimming goggles → get fog .

Step 2 : How can we use swimming goggles more comfortably?

Action 2: unclear view → clear view .

Step 3 : How can we help many people use it?

Action 3: Document the idea → Patent the idea

The Brainstorming was effective in helping participants approach the problem-solving process with knowledge they already had. However, the method also brought a challenge when negative ideas followed new ideas for solution. In the step 2, a variety of TRIZ tools made it easier to find the solutions. Following study will be on visualizing familiar stereotypes using brainstorming and various TRIZ tools to come up with ideas.

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- Algorithm of Improving Problem Situations : Nikolay Shpakovsky
- Systematic Innovation for Business : Darrell Mann
- Algorithm of Engineering Provlem Solving : Gennady Ivanovich Ivanov

Paper ID: 490

Framework and Process of Collaborative Design System for Product Innovation

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Abstract

The development of green creative products has been the current trend and challenge facing the development of a sustainable society. In this paper, a framework along with process of software system was developed for improving existent product as green innovative product. The developing process for the software system include IDEF0 system analysis, system framework planning; and Unified Model Language (UML), etc. A fire-extinguisher for household kitchen was used as an example to demonstrate the improving process with this software platform. The objective of this research is to use the object-oriented modeling method to develop the knowledge process representation for green inventive product. Besides, the software system could be used for collaborative design.

Keywords: Green innovative design, Collaborative Design, Object-Oriented System Analysis and Design

1. Introduction

In the past, products were designed without considering environmental impacts. Traditional factors considered in product design stage are frequently function, quality, cost, ergonomics and safety. Now, it is imperative to consider the environmental influences of a product throughout its entire life cycle. Traditional end-of-pipe directives or regulations only focused on the emissions from the manufacturing processes of a product. However, adverse impacts on the environment may occur on any one of life cycle stages, such as use, recycle, distribution, and material acquisition. Therefore, enterprise need to analyze and evaluate the environmental impacts from the entire life cycle of a product, so as to focus on the core of the problem and effectively resolve the problem.

Facing the growing societal concerns with the global environment, enterprises are responsible for many directives and regulations, such as Restriction of Hazardous Substances Directive (RoHS), Waste Electrical and Electronic Equipment Directive (WEEE), the Registration, Evaluation and Authorisation of Chemicals (REACH) Regulation, and the Eco-Design for Energy Using Products (EuP) . In order to comply with these directives and regulations, the cost of product involving entire life cycle stages will increase. Although these costs are considerable, the costs of non-compliance are even more significant. Enterprises may face the risk of exclusion from key markets, stopped shipments, product recalls, etc. they will result in not only loss of revenue, but also disastrous consequences for brand image and corporate reputation.

In the early design stage, especially in preliminary design, it greatly affects the eco-effectiveness of a product. In recent years, many eco-design methods have been proposed (Tukker and Eder, 1999; Gottberg et al., 2006). Furthermore, there are many innovative thoughts and tools integrated in eco-design tasks to evolve many eco-innovative methods (Pujari, 2006; Smith, 1999). In this paper, a framework along with process of software system was developed for improving existent product as green innovative product. In this paper, the developing process for the software system include IDEF0 system analysis, system framework planning; and Unified Model Language (UML), etc. A fire-extinguisher for household kitchen was used as an example to demonstrate the improving process with this software platform. The objective of this research is to use the object-oriented modeling method to develop the knowledge process representation for green inventive product. Besides, the software system could be used for collaborative design.

2. Literature Review

The TRIZ method was developed by Altshuller, who had analyzed over 400,000 patents to build the contradiction matrix and 40 inventive principles. TRIZ shows the feasibility of the problem solving by extracting generic principles from patents (Terninko et al., 1998). Mann (2007) proposed a hierarchical view of TRIZ including excellence, philosophy, , method, and tools. Recently, considering the specific situations and scenario in different disciplines, many scholars have proposed some new contradiction matrices in their researches.

Product design concerning environmental impacts has many expressions that include ecological design, environmental design, environmentally conscious design, environmentally responsible design, sustainable design, green design , etc. The aim of eco-design is to reduce the environmental impact during the product life cycle: raw materials, preliminary design, detailed design, manufacturing, assembly, packaging and transportation, use, and disposal (Jones and Harrison, 2000). Fleischer and Schmidt (1997) proposed a top-down 3-layered e co-design tool for the selection of materials. Michelini and Razzoli (2004) developed a knowledge-based infrastructures for product-service eco-design. Trappey et al. (2008) proposed an integrated green product design methodology and system.

Though there are many researches on eco-design, it is necessary to develop a systematic methods in order to design products complying with ecological and economic requirements.

3. Framework and methodology

In this paper, a framework for eco-innovative product design system was proposed and shown in Figure 1. The framework includes three design modules - problem analysis module, problem solving module and solution evaluation module, along with two auxiliary modules, database & information recording module and computer-supported cooperative work (CSCW) (Santos, 1995) module, to assist the design process with collaborative coordination and information recording. The problem analysis module is the most important stage in product design and development as a wrong direction and object of a problem will not result in the correct solution and will waste resources (time, money, etc.) The essence of problem analysis is problem definition which should simultaneously note the requirements of members in the supply chain and green directives and regulation. The database & information recording module includes STEP (STandard for Exchange of Product model data) based data (Lee et al., 2003), TRIZ-based data, eco-based data, and patent resources. The CSCW module can support the collaborative tools and method for members located on different places.

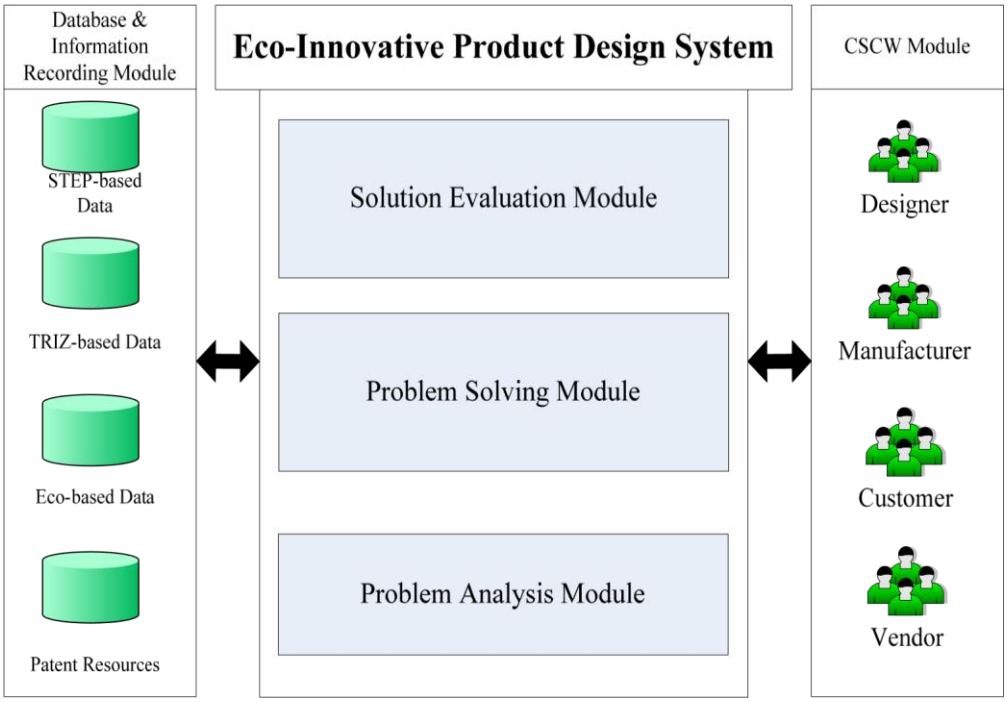

Figure 1. Proposed framework of eco-innovative product design software system

In this paper, a traditional fire extinguishing device, a dry-powder extinguisher, is used as the original design which needs to be improved due to some disadvantages occurring in a household kitchen. Figure 2 shows the IDEF0 analysis diagram used as a tool to analyze the entire product life

cycle of a product so as to know what constraints and resources could be utilized. From this figure, we find the focus of the problem located on the stages of product use and product recycling.

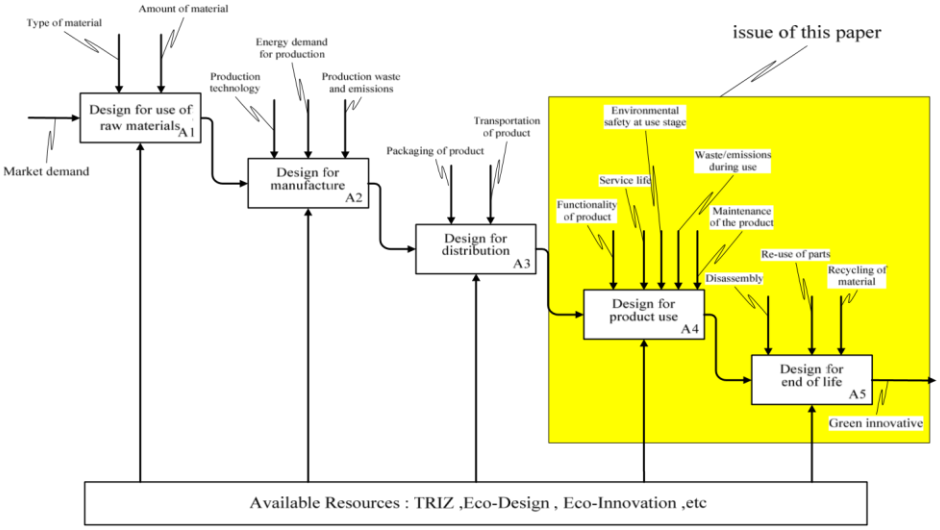

Figure 2. IDEF0 system analysis diagram of green innovative product design

4. System Implementation

This paper adopted the object-oriented modeling method to analyze and model the the knowledge process representation for green inventive product. The modeling of requirement analysis in the system was developed by using use case diagram and activity diagram. Class diagram and object diagram were used for the modeling of data structure, and sequence diagram and status diagram were adopted to develop the modeling of interactive behavior. **Figure 3** shows the use case diagram and sequence diagram of the developed system. Some snapshots of the developed system for a fire-extinguisher for household kitchen were shown in **Figure 4**.

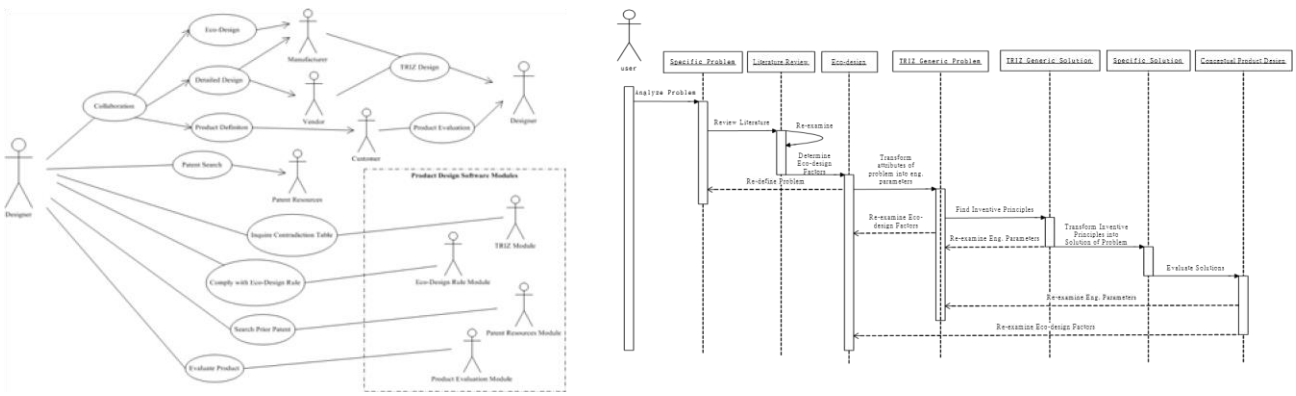

Figure 3. Use case diagram and sequence diagram of the developed system

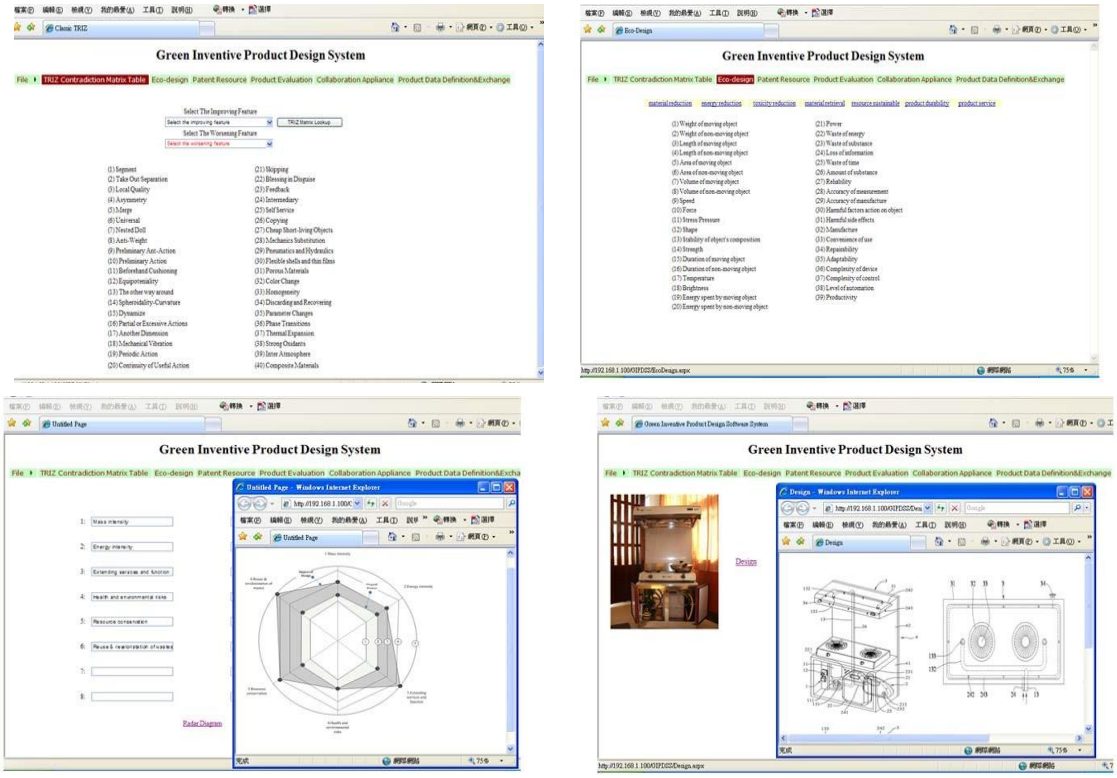

Figure 4. Snapshots of the developed system for a fire-extinguisher for household kitchen

5. Conclusions

The main contribution of this paper is to propose an framework and process for developed a collaborative software system for designing an eco-innovative product. Object-oriented modeling method to adopted for the knowledge process representation for green inventive product development. An example was also used to illustrated the design process so as to prove the feasibility of this framework and methodology.

Acknowledgement

This work is supported by the National Science Council, Taiwan, under grant numbers: NSC 95-2745-H-269 -002–HPU, and the fruit of this research (Fire Extinguishing System of Kitchen Equipment) has acquired the gold medal in 2007 Taipei International Invention Show and Technomart.

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Lifecycle of a quick electronic industry in the new product and respond to ideas and improvement ideas.

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Abstract

This is looks into ways of using the invention tool of TRIZ to come up with or apply ideas to develop and improve products in the electronic industry where product life cycles are extremely short

This methods are based on the experiences of both working in the semiconductor industry and researching TRIZ .

Semiconductor industry's rapid pace of product renewals have been shortening the time to respond to the changes. Therefore, enterprises could lose technological edge and market share in the competition unless they help engineers generate creative ideals quickly to develop and improve products in a timely manner using the existing invention tool provided by TRIZ. This paper proposes TRIZ methods that the semiconductor makers can use to promote engineers' quick idea generation through immersion, and to select ideas by harnessing creativity and expertise.

Keywords: idea generation, Electric industry, Quick idea generation

1. Introduction

There are many scientific theories that have developed on a foundation of knowledge creation and creative research. Among them, Theory of Inventive Problem Solving (TRIZ) is the world's most popular theory. TRIZ was developed by Genrich Altshuller who had analyzed a variety of international patents, and engineering and technical innovative cases, and theorized an inventive problem solving approach. Since Glasnost in the Soviet Union, TRIZ has helped to give a problem solving approach and idea to not only engineering fields, but non-engineering fields such as management and business areas around the world [1]. In Korea, however, well-known enterprises and schools have experienced trials and errors since the introduction of the TRIZ in the 2000s.[2] Some companies urgently have pushed for the results of the problem solving approach, believing that TRIZ is a tool of Problem solving, so such an activity has aroused the repulsion from engineers dealing with actual problems. Korea's export industry structure characterizes the attachment of weight to the electronic telecommunications

industry including semiconductor and mobile phone industries. And companies in the industry mostly focus on performing their investigation on research and production processes.

In addition, because a development period of products and their life-cycles in the semiconductor and electronic telecommunications industries remarkably shorten those of the products in other industries, the periods of research, design, and process respond to the short development period and life-cycles. Many Korean enterprises have introduced TRIZ as an approach of developing and of innovating an idea to achieve their research goals within a short term. However, the thing is that, in reality, engineers and developers have had limited time in order to apply the TRIZ tool to develop a new idea with their research period.

Therefore, it is required for the semiconductor and electronic telecommunications industries to develop a new problem solving and idea creation approach which enables them to utilize the existing TRIZ approach and to analyze the causes of a problem.

In this thesis, on the basis of experiences in consulting the projects of a semiconductor company, we propose an approach of creating an idea within a short period of time

2. TRIZ use by the semiconductor and electronic industries

▪ 2.1 Problem solving process

The problem solving process using TRIZ is presented as follows [Figure 1]. The process below displays a problem solving process used by most enterprises. In the process, each idea is created when each TRIZ tool according to contradictory elements, is used in sequence.

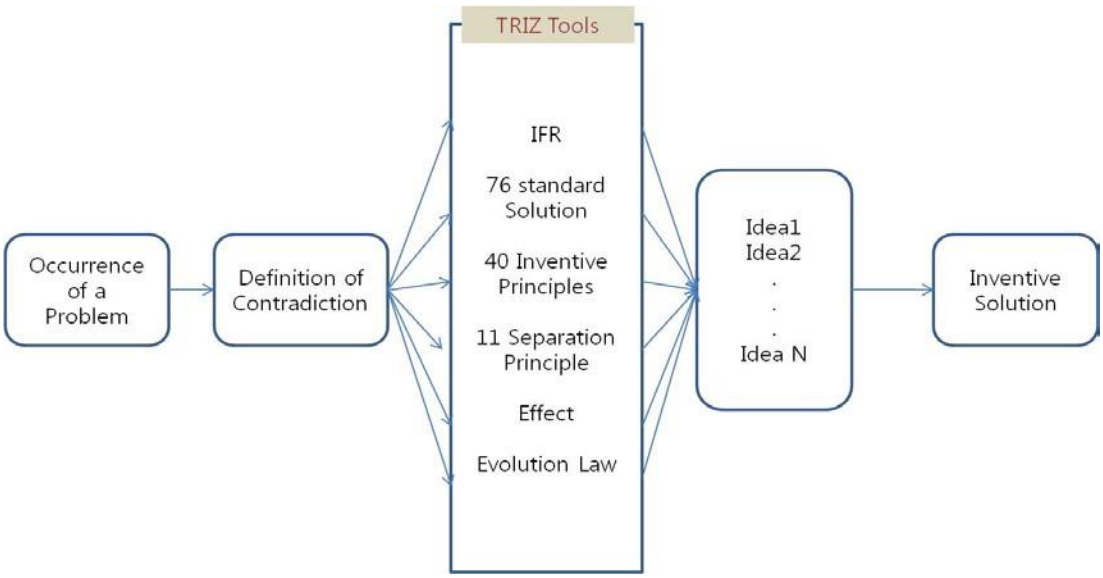

Figure 1. General TRIZ Process Of Problem Solving

. In the TRIZ approach, problem circumstances and desirable systems are described, and contradictions are derived through functional analysis and Root Cause Analysis (RCA) to define ideal solutions. And then, TRIZ tools-76 standard solution, 40 inventive principles, 11 separation principles, effect, and evolution law-are used to find solutions.

▪ 2.2 Limitations of TRIZ in the industry

TRIZ is a problem solving theory developed in the 1940s, based on principles that have been most frequently used in a variety of patents and technologies. TRIZ has advantages of finding contradictory elements of problems occurring in the stage of production development to provide solutions, and thus of decreasing errors occurring during the production development period to improve development speed. The advantages have led many Korean companies to introduce TRIZ to create an idea in the R&D stage. However, the companies raised a question about the reliability of the process of finding critical problems and the derived idea. That is because, in terms of the inventive ideas and the shortening development period, there is no difference between the TRIZ approach and other inventive tools and approaches[3]. Moreover, since the derived idea is far from innovation-oriented reliability and process reliability, it has been difficult for the industry to apply the TRIZ as a problem solving approach. Because the industries with limited-time such as semiconductor and electronic industries are seeking to develop a system, which has a minimum size, weight and volume and efficiently performs a lot of operations, within a short term, they count on the existing inventive tools (e.g., 6Sigma, TPS, etc.) and TRIZ to develop inventive products, yet face the limitations of time and creativity.

2.3 Limitations of TRIZ for Engineers

Since companies in the electronic and semiconductor industries are seeking to develop a system with a minimum size, weight and volume in a short period of time, the needs of the companies and customers put pressure on engineers to the extent that they create a lot of ideas. Such pressure makes engineers face more difficult inventive problems. And it requires them to transform the previously found solutions to get an idea of solving problems. The engineers, moreover, come under pressure of making the idea fulfilled in a given time as well as creating a unique, bold and inventive idea. The companies, which have introduced and used the TRIZ, agree on the utilization of the TRIZ, but transform the existing TRIZ for their use because using the existing one takes longer than expected. Still, the engineers in the companies are reluctant to use the tool. In facing a problem, engineers spend a lot of time transforming the traditional problem solving approaches of their company by making use of their knowledge. They immerse themselves in “psychological inertia’ to create an ideal transformed solution of the existing solutions. In addition, regarding the recognition of a problem, they are afraid of turning their attention away from their own research areas-electronics and semiconductor engineering-and put priority on analyzing a problem within a short time. Such activities can make the problem difficult in being generalized and solved with TRIZ.[4]

To address the issue an idea creation approach through Immersion & Brain Storming activity as shown in the following section is used so that engineers can easily make use of TRIZ and create an idea to timely, quantitatively solve a problem in a given time.

▪ 2.4 Idea Creation

A problem solving process with the use of TRIZ can help to find contradictory elements of a

unsolvable problem in developing and improving a product and thus to provide solutions to speed up the development. But in fact, there are problems not to be solved through TRIZ and engineers frequently create an idea by using other tools (creation of an idea by themselves or citation of a thesis and a patent) than TRIZ in the process of solving a problem because of their limited time.

To overcome the limitations the approach proposed in this study adds Immersion & Brain Storming activity to the TRIZ problem solving process to create an idea within a short time. The proposed problem solving process is performed as follows.[Figure 2]

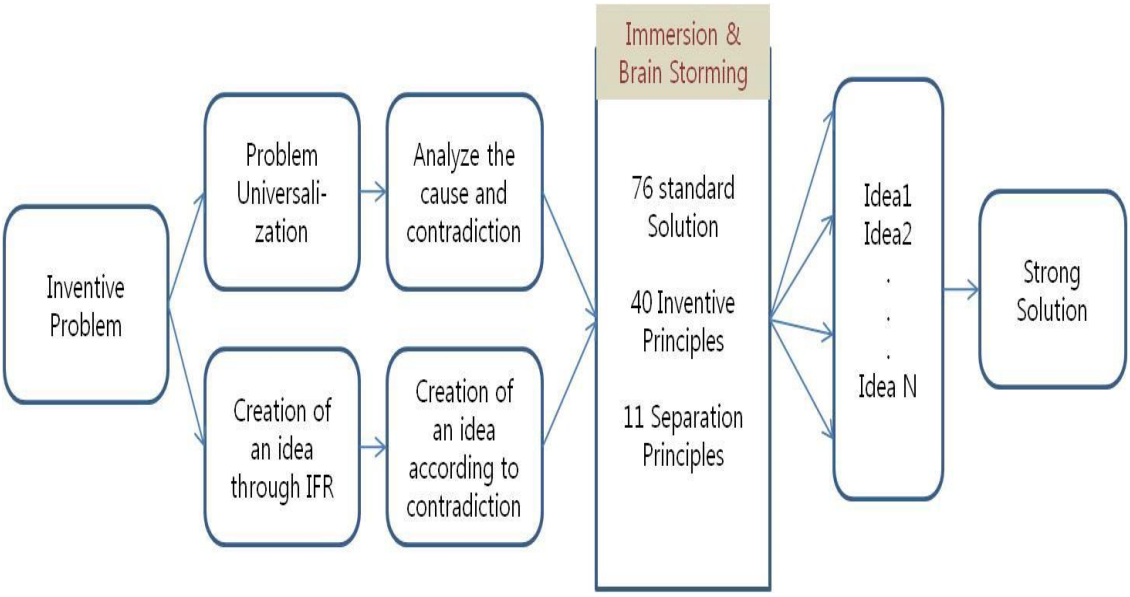

Figure 2. Problem solve Process Use Of immersion & Brain Storming

An engineer solving a problem immerses him/herself in creating an idea at the time when s/he faces a problem, and then continues to focus on the problem according to the following three rules. 1st Rule: Start your day by pondering the problem

2nd Rule: Concentrate on the problem always.

3rd Rule: Repeat any activity related to the problem steadily.

For Immersion and Brain Storming, an idea group consisting of relevant researchers and engineers, which are involved in the problem affecting pre-and post-processes, is formed to intensively and quickly create an idea within a couple of days. An idea is created through Brain Storming activity based on the following principles.

(1) Create as many ideas as possible.
(2) Follow other people's idea.
(3) Do not criticize while creating ideas.
(4) Take irrelevant opinions pleasantly.
(5) Make more than 2 new employees join together.

During the Immersion and Brain Storming session, participants do not engage in the activities of their works except for the creation of ideas in a limited space, and no one can interfere with the session.

For Immersion & Brain Storming activity, 40 inventive principle cards and separation principle cards and computer-based TRIZ software application are used. The inventive principle card and separation principle card approach is one of creating ideas where participants are forced to take 5-7 minutes to read a key word written in a card and then create an idea. The participants are forced to create less than 10 ideas for an hour and their immersion in creating ideas increases. After a short break, they are forced to create ideas again. Like this way, the participants join Immersion & Brain Storming activity for 4-8 hours. The created ideas are to be evaluated by the participants next day. The ideas are to be grouped with the use of KJ technique, and be evaluated along with experts as to whether they can be applied to current work or can be patented. After than, the ideas that can be immediately applied to a product design, are selected, and other ideas difficult in being applied are to be patented. In addition, the ideas evaluated as a low grade are saved in an individual database to reuse them to solve a similar problem.

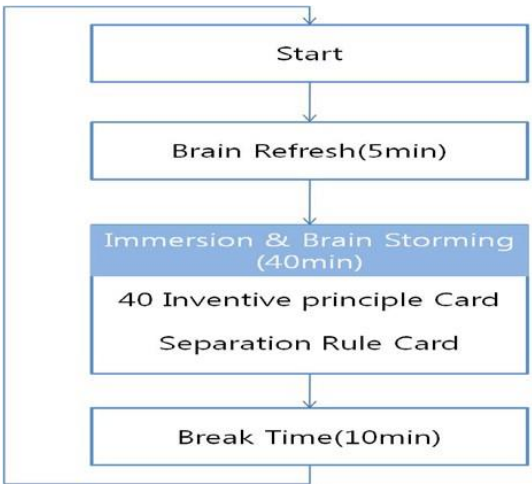

Figure 3 Immersion & Brain Storming Time Table of 1Hour

Many TRIZ researchers make use of Contradiction Matrix to quickly create ideas. But the Contradiction Matrix should be limited when ideas are created during Immersion & Brain Storming activity, and it is desirable to use it when some supplementation is needed for the created ideas.

▪ 2.4 Effects of Immersion & Brain Storming Activity on idea creation

The idea creation approach with the use of Immersion & Brain Storming activity helps to create a lot of ideas in a quantitative way. The table presents the comparison of the idea creation through TRIZ process and one through Immersion & Brain Storming activity when engineers seek to solve a problem.

	No. of ideas	76 standard Solution(%)	40 Inventive Princioles(%)	Separation Principle(%)
Creation of ideas with the use of TRIZ process	0~2	30	15	45
	3~5	44	22	37
	5~10	19	40	10
	10 higher	7	23	8
Creation of ideas with the use of Immersion & Brain Storming activity	1~2	16	7	4
	3~5	40	16	47
	5~10	25	34	23
	10 higher	19	43	26

Figure 4. Creation idea No. of General TRIZ Process and Immersion & Brain Storming Process

Usually, Immersion & Brain Storming activity helps to create more ideas than TRIZ process does[Figure 4]. In addition, when new employees or engineers in other departments join the activity, more ideas are created. In this respect, Immersion & Brain Storming activity can allow those facing a problem to look at it from different perspectives and thus to overcome their restrictions.

Immersion & Brain Storming approach helps to save times in creating ideas. In the existing TRIZ process, ideas are created step by step through each tool. However, in the approach are the causes of a problem precisely analyzed, and thus Operation Zone and Operation Time defined to create more ideas intensively within a short time through Immersion & Brain Storming Day.

▪ 2.6 Utilization of non-experts

Engineers who will solve a problem are experts in developing and improving products, and well aware of the limitations of a problem so that they have difficulties in creating inventive ideas with the use of TRIZ because they bear the limitations in mind. Therefore, it is important for non-experts to join Immersion & Brain Storming activity. The limitations of a time can be solved through Immersion

& Brain Storming, and the restrictions of an expert can be overcome through the ideas of non-experts (e.g., new employees and engineers in other departments)

▪ 2.5 Configuration of Time Table

The time to develop products in the industry is restricted, and unexpected issues or requirements can frequently occur. So the time to solve a problem and to apply it to a product is limited. Moreover, it is impossible to spare a lot of time for TRIZ to solve a problem.

It is necessary for TRIZ consultants and engineers to discuss together to develop a problem solving process suitable for a project. In addition, the process should be capable of dealing with unexpected issues.

When a problem arises, the problem should be figured out. So either improvement or new design is to be made depending on the problem. If any improvement is to be needed, the causes of the problem are defined; OT and OZ are selected to find root causes; and contradictions are defined. If a new design is in need, required functions are defined; the problem to be solved is defined through knowledge search; and contradictions are defined.

After the completion of the process, ideas are immediately created through Immersion & Brain Storming activity in a couple of days; a product is designed; and whether the problem is redefined or the development of a product is completed relies on the availability of desirable functions.[Figure 5]

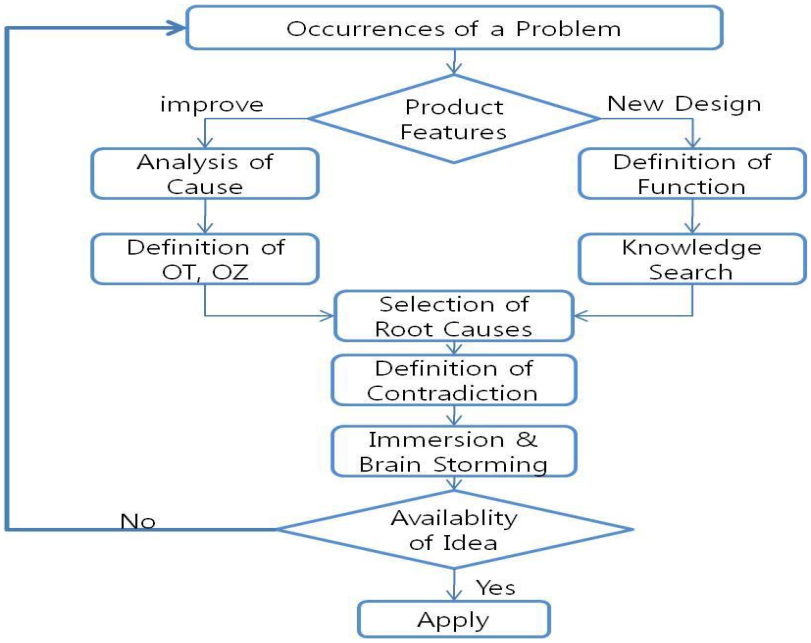

Figure 5. Immersion & Brain Storming Process depending on the Product Features

3. Conclusion

Because there is limited time to develop products in the industry, it is not easy to find an inventive solution. In addition, there are not appropriate systematic approaches to find solutions and apply them. Currently companies utilize TRIZ by changing it according to the production development cycle rather than simply follow the process of classical TRIZ. The industries requiring quick life-cycle such as the electronic industry force engineers to define a problem and to create and apply ideas. In this respect, they require a simplified TRIZ process and an approach of improving work process reliability. Therefore, in this study, we propose a problem solving process with the use of Immersion & Brain Storming activity to quickly create ideas. And the results of the study showed that the proposed approach helps to create a lot of ideas to solve a problem in a couple of days.

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TEACHING CREATIVE THINKING AND PROBLEM SOLVING SKILLS BY TRIZ

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Abstract

Systematic thinking and problem solving skills are considered as the significantly important factors in many professions. This paper shows that the Theory of Inventive Problem Solving (TRIZ) can be a good method to teach students systematic thinking and creative problem solving skills. Students surveys showed that the perception of their abilities in problem solving changed vastly as a consequence of the TRIZ course.

Keywords: TRIZ, Systematic Thinking, Problem Solving, Creative Thinking

Introduction

The development of creativity is a topic of great significance and is newly recognized as the most important subject of education in modern society. The interest in creativity is not just the matter of today. The reason it creates a new awareness is that modern society is in the age characterized by rapid change and variety. The nation-level curriculum states in detail the timely needs of creativity education. According to the Ministry of Education and Science of Republic of Korea (Feb. 1998), "The 21st century does not mean the turn of the century, but that of the millennium. In preparation for it, we have to cultivate sound character and creativity". The Committee on Education Innovation also determined it as the basis of the reform of curriculum[1)]. In line with this reform policy, the desirable human character targeted in education objectives is “the people exercising ingenuity with basic knowledge". Also, the modern businesses as well as national levels require experts with creativity as their desirable employees. Recently, US President Obama invited 20 business CEOs in the White House and referred to the importance of developing creativity by saying, " The first engine for the success of the United States is not the government but the creativity of entrepreneurs"[2)] The recent topic of Samsung's "Creative Administration" can also represent the importance of creativity very well".

While cultivating the ability of inventive thinking and problem solving has become the core subject in education, the detailed methodology on how this ability can be acquired is not yet fully set up, considering the recognition of necessities of it. In addition, universities have yet to discuss and develop in earnest the methodology on teaching students how to think systematically and the inventive problem solving. The conveying of knowledge still remains unchanged even today as was usually the case with the "encyclopedic" type of education of the past. Acquiring knowledge and learning it is very important but not enough. In the past, society needed and considered only knowledgeable persons as competent. Today however, in the age of knowledge and information, everyone can easily obtain knowledge through the Internet and IT media, which means that the person with just knowledge itself is no longer regarded as the

competent one. In other words, current society needs the person with inventive thinking that can make systematical use of their knowledge.
TRIZ is a methodology of thinking that helps solve problems inventively through systematic and logical thinking. It is a useful tool that helps foster creativity required in current society and teaches how to think logically. It is a methodology on problem solving that can be used to inventively solve problems, particularly in the field of engineering. TRIZ, which was developed and proved to be highly effective in the secondary education in Russia as an established methodology, has been introduced in many countries around the world. At Korea Polytechnic University, the education of TRIZ has been performed as an EH course so as to certify how it affects the cultivation of students' logical thinking and inventive problem solving, and to analyze the result of it.

The Training of Systematical Thinking and Creativity Education Using TRIZ

TRIZ is the acronym of **T**eoriya **R**esheniya **I**zobretatelskih **Z**adach in Russian which means "Theory of Inventive Problem Solving". It was developed by a Russian scientist Altschuller, beginning in 1946, and has since been complemented and completed by many of his disciples. It was formed by analyzing many patents[3)]. Altschuller analyzed over 20,000 patents of various areas with his disciples and classified them into 5 levels. He eliminated the simple patents involved in levels 1 and 2 that solve problems by simply changing the materials or using the technique of the same fields. Instead, he made his theory by analyzing the high-level patents (level 3-5) that needed inventive thinking or resolved contradiction. Through the analyses, he discovered the principles that were used commonly and repeatedly in the methods to solve problems regardless of fields and kinds of the patents, and had since improved the problem solving theory, systematizing the principles. The initial theory of TRIZ was developed by establishing the 40 Inventive Principles that systematizes the commonly and repeatedly used principles, and developed into the comprehensive inventive problem solving theory including Substance - Field Analysis, Standards, Law of Technical System Evolution, Separation Principle, and Algorithm of Inventive Problem Solving. Especially, by theorizing the scientific and logical thinking process, TRIZ draws much attention as a methodology of inventive thinking. Currently, TRIZ has spread around the world, applied in the fields of education and industry. In Korea, Samsung Electronics has been actively giving the TRIZ education to its engineers and in February 2010, POSCO selected TRIZ as an innovative tool and founded the TRIZ College to spread it. We established the TRIZ Innovation Institute together with Russian TRIZ experts in September 2010 and have been popularizing TRIZ.

During the second term of 2010, the course, "TRIZ, the theory of inventive problem solving" was given as a special course. Out of TRIZ tools, Systematic Multi-Screen Thinking, Resources, Contradiction, Ideal Final Result, (IFR), Technical Contradiction and Inventive Principles, Theory of Technical System Evolution, Substance-Field Analysis, and Standards were lectured in the 40-hour program. The students were 32 juniors and seniors from 8 departments as can be seen in Table 1. A large number of students applied, but part of them was not admitted in order to improve the effectiveness of this newly set-up experimental course and to analyze its result targeting students of various majors.

Table 1. Number of students taking the course by majors

major	Mechanical Design Engineering	Mechatronics Engineering	Electronics Engineering	Game&Multimedia Engineering	Advanced Material Engineering	Industrial Design Engineering	e-Business	Nano-optical Engineering	Total
Number	2	5	3	1	7	2	2	10	32

In the course, the theory was first taught to help understand the basic concept of TRIZ, and then the students themselves were asked to use the thinking tools of TRIZ to solve problems from the actual industrial fields. With the theory of TRIZ and the education method to be discussed later, next is the analysis on the result of the 40-hour course in one semester.

The Analysis on Education of TRIZ

After the 40-hour course, the analysis was made on the result of this course through the questionnaires by the students. There is no simple method of analysis that objectively evaluates intellectual faculties regarding logical thinking and inventiveness. Although an indirect analysis can be made by the IQ and the psychological tests, they cannot evaluate the thinking power and inventive problem solving ability correctly. Besides, 40 hours is rather too short to apply the objective evaluation system and analyze them, which led to the questionnaires that left the evaluation of themselves to their own judgment.

The questionnaires consist of 10 questions in all. Some of them were made up by the University team that opens and operates special courses to acquire the data needed to operate them, and the others were to analyze how the education of TRIZ influences the development of creativity and logical thinking. This paper analyzed the result of the questions only related to the subject of inventive thinking. A very good response to the course "TRIZ, the Theory of Inventive Problem Solving" can be seen in Table 2.

Table 2. Evaluation of TRIZ Course
(TRIZ, the Theory of Inventive Problem Solving)

Q: Was EH course satisfactory?	strongly agreed	agree	not sure	disagree	strongly disagree
Response (%)	71	21	8	0	0

TRIZ is a theory of problem solving, helping to effectively utilize our knowledge. People use on average only 5-20% of the knowledge they have in daily life[4)]. The more education one has, the less knowledge he or she uses. What is worse, experts use less and less knowledge of the areas other than their own, ending up losing more and more of it, which in turn makes them use far less knowledge than what they have. The thinking tools of TRIZ help us use all of our knowledge in the course of problem solving, enhancing the possibility of using the knowledge we have obtained. In addition, compared to the ones from the usual methods, it can make an unparalleled ideal solution as it systematically goes through the methodological thinking process of inventive problem solving.

TRIZ is a comprehensive thinking methodology on problem solving. As in table 3, 92% of the students think that their ability to solve problems has improved through the education of TRIZ. The fact that they took the TRIZ course can be demonstrated by whether or not they can solve the problems they face. The engineers that society needs are not the ones knowing a lot, but the ones that can resolve the technical problems in the field. The ability of problem solving does not mean a lot of accumulated knowledge, but the thinking power needed to put their knowledge to practical use. As the training of problem solving and thinking faculties is considered important, many universities now have much interest and are trying to develop relevant courses. Although not much time was given for the course, TRIZ proved to be an excellent methodology that can improve the students' ability of problem solving.

Table 3. Evaluation by students of whether TRIZ course improved their ability of problem solving.

Q: Has the course improved your ability of problem solving?	strongly agreed	agree	not sure	disagree	strongly disagree
Response (%)	72	20	8	0	0

After the course, the students' confidence in resolution when confronted with problems has dramatically improved. Table 4 shows the result of self-evaluation by students of how confident they are in the face of new problems. In Table 5, the result of analysis can be seen of the evaluation by the students themselves of whether the course was helpful in improving their thinking power and creativity. The figures of Table 4 and 5 are very encouraging. TRIZ had a highly positive effect on the development of students' creativity, thinking power, and confidence in resolving problems when facing them. Particularly, every student who took the course believes that TRIZ positively influenced their thinking power and creativity (strongly agreed -68%, agree -32 %). Despite taking into account that students decided on a subjective basis, TRIZ turned out to be highly effective in the education of students.

Table 4. Evaluation of improvement of students' confidence in solving problems after course.

Q: Was TRIZ helpful in developing thinking power and creativity?	strongly agreed	agree	not sure	disagree	strongly disagree
Response (%)	68	32	0	0	0

Conclusion

Nurturing creativity and problem solving ability of is a core element in education. It is considered very urgent to develop programs and make a study in order to equip students with these faculties. Torrance(1979) states that creativity should be combined with an individual's ability, the proper function of thought, and the motives such as energy, effort, and passion, etc[1)]. The first mentioned "an individual's ability" represents the amount of knowledge that one has accumulated, not a simple intelligence. Now, the second one, the proper function of thought, should be underlined. In other words, the systematic method of thinking plays a vital role in improving creativity. Educational facilities have to make an effort to help enhance thinking power and the ability to solve problems as well as perform a function of conveying knowledge. Not only secondary schools but universities as well should educate the students by giving them the training of a methodology of thinking and inventive problem solving so that they will become competent engineers in the industrial fields after graduation.
Students had a high opinion of the effectiveness of the TRIZ education. After taking the course, they agreed that their ability to solve problems improved dramatically and they came to have confidence in solving various problems they would face later in everyday life. All the students reached a conclusion that TRIZ was helpful, which means TRIZ education has a bright future. Of course, it is impossible to completely analyze and research the study of problem solving and creativity by the result of students' evaluation in just a one-semester course. Thus, a more systematic and objective research remains to be done later on. Nevertheless, TRIZ was demonstrated by this result to contribute to developing creativity by reinforcing the students' systematic thinking method. Anticipating that TRIZ will be conducive to the development of Korea Polytechnic University that aims to cultivate the competent persons with creativity, I find it meaningful just to discover the necessity of actively popularizing TRIZ.

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Critically explore the view that the monitoring role of institutional investors

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Abstract

This paper focuses on study how shareholders particularly large institutional shareholders can play a more effective monitoring role of their investee companies, via various modes of engaging with them such as voting, dialogue etc. Meanwhile, the Stewardship Code of UK and the effectiveness of which will be discussed too.
Keywords: Stewardship Code; shareholder activism; institutional investors; private consultations;

1. Introduction

With the holding size of institutional investors in the investee companies and the accompanied resulting "voting by foot" cost rose so that they have the ability and power to engage in the governance of listed companies. The role of institutional investors in corporate governance changed from "passive shareholder" to "active participant". This shows that institutional investors play an increasingly important role in both promoting corporate governance structure perfected and upholding the interests of shareholders. This essay mainly discusses the monitoring role of institutional investors in investee companies based on the viewpoint of shareholder activism. Meanwhile, the "stewardship code" will be explained too.

2. Institutional investors and shareholder activism

Up to now, there is no definition widely accepted in the theoretical circles for institutional investors. Generally speaking, the broad institutional investors include not only the securities intermediaries, securities investment funds (investment companies), pension funds, social funds, insurance companies, also including private donations of foundations, community church, religious organizations and so on; the narrow

institutional investors mainly refers to the various securities intermediaries, securities investment funds, pension funds, social insurance funds and insurance companies. (Dowries et al, 1999)

Because this paper is to study Institutional Shareholder activism of institutional investors, so the concept of shareholder activism must be explained. In fact, shareholder activism refers to institutional investors participate in corporate governance actively via shareholders voting system, or even become the member of Board of Directors; meanwhile, propose recommendations as to daily governance and development strategy of listed companies so that safeguard the interests of institutional investors. (Gillan & Starks, 1998)

3. The way to implement the shareholder activism and empirical evidence

Currently, as to institutional investors engage in corporate governance, the means of implement the shareholder activism mainly include shareholder proposals, private consultations, proxy fights for control, exposed the underperforming companies and class action. Here we analyzed one by one.

▪3.1 Shareholder proposals

It is widely used by institutional shareholders that submit a shareholder proposal to the investee company. For example, the five largest pensions fund TIAA-CREF, Ca ERS, CalSTRS, SWIB, NYC shareholders submitted 266 proposals, representing 18% of the total of all shareholder proposals among 1987 to 1993. (Guereio et al, 1999) Before 1980s, the content of shareholder proposals relate to corporate governance generally involved: the remuneration of managers, cumulative voting and the place of the annual meeting of shareholders and so on. After 1980s, the content of proposals mainly focuses on stop anti-merger measures, restrict high remuneration of managers and the impendence of Board of Directors, etc. (Romano, 2001). Of course, after shareholder proposals proposed, most of the investee companies will respond to those proposals; and the approval of proposals usually reaches 20% - 40% at the annual meeting of shareholders, sometimes more than 50%. (Bonnie, 2010)

▪3.2 Private consultations

In the UK, institutional investors mainly adopt official letter or telephone and other informal dialogue to private consult with investee companies as to corporate

performance and governance. If institutional investors could solve problem with private consultations, they won't choose other more costly approaches in general. In1998, the 40% of proposals proposed by the members of U.S. Committee of institutional investors are withdrawal after effective consultations. The result of private consultation of TIAA-CREF and 45 firms is 71% of shareholder proposals were solved before proxy voting. (Gillan et al., 1998) Studies have shown that the activities of institutional investors private consult with management usually produces positive effects of the stock. (Dowries et al., 1999)

▪3.3 Proxy fights for control

The essence of the proxy fights for control is to dominate the vote of general meeting on certain important issues through have sufficient right to vote. Like the election of members of Board of Directors. This approach does not involve the change of ownership, but win the right of control. Institutional investors often use it while other measures are ineffective. With the holding proportion of institutional investors rapidly increasing, the proxy fights for control becoming fiercely.

▪3.4 Exposed the underperforming companies

Exposed the underperforming companies refers that institutional investors take those companies performed poor to "blacklist" so that those companies improve operations through exposure. However, the exposure of listed companies performed poor is generally dealt with by the committee of institutional investors in order to avoid retaliation that single institutional investors or fund manager come forward to criticize the investee companies incurred. In 1980s late, CalPERS began publishing a directory of underperforming companies; aims to encourage those companies proposed reform measures to corporate governance. In 1993, the committee of institutional investors also published a directory of underperforming companies. (Woidtke. 2002)

▪3.5 Class action

This measure originated in UK mostly 12 century. Class action refers that one or two plaintiff as "Lead plaintiff" on behalf of most victims sues to protect the interests of shareholders. In a class action, lead plaintiff's allegations should be consistent with other members of the alleged interests of both parties must also be consistent. In a class action, lead plaintiff's allegations should be consistent with other members, and both

benefits must also be consistent. In 2001, the case of false income of U.S. listed company Cendant is solved by class action; the lead plaintiff safeguarded the interests of shareholders through negotiation with the defendants, the 2.851 billion dollars of compensation agreement was reached.

4. Stewardship Code for institutional investors

The engagement of institutional investors becomes increasingly important following the financial crisis. UK's Institutional Shareholder's Committee issue the "Stewardship Code" so as to improve the responsibility of institutional investors. Then, Financial Reporting Council adopts the Stewardship Code and contends that the stewardship code aims to improve the quality of engagement between institutional investors and investee companies so as to enhance long-term returns to stakeholders and the efficient exercise of governance responsibilities. Although the stewardship code is not fully developed, it is an effective and potentially method which make the institutional investors realize that many responsibilities must be added. According to the report of FRC issued in July, 2010, the way of engagement mainly includes pursuing purposeful dialogue on strategy, performance and the management of risk, as well as on issues that are the immediate subject of votes at general meetings.

5. The likely effectiveness of Stewardship Code

With the implementation of Stewardship Code gradually, this essay believes that it will play a significant role in the following: improve corporate governance, stable relationship between institutional investors and investee companies, and prevent the malicious purchase. Specifically speaking, including the following:

First, effectively easing off the "Prisoner's Dilemma" of corporate governance.

Prisoner dilemma refers to "collective action" or "free-rider". When institutional investors as an effective supervisor directly engaged in corporate governance, its positive interests generated is actually kind of "public goods", and this will be enjoyed by other investors through "free-ride". (Grossman & Hart, 1980) However, if most of shareholders give up their rights of supervisor, internal control of manager will become increasingly eminent. Therefore, institutional investors will proactively participate in corporate operate and governance, and this will make up the difficulty of "Berle-Means" under the background of equity diversified.

Second, promote the development of "relationship investment".

Relationship investment refers to investors is neither passive nor unrelated to each other, but to work together with management. (Pound，1993) Because institutional

investors are more stable than individual investors, and may form a lasting with investee companies, so investee companies have enough promotion to improve the effectiveness so as to improve corporate performance and enhance the competiveness of investee companies. In general, institutional investors hope to have a partnership with the investee companies, willing to focus on product and market development, staff training, technological innovation and long-term growth through communicate with management, neglect the reaction of pundits, to form a so-called "the third" supervision mechanisms to ease the difficulties of operation and governance.

Third, form a major force to prevent malicious purchase.

Generally speaking, institutional investors can increase the value of investee companies through resist the malicious purchase. In usual, as to malicious purchase, its purchase price is much higher than the market price of target companies, which is temptation to the majority of individual shareholders. Therefore, as the majority of shares in circulation and the proportion of shares held by institutional investors are small, it is difficult to against the malicious purchase. (Agrawal & Mendelker, 1990) However, as to the institutional investors that has a larger proportion of shares, because they are more concerned about the long-term and stable benefits, so it can serve as a force against the malicious purchase.

Forth, improve the corporate performance.

Becht et al (2009) study on the famous Hermes UK Focus Fund found that activism can bring generous returns (5.3%) to investors. In fact, this fund usually uses private consultation or even through a special shareholders meeting to express its requirements so that target company change governance structure and replace the CEO or Chairman so as to increase the dividends.

6. Conclusion

Actually, many scholars and exports home and abroad have never stopped on the research to institutional investor's shareholder activism. This essay based on previous studies and combined with the latest UK Stewardship Code, critically evaluate the likely effectiveness of implementation of Stewardship Code, and believe it will helpful to improve corporate governance and operation, strengthen the relationship between institutional investors and investee companies, against malicious purchase, and enhance corporate performance. In addition, this paper also explain the usual way of engagement, including shareholder proposals, private consultations, proxy fight for control, exposed the underperforming companies, and class action. From the above analysis, the Stewardship Code plays an important role in the near future.

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A TOC Problem Solving Model Incorporating with ANP Measurement Concepts

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Abstract

The Theory of Constraints (TOC) has been recognized as a very effective problem solving model, and is used extensively in business circles. The strength of TOC lies in its exploiting of common-sense and systematic thinking and employing of cause and effect analysis that it is apt to be understood. However, TOC is found in practice to have some drawbacks. Namely, it lacks an objective mechanism for selection of key problems. Besides, after feasible solutions are proposed, it also lacks an objective mechanism for finding out the optimal solution set. Moreover, there are no evaluation mechanisms for effectiveness of problem solving. In essence, the drawbacks originate from the fact that the TOC model lacks an appropriate measurement scheme. Based on the above observations, we are to reconstruct a new TOC problem solving model incorporating with the Analytic Network Process (ANP) measurement concepts so as to enable TOC solving its own three "problems" at one time. We first employ the voice of customers (VOC) and develop measurement indexes in accordance with the Critical to Quality (CTQ). It is followed by finding out the internal and external relationship among the measurement indexes, core problems, and schemes. Finally we use ANP for systematic calculation of weights in ratio scale, to be assigned for the decision makings involved.

Keywords: Theory of Constraints, systematic thinking, Analytic Network Process, Critical to Quality.

1. Introduction

Problem solving is a task common to all disciplines. It is also very important in the quality management. Facing the sheer competition in the global marketplace, the solving of quality problems has become tougher than ever before. It is manifested not only in the higher frequency of occurrence, the wider scope of influence and heavier strength of impact, but also in its much more sophisticated and complicated problem structure. Especially when a system problem is large and complicated, and when the characteristics are hardly quantifiable, the task for solving the problem is extremely tough. Under such a circumstance, simple quality problem solving tools are often insufficient for the purpose. Wherever the timeframe and the resources for problem solving are limited, the Theory of Constraints (TOC) has proved itself as a good alternative model for problem solving.

In essence, TOC problem solving model emphasizes common sense management and, is an intuitive framework that integrates the systematic thinking process with the logical structure. It features the use of three inquisitive questions and five logic trees. The three inquisitive questions are (1) What to Change? , (2) What to Change to? , and (3) How to Cause the change? While the five tree diagrams are (1) Current Reality Tree, (2) Evaporating Cloud, (3) Future Reality Tree, (4) Prerequisite Tree, (5) Transition Tree.

The first three inquisitive questions can be regarded as corresponding to the three major stages of the problem solving process. In each problem solving stage, different logical tree diagrams based on rigorous causality are employed.

According to Goldratt, the developer of TOC, every system has hidden constraints embedded underneath the phenomenon of the problems. Only when the most significant constraints that bring out the major impact on the system output are identified through logical causality analysis, and are relieved afterwards, we can claim that the problem is solved.

Usually, TOC encounters a problem by starting from a set of qualitative undesirable effects (UDE's), and followed by tracing back to the upper stream and looking for the root cause(s) in depth. The cause(s) in the lowermost bottom are called the core problem set. While the timeframe and resources do not permit solving all the problems at the same time, it is then necessary to disintegrate the problems into sub problems and to select among them the most influential one and treat it as the key problem for action. The selection of the key problem is to look for the weakest ring (constraint) of the system and to assign a higher priority for solving. Therefore, only when the real key problem is identified, we are in control of the core of the problem, and the remedy can be provided based on the diagnosis.

As a widely quoted saying goes, a problem well chosen is already half solved. However, it is equally important to find out the key solution set, once the key problem is properly selected. Through similar use of logical tree diagrams, numerous feasible action schemes will emerge as an output. However, being limited by the timeframe and also the resources available, it is unlikely to have all the

proposed schemes put into action in the same time. The only alternative is to screen the most effective ones according to their individual contribution to the overall result. It is the important to have this done to ensure effective and efficient solving of the problem.

Although it is the advantage of TOC to have qualitative problems solved effectively, it does have a shortcoming in lacking quantitative indexes to objective measures for evaluating the effectiveness of the problem solving. Therefore, in what is to follow, we will address the issue and develop a scheme to alleviate this drawback. In order to resolve this problem, we shall resort to conventional quantitative approaches for the way out.

2. TOC problem solving model and selection of key problem, key solution set, and key indexes

In solving a problem, the Theory of Constraint employs a set of 5 tree diagrams in the three major stages corresponding to the three inquisitive questions. As a matter of fact, the problem is solved through the interaction between the three inquisitive questions and the five tree diagrams. In other words, the solving process proceeds with a negative awareness of the problem as a starting point and a set of UDE's is then collected. The Current Reality Tree is established afterwards basing on the logical inter-relationship among the UDE's. By following the stream upward, the root problem or a set of core problems that cause these UDE's are identified thereupon. Imposed by the limitation in the timeframe or human resources and technical capability, it is often necessary to select a key problem basing on its coverage over the majority of UDE's. It acts then as the focal point for consequent solving efforts and thus completes the first of the three stages of problem solving. In the stage, the center of the thinking process lies in the selection of the key problem. The primary task is to answer the question of 'What to Change?', whereas the output is the key problem so selected.

In the second stage, the positive way of thinking is adopted. The target of the key task is set by employing a way similar to the mirror imaging and transposing the key problem selected in the previous stage into the key target. This is to serve as the basis of the consequent solving actions. It carries on by way of the same mirror imaging; the negative UDE's in the Current Reality Tree are transposed into positive desirable effects (DE's). The Future Reality Tree is then established, based analysis of the one-to-one causality relationship among the key goal and the DE's. Following this, the connections between the pairs of intermediate goals are checked at this point. These connecting channels are classified into one of the following three, i.e. (1) freely accessible channel; (2) blocked channel; (3) potentially risky channel. A freely accessible channel refers to the type of channel connecting the two intermediate goals that one intermediate goal can be realized without any difficulty by fulfilling another. However, a blocked channel refers to the opposite type of connecting channel that one intermediate goal can not be realized even though another is fulfilled. The potentially risky channel refers to the type of channel that connects two intermediate goals where fulfillment of one does not guarantee the realization of anther. In other words, a potential risk exists in this type of channel.

Whether the key goal or the intermediate goals that are extended from existing DE's, they both corresponds to the question of 'What to Change to?' The outcome of this inquiry in this stage ends up with a tree diagram such as Future Reality Tree. The center of the thinking process in this stage lies in the goal-setting. Its primary task is to answers the question of 'What to Change to?' The output is a set of feasible solution schemes.

In the third stage of the TOC problem solving process, its thinking lies essentially in the solution-finding. The primary task is to answer the question 'How to Cause the Change?' It proceeds from the Future Reality Tree established in the previous stage and aims at clearing the blocked channels and also the potentially risky channels. The Prerequisite Tree is employed to generate the Clearance actions that ensure the fulfillment one on intermediate goal will realize another. The Enhancement actions are also generated similarly to eliminate the potential risk that lies between the two interrelated intermediate goals. Both the Clearance actions and the Enhancement actions so generated in this manner can be used collectively to meet the ultimate goal. That is to say, they are capable of eliminating the UDE's identified at the time when the problem emerged. The TOC problem solving model usually employs, during this stage, the Transition Tree Diagram to present the corresponding intermediate goals, the obstacles or risks, and the feasible actions side by side. The TOC problem solving process is shown in the form of flow chart as in the Figure 1.

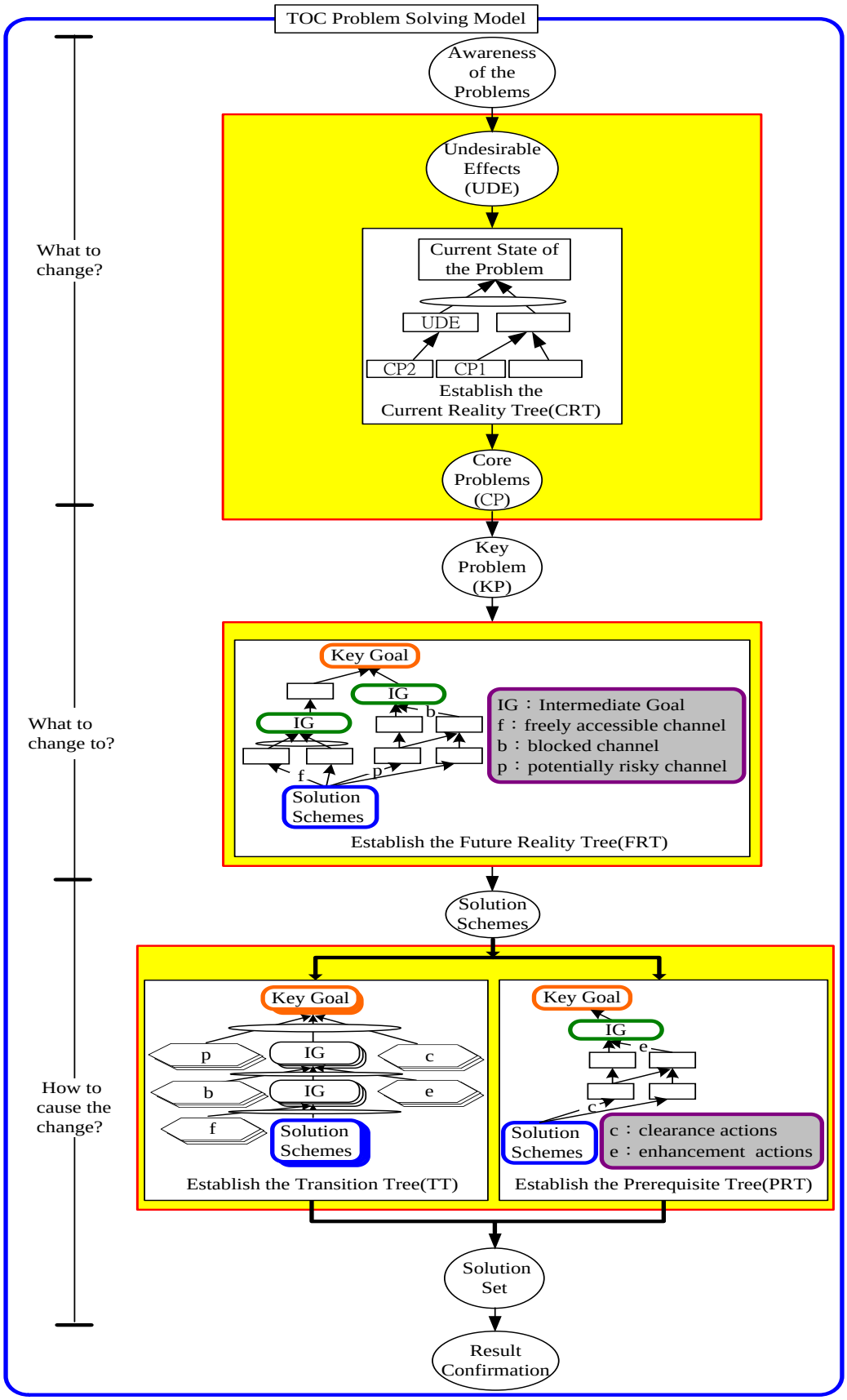

Figure 1. TOC problem solving flow chart.

As mentioned earlier, the primary task at the first stage is to select the key problem. The typical approach is shown in Figure 2. Illustrated in the figure is the Current Reality Tree built up with a group of UDE's interconnected basing on their causality. Laid in the second tier near the bottom are three core problems which are considered to be of significance to the ultimate UDE laid on the top. The gray grids are the ones that are connected through causality arrows to the core problem in the center position. As the coverage is over eighty percent of overall UDE's down the stream of the cause and effect arrows, the core problem is eligible to be identified as the Key Problem in this case (Scheinkopf, 1999).

In case the core problems don't cover over the eighty percent of UDE's, the search for the key problem continues.

Inspection is conducted to look further down the stream beyond the existing core problems for the common cause undiscovered so far. The percent coverage is calculated again in order to identify the key problem which is significant to the problem undertaken.

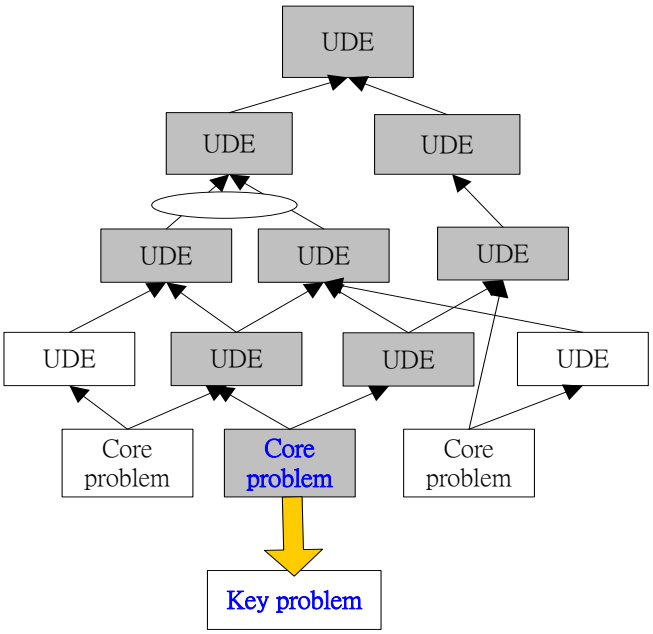

Figure 2. A typical current reality tree diagram.

What is stated above illustrates how a key problem is selected in a typical TOC problem solving process. However, it is to be noted that no further selection scheme has been found in the literature regarding how further selection is carried out once numerous feasible actions are available. The same is true for the scheme for measurements in the complete problem solving process.

In summary, it is obvious that some blind spots and drawbacks do exist in the conventional TOC approach for problem solving. Listed below are some of the significant ones.

1. The objectivity of the selection of key problem is hampered by equal treatment of the UDE's.

It is obvious that, in selecting the key problem, TOC carries a underlying assumption that every UDE bears equal weight in terms of their impact on the overall problem. However, in reality, not all UDE's are born equal in terms of their impact on the overall problem. Lumping the highly important and the less important UDE's together may lead to selection of a core problem covering numerous insignificant UDE's as the key problem, whereas a core problem covering few but vitally important UDE's may be left out because of the conventional selection scheme.

2. While the numbers of feasible actions are numerous in a complex problem, no scheme is available to pick the most effective solution set.

In solving a complex and large scale problem, it is likely that a large number of feasible actions are generated through the Future Reality Trees, Prerequisite Trees as well as the Transition Trees. As it is true for the UDE's, it is also true for the feasible actions to be taken. They are not born equal in regards to their contribution to the solving of the problem. As the renowned Pareto Principle, known also as 80/20 Principle, goes, the properly chosen 20 % of the feasible solutions can contribute to solving 80 % of the problem. The underlying assumption of equal weights of the actions needs to be addressed seriously.

3. An effective mechanisms is lacking for evaluating the performance of problem solving.

In solving a problem, it is important to ensure that not only the outcome of the solving process reaches the target set in terms of ultimate Desirable Effects, but also the overall efforts are effectively and efficiently utilized in the process as a whole. To meet this goal, a measurement scheme has to be setup, measurements have to be carried out, and data have to be collected, processed and analyzed. Moreover, this is important for the sake of objectivity in decision making, including selection of the key problem and the key solution set. However, this is not explicitly available in the TOC problem solving model.

Considering the above three drawbacks as a whole, it is obvious that the three drawbacks are three in one. That is to say, the root of the issues lies in the lacking of measurement scheme in the Problem solving process. It prompts us to find a way out for this issue.

3. TOC problem solving model incorporating with ANP

Analytic Network Process (ANP) is an extension of Analytic Hierarchy Process (AHP). Both have been developed by Saaty for the purpose effective decision-making. It is aimed to obtain accurate prediction by proper utilization of interdependency among all criteria, goals, schemes in terms of ratio scales. ANP is particularly applicable in the case when feedback relation exists in the system. ANP allows inner dependence inside the clusters and outer dependence between the clusters. It offers a complete structure that includes connection between the clusters and the elements, and also studies the whole problem procedure from the expectation of decision maker. The researcher can find out the interaction between each element and the clusters from the problem, and then derive from priority of

ratio scales of every scheme. ANP provides problem solvers a convenient decision making by employing the unique function of matrix and quantification. In this context, ANP is employed as the complementary quantitative tool to encounter the shortage of TOC in lacking measurement scheme. Based on the TOC problem solving process as shown in Figure 1, we propose a modified TOC problem solving model incorporating with ANP. The flow chart is shown in Figure 3.

In the context of this new TOC problem solving model, the problem process starts, as usual, with the problem awareness. The voice of customers (VOC) is collected for two purposes. On one hand, the "negative voices" are processed as the UDE's and used to establish the required Current Reality Tree. Based on the causality in CRT, the major core problems are identified. On the other hand, from the whole customer's voice, the CTQ (Critical to Quality) are identified. They are to serve as the interface for transforming the qualitative problem into the quantitative one. The CTQ is extended to construct a set of measurement indexes. The ANP process is introduced into the system at this point. Both the core problems set as established by the CRT and the measurement index set as constructed by the CTQ's are embedded in the quantitative structure of ANP. The interdependent relations inside and between the clusters are assessed. The relative weights are also calculated through the operation of super matrix in order to evaluate the priority of the elements in every group. On one hand, the most significant key problem and key indexes are determined as the basis of the continuing problem solving operation. On the other hand, the numerous actions generated by Transition Tree generates, together with the key measurement indexes set generated in the previous stage, are fed into the ANP structure. At this point, through the structure of ANP, the relatively important key solution set is determined thereupon. Besides, the key index set useful for measuring the effectiveness of problem solving is also ready on hand.

4. Conclusion

In this article, we explored the TOC problem solving model and have identified its drawbacks including the lacking in an objective mechanism for selection of key problem and key solution set and also the lacking in an appropriate measurement mechanisms for evaluating the effectiveness of problem solving. From thereupon, we incorporate the VOC mechanism and the CTQ concept, together with the ANP structure and developed a new TOC Problem solving model. The issues of objective selection of the key problem and the key solution set are thus resolved. An objective set of measurement indexes is also available for assessment of the effectiveness of problem solving. The result of a separate empirical study applying this model in solving a famous underwear company management problem indicates that the model is workable.

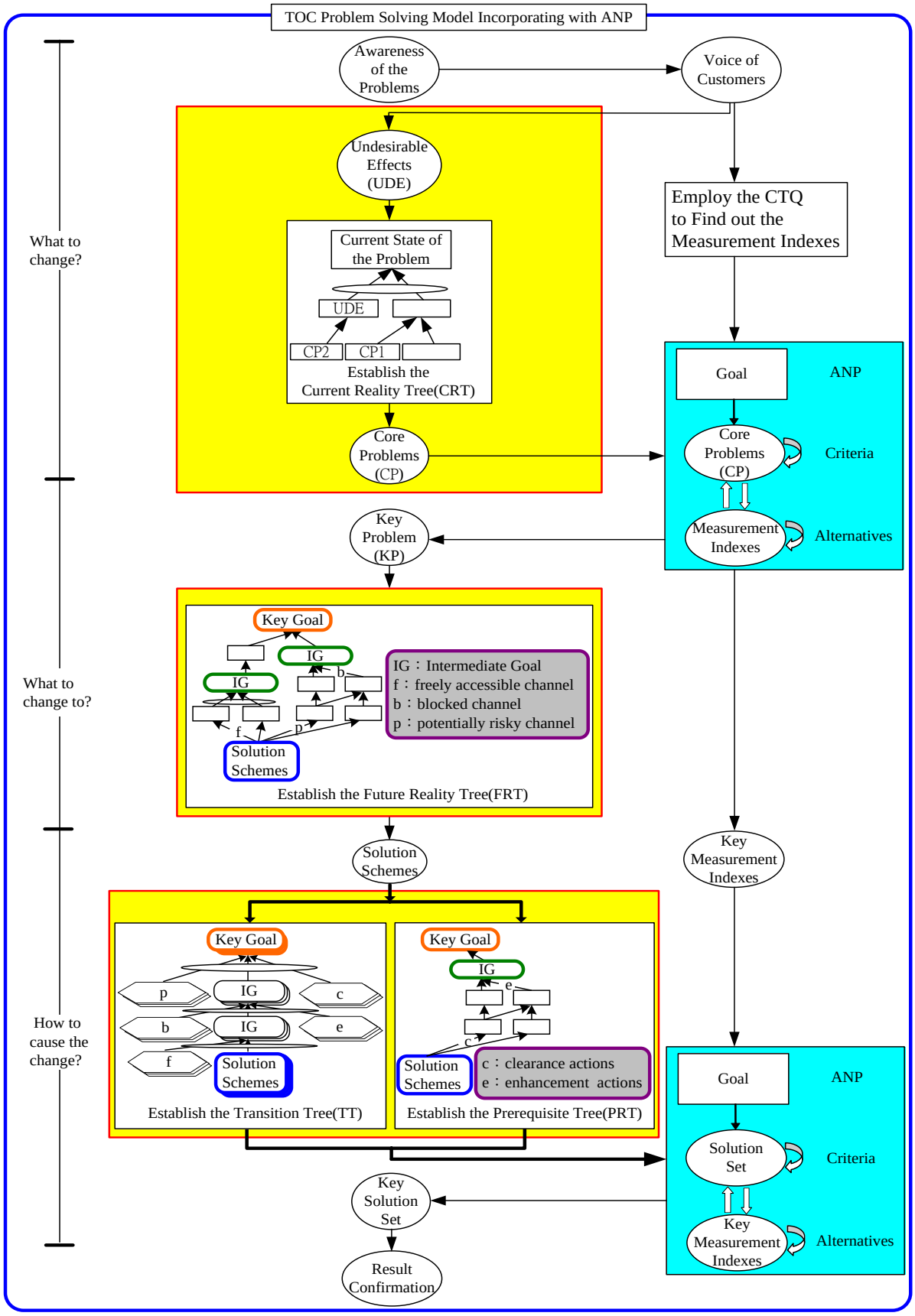

Figure 3. TOC problem solving incorporating with ANP flow Chart.

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Integration of TRIZ derived eco-guidelines and Life Cycle Assessment for sustainable design and process

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Abstract

In this work a method for identifying the key points and supporting an eco-design activity for companies is presented.

Amongst the different concurrent approaches in the literature, Active Innovation Management (AIM), is currently developing, jointly with the University of Bergamo, an integrated approach based on Life Cycle Assessment (LCA) and TRIZ eco-guidelines. The main goal of this integration is to simplify the eco-design approach in order to make it accessible to companies and particularly to small medium enterprises (SMEs).

The proposed method consists of a preliminary scan of a given product or process in order to disclose all involved flows of material and energy, and to assess its environmental impact by means of traditional LCA approach and related indexes. The “hot spots” of the process are then identified adding to classical LCA criteria a brand new index, called the “IFR index”, conceived from the TRIZ “Ideal System” concept.

Once key points are identified, a set of 330 eco-design guidelines are introduced to develop alternatives and modifications to the given system with the aim of providing a lower global environmental impact.

A first version of those guidelines (Russo and Regazzoni 2008; Russo, Montecchi et al. 2009) was conceived starting from the eight natural Laws of Evolution of Technical System (LTSE) introduced by Altshuller (Altshuller 1984). Here an extended version allows the user to work in each phase of the product life cycle, and integrates other TRIZ tools and best eco-practices.

Preliminary results of the application in SMEs will be presented with a case study concerning a textile home-furnishings and bed linen painting company.

Keyword: Eco-Design, TRIZ,IFR, LCA

1 Introduction

Nowadays, the importance of sustainable development no longer needs highlighting. The scarcity of resources and higher pollution levels are progressively orienting consumers and therefore industry towards cleaner production.

This topics is currently at the heart of reflections in European Community, and in this context AIM is strongly involved in the setting-up, testing and training of new eco-innovation approaches, adapted to a SME context.

Performing a state of the art analysis on current existing methods for eco-design, we noted that Life Cycle Thinking (LCT) and LCA are recommended best practice for industries, but their penetration is still weak.

Amongst the causes of this poor penetration, some authors indicate the complexity (Consultants 2000). This fact is strongly limiting the adoption of LCA in SMEs.

Moreover, we discovered that in eco-design it is a common practice to under-evaluate the role of resources; actually, most methods focus only on materials and energy and with quite a superficial attitude. For instance the "companies‟ guidelines" for the choice of material are limited to a simple classification that goes from good materials to be used freely to awful materials not to be taken into account (Russo, Montecchi et al. 2009). More generally, all methods are very effective in the assessment phase or in the improvement phase, but not in both.

Based on this analysis, we defined the following research approach:

- Modeling of eco-design activity: we identified then two phases: a first phase of product assessment, then a phase of product improvement (or process).
- Putting together the most ecologically efficient assessment tools with the most efficient problem solving tools based on TRIZ
- Performing a selection of alternative generated solutions based on a quantified but simple impact evaluation.
- Simplifying the global approach in order to make it accessible to European SMEs. In the following paragraphs this approach will be described. Then, a case study will be presented with some results, considerations and perspectives. Due to the work in progress, more detailed examples will be presented during the congress.

2 An introduction to abridged LCA

In former times, engineers were only concerned about designing a product that met its objectives. The natural consequence was the manufacturing industry has been accused of operating a system that takes, makes and wastes, although it also has the potential to become a creator of products that generate ecological, social and economic value. One possible way to improve on this viewpoint is for industry to embrace the „eco-efficiency‟ approaches. In the specific case

of the design process, this might involve the adoption of „Eco-design" techniques (Knight and Jenkins 2009). So the challenge for eco-product developers has become to fulfill a need or to provide a benefit to the customer/user at the lowest environmental/economic „„cost"" (Luttropp and Lagerstedt 2006).

Due to the growing interest in environmental aspects, over the last three decades many tools and indicators for assessing and benchmarking environmental impacts have been developed (Finnveden and Moberg 2005; Ness, Urbel-Piirsalu et al. 2007).

Amongst different environmental assessment tools and methods, LCA is the most established and well-developed tool to evaluate the environmental impacts of a product or a service throughout its life cycle. It is an approach that analyses real and potential impact that a product has on the environment during raw material acquisition, production process, use, and disposal of the product (Ness, Urbel-Piirsalu et al. 2007). LCA results provide information for decisions regarding product development and eco-design, production system improvements, and product choice at the consumer level.

Although the interest in LCA grew rapidly during the 1990s, and a strong development and harmonization has occurred (Finnveden, Hauschild et al. 2009), many authors identified some weaknesses in the LCA approach, hoping for its further developments (Finnveden 2000). According to the Swiss Agency of the Environment and the Dutch Ministry of the Environment: "Although LCA is a good tool to assess the environmental performance of a product, and although it is widely adopted by designer, is time consuming and costly…and results need to be interpreted and weighted" (Consultants 2000; Hur, Lee et al. 2005). Other barriers to a wider LCA diffusion (mainly in SMEs) are:

- complexity of data collection;
- complexity of interpretation of results;
- expensive Software and databases;
- high LCA required knowledge;
- no support provided to designers to improve situation AS-IS.

Therefore, there is a need for simplified methods that involve less cost, time and effort, but yet provide similar results (Hur, Lee et al. 2005).

Specific simplified (or abridged or streamlined) LCA methods have so been developed (Hochschorner and Finnveden 2003; Hur, Lee et al. 2005) and different depth levels of LCA analysis were defined (Wenzel 1998).

In order to improve LCA approach, some specific development projects have been supported by the EC (European community) such as the E-LCA (Sára, Buonamici et al. 2002) and E-LCA2 (ENEA 2002) projects. These projects goals are to develop a simplified LCA methodology, with a related software tool and database called Abridged LCA that:

- has to maintain the life cycle approach;
- simplify the methodological aspects of ISO 14040;
- minimized time and resource investments;
- doesn‟t require high LCA knowledge;
- has to be clear end easy to use;
- has to contain high quantity of supporting "background" information such as databases of substances and processes;

Even if these improvements have increased the ease of use, nevertheless the interpretation of results demands yet people skill in the art. Therefore Databases of materials and processes are often inadequate.

In this work, abridged LCA is not exploited as a tool for environmental certification but it is integrated into an ECO-Design procedure as a strategic tool for identification of the hot points to work on.

3 TRIZ Eco-guidelines

As defined by Knight (Knight and Jenkins 2009), Fitzgerald (Fitzgerald, Herrmann et al. 2007) and Luttropp (Luttropp and Lagerstedt 2006) there are tools for eco assessment (as LCA) and tools dedicated to the eco-improvement of product/process that are mainly of two types: guidelines and checklist.

Especially, in (Knight and Jenkins 2009), guidelines are defined as providing broad support, with little detail, but applicable either across the whole product development process and lifecycle, covering a significant area (e.g. design for X).

Despite the apparent benefits of eco-design, it is unclear if these tools are being used and if they have any real effect on product system developments (Luttropp and Lagerstedt 2006). Indeed some researches indicate that the application of eco-design tools by SMEs is limited (Baumann, Boons et al. 2002). The main reason is the poor level of detail and the scarcity of indication for implementing the guidelines in a practical way.

TRIZ methodology has been evaluated as a potential ally for existing eco-design methods. Some TRIZ fundamentals, such as ideality, resources and laws of technical evolution (Altshuller 1984), have been re-organized in the form of practical eco-guidelines (Russo, Montecchi et al. 2009).

The main goal of the guidelines is not only limited to providing a tool to better understand what element of our system needs an intervention to reduce its environmental impact. They are also conceived to support designers improving a product, process or service according to the eco-parameters until the end of the problem solving process, suggesting the direction of work and the best tools at the designers‟ disposal, and the tricks and best practices.

These guidelines, being extracted from the TRIZ laws of evolutions (Altshuller 1984), have a main theme that is to reduce resource consumption (mainly material and energy) increasing efficiency. This is possible by taking into account the best heuristics and theories of problem solving, and also taking into account new trends, technologies and best practices in green design.

In the first versions only eight guidelines (as shown in Figure 1), conceived mainly for TRIZ experts, were developed with the aim of improving the initial system in the phase of use.

GUIDELINES	RULES	
N. Name	N.	Short Description
ASSESSMENT		
G1 System modelling	R1.1	Main Function identification
	R1.2	Physical description
G2 Resource assessment	R2.1	Resources exploitation indexes
	R2.2	Analyze present/past system condition
	R2.3	Identify external resources
INNOVATION		
G3 Resource saving	R3.1	Use IFR concepts
	R3.2	Reduce Energy conversion to zero
	R3.3	Explore other technologies
G4 Components interaction	R4.1	Make the actions resonant
	R4.2	Coordinate Fields
G5 System dynamization	R5.1	Dinamyze the system
G6 System simplification	R6.1	Eliminates useless components
	R6.2	Solve contradictions
G7 External resources exploitation	R7.1	Merge technical systems
	R7.2	Shift to super-system
G8 Fields cooperation	R8.1	Increase S-Field involvement

Figure 1: Initial framework of TRIZ-based eco-guidelines conceived by the University of Bergamo for the phase of use.

Previous work was then extended to all phases of the product life cycle, and new directions for action were added. The guidelines actually constitute over 330 actions organized by pre-manufacturing, manufacturing, product use and end of life.

Each phase contains a set of the objects to which the guidelines refer to. For every object a list of goals to be achieved, opportunely translated in terms of resource abatement, is provided in order to design a better product.

Then, goals can be achieved by eco-design directions, that is detailed suggestions dealing with the way the "resource reduction" target can be achieved by specific problem solving paths, often inspired by classical TRIZ approaches and best green practices (Russo, Birolini et al. 2010).

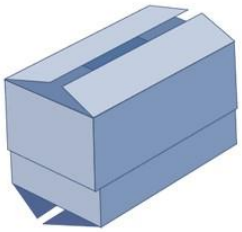
The last part of the directions contains examples of applications as a trigger to stimulate ideas by analogy.

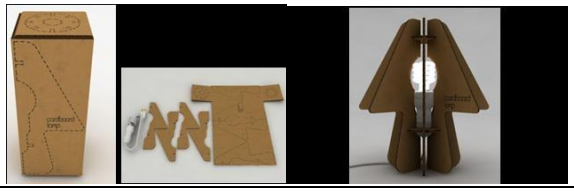
The first level contains the objects to which the guidelines refer to, the second level deals with the kind of resource involved, the third level is a synthesis of the target to be achieved.

Collapsible functions are introduced in order to ameliorate the diagram"s usability.

Among all the directions from "Guideline # act on packaging in use phase" one of them suggests *reduce the packaging mass*.

Table 1: Example of guideline for to "*reduce the packaging mass*".

DYNAMIZE THE SYSTEM Try to dynamize the packaging: - Allow a packaging or object to change to achieve optimal operation under different conditions. - Split the packaging into parts capable of moving relative to each other. - If the packaging is rigid or inflexible, make it movable or adaptable. - Increase the amount of free motion, then pass to liquid, gas and some kind of field; i.e., pass to a more flexible, rapidly changing, and adaptable structure	Dynamize the packaging: tubes Dynamize the packaging: flexible telescopic box:   Dynamize the packaging: foldable box 
MERGE TECHNICAL SYSTEMS Joining in space homogeneous object (packaging) or objects destined for contiguous operations; Joining in time homogeneous or contiguous operations. Use TRIZ Standards 3.1.X.	Puma clever little bag. This is the merging of a bag and a shoes box. That solution has saved 65% of cardboard, 8500 tons of paper. 
IFR Think about products that don't need packaging (the packaging is already included in the product) **Use packaging mass index** Assessment index: IFR: Zero packaging: 100 ACTUAL: Mass of packaging used Index: ((MASS OF PACKED OBJECT - ACTUAL)/ MASS OF PACKED OBJECT)* 100	IFR: absence of packaging, solid inks. The cartridge has been eliminated.  The packaging is already included in the product: Scratch-proof glass

ELIMINATES USELESS COMPONENTS Simplify the packaging trying to eliminate useless components up to the four essential components. To do this perform a trimming activity associated with a traditional TRIZ functional analysis. Explorer other technologies for the deposition of the packaging only where is necessary.	Material reduction: Nestlé redesign the bottle and cap to make them lighter. Also narrowed the label.  Material reduction: Coca cola redesigned the bottle to make it smaller and lighter 
	Integrate the packaging into the product: Procter & Gamble introduced a stand- alone rigid tube. So it was been possible eliminate the box. 
	Eliminate the useless component: Colorless coca cola cans  Integrate the packaging into the product: Cardboard Lamp by Luis Morales 

4 The integrated approach

Therefore, LCA software and eco-guidelines have been integrated in order to jointly provide a quantitative assessment of product or process ecological impact, and to provide relevant improvement strategies to designers.

The LCA assessment approach has been chosen as a foundation system in order to integrate inventing TRIZ capabilities to provide a complete approach; then, guidelines have been

structured following the life phases decomposition, as in *eVerdEE* software, that is a software for abridged LCA developed by ENEA (Italy). The phases are, respectively, as follows:

- Pre-manufacturing, i.e. the identification of all elements bought and that will be transformed inside the company later on.
- Manufacturing, i.e. the industrial operation of transforming the components into a product.
- Operation (product use), i.e. the time during which the product operates, including maintenance activity and consumptions.
- End of life, i.e. the recycling part of the product.

In order to map a given process, previously to the use of LCA software, we adopted an IDEF0 modeling based approach, specifically set-up for this application (see Figure 2). The aim of the modeling phase is to chart all the data of process and products, keeping track of the quality and others metadata and additional information, needed for the use of *eVerdEE SW*. As shown in Figure 2 a dedicated and customized symbology has been created.

Employing such a model allows us to show clearly the AS-IS situation; in particular it is easy to define all flows as well as their loops, with the values really used into *eVerdEE* SW during the quantitative analysis.

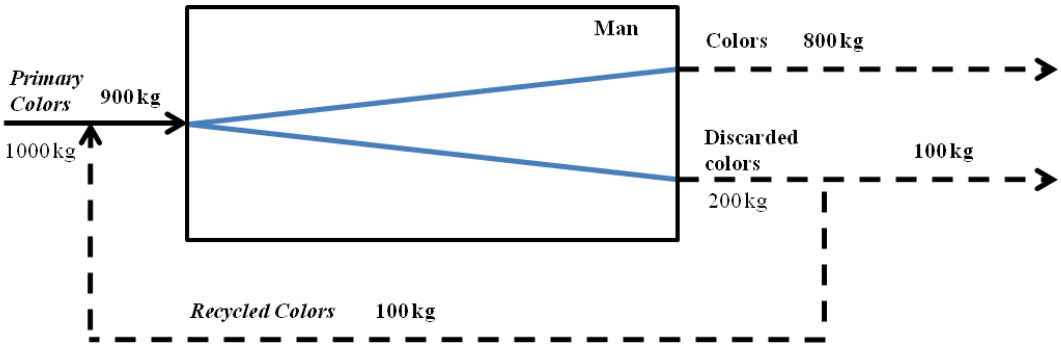


Figure 2: IDEF0 modeling

Then IDEF0 modeling is used again after the *eVerdEE* calculation and it is enriched of specific indicators associated to the flows and the operations inside each phase.

Particularly, in order to highlight the hotspots on which act, a diagram for every considered environmental indicator has to be made, and every flux is mapped with its percentage impact rate on the considered indicator. The environmental indicators and the percentage impact of every flux are provided by the output of *eVerdEE* SW.

To amplify the simplicity and the immediately of reading, in addition to a label with the flux rate, more high is the percentage rate, more high is the size of the arrow referring to that flux.

Finally, with the aim to identify the hotspot, that is the flux with the greater potential improvement, the IFR index is applied to every flux. In order to reduce the environmental impact of the identified hot spot, the guidelines are then applied.

The overall eco-design process is shown in Figure 3:

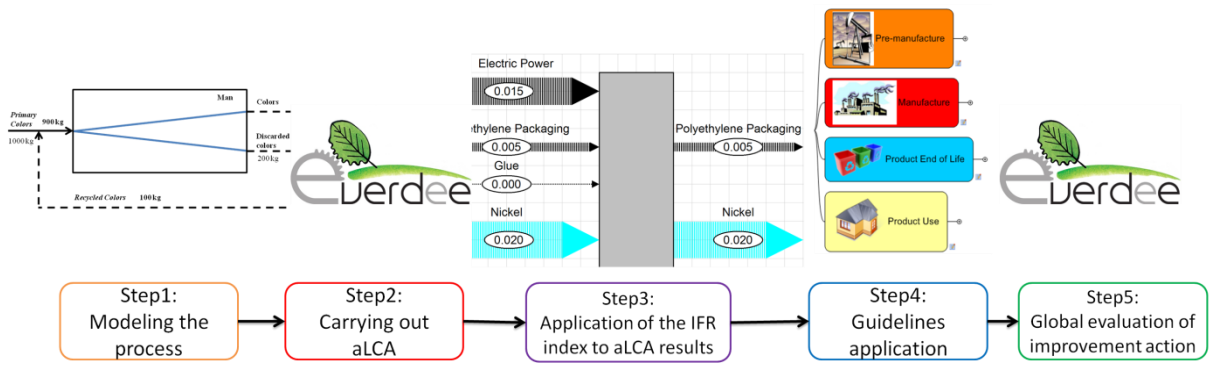


Figure 3: Proposed Eco-Design approach

4.1 Assessment phase – IFR index

The evaluation of the environmental impact for a substance or a process is connected to two main factors, the quantity of material flows and the energy entering inside the cycle and their specific environmental impact coefficients (eco-indicators). In the literature most available eco-tools mainly focus on assessing how a flux impacts on the environment without any suggestions on where to perform an improvement and how to do it. The easy pick approach is to start from the flow that generates the higher impact on the most environmental indexes (climate change, acidification, eutrophication) regardless of the amount of material it constitutes.

The novelty of the proposed approach is to introduce an index in order to identify critical areas on which to perform redesign actions.

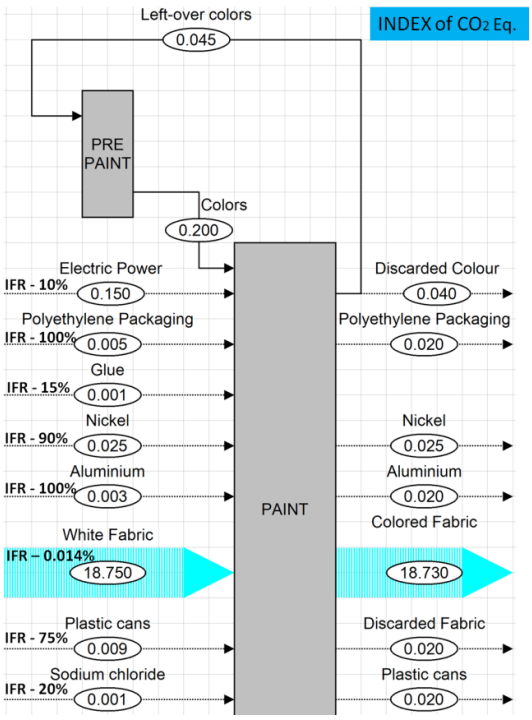
The index is called IFR, as inspired by the homonymous TRIZ tool. The IFR index is calculated on the base of the following definition:

"The technical system should not only be a suitable power conductor but should also operate with minimal energy losses (such as losses incurred by transformation, production of useless wastes, and withdrawal of energy with ready-made artifact).

The IFR system should use energy and materials only to provide the main useful function in according to TRIZ IFR concept".

Adopting this index we are capable of associating each flow of energy or substance in input with the maximum potential reduction that can be achieved theoretically. In this way we perform a sensitivity analysis on all flows based on realistic design criteria. Using this new index the assessment is then made not only on actual criticality of existing flows but also on possible future theoretical improvement.

An example of hotspot identification is shown in Figure 4 and Figure 5. Here, percentage impact rates are calculated by simplified LCA software and the hotspots are found after the calculation of the **IFR potential reduction index** and the application of that index to every flux. In this example it"s considerable and easy to see how the flux that initially have the greater impact is not the primary hot spot on which operate. That means the application of the IFR index can overturn the initial ranking of the percentage impact rate of the considered fluxes.



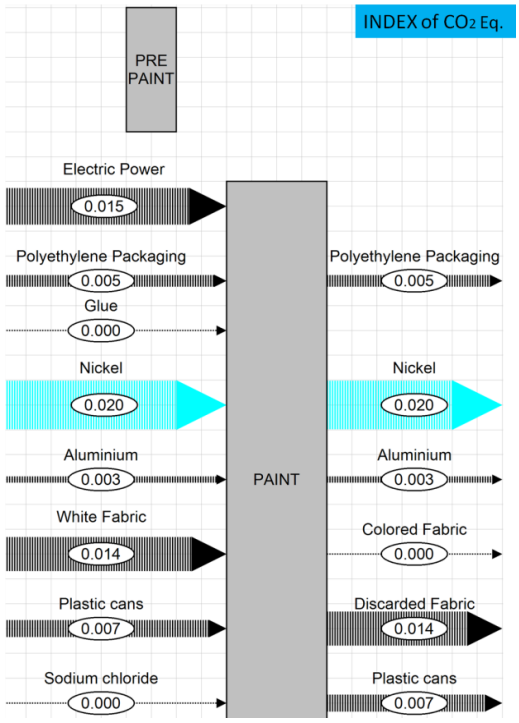


Figure 4: IDEF0 model of aLCA results, with IFR index indication

Figure 5: IDEF0 model of aLCA results, with IFR index applied and hot spot identification

4.2 Improving phase – eco-guidelines

Existing eco-improvement guidelines have been organized in order to let an identification of hot spots using dedicated IFRs index. Once indicated the hot spot on which specific guidelines operate can be easily selected following the path inside the classification tree. Following these guidelines the user is supported to generate alternative solutions within the main goal of incoming flow reduction. The goal is to give to the user all means to limit the use of material and energy flow of the system. They work firstly on system efficiency, on technologies substitution and secondly on flows substitution and optimization.

If the solution is obtained by reducing only existing flows (without introducing any new ones), automatically the reduction of environmental impact is given, if new flows are added to the previous system, then it is necessary to realize a variant analysis in order to verify the global effectiveness of the improvement action.

5 Case study

The case study concerns an industrial textile home-furnishings and bed linens painting company. The company itself produces the machines for painting and produces over 30 million m^2 of colored fabric.

Actually the process can be synthetically described by four different phases:

Pre-manufacturing. Pigments and varnishes are prepared combining additives and other substances with water. Then auxiliary devices mix and transport the colors into the painting machines.

Manufacturing. Four painting machines manage the color delivery onto the fabric; another device recovers extra painting and cleans the dirty parts of the machines and auxiliaries. Another important phase of the manufacturing is post painting: here all processes dealing with drying are grouped: polymerization, vaporization, surface treatment, extra colour removal, and packaging).

Use: the phase of use of the fabric is not taken into account, all other related aspects were put into the manufacturing part.

End of use: this phase concerns all treatments of wastes, polluted water, solid/liquid chemical substances, exhausted colors, gas etc.

All the main functions of the painting process have been filled into the IDEF diagram decomposing in energy flows and used substances.

Compatible with the availability of data (type of substances and energies) of our simplified LCA software database, the quantitative data associated with each flow has been broken down as much as possible, to ensure better accuracy of the analysis (for example, instead of entering an aggregate date relative to paint flow, it has been broken down in each chemical substance that composes the paint).

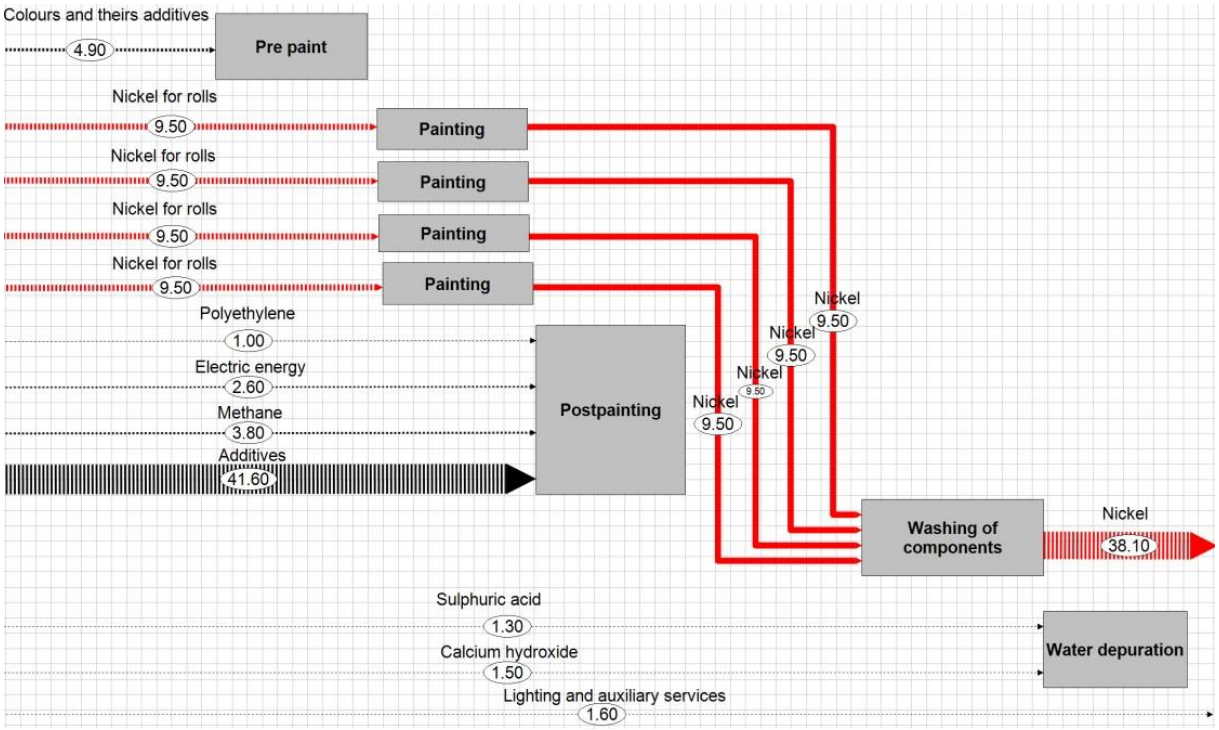


Figure 6: The IDEF0 shows the SO_2 production. In the diagram all the fluxes are depicted with a relevant impact on SO_2 production, with their relative percentage rate.

Once the diagram is complete, all collected information mapped as input in the diagram was put into eVerdEE in order to generate results of the impacts of every flow.

The authors decided to focus only on a set of potential indexes as criteria to determine the hot points:

- amount of material flow (kg);
- amount of energy flow (MJ);
- consumption of non-renewable energy (MJ);
- consumption of fresh water (m^3);
- climate change (kg CO_2 eq.);
- acidification (kg SO_2 eq.);
- eutrophication (kg PO_4 eq.).

Looking at a classical result from the simplified LCA software, elements that have the highest environmental impact are methane, fabric and some chemical substances used in post painting treatments.

The fabric in particular has been preliminary highlighted as a hot spot, but then discharged because it is the product of the entire process, and therefore to be maximized for the company economic point of view.

Here it is important to introduce for any flow the IFR index in order to evaluate flows according to the potential maximum reduction.

Results can be shown by IDEF0 of impacts. Here a new perspective of the given process is provided, just substituting input flows by impact flow. A set of diagrams was built for every index taken into account. In this case, new elements appear in the top ranking, for example nickel.

Nickel is used for micro-perforated rolls employed in the painting phase. Every year over 1,500 rolls of nickel are substituted and thrown away because small local deformations appear on the external surface.

Every roll is longer than 3 meters, it is constituted of a very thin sheet of nickel and it works in contact with the fabric that over time can make a dent that compromises the right functionality. Moreover, every roll is a very expensive component.

In Figure 10 the acidification diagram of impacts is shown.

As it is possible to see, nickel represents a strong impact on the global amount of SO2, (over 38%) and its IFR index indicates a high potential reduction until zero % in the cases where we are able to introduce a recovery cycle inside the manufacturing process.

This means if we introduce a recovery cycle for nickel tubes, we can obtain a maximum global reduction from 21,200 to 12,300 kg of SO2 eq. per year.

The eco-design goal can be achieved by introducing directions suggested by the eco-guidelines. Looking at maintenance parameters, the main goal is to optimize the maintenance of this system. Some guidelines are advised, in particular:

a) the re-design/use of products with the highest reliability and requiring the lowest maintenance;
b) the re-design/use of reparable products;
c) the re-design/use of modular products.

Eco-guidelines for direction "a" suggests thinking about a self- repairing/self-regenerating tube.

A spiral inside of the tube can perform this function, keeping in traction the tube and avoiding wrinkles on the external tube surface. Also the heat can be used to make a deformation in opposition to those that arise during painting deposition.

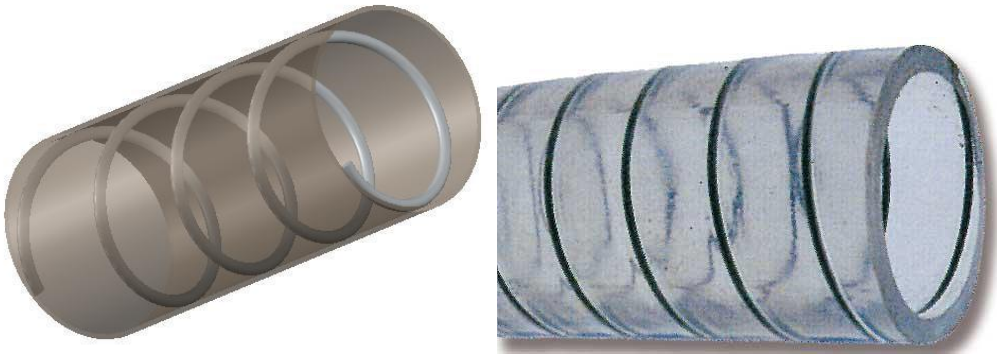


Figure 7: Tube with an internal spiral that is maintained in traction with the tube.

In this way the increase in the useful life of the product has a positive impact on the reduction of the number of pieces used per year.

The detailed description of guideline "b" suggests using segmentation. It can be achieved by avoiding employing a monolith tube and substituting it with a tube in more parts. So only damaged parts are removed and parts with the highest wear or with the highest probability of damage are made independent.

Segmentation can be achieved in different ways: a longitudinal segmentation and a transverse one, as shown in the picture:

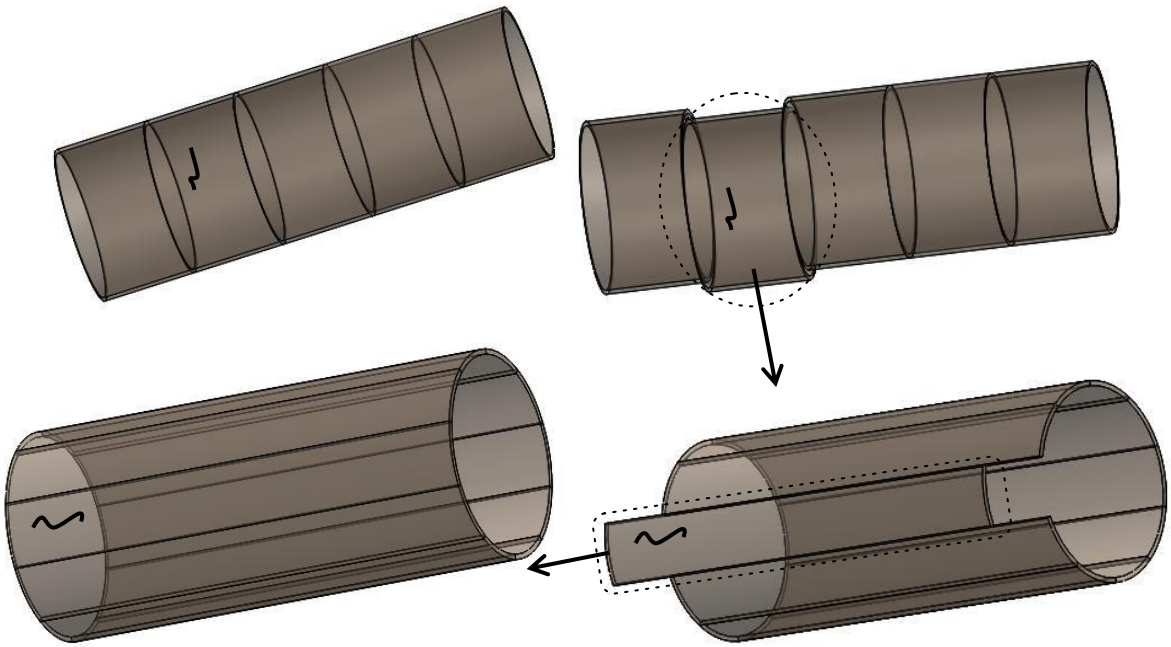


Figure 8: Schematic representation of the application of the segmentation. On the top there is the transversal segmentation, on the bottom the longitudinal one.

All proposed solutions are currently under study and evaluation.

6 Future developments

During the next months, the approach will be tested with various SMEs in Europe, over the six countries engaged in the European project REMake project: Germany, France, Italy, Spain and England, Belgium.

This large panel of test cases will enrich the approach and will allow the refinement and finalization of the eco-guidelines tools. The end of the deployment phase is 2012.

At the end of the REMake project, various dissemination activities are foreseen. This will support the diffusion of eco-design best practices around European SMEs. These guidelines will suggest the most adapted methodologies according to specific SMEs" needs.

7 Conclusions

Once again the pertinence and actuality of TRIZ theory has been proven, in fact several TRIZ fundamentals have been adopted in this research in order to complement state of the art environmental assessment tools.

The proposed method consists of a new way to assess eco-problems taking into account not only environmental impacts by means of traditional LCA indexes, but adding new indexes taken from the TRIZ "Ideal System" concept to them. In order to manage this index a combination of LCA software and a modified IDEF0 diagram is shown.

Once hot points are identified on the diagram a set of 330 eco-design guidelines, developed by the University of Bergamo are introduced to develop alternatives and modifications to the given system with the aim of providing a lower global environmental impact.

Preliminary results of the application in SMEs are shown in a case study concerning a textile home-furnishings and bed linens painting company. For the elimination of wastes of nickel during the painting phase, solutions are under development and could potentially produce a saving of 9,000 kg of SO2, contributing significantly to the reduction of eutrophication problems in the environment.

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The impacts of grouping and assigning tasks on web game based learning

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Abstract

There are great changes in creativity education due to learning technology. In addition, several previous literatures such as "Brainstorming and Collaborative Design" have shown that the heterogeneous cooperative learning is better than individual learning and traditional group learning. In this article, two grouping ways of heterogeneous cooperative learning have been compared with a web game model. They are learning style and cognitive style. The purpose of this research is to study the impacts of grouping and assigning tasks to cooperative learning on Web learning effects.

Keywords: Cooperative Learning, web game, Learning Effect.

1. Introduction

As the Hollywood 3D movie, Avatar, has been released, it has sparked off a zeal for 3D stereo vision. Coupled with the advancement of hardware technology, 3D televisions have been put into mass production and are becoming popular. The public are able to enjoy 3D vision at home. In the near future, instructors in the educational contexts will use the 3D television as one of the educational aids in class. Currently, the courses of the 3D game design at universities and colleges in Taiwan mainly focus on developing the students' abilities of producing 3D digital teaching materials. The course content is generally divided into the script design (including story, characters, and scenes), modeling, texture mapping, light setting, color rendering, post-production, and etc. Learners need to be equipped with professional skills to apply 3D software programs, such as 3DsMax® and MAYA®. Thanks to the complex and intricate functions of the 3D software programs with the English interface, it is very important for learners to overcome this hurdle. How to facilitate learners to efficiently use the complicated interface of the programs is a critical issue.

2. Theoretical background

2.1 The 3D course types in Taiwan

Currently, the types of the 3D courses in Taiwan can be mainly classified into the parameter type and the semi-parameter type. The parameter type programs, such as the typical Pro/Engineer®, Catia®, and Solidwords®, are mostly used in the departments of the industrial design, architecture construction, and so on. The semi-parameter type programs like the exemplary 3DsMax® and MAYA® are used in the departments of the multimedia and game design. The major differences between both types of the programs lie in the requirement of size accuracy. On the one hand, the 3D parameter type programs are not able to proceed to the next step if either the size inconsistency or the component interference occurs. On the other hand, the 3D semi-parameter programs emphasize the aesthetic appearance and are better tolerable for errors. The programs can be used for the non-manufacturing digital content industry to reduce the amount of work time and enhance efficiency.

2.2 The concept of 3D curriculum design relevant to education

The needs for 3D curriculum design vary in terms of different departments at different universities and colleges. Both the industrial and the architecture designs put an emphasis on the output of physical objects, including mechanics, institution design, cost evaluation, and so on. Therefore, the foundation of modeling and the study of the engineering blueprint are the core of the curriculum. The multimedia and digital content-related departments take character and scene modeling, light setup, and textual mapping as the essence of the course (Hsiao, Chiu, & Lu, 2010). The education-related departments are inclined to the latter, mainly focusing on the production of teaching materials with 3D teaching videos and interactive games. The courses offered by the multimedia and digital content-related departments center on the authentic level of roles and the change of light and shadow, and the roles and the selection of the scenes must have storytelling elements. When it comes to applying digital games to facilitate learning, the students benefited from applying the cross-culture learning tools and the simulation games developed by the scholars in German on the basis of computer technology (Klinge, Rohmann, & Piontkowski, 2009). The scholars in Canada applied the video games on the study of biology at the level of junior and senior high schools. It was found that the students became more involved in learning. The video games were helpful to the scientific instruction (Jaipal & Figg, 2009). The British scholars used the virtual coffee shop to help two youngsters with autism by means of authentic 3D daily life scenes and discussions. The results suggested that the youngsters better realized the social knowledge and were immersed in life (Parsons, Leonard, & Mitchell, 2006). Once the roles and scenes have been determined, the next step is the production of scripts. The common production of teaching videos adopts the editing model of A.D.D.I.E.; that is Analysis, Design, Development, Implementation, and Evaluation. So far, the model has been applied on web-based simulation environment (Karal, Çebi,
& Pekşen, 2003), instructional designers (Ozdilek & Robeck, 2009), adult learning (Stern & Kaur, 2010), and so forth. The focus of the present study aimed at developing digital materials mainly by the A.D.D.I.E. model.

2.3 3D course aided instruction

In the presentation of the production in the course, it is usually categorized in three ways as the animation, the virtual reality, and the interactive game. If the character model is included, some departments operate machines with the same quality as Hollywood movies, and produce animations, like motion capture systems. The principal function of the motion capture system is to reproduce the actions of living persons in the virtual scenes. It has been widely applied in the sports field, illustrated by bicycle dynamics (Moore, Hubbard, Schwab, Kooijman, & Peterson, 2010) and long jump (Ashby & Heegaard, 2002). Produced by the motion capture system, the animation makes 3D characters act naturally. Most important of all, it saves much time to adjust models, and improves the quality of animation work. In the instruction of virtual reality, the interaction between people and contexts is most crucial. In addition to the traditional use of the keyboard and the mouse, the most common facilities used for interaction are Wiimote® (Chen & Hung, 2010) and Microsoft's Kinect® (Giles, 2010). As for the production of interactive games, the application software programs, exemplified by Unity3D®, Quest3D®, Virtool®, and etc., are able to output the work into stand-alone games, online games, and mobile games.

3. Case Study

The present study provided for the instructors of the 3D game design an evaluation approach of students' creativity, especially assessing the game script, the interactive design, and visual effects configuration. The research procedures were as follows:

3.1 Grouping by Creativity Assessment Packet

Creativity Assessment Packet (hereafter as CAP) was adopted in the study. CAP is a test packet that consists of three tasks: an exercise in divergent feeling, an exercise in divergent thinking, and the Williams scale (Williams, 1980). Lin and Wang (1999) developed the Mandarin edition, which demonstrated good internal consistency (.765–.877) and test–retest reliability (.489–.810) demonstrated in Liu, Shih, and Ma's study (2011). Seventy Taiwanese undergraduate students from 19 to 23 years old first took the test. According to the results of the test, the students were classified as four creativity types, which were curiosity, imagination, challenge, and risk-taking. Then, the students were organized in groups of seven. The project topic of each group was determined by the creativity type to which most members in the group belonged. For example, the project topic of the group with more members having the imagination type was "secret Egypt," and the topic of the group with more members having the challenge type was "extreme sports."

3.2 Game script design

The mind mapping approach was used to design game script in the study. It is a creative development system for capturing ideas and insights horizontally on a sheet of paper (Mento,

Martinelli, & Jones. 1999). After the topics of each group were confirmed, the students discussed with their members of the same group in a way of handwriting the mind mapping plot. The production of mind mapping was limitless, and did not take into consideration if the students were able to accomplish the construction of 3D scenes. After completing the handwritten mind mapping plot, the students digitalized the production of mind mapping, and presented it via Powerpoint® (see Figure 1). The preliminary scoring was finally taken place. In the scoring approach, the mind mapping plots were transformed into concentric circles (see Figure 2). The number of levels and the complexity of each level were used as the scoring evaluation. For example, every item in the first level was scored as one point, every item in the second as one and a half points, and so forth. Finally, all items were integrated in the game script for the purpose of collaborative creation.

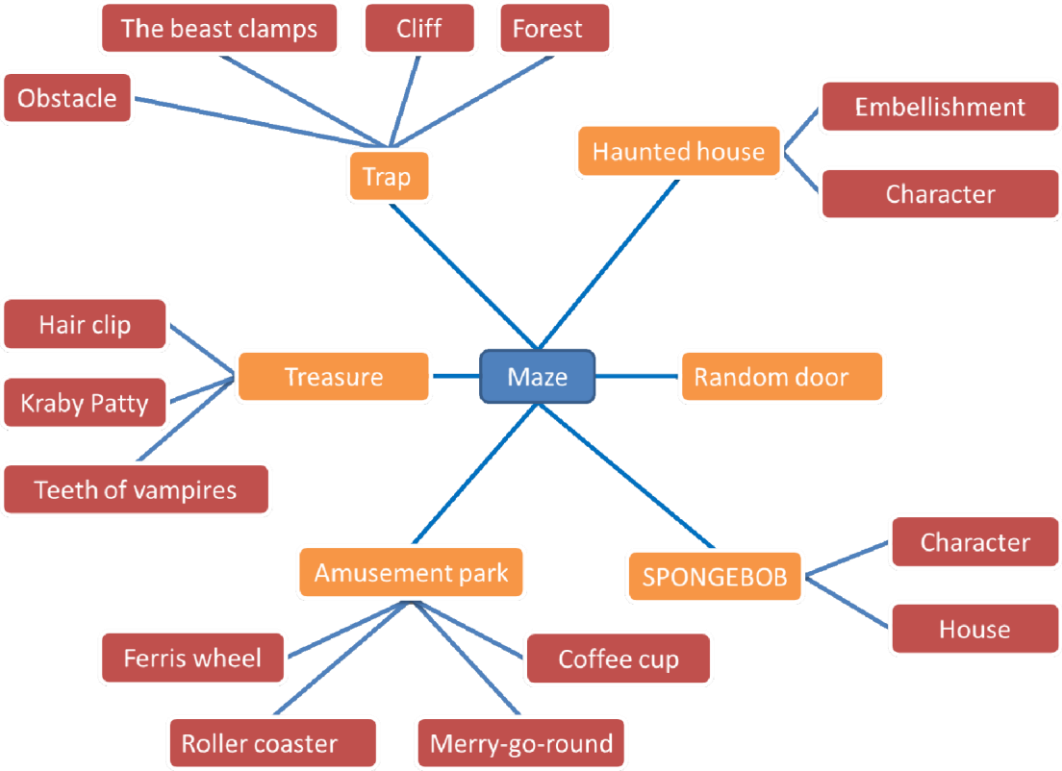

Figure 1. To present the mind mapping plot via PowerPoint® mode

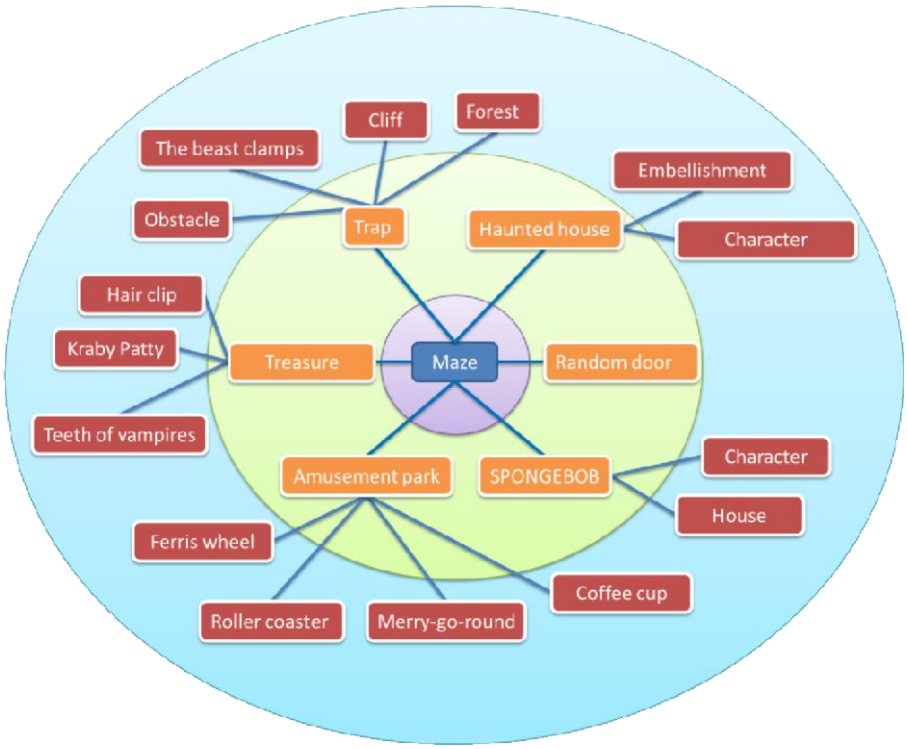

Figure 2. The transformation of the mind mapping plot into the concentric circle mode

3.3 The production of characters in games

The study took advantage of the online, free 3D model library from Google® to assist learning because most of the students in the study were beginners of the 3D software program. The resources of the online and free 3D models can be imported in 3DsMax® for further editing and be used to train the students' basic interface use capacity like 3D perspective transformation, moving objects, object rotation, object scale, and object alignment. The complicated modeling procedure had been temporarily skipped. Not until the students' learning interests were elicited did the modeling instruction start.

3.4 The instruction of the character model

Owing to the powerful functions in 3DsMax®, the toolbars are, correspondingly, complex and miscellaneous (see Figure 3). Specifically, proper nouns, the main focus in the English-based interface, caused a learning hurdle for students. To solve the difficulty, the software interface was optimized before the instruction was given. All options in the modeling and editing tools had been transferred from texts into graphics in line with international standards (see Figure 4). By means of the understandings of graphics, the students can more skillfully apply the functions of modeling, promote the familiarity of the software interface, and increase their learning willingness.

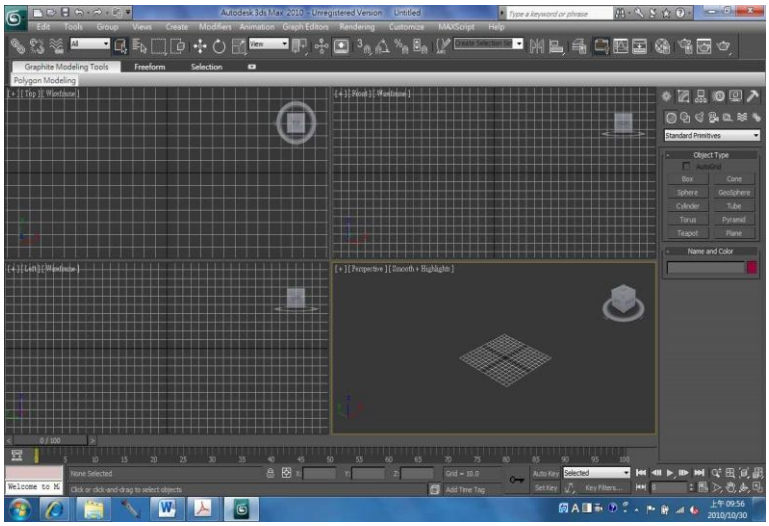

Figure 3. The original interface of the 3DsMax® software program (text-oriented)

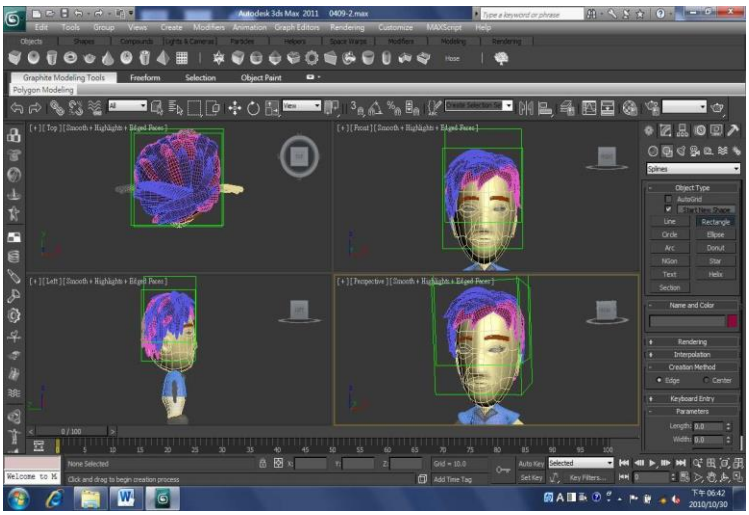

Figure 4. The interface of of the 3DsMax® software program after optimalization (graphic-oriented)

4. Discussion

The course in the study will eventually integrate the scene objects of the Google® 3D model library and the character models produced by 3DsMax® into the game software programs of Unity3D®. In Figure 5, the robot and the house were the models in the Google® 3D model library. The game characters were created via 3DsMax® and the rest of the scenes such as the terrain and the trees were via Unity3D®. The combination of the productions from the three sources became a complete set of the role-playing game. The 3D characters created by the students can walk freely in the virtual space and accomplish interactive tasks by throwing fireballs. Take the case presented in the study for example, the purpose of the game was to establish the awareness of the environmental protection for

primary schoolers. The task was designed to get points by defeating monsters which stood for environment-unfriendly stuff (see Figure 6). By doing so, the effects of education through enjoyment and subtle influence on the schoolers' thinking could be achieved.

Figure 5. The snapshot of the role-play game

Figure 6. The snapshot of executing interactive tasks in the game

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APPLYING TRIZ IN MAN MADE BOARDS PATENT ANALYSIS

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Abstract: Man made boards is traditionally applied to many fields. This paper makes the research about technology development of man made boards technologies. Based on the Chinese patent search and filter, the research used Logistic model and Loglet Lab 2 software to generate the patent S-curve of time - the number, and emplied S-curve for evolution of TRIZ to analyze the current stage of the technology fields. The analysis result shows that the current stage is of growth period and the small and medium forest enterprises can improve on the technology with the feature.
Keywords: Patent Analysis; TRIZ; S-curve; Man-made board

0 Introduction

Man made boards often made use of waste wood materials. Man made boards are cheap so are often used as instead of real woods. China's transition to a market economy, its accession to the WTO and ongoing globalization offer greatly expanded market access. Market development brings a greater degree of market competition that will penalize inefficient producers. Due to wood shortage, economic growth, and environmental protection, it is important to improve the efficiency of forestry sources. However, little has been done in discussing the technology forecasting for the man made boards development.

The specific behavior of technology patent represents the amount of investment to the area of technology. Patent not only can protect intellectual property rights, but also can predict the development of technology and get competitive conditions, strategies, and advantages coming from different companies.

During the past several decades, there has been growth in the number of growth curve methods for examining the development of technology, and the subsituation of technology. Growth curve method involves fitting a growth curve to a set of data on technological performance, then extrapolating the growth curve beyond the range of the data to obtain an estimate of future performance (Cheng et al., 2008; Frank, 2004; Meade and Islam, 1998; Porter et al., 1991; Watts and Porter, 1997).

Many successful technology forecasting models have been developed but few researchers have explored a model that can best predict short product lifecycles. This research studies the forecast accuracy of long and short product lifecycle datasets using logistic models. The purpose of this paper is to analyse the evolution of the technology of man-made board using the technological S curve model and technical forecasting by integrating TRIZ and patent analysis. A case study of Chinese man made boards patent forecast is also presented to demonstrate the selection procedure proposed in this research. Finally, the suggestions for product lifecycle management strategies in different lifecycle stages are also discussed.

1 An overview of forecast method

Genrich Saulovich Altshuller, born in Tashkent in Russia in 1926, studied the Theory of invention and, by researching thousands of patent certificates, developed the methodology to show that the same generic heuristics can be re-applied in various technical fields. TRIZ

(Theory of Inventive Problem Solving), is a systematic human-being-oriented and knowledge-based methodology (Savransky 2000).TRIZ is a systematic approach to innovation and such is ideally suited to managing complex data and brainstorming new options for technology intelligence.

As a technique evolves during a life cycle of birth, childhood, growth, maturity, and decline it should become better (Fig.1). Its performance follows the S-Curve. To understand the stage where a technique is on its evolution, TRIZ suggests to use two metrics from patent analysis, i.e. number of patents and level of invention in addition to conventional metrics of performance and profit.

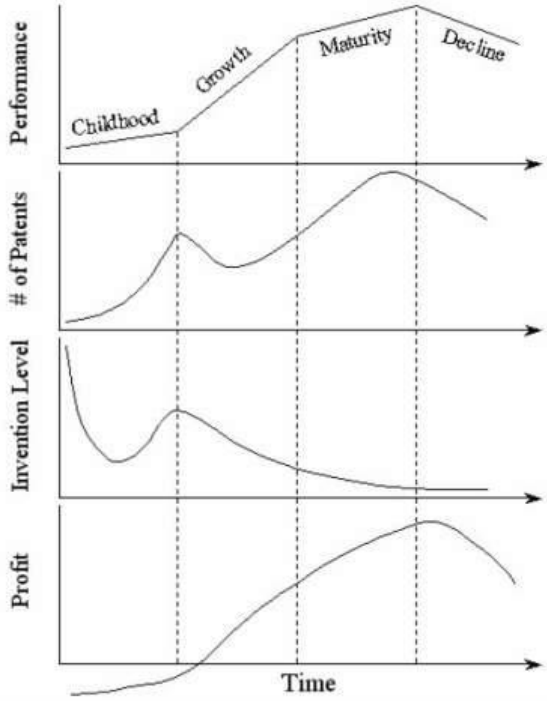

Fig.1. Product Evolution S-curve

2 S-curve in TRIZ

In the scope of TRIZ research, in the mid 1970s it was proposed to employ the S-curve model for the qualitative study of technical systems evolution. In order to facilitate the positioning of the analysed system onto a logistic curve G.Altshuller proposed the application of three supplementary statistical curves: changes of number of inventions, changes of level of inventions, and changes of profitability during time. The law of natural growth and the S-curve play a key role in the set of height laws of technical systems evolution, postulated in TRIZ. The law of increasing ideality of technical systems is in fact the derivation of the enveloped curve of successive substitutions of technical systems.

What stage the system is on this curve can be determined by a number of means:

The main activity per time period (to begin with you are focused on making your product work; this progresses through efficiency and then finally reducing cost);

Number of patents per time period (patent numbers tend to peak during the growth period and then again just prior to decline);

Level of innovation (the level of innovativeness of patents logged tends to peak during the growth phase and then decline);

Performance level (the performance level tends to follows the S-Curve, so that should have moved to next generation before the performance levels off).

Therefore, if you find yourself in a position where cost-reduction is your main priority and if the performance of your product has leveled off, then you should have already launched the next generation(the next S-Curve) of your product. In this way you can then identify where

your system, sub-systems and super systems are on their respective S-Curves to see where there is still opportunity for growth and where there needs to be a step change to a new S-Curve. S Curve model is used to make predictions about the evolution of the rate of technological change, to detect possible technological ruptures, or to determine the limits of a particular technology.

Defining a system is a difficult task in itself. One of the fundamental ideas in the system approach is that all systems interact with their environment. In order to portray this phenomenon the system operator (multi-screen schema) must link supersystems, systems, and sub-systems as well as past, present, and future dimensions.

3 Methodology and Logistic Model

3.1 Logistic Curve

Before presenting the results of the analysis of the technology performance of man made boards using the S curve model, it is important to reflect upon its theoretical foundations.

The logistic function as a model of population growth was first introduced by Belgian mathematician Verhulst in 1838[Stone, 1980].The logistic equation was introduced to describe the self limiting growth of a population. This equation sometimes calles the Verhulst-Pearl equation according to its rediscovery in 1920 by American zoologist and one of the founders of biometry R. Pearl.Fisher and Pry in 1971 have shown that data describing the substitution of a new product or process for an old one can be fitted extremely well by a simple mathematical logistic function that produces an S curve. Today this model is frequently employed to compute the product life cycle for technological forecasting.

S-curves are most often applied for analyzing past data in orde to disclose new trends and for proving known ones.

$$\frac{dP}{dt} = \alpha P \frac{(k-N)}{k} \qquad (1)$$

(2)

Equation (2) produces the familiar S-shaped curve. As soon as the function parameters can be calculated using a partial set of data it is possible to use the equation in a predictive model.

P（t）-is the numer of ‘species’ or growing variables in question.

α- specifies “width” or “steepness” of the S-curve; growth rate parameter, time required for growth trajectory from 10% to 90% of limit k characteristic duration.

β-parameter specifies the time(t_m) when the curve reaches 0.5k midpoint of the growth trajectory. t_m implies symmetry of a simple logistic S-curve.

K-is the asymptotic limit of growth which called the characteristic duration.

The logistic model is symmetric around the midpoint t_m.

3.2 The growth curve model and Loglet lab software

The term “loglet”, coined at The Rockefeller University in 1994, joins “logistic” and “wavelet”. The loglet lab software package allows users to perform loglet analysis on any suitable time-series data set. Using Loglet lab software and patent publications data, logistic fits are produced for man-made board technologies.

The forecasting models should capture and simulate numerous relationships, in order to represent changes in market, in use, and in technology. However, the forecasting model should apply minimum characteristics, in order to provide a clear unambiguous interpretation of results.

4 The forecast of man made boards technologic development in the future

4.1 Patent Analysis

We have analyzed about thousands China patents issued from 1985 up to 2007 for man made boards which IPC is B27 (Table 1). For instance, to study the dynamics of man made boards, such a result was interpreted “the fastest rate of growth (midpoint) of the first pulse occurred in 1992.

Table.1. The man made boards application and grant number from 1985 to 2007

	Application			Grant		
Year	Total	Inventive Patent	Utility Model Patent	Total	Inventive Patent	Utility Model Patent
1985	32	15	17	0	0	0
1986	44	17	27	8	0	8
1987	71	19	52	23	1	22
1988	118	32	86	50	2	48
1989	99	24	75	71	7	64
1990	135	37	98	71	3	68
1991	149	24	125	66	6	60
1992	179	32	147	95	4	91
1993	182	28	154	211	13	198
1994	254	52	202	147	2	145
1995	209	62	147	144	12	132
1996	242	46	196	146	6	140
1997	181	28	153	111	7	104
1998	224	55	169	103	3	100
1999	228	41	187	210	14	196
2000	431	63	368	216	26	190
2001	615	137	478	370	27	343
2002	475	112	363	306	17	289
2003	431	110	321	285	30	255
2004	549	147	402	259	37	222
2005	583	183	400	306	36	270
2006	1143	441	702	398	50	348
2007	1135	466	669	747	100	647

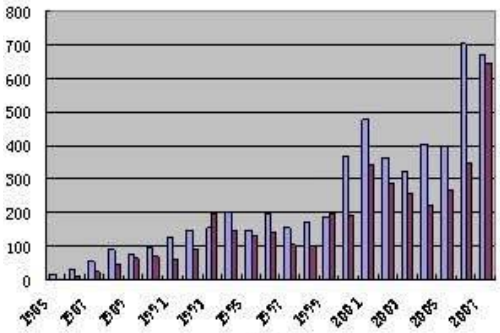

Fig.2 Chronological graph for number of issued man made boards utility model patent

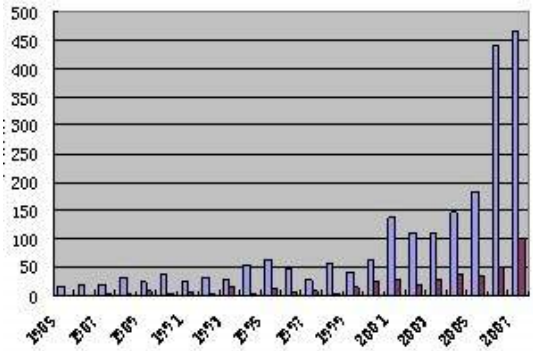

Fig.3 Chronological graph for number of issued man made boards inventive patent

4.2 Life Cycle forecast use the Loglet Lab

Comparing the figure 2 and figure 3 we figured out that man made boards born in 1985 just moved into the second (growth) stage of technique evolution due to many supportive patents

on the low levels. Figure 3 shows that this transition occurred around 2001 after quite long childhood. The heuristics used for innovative developments of man made boards are recovered along with various statistical results about problems and proposed solutions in the field.

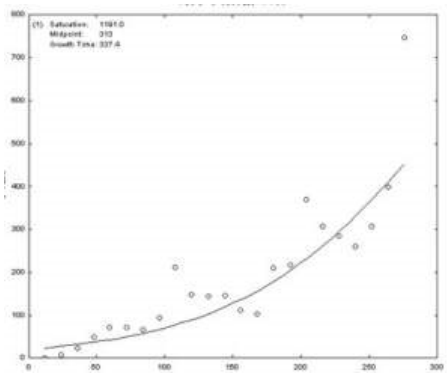

Fig.4. S Curve of man made technologic development

This study leverages "Chinese patent" database to query related key index to develop "S Curve" by using "Technology life Cycle" theory in order to estimate the mature time of each stage of the life cycle. Especially man made boards technology life cycle is estimated with "logistic growth model" and software "Loglet Lab 2" is utilized to analysis the life cycle of small and medium forest industry.

5 Conclusion

We have analyzed few hundreds Chinese patents selected in the field of man-made board in the framework of TRIZ. Such patent analysis helps to figure out used heuristics, to prioritize technical problems, to foresee possible solutions, to identify evolution trends for board technique and to envisage future board roadmaps. The statistical results reported in this paper indicate that the man-made board grows up presently at the second stage of the technique evolution. We figure out that only a few heuristics are used by inventors in the man-made board field.

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