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FULL PAPERS

Innovative Design of Customized Fashion Handbags

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Abstract

Regardless of the times or backgrounds, nearly every woman who leaves her home has a handbag with her. Handbags are always indispensable, important, and intimate items for women, and handbags not only need to be practical, but are also features of fashion and functional beauty. However, due to the influence of the global recession, past fashion trends of "LOGO craze" have gradually declined. Now, smart consumers are willing to pay for "good products". Thus, only quality products with unique appearances, excellent manufacturing quality, and intricate handiwork can demonstrate uniqueness and beauty of personality, in turn, attract consumers and gain their favor. Thus, this study first uses market surveys to understand the needs and expectations of consumers regarding customized handmade handbags, and then uses "TRIZ systematic innovation" to distinguish consumer market opportunities and seek resolutions to related problems. After following design procedures to design image drafts for innovation in the design styles, the materials are tested and calibrated to ensure that materials are well-made and conform to functional needs. Handmade test is conducted manufacturing and model modification to make the product intricate and perfect. Finally, customized handmade handbags are created to satisfy personalized needs, in hopes of creating new business opportunities for the creative design industry.

1. Introduction

1.1 Research Motives

Women love beauty, and when they buy handbags, the first priority is usually for aesthetics, and the second priority is practical use. A beautiful and practical bag can categorize the items in the bag, is convenient to use, and adds unique style to the users. Psychologically, it can satisfy personal style, self-accomplishment, and demonstrate one's economic abilities. Thus, regardless of the times or backgrounds, nearly every woman who leaves her home has a handbag with her. Handbags are always indispensable, important, and intimate items for women. They not only need to be practical, but are also features of fashion and functional beauty. However, due to the influence of the global recession, past fashion trends of "LOGO craze" have gradually declined. Now, smart consumers are willing to pay for "good product." Thus, only quality products with unique appearances, excellent manufacturing quality, and intricate handiwork can demonstrate uniqueness and beauty of personality, in turn, attract consumers and gain their preference.

1.2 Research Purposes

Based on the above research motives, this study attempts to explore the feasibility and development of customized handmade handbags, analyze the difficult problems encountered in customization of handbags and resolutions, and apply procedures and models of innovative design in customized handmade handbags in order to create unique products with market value. Thus, this study first uses market surveys to understand the needs and expectations of consumers regarding customized handmade handbags, and then uses "TRIZ systematic innovation" to distinguish consumer market opportunities and seek resolutions to related problems. After following design procedures to design image drafts for innovation in the design styles, the materials are tested and calibrated to ensure that materials are well-made and conform to functional needs. Handmade test is conducted manufacturing and model modification to make the product intricate and perfect. Finally, customized handmade handbags are created to satisfy personalized needs, in hopes of creating new business opportunities for the creative design industry.

2. Literature Review and Research Questions

The characteristics of fashionable handmade customized handbags

Each customized bag is given a symbolic meaning, with new trendy elements in the new styles, new ideas, and new materials, creating a sense of quality and novelty with new beginnings. There is emphasis on the psychological feelings of the users, and innovative change is used to attract consumer attention. For instance, LV sells legends and stories, inspiring consumers the precious feelings for uniqueness.

In terms of consumption market channels, handbags have many different types and levels: there are luxury goods stores, exclusive counters, creative markets, online auctions, and street vendors, with over a hundred different brands attempting to fight over market share. Why can handmade handbags hold their positions in the consumer market with prices near the average unit prices of luxury brands? Why are consumers willing to spend money to order a customized handbag? It is because customized bags are selling a kind of tradition, a kind of craft, a kind of culture, and a kind of perseverance. When traditional craft and culture are no longer being insisted upon, the focus on mass production in assembly lines have caused traditional handbag production speeds to be unable to keep up with the massive sales or control over quality. Then, what remains is a brand without culture, and meanwhile, they lose the unique meaning to be fought over by people.

Why are people willing to wait for one year for the manufacturing of customized bags? This is because customization emphasizes the value of handmade manufacturing. For instance, the French brand Hermes, known for handmade artisan quality, has a classic Kelly Bag. Its manufacturing requires at least 13 hours, and the inside is required to be labeled with the artisan's name. If customers require maintenance for the bag in the future, the same artisan can be responsible. This produces a unique exclusive value and sense of belonging. Designers of handmade customized bags can use different material styles, materials, and textiles that consumers can ask to match together, turning them into exclusive handbags, used to realize the dream of owning unique styles; or with the good handiwork and craft of old masters, who carefully make the buttons and seams carefully. The artisan feels like he is completing an artwork from selecting the style to matching the colors. It is a guarantee of outstanding character, insisting on handmade quality, the essence of which will be transferred to the consumer bit by bit, so that every detail is forever imprinted on his heart forever.

2.1 Current conditions of fashionable handmade customized handbag market

The origins of the term "fashionable handmade and customization" can be traced back to Paris in the 18th Century. According to Ku (2004), after the French Revolution in the 18th century, at the time the rise of the bourgeoisie and middle class led to the liberalization of clothing and accessories, and high-end customized clothing came on the scene. Later, in the mid-19th century, stores that sell high-end customized clothing or other brands of handmade customized luxury products gradually came into being in France, Italy, and England. Early on, in Taiwan, so-called "customization" services refer to the "current apparel" in the fashion field. For men's Chinese-style suits, western-style suits, or women's western-style cuts and qipao, these were all mainstays of the customized handmade apparel market. In recent years, the influence of globalization has led to the gradual rise of Taiwanese designer brands. Chen (2009) mentioned that Taiwanese designers not only have their own brands, but also provide customization services. For instance, well-known designers such as Go-Ji Lin, Gou-Chiang Fang, Dai-Lee Pun, Ji-Min Chen, Shu-Chi Huang, Yi-Liang Pan, and Ching-Chu Wun are all world-class. Shiatzy Design Director, Wang Chen Tsai-Hsia, also frequently designs dress gowns for Taiwanese businessmen and socialites. In fact, in terms of market demand, these brands all have professional teams behind them, and also design and produce handbags, shoes, leather products, and accessories. Regarding the professional issues of production management, along with the changes in economic forms, scholars in Taiwan have found that product manufacturing or service procedures of mass customization can provide low quantities and many types of products or service through flexible manufacturing processes. It seems that this is a key in resolving the problem of product diversity and competitive advantage. According to Wu (2009), product diversity and mass customization can both have positive influences on competitive advantage, while product diversity will make activities internal to the organization more complex. Conversely, mass customization would help in simplifying activities within organizations.

With the advent of the 21st century and under the influence of globalization, Taiwan also found the attraction of fashion irresistible. Fashion is no longer a symbol of power for the royalty, but can be the symbol of fashionable matters during a period of time. The February issue of ARCH Glamour Style Magazine (2008), the article Spatial Fashion Code defined fashion as "the popularity of something over a period of time." Lin and Chen (2009) suggested that fashion is not only popular culture, but is

also a life attitude, since the changes in lifestyles result in the endless changes of the lifecycles of consumption markets. Therefore, the above perspectives show that everyone can have fashion. It does not have to be extremely extravagant, but must be trendy at the time or have personal style features. Based on this position, handmade customized products or items are a part of the fashion industry. Facing customer groups with different demands, there are different marketing strategies and channels. The next section will focus on the research subject, "handbags," to summarize the brands of cases that accept orders for customization and organize the strengths and weaknesses of the marketing channels.
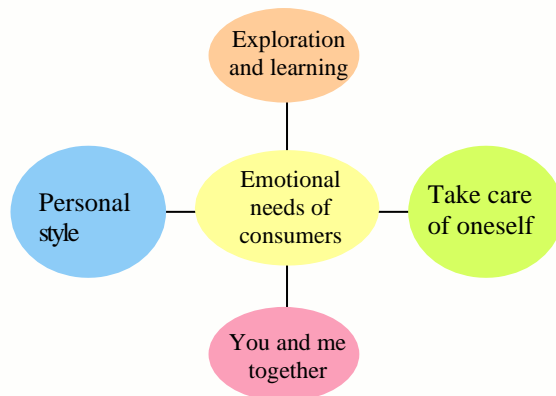
2.2   nalysis of consumer emotional needs

Smart consumers in the new age are inclined toward considering: how to satisfy their wants, placing the focus on innovative unique products and services, preferring products and services with authenticity. They are independent and individualistic, and they are willing to participate in the consumption process and have knowledge relating to consumption. They would ask vendors to tell them simply: what can this product give me? How is this product special? Is the price reasonable? Are the functions suitable? What kinds of guarantees can you give me?

Consumption behaviors originate from need, and the source of these needs can be divided into two types: (1) personal intrinsic factors, including lacks or dissatisfaction in terms of personal clothing, food, residence, transportation, education, or entertainment, or personal expectations for change and novelty; (2) external factors, including marketing stimulations or imitation and In the product development process of many popular fashion industries, they should pay more attention to the value perceived by the consumers of the brand, and create irreplaceable new luxury items. Products or services that appeal to emotion can better move people, and this phenomenon is more salient for fashion products. This is because consumers do not really "need" this product, but rather they believe that it is "worth" having; therefore, products themselves must emphasize expression of cultural content, sense of quality, and unique characteristics, to use creativity, channels, and consumer connections to enhance product value (Lin & Chen, 2009). Another issue to appreciate is that the fashion products that have successful sales and have made most money are ones that have focused on emotional needs. For many consumers, consumption relating to food, clothing, residence, transportation, education, and entertainment would all encounter the four emotional needs. Customized products demonstrate that buying a customized handmade handbag

learning in social life. These different intrinsic and external factors would cause individuals to have the demand for consumption, eliciting consumption to satisfy related demands (Jian, 2008).

Social changes have given consumers in the new age greater purchasing power and consumption knowledge, giving them more diverse products to choose from. Consumers search among different products, but now they want more, and hope that the products they buy can increase their own value, or demonstrate their own style and tastes, while helping them resolve pressures of daily life. Smart shoppers have sufficient self-perception abilities to understand which products can care for their own internal emotional needs (Silverstein…etc, 2004). New consumer emotional demands are analyzed as follows:

Figure 1. Types of consumer emotional needs

can accentuate one's own characteristics and tastes (personal styles), can be used to reward oneself after hard work (take care of oneself), can express the attraction of outstanding value in socializing (you and me together), participate in the design and creative process, learn more about products and experience the fun of creativity (exploration and learning).

Table 1. Analysis of marketing channels and brand cases that accept orders for customized handbags

Marketing channel	Brand or case		Strength	Weakness
Luxury brand stores or exclusive counter brands	Foreign brands	Louis Vuitton	International brands have careful customization services. Other than product assurances, customization procedures are clear, and the prices are cheaper than the limited edition bags.	Consumers can only make certain types of changes. After the orders are made, they must be sent back to the original factory overseas, so the turnaround time is longer.
		Hermes		
		Cartier		
		Roger Vivier		
	Taiwan	Amopola customized handbag series	Can use lower prices to design handbags with a sense of quality and style	Lower name recognition, fewer exclusive counters, limited service ability.
		Caltan design		
Online marketing	Catwork: photo bag customization MINAS: photo bag customization Mimi tailors: production of canvas bag orders kitty.dog: production of canvas bag orders Happy workshop: production of canvas bag orders SewZakka Handmade: production of canvas bag orders		Uses yahoo, open-air auctions, and other online shops as marketing platform, save on costs of products and store costs; looking for consumer groups who love creativity and individualism; handbag designs are generally cute and stylish.	Businesses would set a few styles and specifications to be chosen by consumers, less uniqueness. Consumers cannot directly see the materials and the production processes, and there is a lower sense of trust; further, the method of material selection is more likely to produce errors.
Micro-workshops	Private textile mosaic classrooms, print and dye workshops, or leather sculpture workshops can accept customized orders.		The consumer can communicate with the designer face-to-face, and can go to the site to choose the materials and styles, view the production process, or even learn and experience the process.	Storefront or workshop addresses are generally in communities or margins of city center, with limited promotional ability, insufficient human resources, and less standard prices.
Creative markets	Creative markets or holiday markets have vendors who focus on handmade textiles, leather sculpture, weaving, and techniques with other materials; consumers can communicate with the vendor, creating different handbag styles according to personal preference.		Save capital and human resource costs, service scope can expand all over Taiwan, and is one of the easiest ways for entrepreneur to earn name recognition.	Impossible to complete the sale of the ordered customized bag, less post-sale service for consumers; the prices cannot be set too high, which may result in uncertainty in terms of materials or quality.

2.3 Apply TRIZ creativity concepts into creative design

(1)TRIZ systematic innovation theory and meaning

Stan Kaplan; Jiang (trans) (2008) points out that: TRIZ is the acronym of Russian Teoriya Resheniya Izobreatatelskikh Zadatch, which means "the theory of inventive problem solving," and was invented in 1946 by Genrich Altshuller. Genrich Altshuller (2008) pointed out that TRIZ theory was found after 200,000 patent analyses, picking out 40,000 that have more innovative patents to explore their resolutions and application methods, in attempt to find basic principles and forms. Thus, TRIZ is unlike using brainstorming to produce new concepts or creativity, avoiding blind spots or lack of systematic character produced by participant member breadth of knowledge. TRIZ stresses that invention or innovation can follow certain procedures and steps, rather than just random ideas or disconnected brain stimulation (Lin, 2009).

Song (2009) suggested that systematic innovation-TRIZ is the most important tool for the cultivation of creativity and innovation. According to Hong (2004), it can be found that, the proposition of TRIZ theory is because the phenomena or process of product development produced physical contradictions or technical contradictions and other problems. The matrix system is used to point out the problems, and find the solutions to form the TRIZ systematic innovation theory that can resolve older problems and invent new inventive methods (see Fig. 2). Gao (2005) indicated that TRIZ includes four primary methods and tools, which are (a) 39 contradiction matrix and 40 innovative problem-solving principles; (b) materials, context analysis, and 76 standard solutions; (c) science and technical achievements database; (d) ARIZ.
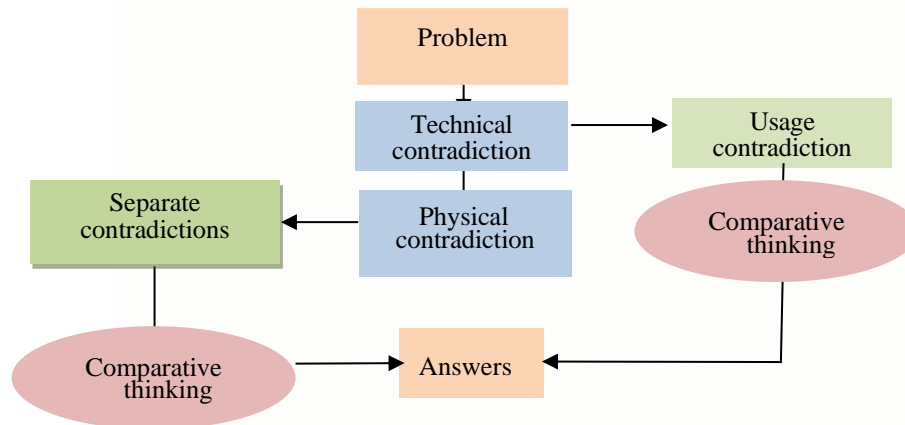

Figure 2. Procedures for using TRIZ to resolve contradictions

**(2) Applying TRIZ innovation concept into creative design**

Today, when personal needs have received more attention, in order to satisfy user needs, regardless of food, clothing, residence, and transport, manufacturers have promoted personalized services to keep or attract more consumers. For e-mail, auction websites, online audiovisual websites, instant messaging software, and search engines to personal online photograph albums and blogs, it is easy to find personalized services. Actually, top-level consumers are not concerned with price but a service value and respect, for instance: (a) use the highest-quality tools and materials; (b) specialized services; (c) listen to the decisions and requirements of customers; (d) make one's own designs longstanding and even become a classic. It is not only necessary to satisfy customer needs, but also necessary to cover aesthetics, appearance, and practicality, because the top-level customers want these things. Of course, the services must be very detailed as well; in turn this would leave deep impressions on the customers. Since society is approaching an M shape, this study argues that handmade customized handbags are feasible alternatives, and the market would have these demands as well. Thus, this study hopes to design a TRIZ systematic innovation-based design procedure for customized handbags that is convenient and practical, and can be used to find a developmental path for the demand for customization in Taiwan.

3. Research Method and Design Procedures

3.1 Research Method

This study first conducts literature review to explore the characteristics of customized handbags, and carry out analysis of the Taiwanese market in the handmade customization orders in the fashion industry, as well as analysis of customer emotional needs, TRIZ systematic innovation theory application on innovative design. Then, using customer questionnaire analysis and interviews with store owners, this study collects consumer opinions and perceptions for customized handbags, and explores the problems that stores seek to improve upon in the process of producing or marketing customized handbags. After integrated data analysis, this study summarizes customer demands for handbag customization as well as current issues and contradictions faced by business owners, and uses concepts in TRIZ systematic innovation theory to construct the procedures for designing customized handbags. After the material is analyzed and tested, actual production of customized handbags is carried out to complete developmental design. Finally, this study proposes conclusions and related suggestions.

3.2 Research and Design Procedures
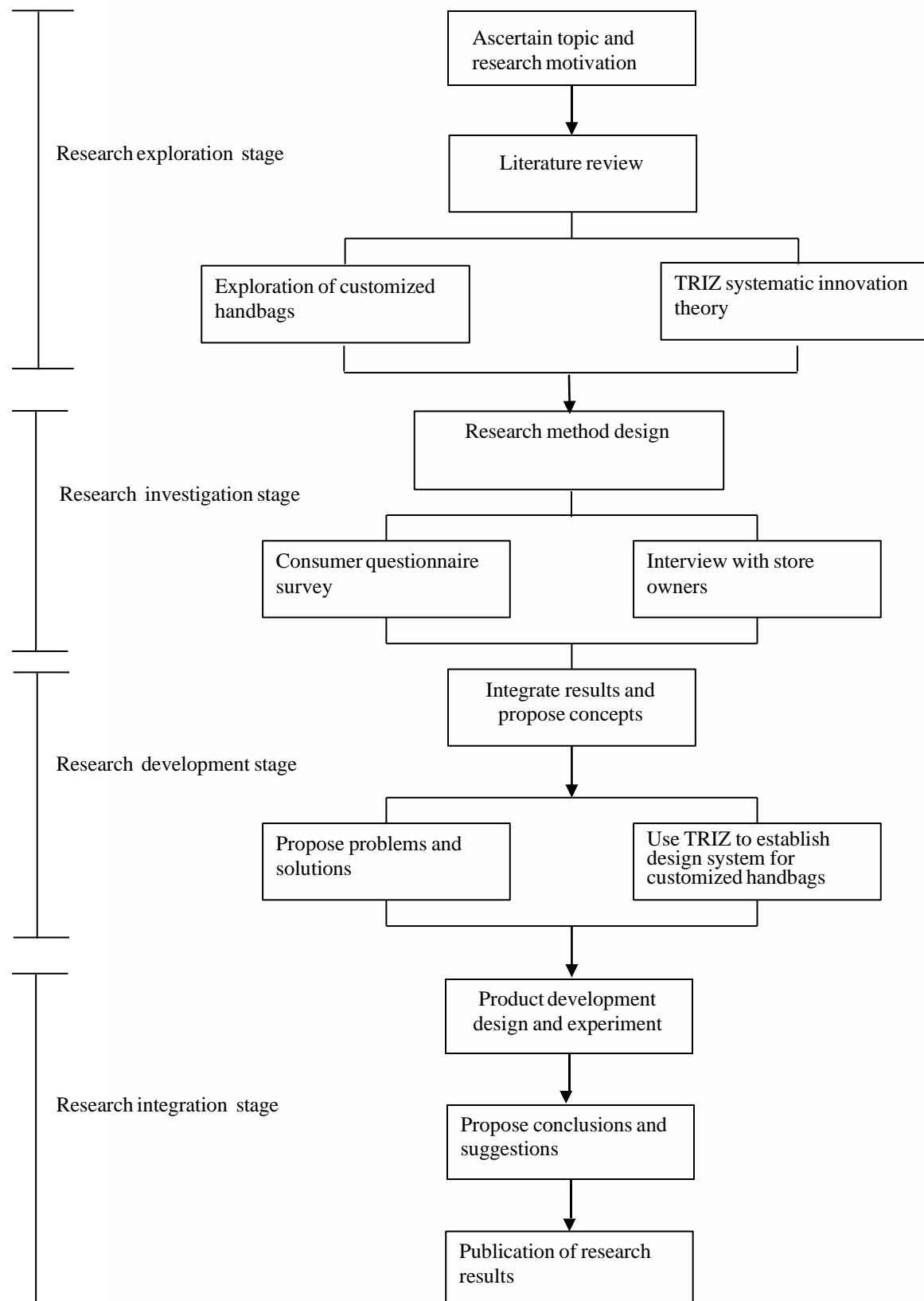
Figure 3. Research procedures

4. Research Result Analysis

4.1 Results of consumer questionnaire survey

Considering that handbags cover a wide range in terms of materials and forms. For instance, in terms of handbag form, there are clutch, large backpack, small backpack, small purse, coin purse, and party handbag. In terms of material, there are genuine leather materials, nylon materials, woven materials, bead materials, and wool materials. There are major differences in the customer groups, so this study focuses on the handbag market in Taiwan. Questionnaire survey was conducted on individuals who currently intend or do not intend to purchase customized handbags. The area of research included seven cities and counties in Taipei, Taoyuan, Taichung, Changhua, Tainan, Kaohsiung, and Pingtung. A total of 600 questionnaires were released, and 600 valid questionnaires were retrieved, with 200 each in the central-north, central, and south.

(1) Handbag functionality analysis: the top consideration is Portability (convenient mobility), followed by practicality
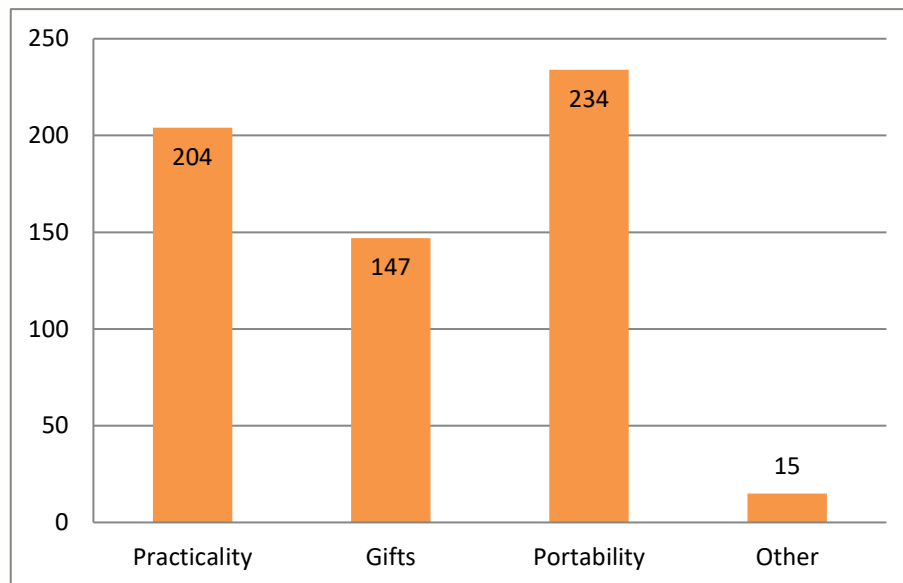

Figure 4. Survey of handbag functionality
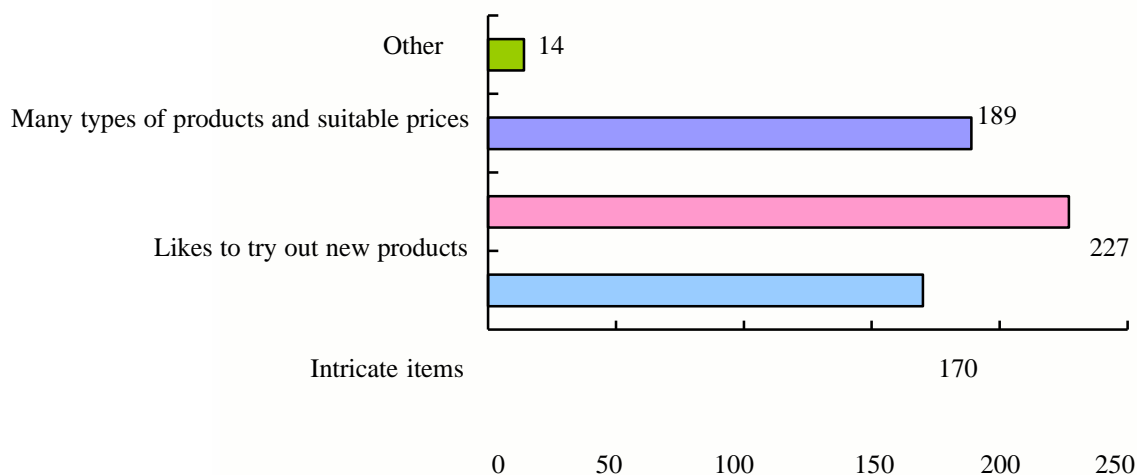
(2) Analysis of consumption reasons

Figure 5. Analysis and survey of consumption reasons

(3) Analysis of handbag categories and types: the questionnaire surveys show that if consumers want to purchase customized handbags, as many as 33% of the consumers in Taipei and central Taiwan prefer more glamorous or banquet-style handbags
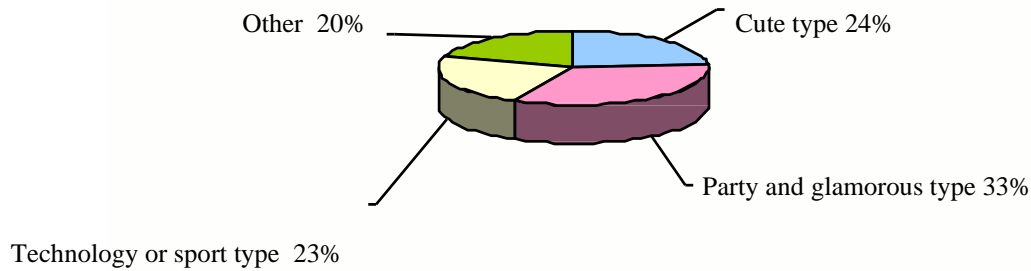

Other 20%   Cute type 24%

Party and glamorous type 33%

Technology or sport type 23%

Figure 6. Survey of the forms and styles of handbags preferred by consumers

(4) Hope to have a handbag customized for oneself
Customization analysis shows that as many as 80% of the consumers are willing to accept customized handbags. This finding shows that the feasibility of customized handbags is a business opportunity and a trend for future shopping by consumers.
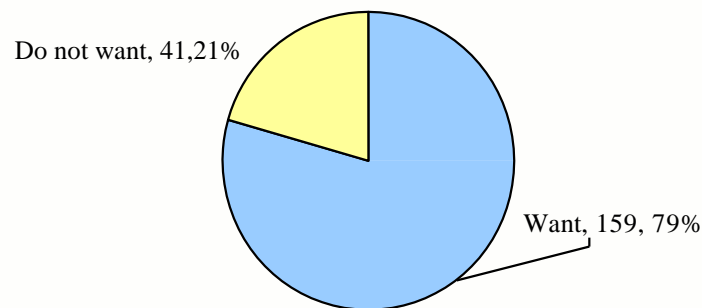

Do not want, 41,21%

Want, 159, 79%

Figure 7. Statistical chart for northern Taiwan: want to have a customized handbag
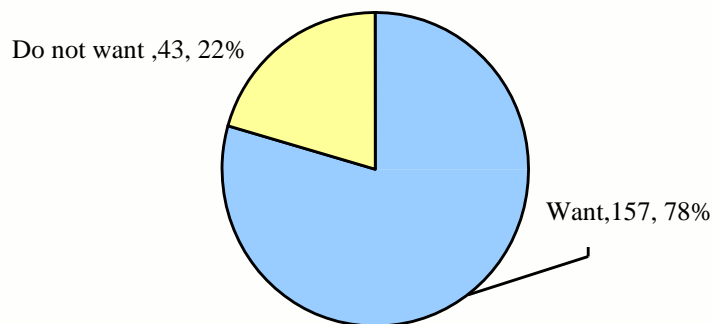

Do not want ,43, 22%

Want,157, 78%

Figure 8. Statistical chart for central Taiwan: want to have a customized handbag

(5)   Analysis of greatest reason for willingness to order customized handbags

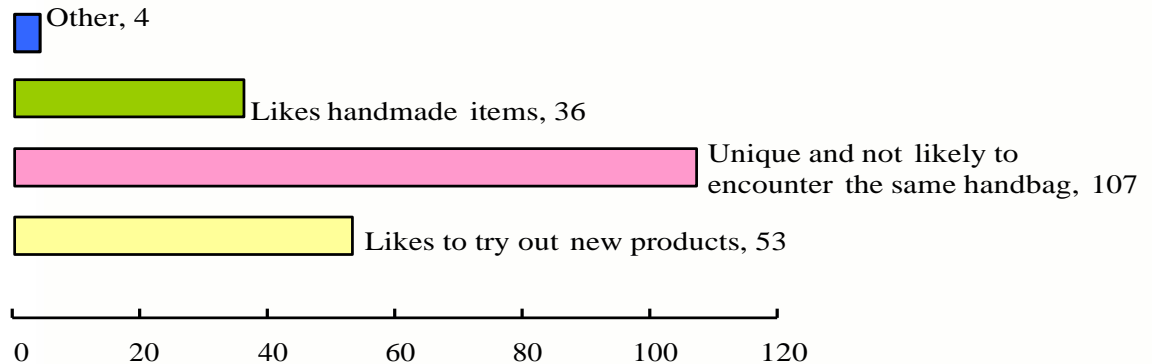Statistics for the 600 questionnaires in northern, central, and southern Taiwan.

Figure 9.Statistical chart for northern Taiwan: how to attract you into buying a customized Handbag
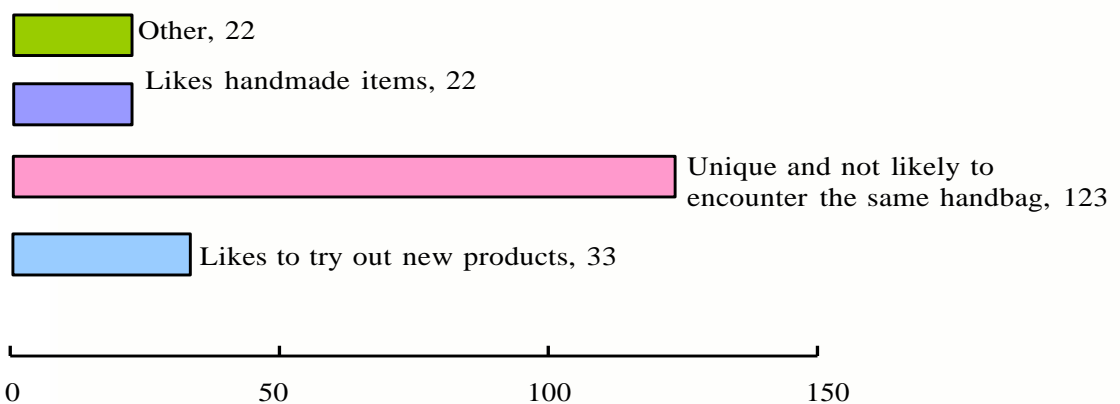

Figure 10.Statistical chart for central Taiwan: how to attract you into buying a customized handbag
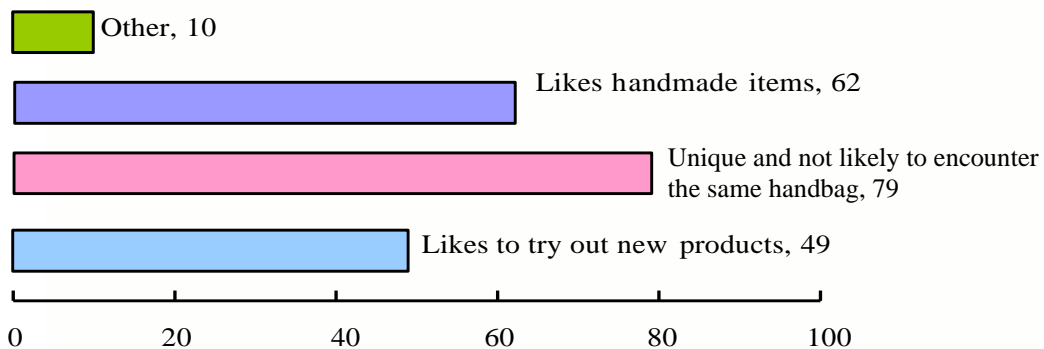

Figure 11. Statistical chart for southern Taiwan: how to attract you into buying a customized handbag

As high as 52% of consumers who order customized handbags are willing to accept customized handbags because they are unique and unlikely to be in the presence of the same bag

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4.2   Contradictions and innovative problem-solving principles in customization procedures for handmade cus tomized han dbags

This study uses the 3 9 c ontradiction m atrix and 40 innovative problem-solving principles according to TRIZ theory in attempt to discover the problem contradiction parameters for the development process of customized handbags, and find the items   that are suitable from 40 innovative problem-solving principles (see Table 2).

Table 2. Contradiction matrix analysis of customized handbags

Contradiction parameter	Feature for Improvement / Prevent deterioration	Shape (12)	Durability of moving parts (15)	Waste of materials (23)	Waste of time (25)	Precision of manufacturing (29)	Manufacturability (32)	Convenience of usage (33)	Maintainability (34)
1	Shape (12) *Formal design*	+		35、29、3、5	14、10、34、17	32、30、40	1、32、17、28	32、15、26	2、13、1
2	Durability of moving parts (15) *Durability*	14、26、28、25	+	28、27、3、18	20、10、28、18	3、27、16、40	27、1、4	12、27	29、10、27
3	Waste of materials (23) *Testing*	29、35、3、5	28、27、3、18	+	15、18、35、10	35、10、24、31	15、34、33	32、28、2、24	
4	Waste of time (25) *Production process*	4、10、34、17	20、10、28、18	35、18、10、39	+	24、26、28、18	35、28、34、4	4、28、10、34	32、1、10
5	Precision of production (29)	32、30、40	3、27、40	35、31、10、24	32、26、28、18	+		1、32、35、23	25、10
6	Manufacturability (32) *ease of production*	1、28、13、27	27、1、4	15、34、33	35、28、34、4		+	2、5、13、16	35、1、11、9
7	convenience of usage (33) *Usage needs*	15、34、29、28	29、3、8、25	28、32、2、24	4、28、10、34	1、32、35、23	2、5、12	+	12、26、1、32
8	Maintain ability (34) *Post-sale*	1、13、2、4	11、29、28、27	2、35、34、27	32、1、10、25	25、10	1、35、11、10	1、12、26、15	+

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4.3 TRIZ innovative procedures for designing customized handbags

TRIZ theory is generally used in scientific inventions. Even application in the design field is generally for highly industrial or technical product designs; thus, this study first extracts the meaning of TRIZ theory and refers to some of what can be applied to innovative problem-solving principles. This study finds that for handmade customized innovative product design, 39 contradiction matrix and 40 innovative problem-solving principles in TRIZ theory are more suitably applied.

However the customized creative design procedures are not completely in conformity with the 39 contradiction parameters and 40 innovative problem-solving principles in TRIZ theory. Research finds that in terms of design semantics, procedures, and conceptualization in the customized creative products: the four steps of "designer and consumer communication", "material selection and production techniques", "design and production procedure", and "marketing strategy" are parts that need more systematic confirmation to benefit selection by micro-corporations or brand. Thus, after the summarization and analysis, the TRIZ systematic innovation procedures for designing customized handbags are planned as follows:
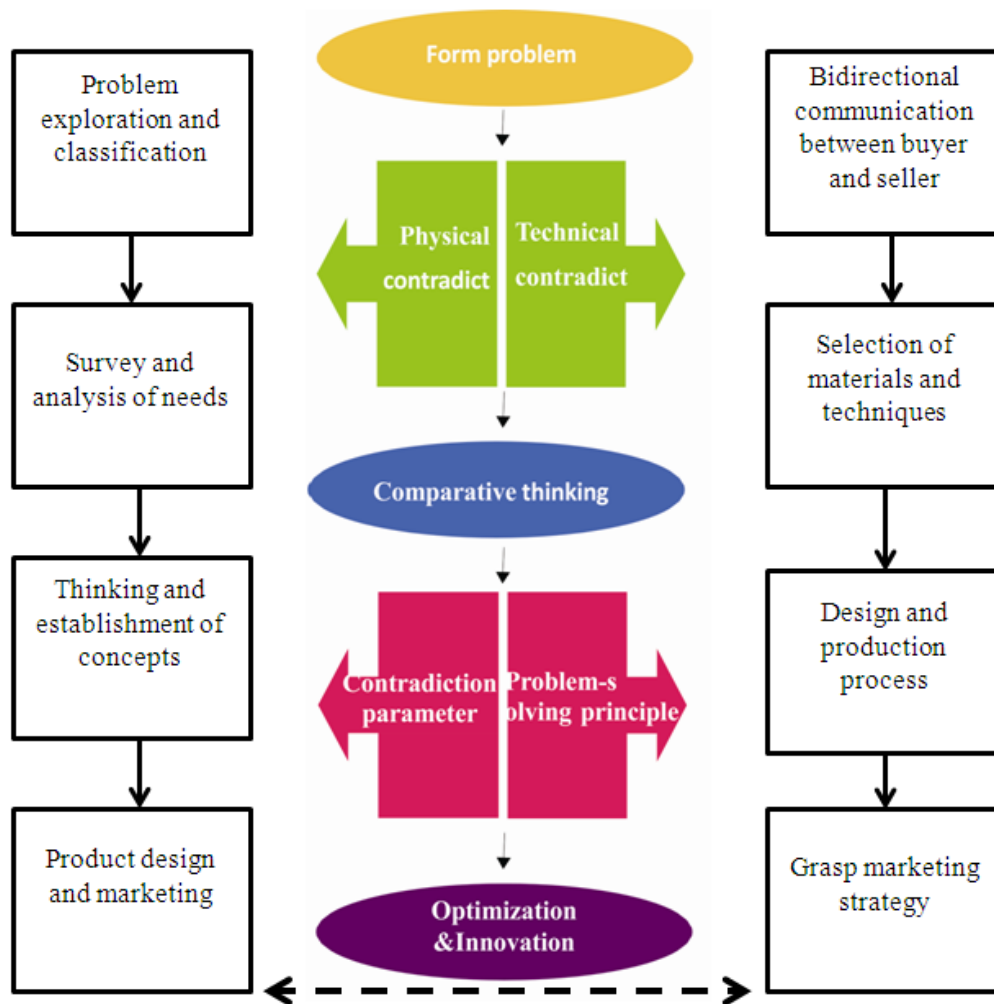

Figure 12. TRIZ systematic innovation procedures for designing customized handbags

4.4 Analysis of main points in materials and techniques

The study finds that in terms of design semantics, procedures, and conceptualization in the customized creative products: the four steps of "designer and consumer communication", "material selection and production techniques", "design and production procedure", and "marketing strategy" are parts that need more systematic confirmation to benefit selection by micro-corporations or brand. Thus, after the summarization and analysis, the TRIZ systematic innovation applied for designing customized handbags are finished as follows：

(1) Use different materials, shapes, forms, and techniques to compare the materials that lead to different quality feels of handbags.

(2) Consider using new materials for examination and creation, introducing new forms in experimental creation, then ascertain the feasibility of materials, and the final purpose is for production of the actual products.

Table 3. Common categorizations of customization techniques

Material / Technique	Glass crystal	leather	Cloth or wool	Cotton or wool rope	Wood and bamboo	plastic	Silk fiber
Weaving	◎	◎	◎	◎	◎	◎	◎
Printing		◎	◎	◎	◎	◎	◎
Sewing or embroidery	◎	◎	◎	◎		◎	◎
Pasting or embedding	◎	◎	◎	◎	◎	◎	◎
Coloring or filling	◎	◎	◎	◎	◎	◎	◎
Tying or knotting	◎	◎	◎	◎	◎		◎
Sculpting or hold-punching	◎	◎			◎	◎	

Table 4. Analysis of wool materials

Name	Price（NT$ /Per Roll）	Special points, strengths and weaknesses
Cashmere wool	(100% most expensive, one roll 1000~1300)	Lightweight, most insulating
Merino wool	(100%Merino cheap 140~as expensive as 380)	Lightweight, insulating
Wool	Wool (100%Wool, 45~100)	Insulating, low price
Baby Alpaca	Alpaca (100% is about 130~160)	Good insulation
Alpaca	Alpaca (100% is about 85~110)	Good insulation
Acrylic	100%ACRYLIC 30 NT	Weakness: does not absorb sweat, unsuitable for wearing

Table 5. Compilation of various materials

Various types of rope and string		
Hemp rope	Silk strings	Five-color strings
Sewing thread	Mink wool balls	Fishing wire
Handle images		
Bamboo knot handle	Synthetic leather	Acrylic handles
Various plastic beads		
Diamond-shaped beads	Glow-in-the-dark beads- yellow	Solid-color candy
Plated round beads	Colorful plastic beads	Rice beads
Earth beads	Trapezoid wooden beads	Oil Beads
Bead-in-bead	letter beads	Glass pearls
Bead-in-bead	letter beads	Glass pearls
Marbles	Oil beads	Glass pearls
Various glass crystal beads		
Rice beads	Pointed beads	Fish-shaped beads
UFO beads	Water drop beads	Heart-shaped

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Sky beads	Wavy circles	Snowflakes
Artistic pendants	Sea star/coral	cross
Square	Butterfly-shaped	Flower-shaped
Earth beads	moon/star	Maple leaves

4.5 Results of product design

This study first uses market surveys to understand the needs and expectations of consumers regarding customized handmade handbags, and then uses "TRIZ systematic innovation" to distinguish consumer market opportunities and seek resolutions to related problems. After following design procedures to design image drafts for innovation in the design styles, the materials are tested and calibrated to ensure that materials are well-made and conform to functional needs. Handmade test is conducted manufacturing and model modification to make the product intricate and perfect. Finally, customized handmade handbags are created to satisfy personalized needs.

Table 6. Case of creative process of handmade customized handbags

| Process / Weaving | Images

Design of glamorous customized handbag - Austria crystal bead |
|---|---|
| knotting | |

Table 7. Completed handmade customized handbags

(1) Glamorous Styles	(2) Pure Years
名稱:華麗風采 材質:日本進口框.角珠.棉線	名稱:純美年代 材質:日本圓珠.單環手提扣手
(3) Colorful Murmurs	**(4) Green Fields and Magical Shoes**
名稱:七彩呢喃 材質:日本角珠為素材,日本進口拉鍊和棉線串起。	
(5) Amber fields	**(6) Mysterious Night**
名稱:琥珀原野 材質:使用施華洛世奇的水晶和日本棉線	名稱:神秘之夜 材質:使用施華洛世奇的水晶和日本進口框

5.   Conclusions and Suggestions

5.1   Conclusions

(1) Product demands of consumers have transformed from "need" to "worth" the added value

Modern consumers are a unique group, which have financial capability and distinct tastes. They desire for quality products, are generous to themselves, and take social   responsibilities. Their pursuit for fashion may be influenced by others, but still holds their exclusive tastes. They have abundant consumption knowledge, and know their own consumer needs. Once our products can touch their heart and satisfy their needs, they would spend money to buy these products and even become loyal consumers. They are a rising force among consumer groups, and are the main group of customers that the fashion industry should emphasize and be concerned about.

Consumers in the new age are concerned with "emotional consumption." They do   not only buy function, but also want the positive emotions brought by this product, including self-confidence, carefree, happiness, and price (Lin, 2002). Thus,   "emotions" have gradually come to play the main role in consumption. Emotional consumption generally buys fashionable products or "luxury goods," and they hope to buy a unique product that can express the ideal self.

(2) Consumers are concerned with product hand feel design, style aesthetics, intricate quality, unique innovation, and experiential services

This is an age of pursuit for hand feel. Handmade eyeglasses, jeans, knit-bags, figurines, soap, and cookies are some of the consumer products that are "made by hand," and the prices are not cheap. Even though some products are not a hundred percent "made by hand," they intricately extend the emotions, temperature, and tactile sense from "hands" into design concepts. Hand feel transmits the temperature in the   hands of designers, and are deep experience processes, these are also sources of vendor pursuits for differentiation under market competition.

The popularity of hand feel products mean that people hope to use their hands   to create something to prove one's existence to fight against mass production rather than being a part of capitalism. The advent of the age of hand feel expresses that   more consumers choose to be loyal to personal style rather than brand. Meanwhile, this reflects a dissatisfaction and protest for their life environments, protesting   against an age with mass production and too many choices.

(3) Use TRIZ systematic innovation theories and concepts, as well as the thought framework on customized handbags for creative design is feasible and visionary

This study finds that in terms of the design semantics, procedures, and conceptualization of creative customized handbag products: the four steps of "designer and consumer communication", "material selection and production techniques", "design and production procedure", and "marketing strategy" are parts that require more systematic establishment for the reference and selection by micro-corporations and brands. Thus, this study uses the 39 contradiction matrix and 40 innovative problem-solving principles in TRIZ Theory to find the parameters and solutions that conform to the four steps above. This study finds that there are 8 contradiction parameters that conform; which are shape (12): formal design, durability of moving parts (15): durability, waste of material (23): material test, waste of time (25): order and production process, precision of manufacturing (29): communication gap, manufacturability (32): ease of production, convenience of usage (33): usage needs, maintainability (34): post-sale service.

Thus, using the theoretical concepts and ideas of the framework of TRIZ systematic innovation in the creative design of customized handbags is feasible and visionary. The Delphi method is a structured communication technique, originally developed as a systematic, interactive forecasting method which relies on a panel of experts. The experts answer questionnaires in two or more rounds (Rowe...etc,2001) .Later studies can use Delphi method or experiment method to again confirm whether the innovative problem-solving principles of the eight contradiction parameters and be applied on the creative design of customized handbags, so that this innovative system would be more comprehensive.

(4) Handbag customization service should establish the procedures and systems, so designers, workshops, or micro-proration can refer to them and apply them

Currently, handbag customization service is not just a marketing strategy of well-known luxury brands. For consumers in the new age, the uniqueness, creativity, or personal styles of customized products are all marketing trends in future fashion. Thus, the establishment of a procedure and system for the creative design of customized handbag can help designers, workshops, or micro-corporations to effectively control the customization process, to dispel or improve upon

problems encountered in the customization process.

5.2 Suggestions

(1) Use the process of customized experiences to satisfy the emotional demands of customers

Since feeling "worth" has gradually become a part of what consumers expect, products or services with emotional appeal can better move people. This is because when products themselves or their added value can form a connection with an emotional need of consumers, it would better satisfy them, and they would think it was more "worth having," and be more willing to spend money.

Thus, in the experience process of customization, if it is possible to understand consumer feelings, with "emotions," "contexts," and "feelings" as the key points in consumption, to take care of emotional needs and the objectives desired by consumers, make considerations based on their position, and engage the consumer's points of benefit, provide consumer with the economic value of in-depth experiences and high-quality aesthetics with the core knowledge and professional ability to integrate the beauty of life with creativity. With the uniqueness of "customization" for customers, they can "be fully willing" and "buy generously," so that they can be "satisfied" and feel that their money was "worth it." (Lin, 2009), and further promote customized products as life necessities after being packaged by emotional appeal.

(2) Use customized products to create added commercial value in "hand feel economy"

For modern people, slowness is the real luxury, this is an age in the pursuit of "hand feel". More and more 100% "handmade" products, or those that emphasize a sense of touch, temperature, and exclusive production receive more attention in the market. More people are spending money to buy "works," rather than "merchandise." This type of consumer trend means that craft art is returning. People come to workshops in small alleys to find totally unique original works.

When "hand feel" is a new marketing element, then how is it possible to communicate with consumers? How to create a unique "hand feel brand"? This is an important issue that requires deep thought. Thus, hand feel economy is an experiential economy, with deep communication between consumer and designer as well as deep aesthetic experiences, emphasize that the "humanity" and "touch" of "customization" cannot be mechanized and mass produced, in turn causing consumers to be loyal to the individual and not the product. Taiwan has entered a new economic age of

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hand feel consumption, where creative design and marketing management have to be combined with culture, and use a sense of quality to correspond to the consumption needs of certain groups; hand feel is a kind of subtractive aesthetic. If it possible to perfectly balance traditional and modern elements, and extract the beautiful elements of history, memory, and emotion (Wu et al., 2006) to get closer to the senses of the consumers, grasp a feeling of being moved in their hearts, this would be successful addition of value via hand feel.

(3) Suggestion to use KJ method to find the contradiction parameters in design of handmade customized handbag to establish comprehensive principles for the creative design of TRIZ systematic innovation

This study only finds eight TRIZ contradiction parameters that conform to the procedures of creative design for customized handmade handbags. The K-J Method was developed as the the Affinity Diagram, the Seven Management and Planning Tools used in Total Quality Control , the basic K-J brainstorming process becomes a problem-solving process （Raymond Scupin,1997）. Future studies can use KJ method or other methods to construct more contradiction parameters and problem-solving principles that conform to customized creative design, so that the usage of TRIZ systematic innovation principles in the professional field of creative design can gradually become more comprehensive and assist in the development of cultural and creative industries.

(4) Establish a database system for materials and techniques for customized handbags to facilitate communication between designers and consumers

Using the forms of creative design, novel colors, development of unique materials and practical functions, integrating new technological production methods, and production of personalized styles can all accentuate product originality and uniqueness to attract the attention and preference of consumers. Future studies can further test the various materials and techniques, and use the processes and results to construct a database system for convenient checking, applying, comparing, and analyzing. It would help designers and consumers communicate and exchange opinions at any time, to jointly participate and design the creative products that both sides are satisfied with.

(5) Establish online marketing platforms for creative

design of customized handbags, Allow consumers to participate in design with internet databases

Allowing consumers to experience the design process is one of the emotional demands for consumers. It is suggested that businesses should use Internet interaction platforms and context simulation methods, so that consumers can participate in the complete creative process, so that they can deeply experience a sense of reality and value.

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Brand Selection Model with the Expansion to the Second Order Lag

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Abstract

By focusing the following condition that consumers' are apt to buy superior brand when they are accustomed or bored to use current brand, a new analysis method is introduced. The data set of "before buying data" and "after buying data" is stated using the liner model. When above stated events occur, transition matrix becomes upper triangular matrix. In this paper, equation using transition matrix is extended to the second order lag and the method is newly re-built in order to improve forecasting accuracy. These are confirmed by the numerical example. S-step forecasting model is also introduced. This approach makes it possible to identify brand position in the market and it can be utilized for building useful and effective marketing plan.

Keywords: brand selection, matrix structure, brand position

1. Introduction

It is often observed that consumers select the upper class brand when they buy the next time. Focusing the transition matrix structure of brand selection, their activities may be analyzed. In the past, there are many researches about brand selection (Aker, 1991; Katahira, 1987; Katahira & Sugita, 1994; Takahashi & Takahashi, 2002; Yamanaka, 1982). 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 numerical example. 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 in prior researches (Takahashi & Takahashi, 2002; Yamanaka, 1982. Yamanaka (1982) examined purchasing process by Markov Transition Probability with the input of advertising expense. Takahashi and Takahashi (2002) made analysis by the Brand Selection Probability model using logistics distribution. Takeyasu and Higuchi (2007) suggested that matrix structure was analyzed for the case brand selection executed toward upper class.

In this paper, equation using transition matrix is extended to the second order lag and the method is newly re-built in order to improve forecasting accuracy. Such research is quite a new one.

Hereinafter, extended analysis method is stated in section 2. Matrix structure is clarified for the brand selection in section 3. Extension of the model to the

second order lag is executed in section 4. Forecasting is formulated in section 5. Numerical calculation is executed in section 6. Section 7 is a summary.

2. Extended Analysis Method

Zlotin and Zusman (2006) proposed the concept of "Trends" in TRIZ CON 2006. We can further develop this concept as shown in Figure 1.
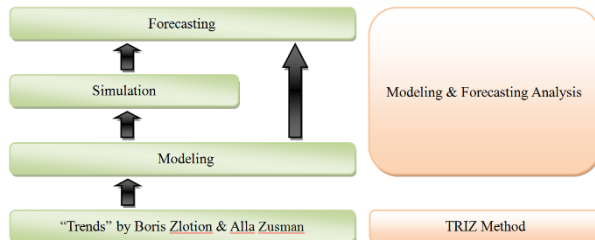
Fig. 1. Extended Analysis Method

Based on the TRIZ method, modeling and forecasting analysis method is developed. Extending "Trends", modeling is constructed first. Then we can make simulation by utilizing them. We can make forecasting utilizing the simulation function or directly from the utilization of the model built. These are the process of "Modeling & Forecasting Analysis" based upon TRIZ "Trends" analysis method. In this paper, the problem is to improve forecasting accuracy. The way to solve or cope with this problem is exhibited in Figure 2. Method is taken by building the expansion to the second order lag model in order to improve forecasting accuracy to the objective value. Detailed inspection is executed in Section 5 through 7.
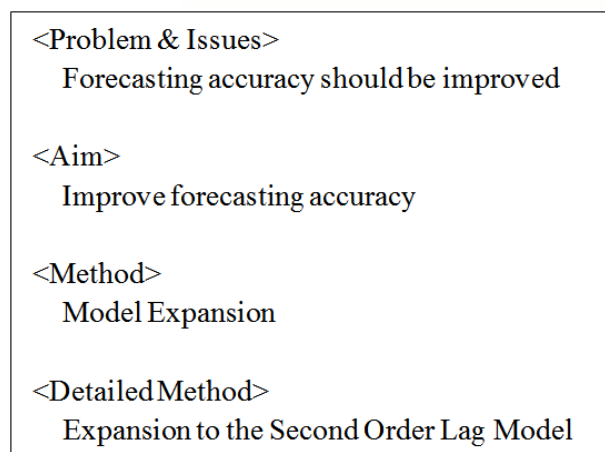
Fig. 2. The way to solve or cope with the problem

3. Brand Selection and its Matrix Structure
3.1 Upper Shift of Brand Selection

It is often observed that consumers select the upper class brand when they buy the next time. Now, suppose that x is the most upper class brand, y is the second upper brand, and z is the lowest brand. Consumer's behavior of selecting brand would be $z \rightarrow y$, $y \rightarrow x$, $z \rightarrow x$ etc. $x \rightarrow z$ 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, $\quad y = a_{22}y_b + a_{23}z_b$

And $\quad z = a_{33}z_b$

These are re-written as follows.

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

Set:

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

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

$$\mathbf{X} = \mathbf{A}\mathbf{X_b} \quad (2)$$

Here,

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

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

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

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

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

Parameter can be estimated using least square method. Suppose

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

Where

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

And

$$J = \sum_{i=1}^{N} \boldsymbol{\varepsilon}^{iT} \boldsymbol{\varepsilon}^i \to Min \qquad (6)$$

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

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

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),

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

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

If $\mathbf{X}_{\mathbf{b}}$ is replaced by $\mathbf{X}$ in the right hand side of Eq.(2) and by utilizing $\hat{\mathbf{A}}$, forecasting can be executed by Eq.(2) (The value of the left hand side becomes the forecasting of $\mathbf{X}$).

3.2 Sorting Brand Ranking by Re-arranging Row

In a general data, variables may not be in order as x, y, z. In that case, large and small values 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.

$$
\begin{pmatrix} x \\ y \\ z \end{pmatrix}
\begin{pmatrix} \bigcirc & \bigcirc & \bigcirc \\ \varepsilon & \bigcirc & \bigcirc \\ \varepsilon & \varepsilon & \bigcirc \end{pmatrix}
\xleftarrow{\text{Shifting}}
\begin{pmatrix} z \\ x \\ y \end{pmatrix}
\begin{pmatrix} \varepsilon & \varepsilon & \bigcirc \\ \bigcirc & \bigcirc & \bigcirc \\ \varepsilon & \bigcirc & \bigcirc \end{pmatrix} \qquad (8)
$$

3.3 Matrix Structure under the Case Intermediate Class Brand is Skipped

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

$$v \leftarrow z, \; v \leftarrow y$$

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.

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

4. Expansion of the Model to the Second Order Lag

We extend Eq.(2) to the second order lag in this section in order to improve forecasting accuracy. We have analyzed the automobile purchasing case (Takeyasu & Higuchi, 2007). In that case, we could obtain the data (current buying data, former buying data, before former buying data). We have analyzed them by dividing the data (current buying data, former buying data) and (former buying data before former buying data), and put them to Eq.(5) to apply the model.

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

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

Where

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

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

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

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

In order to estimate $\mathbf{A}_1, \mathbf{A}_2$, we set the following equation in the same way as before.

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

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

Eq.(11) is expressed as follows.

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

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

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

This is re-written as :

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

We set this as :

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

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

5. Forecasting

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

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

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

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

$$\hat{\mathbf{X}}_{t+4} = (\hat{\mathbf{A}}_1^4 + \hat{\mathbf{A}}_1^2 \hat{\mathbf{A}}_2 + \hat{\mathbf{A}}_1 \hat{\mathbf{A}}_2 \hat{\mathbf{A}}_1 + \hat{\mathbf{A}}_2 \hat{\mathbf{A}}_1^2 + \hat{\mathbf{A}}_2^2) \mathbf{X}_t + \{ \hat{\mathbf{A}}_1 (\hat{\mathbf{A}}_1^2 + \hat{\mathbf{A}}_2) + \hat{\mathbf{A}}_2 \hat{\mathbf{A}}_1 \} \hat{\mathbf{A}}_2 \mathbf{X}_{t-1} \qquad (20)$$

6. Numerical Example

In this section, we consider the case there is no shift to lower brand. We consider the case that brand selection shifts to the same class or upper classes. As above referenced, corresponding part of transition matrix must be an upper triangular matrix. Suppose following events occur. Here we set $p = 3$ in Eq.(10).

	< $\mathbf{X}_{t-2}$ to $\mathbf{X}_{t-1}$ >		< $\mathbf{X}_{t-1}$ to $\mathbf{X}_t$ >	
①	Shift from lower brand to middle brand	4events	Shift from middle brand to upper brand	4events
②	Shift from lower brand to lower brand	2events	Shift from lower brand to upper brand	2events
③	Shift from lower brand to lower brand	5events	Shift from lower brand to middle brand	5events
④	Shift from lower brand to upper brand	1events	Shift from upper brand to upper brand	1events
⑤	Shift from lower brand to middle brand	2events	Shift from middle brand to middle brand	2events
⑥	Shift from lower brand to lower brand	3events	Shift from lower brand to lower brand	3events
⑦	Shift from middle brand to middle brand	3events	Shift from middle brand to upper brand	3events

⑧	Shift from middle brand to middle brand	2events	Shift from middle brand to middle brand	2events
⑨	Shift from upper brand to upper brand	4event	Shift from upper brand to upper brand	4event
⑩	Shift from middle brand to upper brand	2events	Shift from upper brand to upper brand	2events
⑪	-		Shift from lower brand to middle brand	3events
⑫	-		Shift from middle brand to middle brand	2event
⑬	-		Shift from middle brand to upper brand	4events

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\left(\hat{\mathbf{A}}_1, \quad \hat{\mathbf{A}}_2 \right)$$

$$= \begin{pmatrix} 7 & 11 & 2 & \vdots & 4 & 5 & 7 \\ 0 & 6 & 8 & \vdots & 0 & 2 & 7 \\ 0 & 0 & 3 & \vdots & 0 & 0 & 3 \end{pmatrix} \begin{pmatrix} 7 & 0 & 0 & 4 & 2 & 1 \\ 0 & 17 & 0 & 0 & 5 & 6 \\ 0 & 0 & 13 & 0 & 0 & 10 \\ 4 & 0 & 0 & 4 & 0 & 0 \\ 2 & 5 & 0 & 0 & 7 & 0 \\ 1 & 6 & 10 & 0 & 0 & 17 \end{pmatrix}^{-1}$$

(21)

As we have seen before, we can confirm that

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

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

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

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

$$\left(\hat{\mathbf{A}}_1, \quad \hat{\mathbf{A}}_2 \right)$$
$$= \begin{pmatrix} 0.979 & 0.621 & 0.091 & 0.021 & -0.009 & 0.081 \\ 0.113 & 0.446 & 0.776 & -0.113 & -0.065 & -0.208 \\ -0.091 & -0.067 & 0.133 & 0.116 & 0.074 & 0.127 \end{pmatrix}$$

(22)

One step forecasting can be obtained by Eq.(7) under the utilization of estimated parameters of Eq.(22). When making forecast by this method, "former buying data" and "before former buying data" are

required as is stated at the beginning of 4.

7. Conclusion

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

Formerly we have presented the paper and matrix structure was clarified when brand selection was executed toward higher grade brand. Takeyasu and Higuchi (2007) suggested that matrix structure was analyzed for the case brand selection executed for upper class. In this paper, equation using transition matrix was extended to the second order lag and the method was newly re-built. One of the TRIZ methods was extended and applied. In this paper, the problem was to improve forecasting accuracy. Method was taken by building the expansion to the second order lag model in order to improve forecasting accuracy to the objective value. Detailed inspection was executed in the numerical example, matrix structure's hypothesis was verified. We can utilized the data as it is for the data in which time lag exist by this new model and estimation accuracy of parameter becomes more accurate and forecasting becomes more precise. Such research as questionnaire investigation of consumers' activity in automobile purchasing should be executed in the near future to verify obtained results.

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Subconscious Problem Solving Using Hazy Heuristics

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Abstract

While learning a structured problem solving methodology one typically rues the tedium interfering with inventive thinking. Later, as the methodology inures in one's subconscious, shortcuts take form. This paper focuses on the shortcuts of the structured problem solving.

We have ample evidence that our conscious does not solve problems – our subconscious does. That realization raises the issue of how to communicate problem-solving cues from our conscious to our subconscious and accept any ideas that are returned. Presented here are arguments for the elimination of constraining logic in major parts of current structured, problem-solving methodologies. Unified structured inventive thinking (USIT) is used as an example.

This should not be a bitter pill for logically trained technologists to take. It does not substitute for any of one's early learning of problem-solving methodologies. Instead, once a methodology is mastered, it encourages taking short cuts by eliminating or reducing heuristic constructions that have become second nature in one's logical thinking. Logic is subdued in favor of evocative vague cues – sometimes thought of as the poetic license of the intuition.

Two examples are presented of rapid problem solving using USIT in an abbreviated form. One solution concept resulted in a USA patent, "Pedestrian Impact Energy Management Device With Seesaw Elements".

A problem and its solution concepts refer to the pre-engineering phase of problem solving. In this phase all concepts are accepted without filtering. Proof of concept and model calculations come later. Unfiltered concepts are a potential source of surprising ideas.

1. Introduction

We, who spend a significant portion of our careers solving problems 'consciously', do so using heuristics (formulated clues) in verbal and graphic structures involving symbols. Ostensibly, they all serve as conscious links (seeds) to our subconscious where ideas are assembled from bits of memory. We have ample evidence that our conscious does not solve problems. It communicates them. We learn, invent, and practice heuristics for communicating problems to our subconscious. Uselessness of the conscious brain is an idea a century and a half old, yet it is still a research subject of neural scientists. Here, logic is relegated to introspective and extroversive communications, while subconscious is used to invent.

The idea that the conscious brain is useless in problem solving is not new. To span its history, I'll quote the opening paragraph of a recent book review by Chris Frith on consciousness and the brain.

"In 1874, Thomas Henry Huxley gave a prescient lecture on mind and brain. The biologist argued that subjective experience depends on the brain's 'anterior divisions', and that consciousness has as little effect on behavior as a steam whistle has on

a locomotive's progress – rendering humans little more than 'conscious automata'. He raised two questions that remain key in contemporary studies of the neural basis of consciousness: what is special about the neural processes that underlie consciousness, and what, if anything, is consciousness for?" "Frith, C. (2014, January)".

Conscious-automata is a key phrase for this discussion. At times, we may be those conscious automata. It can happen while learning and practicing structured problem solving (SPS). While learning, we spend time constructing logical heuristics in tables, graphs, words, and symbols as cues to spark links to our subconscious. As we experience success with these methods they gradually become reliable crutches. With crutches in hand, we become conscious automata.

This paper argues for weaning ourselves from these crutches and moving toward making more effective subconscious links. They occur when recognizing when SPS has become engrained in our thinking and then allow minimizing the tedium of writing and drawing heuristics. Consequently, specific heuristics need no longer to be consciously named and graphed, they arise automatically as needed. This has an impact on the logical formulation of a problem as organized in our conscious.

2. Conscious-subconscious Links in Thinking

Consider a common example of using heuristics to solve a problem, in this case, the problem of how to recall a person's name.

The alphabet-pneumonic is popular for this job. It is used to step through the alphabet one letter at a time. It may happen automatically. Within moments a first letter, and maybe even its syllable, come vaguely into view (a subconscious token of information), but often not quite what is recognizable. Mental focus on this first foggy clue may narrow the alphabet search or even evoke a vague characteristic of the person. Then quickly arise in the conscious another syllable, and eventually the name being sought. As the name is recovered, further concentration can evoke more definitive information, such as, the last dinner shared with the person or a

challenging game of chess. This is a path of mental stepping-stones, which recover from the subconscious bits of personal history related to each clue (or sometimes not related). Such links may or may not have been intentionally stored for future use. Chains of links are thought paths to conscious understanding. Considerable introspection is required to become aware, or even suspicious, of the switching back and forth between unconscious and conscious states in this exercise.

It seems evident in the above example that the conscious was involved in deciding to start the solution process using the alphabet heuristic. Or was that tossed up from the subconscious as the thought, 'I can't remember his name', was being formulated in the conscious? I suspect the latter. And it arose quicker than its awareness became conscious focus.

It is also evident that each idea returned from the subconscious was vetted by comparing the latest idea with the previous one being attentively held in the conscious. Then it was accepted or rejected. Who did the vetting? At first, I suspect the conscious, but perhaps with subconscious help.

Furthermore, the speed of forming these conscious-subconscious-links is remarkable. Physicist Hermann von Helmholtz (1821-1894) famously used perception as an example of speed during subconscious inference relative to the more slow conscious awareness.

I also suspect that each word inserted into an oral or written phrase is suggested and vetted by the subconscious.

2.1 The Dynamics of Subconscious and Conscious Thinking

So what is vetting? It can be understood in computer-like terms as follows. A tentative, but dynamic, list of items grows as each new item is compared with each item already in the list. If it is deemed relevant it is added to the list. If not, it is discarded. In this model the dynamics of growth seems to favor the short time constant of subconscious, random selection. Whereas the longer time constant of the conscious would suffice in a holding process for

achieving focus by filing information.

How is it possible that the slowly plodding conscious is able to select effective thought provoking seeds? Are only the conscious ordered and the subconscious disordered? Dreaming comes to mind regarding the last question. Dreams occur consisting of unconscious associations that conscious, logical thinking often would not allow. This raises the question of what is consciousness.ognitive neuroscientist Dehaene offers a definition: "Consciousness is this: we are conscious of whatever we choose to focus our attention on." (Dehaene, S., 2014) That definition suggests there are all manner of associations going on in our subconscious. Consciousness is made up of those we focus on as a result of their relevance. Perhaps then, slowness of consciousness goes with sustaining in focus continuous associations. This dynamic points to the physics of information transfer between neurons at synapse interfaces.

2.2 A Model of Problem Solving

Sleeping is a relaxed state of the brain. In sleep the brain is still active but is not able to maintain focus on relevant associations that constitute cognition. This is causal of the need to awaken and write down ideas caught in dreams before they are lost from our semi-consciousness.

These observations fit the model of signals from the five senses being dealt with subconsciously. Their relevant associations, still around when the brain is resting, are moved into long-term memory. Then making associations for cognition with, for example, an object, attribute, or function now recorded in memory – the keys of USIT analyses.

When we are awake our subconscious is constantly trying to solve problems, whether consciously prodded or not. Our senses feed signals, of their five transduced kinds of electrical information, into our brain where they sail through the neural network. At relevant synapses they are compared with long-term and short-term memory. Successful comparisons support instantaneous vetting regarding any necessary aversive action or a benign incident to be ignored. I use the metaphor that all

unanswered questions, failed immediate vettings, are problems. Problems are defined as unanswered questions. When successful subconscious associations are accessed by the conscious and resolve an issue a problem disappears.

A useful model unfolds here that helps to understand how all of problem solving is done by the subconscious. When the initial surge of neural current finds a relevant synapse, momentary focus marks that connection while the current passes on through the network. When and if a second relevant synapse is encountered the two now bring prolonged focus. As other relevant synaptic responses occur they prolong the focus further forming an instance of developing consciousness (e.g., recall). My mental image of this has one hand holding selected neurons for comparison with one just selected in the other hand.

3. Foggy Thinking

We know words and sentences, and we know how to employ grammar in their use to effect unambiguous written and verbal communication. Typically, however, we are well along in our education and its practice before our communication becomes rigorous and clear to others. Yet, from early beginnings we consciously communicate with our subconscious and we know what we mean in these communications. If that be true, and I believe it is, then grammatical communication has evolved not for internal thinking but for expressing our thoughts to others. It is much too slow for internal communication.

Internal thinking does not require the rigors of grammar. Speaking and writing grammatically require some degree of conscious filtering – think first then speak. Thoughts are too spontaneous to have undergone such filtering. Clear evidence of that lies in the time (and repeated time) it takes to write grammatically. Speech suffers for the same reason. It has, at best, the benefit of practice that enables some automatic pre-correction of speech – the voice of education.

Internalized creative thinking during brainstorming is so spontaneous that often non-grammatical and illogical associations of nouns, adjectives, and verbs are

made. Foggy ideas come to mind that require some correction to render them even internally acceptable. The payoff of word-generification in SPS is encouraging thinking to find new viewpoints while maintaining subconscious control on relevance of the thought paths followed. Thought paths are the root causes of inventive thinking. But are they required to be rigorous?

We don't know how effective a specific word clue is as compared with a different word. We do know that the same idea can be expressed in different ways, and that different people can prefer different words in expressing similar thoughts. Hence, it is unlikely that specific word choice is important in communicating to the subconscious. This allows mental room for generification that reduces rigor of logic, thus opening access to a broader solution space. The A used in beginning the name recall example is likely to be far off the target making it a vague clue. Yet it initiates a working procedure having high probability of success. These realizations beg for diversity in seeding the subconscious.

The forgoing discussion shows that rigor in the solution-concept phase of problem solving is not necessary. This is because the subconscious works in iterative stages of vague thinking. SPS methodologies are heavy in the use of logical heuristics. Let's examine a more intuitive beginning to solution searches where relevant, yet vague, concepts arise. Note the use of introspection in the following.

4. Vague Problem Example – A Fishing-lure Manufacturer's Problem

Here is a quickly formulated and solved problem. Suppose the barb of a fishhook lure gets caught on roots under water, thus defeating the lure's function – an unwanted effect. Here's a scenario of analysis simplification (Table 1.) that came to mind as I wrote this article.

Table 1. A Scenario of analysis simplification

Simple statement development	Vague Solution Concepts
'Barb on hook catches roots.' Three word-clues and no prior sketch	(**1**) Protect barb; (**2**) eliminate barb; (**3**) eliminate roots; Barb can be (**4**) protected part of the time by adding a ventral fin to the lure (**5**) keeping the barb on a lure's topside away from roots below.
'Barb catches objects.' Two word-clues and no prior sketch	(**6**) Eliminate barb when not in fish's mouth; (**7**) Hide it within the lure and (**8**) release it when fish's mouth encloses it. This solves the problem of non-fish contact snagging the lure. But it raises a new issue. (However, no filtering is allowed here.)

The above eight (and two to follow) numbered items are immediate solution-concept associations with only a few word-clues. Mental images were aware but not put to paper until some minutes later.
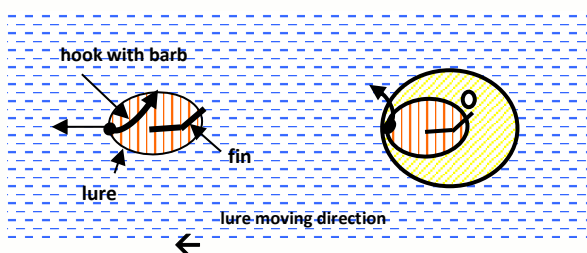
Fig. 1. Post solution sketches: Left, moving lure with retracted hook and bent fin. Right, lure enclosed by a fish's mouth, stopping flow, releasing hook, and snaring fish.

That specific wording, 'fish-mouth closure', sparks a new idea. Mouth closure suggests (**9**) an encircling entrapment. As the lure enters the fish's mouth surrounding water flow slows. (**10**) The reduction of flow could be used to release the hook. Hidden barb is shown on the left side of Figure 1 and released inside of fish's closed mouth on the right side.

Nothing profound stands out in this demonstration, and none were intended. Its purpose is to demonstrate identification of a problem with immediate attempt to find a solution concept and without consciously pausing to recall heuristics or to employ filters. It took a few

moments to think of an example problem that most people would understand. Then several popped up from the subconscious. Unintentionally snared fishing lure was selected. Note how quickly minimal information produced multiple ideas.

As I started to draw a sketch it came to mind to look at the contact with two objects, hook and a generic object. Accompanying this idea came another simplification, focus on barb exposed and barb unexposed – the problem and its solution concept. Most time consuming in this exercise was concentrating on what to type, its grammar, paragraph and table layouts, and the mechanics of typing and drawing. Thinking, writing, and drawing were multiplexed processes. Conscious focus switched frequently between these three efforts. I can't do any two of them simultaneously.

As I examine what happened it is evident that several fundamental heuristics came into use subconsciously: Simplify a problem statement to one unwanted effect, two objects, and a point of contact (fish and hook). Then, if possible, simplify it further to one object in two states, hidden barb (a solution) and exposed barb (the problem). Allow no filtering of ideas – a heuristic. Eliminate unnecessary objects, roots, water, and fish – a heuristic. These are four elementary USIT heuristics, which are not unique to any methodology. Elimination of barb evoked to hide it – one solution concept. One object-attribute-function string (OAF) was visualized during the analysis process, a conscious effort.

In this example a solution concept was quickly found using an abbreviated version of USIT. Its solution is a pre-engineering concept. All of the solution process focused on the problem statement. No formal graphics and procedures of USIT were consciously addressed except for one OAF string. It reminds one to focus on points of contact. Any realistic embodiment of these ideas would follow with a proof-of-concept in the engineering phase of problem solving.

Conclusions of the last paragraph and this section raise the question: if everything is done in the subconscious, how can it be claimed that no other heuristics were used? The answer is: I can't make that claim! My justification is that this example is one of the simplest SPS cases I can recall. It came to mind, was

analyzed, and solution concepts found quickly. The table and sketch were made after the fact of solving the problem. Other, heuristics surely were involved subconsciously, which, by now, are well developed in memory.

Note that those immediate, vague solution concepts that came to mind are the goal of STS. You need only hand to a brainstorming team the phrases 'protect barb', 'eliminate barb', and 'eliminate roots' and they will be off and running, expanding them into the next phase of problem solving for engineering.

5. Pre-engineering Structured-problem Solving Concepts

A more complex example of a problem is one that was assigned to a USIT team to find plausible concepts for making an automobile bumper less harmful to pedestrians. Two teams worked on this problem. The first was a USIT team that produced a variety of concepts and an invention disclosure. Later a second team, whose USIT training was not known, improved on the disclosure and obtained a patent. I served on both teams.

Generification of technical names, bumper and pedestrian, led to two objects of different sizes, O_1 and O_2. This broadened the solution space to be searched in several ways. It helped also to begin without using attributes that bring too specific objects to mind, which might reduce solution space. It is assumed that this helps to mitigate some of the logical control of SPS allowing intuition some leeway. The team chose a standard OAF triad as a problem/solution graphic, Figure 2, to start with. Note that the Os in Figure 2 (see References) can represent one, two, or three objects.

$$
\begin{array}{ll}
O - A & O_1{}' - \text{large} \\
\quad \backslash & \qquad \backslash \\
F - A' - O' \rightarrow & \text{to flex} - O_1' \\
\quad / & \qquad / \\
O - A & O_2{}' - \text{soft}
\end{array}
$$

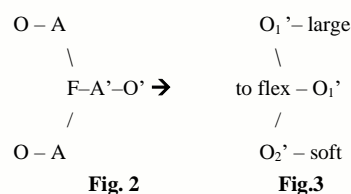   **Fig. 2**   **Fig.3**

Fig. 2. Generic OAF graphic of problem/solution statement. F is an unwanted effect when representing a problem or a wanted effect when representing a solution. A' and O' are in solution space where O_1' and

O$_2$' are in contact.

Fig. 3. OAF-graphic of solution space with adaptation of Figure 2 with example values of A' and F'.

While constructing Fig. 2 and Fig. 3, ideas came to mind that there are two problems separated in time. Simplify the problem by reducing it to two objects. Eliminate O$_2$ and make A$_1$' soft in one situation and hard in the other. Thus, the wanted effect has two conditions to meet, to flex at one time and to stiffen at the other. When flexing, O$_1$'s attribute should be soft, compliant, etc. When stiffening, it should be hard, non-compliant, etc. With these two problems identified the problem/solution heuristic can be inserted into a sentence. Thus, O-A-F-A'-O' (a symbolic sentence) becomes the simplified problem/solution heuristic with O and O' being the same object at different times.

Looking at the word flex suggests that it can be expressed in other attribute words, such as, soft, moveable, elastic, compliant, and plastic, for example. The attributes of O$_1$' can be functions of space and time, A'(x,t). Note that one's subconscious can handle these conditions without additional sketches.

In the pre-engineering stage of problem solving we don't need (and should avoid) engineering parameters requiring numbers or detailed equations, which can act as premature filters. Those are appropriate to use during mathematical modeling for proof-of-concept.

Then came an ah-ha! Time-dependent elasticity, plasticity and mobility brought to mind viscous fluids. That suggested a generalization to non-Newtonian fluids. Two useful concepts arose from this realization: thixotropy and rheopexy, which are complimentary types of time-dependent viscosity. Thixotropic fluids have viscosity that decreases under time-dependent strain – sometimes referred to as shear thinning (e.g., ketchup and yogurt). Rheopexy, on the other hand, has an increase in viscosity under time-dependent shear (e.g., gypsum paste and printer inks). It is not necessary to select particular materials at this point. Such details are a bit premature. They can wait for the proof of concept stage. By then other ways of using one or both of these attributes may arise. Flow of particulate solids comes to mind.

Several solution concepts came from these observations.

(1) The large object could be divided into cells containing one or the other or a mixture of these fluids giving the cells time-dependent viscosity.

(2) Cells allow properties to be distributed inhomogeneously in space.

(3) The fluids used could have, within their cell volumes, dispersed spheres or other shaped solids to allow a larger range of stiffness (disperse and mix).

(4) Elastic particles could be dispersed in the fluids to affect conformability to O$_2$'s penetrating shape into O$_1$'.

(5) Independently suspend individual cells to allow separation when making contact with a small object and prevent separation when contacting a large object.

The last idea, (5), popped up when Nobel's invention came to mind of putting nitroglycerin into isolated cells of dolomite to make dynamite. Ideas spark similar ideas.

Another solution concept that occurred is of a bumper divided into multiple, movable parts. Motion of cells occurs automatically following O-O contact. If the contact area is large, (Figs. 4 & 5), the cells move to more equally spaced regions for non-conformal stiffening. If the contact area is small, as shown in Fig. 6, the segments move around the area of contact for local shape conformance effectively creating a soft region. This work led to a US Patent 6,554,332,B1.
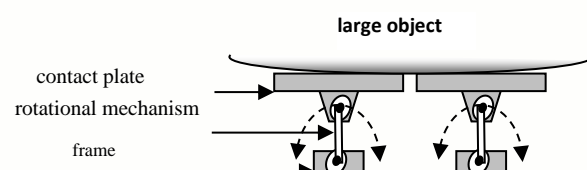

Fig. 4. Illustrating orientation of moveable bumper segments to effectively stiffen contact becoming nearly flat.

Drawings of this concept from the patent application are shown in Figs. 5 and 6. Contact plates have been simplified with fewer parts and a conformal layer added (No. 16 in the Figs. 5 and 6)
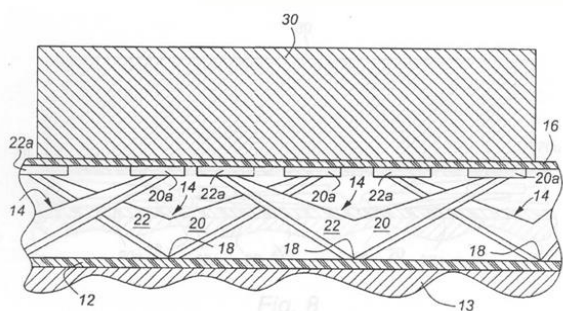
Fig. 5. Large object conformal-shape accommodation design as improved in patent (not to scale).
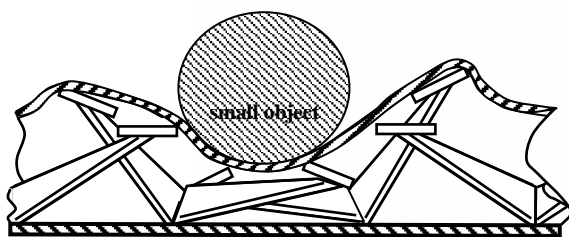
Fig. 6. Small object-conformal-shape design. Contact plates now support the conformal material contacting the small object (not to scale).

Problem solving examples just illustrated are not intended for post-logic analysis by mapping their parts onto heuristic diagrams. Rather, two points were intended: the first to show how little pre-information was used before the first ideas surfaced and second to show how vague the information was compared with final solution ideas.

Mapping solution results back onto a problem-solving methodology, after the fact, in order to give credence to the methodology and to its application can be somewhat questionable. An original problem and the results are understood metaphorically without such mapping. This is especially true when generic words are used to describe a problem. Unfortunately brainstorming teams can waste much time in satisfying all participants' needs for logic not required by the subconscious.

In brainstorming teams, solution results come under instant examination. Each team member quickly tries to improve a solution concept when it arises – perhaps to share in the credit. If they can't improve it they will try to criticize it. This is odd, considering the arguments made earlier, in that no one knows which, if any, of the components in a problem statement actually sparks creative thinking. This supports generification of word choices to make more concepts discoverable. It is also odd to criticize new ideas that may not be obviously valid. It would make more sense to remember that the idea came from an illogical, subconscious, collection of neural network elements and instead try to find its relevance. In other words, ponder why did the subconscious bring up a particular concept?

6. Perspectives of a Problem

A core of inventive thinking is finding unusual perspectives of a problem situation for inspiration. In the above example, perspective developed from three simple symbolic words, O, A, and F. They have already been registered in the subconscious with various logical links to the subconscious; such as experiences presented from our five senses. They may also be registered by metaphors that we may have imagined. In USIT they are fundamental to problem definition and solution.

Different viewpoints can arise in the same brain. Structured inventive thinking preempts such conflicts by encouraging spontaneous thoughts to be recognized without criticism.

Once experience enables, the symbols O-A-F speaks to our subconscious, stepping-stones through solution-space arise automatically. Then follows the mental visualization of the simple graphic for problem definition shown in Figure 2. However, this graphic heuristic, the triad of links, can be reduced to a more generic symbol, a single O-A-F metaphor, from which more complex unions can be formed. (Sickafus, 1999).

Problem perspectives are a critical part of conscious invention. At least we think so. We don't know what solution perspectives the subconscious has, if it has any. We know that the subconscious is faster than the conscious in finding associations of past and present observations. It probably finds them randomly, proffers them to the conscious, and continues its search. Meanwhile the plodding conscious files them for reference. It is this relatively slower speed of our conscious that exacerbates the tedium of writing and drawing heuristics as well as our eagerness to get on

with invention.

Our best effort in structured problem solving is to take a real-world situation into a hazy world of problem space using hazy metaphors. Then enjoy the wealth of metaphoric solution concepts that are served to the conscious.

A confession is appropriate here. The first idea to come to mind in the bumper problem was not a non-Newtonian fluid, but that of a physical impulse, probably associated with an initial image of bumper collision. Then followed recollection of seeing a Jesus Christ lizard dash up a stream in Panama – foot impulse on water. That led to thixotropy and it led to non-Newtonian fluids. "Thank you subconscious!" Retelling a problem's solution experience has its privileges.

7. Summary

Hazy heuristics are proposed as a problem-solving strategy to subdue spontaneous criticism and thereby benefit from the intuitive power of metaphorical thinking. Thus, they broaden the problem solver's search of solution space.

If the process of problem solving is divided into sections like, information gathering, brainstorming, structured problem solving, pre-engineering filtering, modeling, proof-of-concept, etc. Application of hazy heuristics, a la USIT and all of its structure, is the post brainstorming, pre-engineering filtering section. In this scenario brainstorming gathers the low hanging fruit. USIT sweeps up the vetoed ideas and others not previously noticed.

The way hazy heuristics work is treated in three components in the manuscript:

• Evidence that the brain is intuitive and not logical, which implies that we miscue the subconscious when using logical seeds;

• Speed of intuition trumps that of the conscious and is essential for innovative thinking. Logical thinking threatens to veto intuitive thinking;

• Metaphors (hazy heuristics) are more receptive to the intuitive thinking than to logic.

Once mechanical thinking is mastered we move to strategic thinking. Here we drop our automaton crutches, pick up paper and pencil, and proceed rapidly to generate ideas from our memories which are full of training and experience.

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Author Biography

Dr. Sickafus received his Ph. D. in physics from the University of Virginia. He held joint appointments in the Denver Research Institute's Physics Department as research scientist, and the University of Denver Physics Department as a professor. He became a senior research scientist at the Ford Motor Company Research Laboratory and manager of the physics department. In 1985 he introduced structured inventive thinking into Ford and taught it monthly in the US and other countries having Ford engineering facilities. He is currently president of Ntelleck, LLC. He writes and lectures on USIT.

Yield Improvement for a new MCM/SiP IC using TRIZ Processes

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Abstract

Semiconductor packaging technology is advanced and sophisticated for high integration. The MCM and SiP is a modern technology used in IC packaging. It consists of passive tens components, multi chips and more than a hundred wires on the substrate. Low yield often happens in assembling process when introducing a new product or process and it is difficult to find out the root cause in such a sophisticated and highly integrated MCM IC. In this project, low yield problem for a new MCM IC assembling process was analyzed and solved by using TRIZ systematic procedures. The Function Analysis (FA) diagram described the relationship of the components and devices in the MCM package. In the FA, we used FA for device to analyze the total system of MCM and FA for process to analyze the MCM assembling process. CECA was used to figure out the negative factors including target factors and key factors. The CECCA was used to locate contradictions in order to get a clearer picture of the root cause problem of the MCM assembling system. Finally we used FA-solution directive to solve the problem of the process and improve the yield. At the end, the yield problem was resolved from almost 0% to 99% saving millions of NT Dollars for the new product introduction. This project presents a systematic procedure to solve the complex system.

Key words: MCM, SiP, substrate, yield, TRIZ, FA, CECA, CECCA.

1. Introduction

In the advanced semiconductor industry, complex package is used massively in a variety of ICs. In the complex MCM packaging process, low yield happens in assembling process. We use a series of systematic methodology to analyze the problem and find out the root-cause efficiently.

This paper presents the Function Analysis (FA) diagram, which describes the relationship of the components and devices in the MCM package. In the FA, we use FA for device to analyze the total system of MCM and to analyze the MCM assembling process. We used CECA to figure out the negative factors including target factors and key factors. The CECCA were used to locate contradictions in order to get a clearer picture of the root cause problem of the MCM assembling system. Finally we used FA-solution directive to solve the problem of the process and improve the yield.

At the end, the yield problem was resolved from almost 0% to 99% saving millions of NT Dollars for the new product introduction.

2. Package Assembling Process

2.1 Main Functions and Constraints of the System

The assembling system discussed in this research is a Multichip Module IC assembling for a wireless Audio Application. There are 5 chips (ICs) built in a single package. The assembling processing includes passive components SMT, die bonding, wire bonding, and molding. The yield of wafers (chips) and SMT process quality affect the total yield of assembling. And the ICs cannot be 100% good in real world. Therefore, the assembling yield could be 99% x99% x99% x 99% x 99%=95%. Yet that is an acceptable yield in the RF products.

However, if there are some mistakes in processes, the yield will be very low. Since the cost of wafers is very high, we need to find a good way to increase the assembling yield. It is a very important way to make profit and fulfill customer's delivery schedule.

2.2 Purpose of the Systematic System

The processes of assembling include PCB fabrication, SMD on the PCB substrate, die /wire bonding, molding, baking, laser marking and singulation (chip sawing). After the assembling processes, we need to do final test to screen out bad products. In this study, a 2.4 GHz audio MCM IC was assembling and we will use TRIZ to improve low yield problems.

The IC is a high value product which contains 5 chips and 46 passive components with 146 Au-wires. So, it is very important to maintain high assembling yield. However, many elements, such as Chip yield, SMT yield, die bond, wire bond, and molding quality, may affect the assembling yield. Our target assembling yield is 95%. There are 3 CMOS chips and 2 GaAs chips in this SiP. The CMOS wafers are all probed, but the GaAs wafers are not probed because they are for high frequency RF application.

The probing process is difficult and expensive which uses high frequency RF equipment and testing system. There are 46 passive components on the BT substrate. The SMT process will cause loss as well. Die bond and wire bond will fail in certain degree. Thus, it generates yield loss after processing. If the yield can be 95+%, the assembling process will be recognized as a proper process. The yield loss of assembling comes from a set of workings such as: SMT, die bond/wire bond, molding, Laser Marking and IC molding. If we can add some kind of inspection steps to the process, it will guarantee high yield (optimum 98 %+) in the process.

During the Chinese New Year holidays in 2013, our company lost 15000 pcs of SiP IC at an yield of 0%. After checking the test results, we found the problem was chip failure. We checked the surface of the chips, using Microscope under 2000 X. We found there were some pouched holes on the chips. How did it happen? Who did this? The priority here is to find out what caused the holes on the chips and try to retrieve a yield of 95% because customers are waiting for the IC to delivery of our final product.

Table 1. MCM assembling flow

Flow	Description
Substrate	Substrate can be laminated poly-glass or ceramic (LTCC).
Solder past	Solder paste contains 95% Tin and 5% antimony alloy with 0.5% flux.
SMT passive com	Passive components-Resistors, Capacitors and Inductors. Their compositions are ceramic powder with metal terminals.
Reflow	Reflow system using electro-thermal paste dissolves into Tin, passive components are attached to the base plate of metal welding points.
Baking	Baking removed the water within the electric baseboard.
Die bond	Die bond is that an IC chip with silver adhesive bonded on the die paddle. The silver epoxy is 99% silver powder and 1% Binder.
Curing	Baking: the silver adhesive is curried.
Plasma Clean	Plasma cleaning: using argon gas-free electronics, impacting the chip surface achieving the clean results.
Wire Bond	Wire bond: use of ultrasound energy and heating to weld gold wire on chip and substrate.
Vision Checking	According to customer's requirement and specification entitled inspection of product quality.
Molding	Molding: black plastic coating on the chip to reaches proofing and protective effect, Black gum's main ingredients are ceramic powder and charcoal powder to protect the know how in the IC.
Baking	Baking: Using the oven to cure the molding compound material to protect IC.
Laser Marking	Laser marking (Print): with white ink or laser marking to indicate product number and manufacture date on the product.
Singulation	Singulation: saw the substrate into small pcs using cutter and tools.
Testing	Testing: before tape and reel, we need to test based specs.
Tape and Reel	Tape and reel (Packing): pack the single unit piece by piece using plastic tape.
Dry Pack	Vacuum and Dry packing with MSL indicator
Delivering	Shipping: finished products through inspection, packing and transport.

2.3 Constraints

In the system, we need to face two constraints, namely business constraint and technical constraint, and put them into our consideration. The key processing is die bonding.

The business constraints are:
(1) The cost for RF wafer probe is high.
(2) It needs more human power if we add steps to the process to double check.
(3) In a mature IC assembling factory, the final yield is expected to be higher than 95%.

The technical constraints are:
(1) The subcontractor is the one who is responsible for the process in packaging house.

The IC designer has no right to check the assembling processing in the factory.

(2) After molding, there is not a chance to fix the IC because the parts and dies are covered by the molding material.

The two constraints were brought up in the following analysis.

3. Analysis and Procedures

The procedure has 4 steps: defining, selecting tool, generating solution and evaluating. The defining stage is to analyze the problem (case) and then select the right tool to solve the problem.

In the current study, we used the systematic procedures from TRIZ tools which systematically check all the affected parameters step by step.

- The tools are:
- Function Analysis
- Interaction Matrix
- FA diagram
- All of function disadvantages
- Cause Effect and contradiction Chain Analysis
- Sub fields Analysis
- Patent and Web Search
- FOS

In the case presented in the paper, the process is a complete MCM/ SiP IC assembling, which includes PCB SMT, plasma clean, die bonding, curing, wire bonding, molding, aser marking, and sawing. After detailed analysis we found the key problems lied in die bonding. We will present and analyze the key part of the process: die bonding in the following sections.

3.1 Function Analysis (FA) for Die Bonding

FA is the abbreviation of function analysis. It separates the components in order to figure out the relationships among components. Which of them are targets? Which of them are tools? Which one of them is the main function? Which one of them is the auxiliary function? Which are positive and negative functions? Those harmful, excess, and insufficient functions are all categorized as negative functions. From negative functions and other related functions, we can find contradictions and easily focus on the problems.

Table 2. Function Analysis for die bonding

System: die bonding process			
System Components		**Super System Components**	
Die Collet		PCB with SMD	
Preciser		Conductive Epoxy	
Die Bonding Nozzle		Die	

In the Super System, there are components such as PCB with SMD, conductive Epoxy, and die. The System components are Die Collet, Preciser, and die bonding nozzle.

- Interaction Matrix of bonding processing

Through FA, we found out the interactions between components. Based on the FA, we built an interaction matrix of die bonding processing. It shows the interactions between components and their way of interacting.

Table 3. The interaction matrix of bonding processing

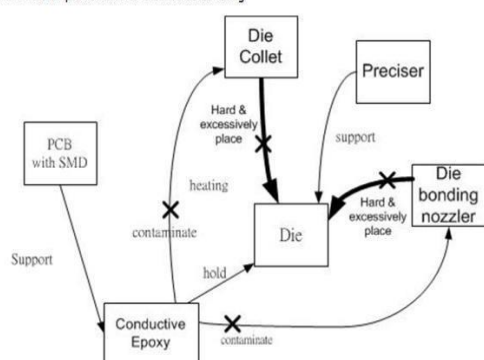System: Yield Improvement for MCM IC
+: interact
-: No relation

From-To	Die Collet	Preciser	Die Bonding Nozzle	PCB with SMD	Conductive Epoxy	Die
Die Collet	X				+	+
Preciser		X				+
Die Bonding Nozzle			X			+
PCB with SMD				X	+ support	+
Conductive Epoxy	+ contaminate		+ contaminate	+ dispense	X	+ attach
Die	+ Pick and force	+ support		+ support	+ attach	X

Table 3 shows the positive and negative functions including contaminate, dispense, attaché, support, pick and force.

- FA for die bonding process

We transferred Table 2 into Figure 1: function analysis diagram for die bonding process, in which the relationships between components listed in Table 2 were shown in detail.

Fig. 1. Function analysis for die bonding processing

"X": harmful interactions, "➡": excess interactions, "----➤": insufficient interactions.

● All Function Disadvantages

Disadvantages or problems and noted types (harmful, excess, and insufficient) are presented in Table 4.

Table 4. All function disadvantages list

Notes: H: Harmful, E: Excess, I: Insufficient.

● In Figure 2, a CECCA diagram is drawn based on the Cause Effect and Contradiction Chain Analysis in Table 4. CECCA can be used to distinguish and find out the key negative factors in the engineering system. From the target problem, we can, step by step, trace out the negative factors until the target factors of origin are located.
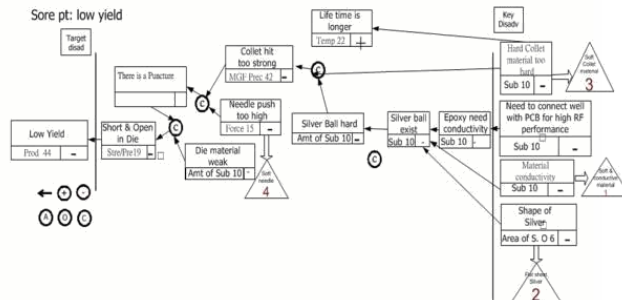
Fig. 2. Cause Effect and Contradiction Chain Analysis Diagram

The target disadvantages and the means to solve the disadvantages are figured out from the analysis in Figure 2.

3.2 Physical and Engineering Contradictions

As we mentioned above, there are contradictions between components. We analyzed them from physical and technical points of view.

● What is the engineering contradiction?

If we use the collet and the nozzle, **then** the chips are successfully picked up. **But** are they vulnerable to particle contamination? (Manufacture)

● What is the physical contradiction?

To have a high performance, **we need to use** collet and nozzle. **But**, **to have endurance** of the system, **we don't want** to use collet and nozzle.

Therefore, we looked into 40 Principles Extend Edition and we found the solutions to solve these problems and contractions.

Table 5. Solutions suggested by 40 Principles Extended Edition

Worse/ Improve	Performance
Harmful emissions (contamination) Other harmful effects generated by system	35 Parameter changes 24 Intermediary 18 Mechanical Vibration 28Mechanics Substitution 19 Periodic Action 15 Dynamization 4 Asymmetry 33 Homogeneity 3 Local Quality

- What is the engineering contradiction?

If picking up the die is necessary, **then** we need to use a nozzle. **But** it is difficult to do so because the dies will be damaged.

- What is the physical contradiction?

An industrial plastic nozzle is usually more durable.

However, if we want to prevent the dies from damage, it is recommended not to use an industrial plastic nozzle.

Table 6. Solutions suggested by 40 Principles Extended Edition

Worse/ Improve	Performance
Control Complexity Manufacture Precision Productivity Manufacturability Measure Precision	1 Segmentation 2 Taking out/ Separation 3 Local Quality 4 Asymmetry 15 Dynamization 25 Self-Service 28 Mechanics Substitution 35 Parameter Changes 37 hermal Expansion

3.3 Sub-Fields Analyses

Sub-fields is a tool to analyze the relationship between Target and tool. And we found out four ideas 5, 6, 7, and 8 to improve our problems.
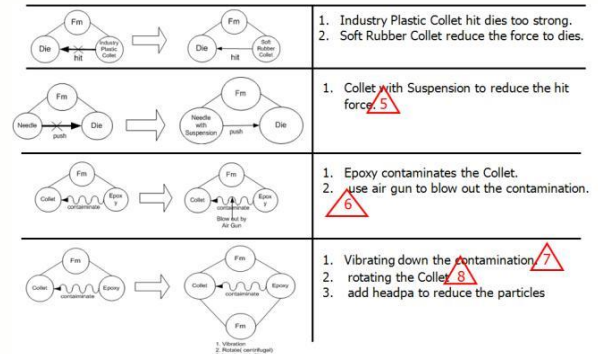
Fig. 3. The analysis using sub-fields to solutions

3.4 Patent and Web Search

Figure 4 is a combination of patent search, in which the whole thinking process is shown.

CONTEXT Words + Constraints
Search commands: Epoxy particle contaminated die, epoxy particle contaminated collet, silver ball hit die, collet mater too hard, need push too hard
Based on classification of USPatents (http://www.uspto.gov/web/offices/ac/ido/oeip/taf/ g s_list/class _name_gov.htm) 1. Increase electrical conductivity 2. Decrease hardness 3. Clean particles (solid) 4. Die bonding ball 5. Collet surface

Fig. 4. A structure of patent search

The steps in Figure 4 lead us to the following patent search results in Table 7:

Table 7. Patent search results

3.5 Function Oriented Search

The key problem which needs to be solved in the die bonding process is that: if we want to achieve an assembling yield over 95%, a conductive epoxy is usually needed to well hold the Chips on to the PCB.

But the conductive epoxy will contaminate the Die Collet and the Bonding Nozzle which causes damage (harm) to the Chips and leads to product failure. The Specific key function of the system is to bond small Chips onto the PCB. But consideration should be given to design specification, diamond saw specification, selecting materials, parameter setting, and contaminations. The required parameter (value ranges) is that Overall Yield must be over 95%. Precision, type of materials, high frequency, materials must be held and joined solidly. The generalized function is Multichip Module IC to be assembled on a single substrate and the overall Yield is expected to be over 95% after final test. A die bonding machine in IC packaging, made by The ID Possible technologies & Leading industry, comes with various types of Collet, some of which are made of steel while others are made of industrial plastic or soft rubber material.

3.6 Search Function Data Base and Patent Data Base

The data bases used in this study for function finding are listed below.
http://www.oxfordcreativity.com
http://function.creax.com/
http://www.triz.co.kr/TRIZ/frame.html
Patent Search web sites
http://patft.uspto.gov/   (USA patents)
http://ep.espacenet.com/   (European patents)
http://www.google.com/patents (free)
http://www.freepatentsonline.com/ (free)
http://www.runride.com/patent/pat_info_all.asp
(Taiwan+Japan+China Patents)
http://twp.apipa.org.tw/default.asp
(Taiwanese Patents)
http://www.patent.org.tw/
http://www.twpat.com/webpat/
http://www.ipdl.ncipi.go.jp/homepg_e.ipdl
(Japanese Patents)

● Original Functions
(1) Surface recovery of contaminated deposition tools.
(2) Suspension design for high shock performance die bonding.
(3) Collet head for placing machine.

● Basic Functions
(1) Surface recovery of contaminated deposition tools.
(2) Suspension design for high shock performance die bonding.
(3) Collet head for placing machine.

● Effects
(1) To prevent contamination in Collet.
(2) To reduce hit by Collet with silver ball.
(3) To change the Collet head with softer surface.

● Specific Approaches
(1) By using centrifugal fan with specific frequency in order to remove attached particle on Collet.
(2) A design of specific machine with air compressed pressure to reduce the contact between silver bonding ball and the die.
(3) Using different axis of design and different material to find the best Collet for semiconductor assembly line.

After summarizing the above discussion, the study comes up with some ideas for improvement.
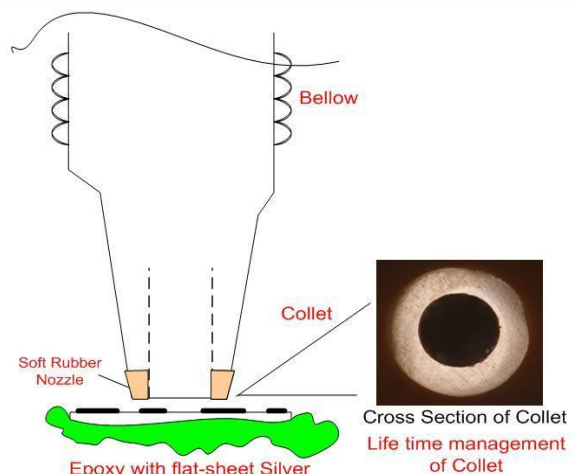
Fig. 5 Ideas to solve the low yield problem

4. Photos Show the Damages on Dies

To check dents, a microscope under 200x and 500x was used and Figure 6 shows that the die was punched.
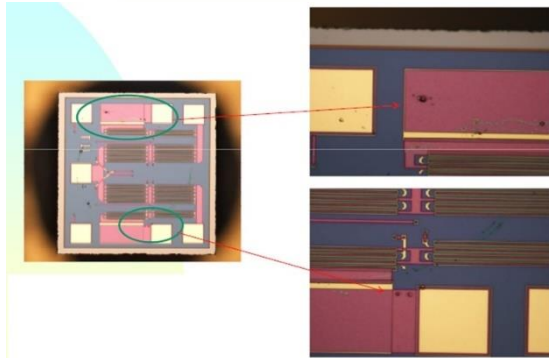

Fig. 6. The die was damaged under microscope

The two photos in Figure 7 are from two different dies. We can see the punched dents occurred in the same place on the surface of both dies. It means the picking nozzle damaged the dies under same nozzle.
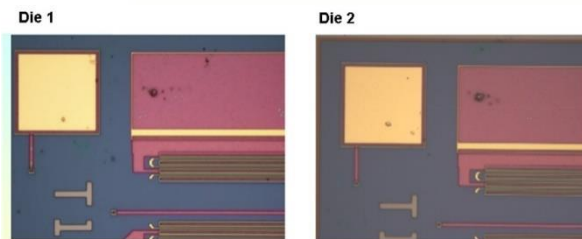
Fig. 7. Two dies were damaged with the same phenomenon in the same place

There are some craters on the tip of nozzle which punches the dies while picking them up.
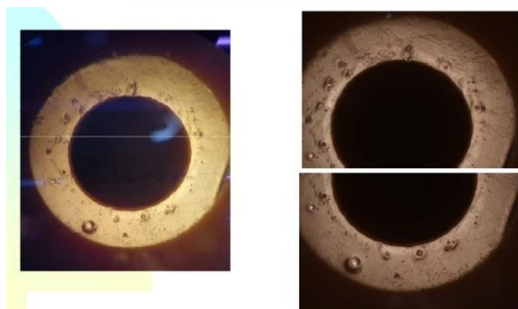
Fig. 8. The tip of Collet (Nozzle) has some craters damaged by silver balls in conductive epoxy.

The photo shows the punched holes completely matched those craters on the nozzle.
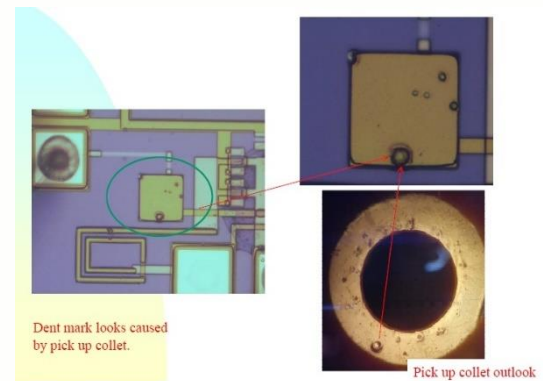
Fig. 9. The dent is matched with the tip of Collet damaged by silver ball.

The photo show that the crater was not punched through. It means it was not damaged by ESD.
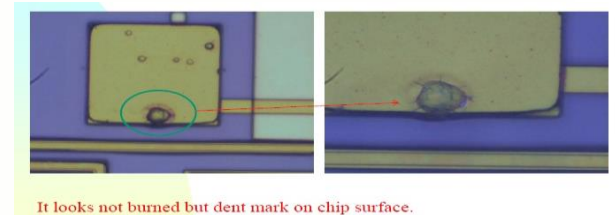
Fig. 10. The dent mark in the chip surface was punched by collet.

The circle on the die (right side) matches the tip of collet.

Fig. 11. The circle matches the round-shape of the Collet tip

5. Sip Process Improvement and Actions Taken

In order to improve the assembling process, we need to update SOP to achieve high yield to reduce the cost. Therefore, the lot size is restrained to lower the risks. The standard size was limited to 1000 pcs/ lot.

Table 8, Table9, and Table 10 describe the changes to MCM/SiP assembling process. These changes are designed to prevent the catastrophic failure during the assembling of the SiPs.
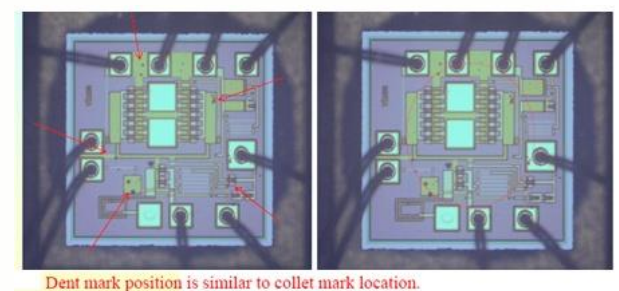
● Nozzle and Collet lifetime management (Table 8)

● Nozzle and Collet inspection schedule (Table 9)

● Die visual checking after die bonding (Table 10)

Table 8. Nozzle and Collet lifetime management

Nozzel (Collet) lifetime

Implementation date:	April 22, 2013	
Required Documentation	SOP that describes the lifetime policy of all collects used on the die bond machine.	
Requirement:	Each collect used on the die bond machine has a defined replacement schedule. The lifetime in time or placement are as follows:	
	Collet used on U4 and U5	Time: 6 months Placements: 200,000
	Collet used On U1	Time: 6 months Placement: 200,000
	Collet used on U2	Time: 6 months Placements: 200,000
	Collet used On U3	Time: 6 months Placements: 200,000

Table 9. Nozzle and Collet inspection schedule

Nozzel (Collet) Inspection Schedule

Implementation date:	April 22, 2013	
Required Documentation	SOP that describes the inspection standard and schedule of each collects.	
Requirement:	Each collect must be monitored for damage. If damage is found the tip must be polished to ensure the surface is smooth.	
	Inspection Frequency	**If fail in die visual inspection.**
	requirement	Acceptance surface:

Table 10. Die visual checking after die bonding

Die Visual Inspection after Diebond

Implementation Date:	April 22, 2013	
Required Documentation	SOP that describes the inspection standard of each die after it has been bonded.	
Requirement:	after die bonding a sampling of each die is visually inspected for surface damage after being mounted on the PCB.	
	Inspection Frequency	1. Inspect the dies surface at 1st article. Sample size 5 SiPs 2. After 1st inspection, check it using microscope once per 500 pcs. Sample size 5 Sips.
	Requirement	No any die damaged.

Example Inspection Criteria:

備註：若有晶片外觀NG，利用無塵布清潔collect，再次點晶確認晶片外觀。
若仍有瑕疵或異常,請退機放,通知製程工程師確認
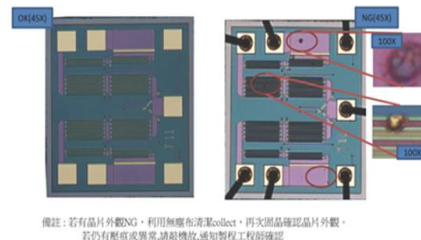
6. Discussion and Conclusion

After we used TRIZ processes, we made great improvement by the following changes:
● Industry Plastic Collet is changed to Soft Rubber Collet.
● Particle control and Collet life checking management are taken.
● Silver-Ball Epoxy is changed to Flat-Sheet conductive epoxy.
● Change thickness of Gold Plating to improve wire bonding.
● Adjust the wire bonding machine's ultrasound power and temperature.
● Change air vent to seal leaking of molding compound.
● Adjust the doping of molding material to change the expansion and extraction characteristics.
● Dicing saw life management.

The contribution and positive impact for the company:
● 15,000 pieces of good products were lost during the Chinese New Year Holiday in 2013 and the total material loss was NTD1.5 million. The delivery schedule to our customers was delayed by two months.
● We solved the MCM problems within 3 days using TRIZ systematic method; otherwise, we would have spent two weeks tracking down the cause of the damage.
● Improve the yield up to 97%.

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Dongliang, Daniel Sheu is a Professor at National Tsing Hua University in Taiwan since 1996. Before then, he has 9 years of industrial experience in the electronic industries with Hewlett-Packard, Motorola, and Matsushita. Daniel received his Ph.D. degree in engineering from UCLA and MBA degree from Kellogg Graduate School of Management at Northwestern University. He also holds a B.S.M.E. degree from National Taiwan University and an M.S.M.E. degree from State University of New York at Buffalo. He is currently the President of the Society of Systematic Innovation and Editor-in-chief of the International Journal of Systematic Innovation. His areas of interests include Systematic Innovation including TRIZ, Design & Manufacturing Management, Equipment Management, and Factory Diagnosis.

Appendix 1: Terminology List

	Term	Full name	Descriptions
1	Curing Oven		molding material baking oven
2	Laser Machine		for laser marking
3	Mold Chase		to shape the IC
4	Epoxy curing Oven		Oven for heating the epoxy
5	Die Colet		A nozzle for picking up dies from wafer
6	Preciser		A plate for aligning the orientation of die
9	Die Nozzle		A nozzle for picking die to bond on PCB
7	Molding Material		Plastic material to cover parts on substrate
10	SMD	Surface Mount Device	Surface mount device
11	Conductive Epoxy		Material gluing the die and PCB
12	Dispenser		A machine spreading glue on PCB
13	Solder Past		A liquid type of Tim to connect the SMD and PCB
14	PCB	Print Circuit Board	Print circuit board
15	Au Wire		Gold wire
16	Diamond Saw		a sawing machine with Diamond cutter
17	SiP	System in package	An integrated multi-chips on a single carry as an IC
18	MCM	Multi-chip Module	An integrated multichip as module but IC outline
5	LTCC	Low temperature co- fired ceramic	Ceramic substrate
6	Molding		The processing of compound material covering on the IC
7	MCU	Main Control Unit	A central unit for a computer system
8	RF	Radio Frequency	Radiated wave which carries signal
9	Transceiver		A part who plays transmitting and receiving
10	yield		The percentage of good and bad rate
11	SMT	Surface Mount Technology	The technology of Soldering the Surface-mount device
12	Curing		After molding, the material was baked for solidating

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