# Developing An Innovative Design Processes of Su-Field Modeling

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*Abstract: TRIZ is a systematic method for providing valid suggestions to meet the requirements of inventive steps. Su-Field analytic method, deduced from TRIZ method, is one of the inventive problem solving tools that can be used to analyze and improve the efficacy of the technological system. By possessing a symbolic system and transformation rules, the Su-Field analysis model can assist designers to diagnose and solve most design problems. This study proposes an innovative design and problem-solving process, based on Su-Field modeling method integrated with extension of matter-element.*

*This research tries to develop a innovative process by introducing "transformation and extension methods of matter-elements" into the Su-Field modeling procedure to improve the efficiency and extent of concept evolutions. We make use of extensibility of matter-element to exchange the descriptions of design problems and solutions into creative fields. The concrete result includes, Proposed the flowchart of extensible innovative design process. The differences and benefits between Su-Field modeling procedure and matter-element modeling procedure are also evaluated. Assess possibility and advantage to combine construction of symbolic system in Su-Field model and the transformation and extension of matter-elements. Introducing concept extension and transformation of matter-element into symbolic developments, more creative solutions can be derived. Besides, some interrogative sentences are proposed to provide the designer facilitate tools while operating transformation methods. Two innovative design cases, staple free stapler and manpower-drive vehicle, successfully demonstrates that the proposed design process is feasible and efficient.*

*Key-Words: TRIZ, Su-Field, Matter-Element, Extension theory.*

## 1 Introduction

Through creative education, the designers' abilities of innovation and problem solving will be increased so that the management and research abilities of enterprises will also be improved. Possessed innovation ability, no matter engaged in any trade and office, can all promote working efficiency and innovative pattern. Thus, develop the suitable innovative method become the most urgent need. TRIZ, providing the guidance to invention, is such a systematic method to meet demand.

Before cold war era between east and west, the research of TRIZ has been the state secret as Soviet Union. But TRIZ method is wide for western countries gradually knows after the disintegration of the Soviet Union, and become the method that the extremely authoritative innovative problem solving. TRIZ is TIPS (Theory of Inventive Problem Solving) Russian synonym word, it means whether it is the methods of question to answer, Savransky (2002) Think TRIZ method is that a answer based on human knowledge invents the question systems approach, Altshuller (the father of TRIZ) [1] Have explained the deduction course innovated and invented in detail. Yung-Chin Hsiao [2] point out that the engineers still adopt Brainstorming method to create new idea although lack of systematic procedure, limitation of engineers' knowledge base, engineer's psychological obstacle and so on are the shortcomings of Brainstorming method. In the design process of innovation, limitation of designer's knowledge field, habitual thinking course, is the obstacle appeared in innovation procedure, especially using the open thinking methods. The TRIZ method can assists the designer in the concept development stage to expand to the knowledge domain that oneself is not skillful at, and has provided a systematic design procedure to define the design problem more distinct and get the innovative idea in design processes.

# 2 Innovative Problem-Solving Method

## 2.1 TRIZ and Su-Field Analysis Model

Scholar Savransky [3] who studies TRIZ method think TRIZ method is that a systematic method for inventive problem solving based on human knowledge. TRIZ is a problem solving method based on logic and data, not intuition, which accelerates the project team's ability to solve these problems creatively. TRIZ also provides repeatability, predictability, and reliability due to its structure and algorithmic approach. "TRIZ" is the (Russian) acronym for the "Theory of Inventive Problem Solving." G.S. Altshuller and his colleagues in the former U.S.S.R. developed the method between 1946 and 1985. TRIZ is an international science of creativity that relies on the study of the patterns of problems and solutions, not on the spontaneous and intuitive creativity of individuals or groups. More than three million patents have been analyzed to discover the patterns that predict breakthrough solutions to problems.

Liu and Chen [4] proposed that one also can make use of innovative rule of TRIZ to improve the project characteristic of the system or solve the engineering problems while under such condition that the systematic contradiction information is unknown. The rules, the more often to be used for solving the innovative problem, indicate to be the higher grade rules. Thus, it would be possible of success of solving problem while adopt the higher grade rules.

In the relevant research of the Su-field method, Terninko( 2000) introduced the operating procedures of Su-field analysis model in detail. Some design examples successfully demonstrate that the Su-field analysis model and corresponding 76 standards solution by Terninko, Domb and Miller(2000). Ko (2006) presented an eco-innovativeproblem-solving design process based on utilizing TRIZ Su-field model and 76 standard solutions. The design case study successfully demonstrate that the proposed process is a feasible eco-innovative process. Mao (2007) proposed that the 76 standard solutions can be summarized/condensed into seven general principles with graphic demonstrations and examples.

The experts familiar with TRIZ will use the Su-field analysis method to analyze the effect relation between the components within system, but often employed contradiction matrix method instead of Su-field method while innovating and designing actually. And also has some scholars to have the negative appraisal to this method, they thought that the Su-field method is worthless, but also had some scholars saying that the Su-field method was not well enough. Therefore, in this research, we hope to improve the incomplete properties and feasibility of Su-field method by integrated with extension method, in order to provide perfect approach in each field.

## 2.2 Matter-Element and Extension Method

Matter-element and extension method, a powerful tool to systematically analyze concrete or intangible products, has been developed by W. Cai in 1983. Extension Theory is a course to study the extensibility, extent rules, performing procedure of matter and try to employ to resolve contradictive problems.

The extension method was derived from the extension theory that involves the matter-element theory and extension mathematics. The major research subject of extension theory is incompatible problem in the real world. The expression make qualitative and quantitative analysis mixed, describing the real world further and visually, providing another way of resolving contradictions. Its applications and research have already extended to each field, including business, management, engineering, economics, sociology, strategy, etc. [5~7]

# 3 Extensive Procedures Method with Su-field Model

This research tries to develop an extensive process of innovative design. Confined solution can be extended by applying the transformation rules and "extension of matter-element" with the Su-Field modeling procedure to improve the efficiency and extent of concept evolutions. We make use of extensibility of matter-element to exchange the descriptions of design problems and solutions into creative fields.

Every technological system can be considered to be a kind of network formed by a lot of subsystems carrying out their particular tasks specifically, so, every system has its subsystems, the subsystem can be subdivided further, until the micro level (Microlevels)

### 3.1 Symbolic System of Su-field Model

A graphical model of a minimal working technique in TRIZ is called Substance-Field, or Su-Field. Su-Field Analysis is an instrument for modeling the most important parts of TS and TP (technical systems and technological processes) for the particular problem and identifying the core of a problem related to this technique. Su-Field models and Su-Field Analysis, created by G. S. Altshuller, provide a fast, simple description of subsystems and their interactions in an operation zone and period via a well-formulated model of the technique in which all subsystems, inputs, and outputs are known or can be quite easily determined. Any technique can be presented as the ordered set of Su-Fields. [8]

As any model of nature, society, or technique, a Su-Field model has some simplifications and conditional agreements, which are described in this section. The term substance (S) has been used in TRIZ to refer to a material object of any level of complexity. S can be a single element (bolt, pin, cup) or complex system (car, spacecraft, or mainframe computer). The states of substances include not only the typical physical states (i.e., vacuum, plasma, gas, liquid, and solid) but also a large number of in-between and compound states (such as aerosol, foam, powder, gel, porous, or zeolit) as well as those states having special thermal, electrical, magnetic, optical, and other characteristics (thermoinsulators, semiconductors, ferromagnets, luminophor, etc.). Substance is itself a hierarchical system. Altshuller and his colleagues, the researchers of TRIZ, graphically represent a Su-Field model as a triangle. According to TRIZ, the rationale of creating a Su-Field model is that a system, with the ultimate objective to achieve a function, normally consists of two substances and a field. The term S1 is used to represent an object that needs to be manipulated. The term S2 is a tool to act upon S1. Both substances can be as simple as a single element or as complicated as a big system with many components, which can also be explained by individual Su-Field models.

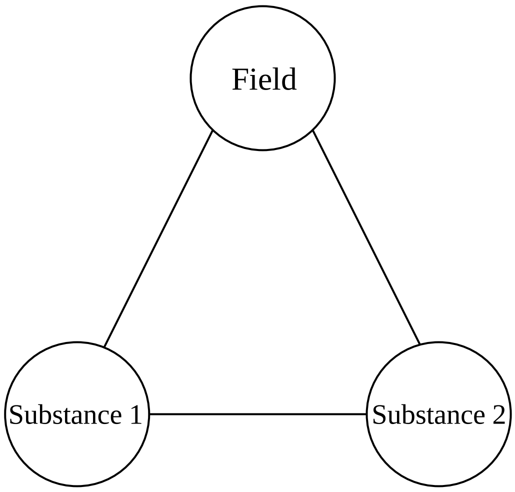


Fig 1. Basic Su-field Model

The term field (F) has been used in TRIZ in a very broad sense, including the fields of physics (that is, electromagnetism, gravity, strong and weak nuclear interactions). Other fields can be olfactory, chemical, acoustic fields, etc. A field provides some flow of energy, information, force, interaction, or reaction to perform an effect. The presence of a field always assumes presence of a substance, as it is a source of the field. Altshuller graphically represent a Su-field model as a triangle. This is a simple and ingenious way to explain a technical system. The minimum technical system was found to consist of a field (F) and two substances ($S_1$ and $S_2$). (See Figure 1.)

Su-Field symbols mirror relationships between the subsystems of a technique. The Su-field model supplies nine connections to describe the relationships among $S_1$, $S_2$ and F; and these connection symbols are shown in Table 1.

It is common practice to place the F symbol above substances for an input field, and below the symbols of substances for an output field. The most important two kinds of connections are “Useful Effect” and “Harmful Effect”, as shown in Figure 2.

TABLE 1 Symbols of connections in Su-field analysis

| relationships | connection symbols |
|---|---|
| Desired Effect | ⟶ |
| Insufficient Effect | - - - - → |
| Harmful Effect | ⇝ |
| Field types | Ftype |
| Useful Effect | U |
| Harmful Effect | H |

Other possible states are: The effect needed has not taken place, caused harmful effect and required effects are insufficient. Besides, in technological conflict, the connecting effects are: 1.Conflict between two subsystems in a system; 2.set up useful effect in a certain subsystem and lead to harmful effect in another subsystem; 3.dispel the harmful effect in a certain subsystem, cause the damage on the useful effect of another subsystem. 4.Strengthen the useful function or reduce the harmful effect, cause unacceptable complication in system or another subsystem.

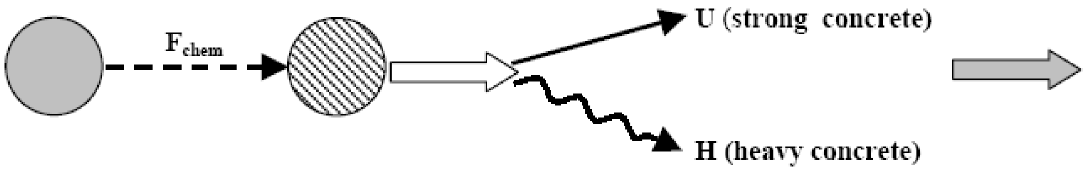


Fig 2. Symbolic representation of useful and harmful effects [9~11]

## 3.2 In what circumstance should we use Su-field method

In the algorithm of TRIZ, it proposed that Su-field method can be used to solve problem while ideal innovation cannot be obtained by utilizing contradiction matrix. Su-field method can be used to analysis the effects on the elements or subsystem what we are absorbing. Usually, we focus on the components needed to be improved or with valueless function. Therefore, a fast and simple model will offer different thinking directions to a designer. Wang [12] proposed that the components needed to be improved can first be symbolized to simplest structure by Su-field method, analyze the unsuitable parts and then guide to standard solutions along different thinking directions.

## 3.3 Problems in Current Standard Solutions

Once a technical system is simplified into a Su-field model, its potential problems can be identified through analyzing undesired interactions resulted from the model. Problematic Su-field models may be fixed by exploring the underlying ideas that generated previous patents. Based on their intensive research of a huge number of patents, Genrich Altshuller and his colleagues identified 76 standard solutions to fixing problematic Su-field models. These 76 solutions may be categorized into five classes:

- Class 1: Construct or destroy a Su-field (13 standard solutions)
- Class 2: Develop a Su-field (23 standard solutions)
- Class 3: Transition from a base system to a super-system or to a subsystem (6 standard solutions)
- Class 4: Measure or detect anything within a technical system (17 standard solutions)
- Class 5: Introduce substances or fields into a technical system (17 standard solutions)

[Generalized Solutions for Su-Field Analysis]

The major implements of using Su-field model for improving system characteristics are the improvement of the useful function and elimination of harmful function. Each adjustment and revision to the Su-field model or substances denotes the systematic transition or modification. The term “Standard,” introduced by G. S. Altshuller, means that a common “trick” to solve different problems results in very similar problem models. Altshuller proposed a system of 76 Standards in 5 different classes and illustrated each Standard by a few inventions. Once a system is symbolized into a Su-field model, its potential problems can be identified and the problematic Su-field may also be fixed by 76 standard solutions. This research will employ matter-element analysis and extension theory repeatedly, tries to integrating "extension of matter-element" with the Su-Field modeling procedure to improve the efficiency and extent of concept evolutions. Extension theory and method are the new science, for applying to the research on conceptual design of the products and innovative design is a new field. Extension methods, a new structure of the basic research, the further studies of its application are important and necessary.

### 3.4 Integrated Extension of Matter-Element and Su-Field Model

In this research, we will use the extensibility of matter-element to formalize and clarify Su-field model (substance or field) which is difficult to understand. The extension method can help people resolve problems separately by decomposing them, recombining the problems, and then searching for the feasible solutions, assist the Su-field model to extend and deduce concepts widely. While using the Su-Field method to realize innovative design, expansibility of matter-element can give extending design based on the advised solution providing by 76 standard solutions. Through the transformation, designers can conceive of other substituting matter-element models effectively and quickly to obtain various innovative design plans.

In the works of Savransky and Fey, there are the solution procedures presented for designer to search for suitable solution. However, the procedure is often so complicated, and is probably unfavorable to practice design. Typical performing procedure of Su-field model is to use basic transformation rules to assist to change problematic Su-field model following the built initial Su-field model. Obviously, in Su-field modeling processes, adequate change or innovate components of Su-field model can effective simplify problem. This procedure is the designer's challenge too. In this research, extension of matter-element has been introduced to assist extensive thinking so that the acceptable schemes and components can be obtained rapidly.

In addition, in general design processes, basic transformation rule 1, rule 2, rule 4 and rule 5 most often used by the designer. Rule 3 belongs to the problems in detection and measurement will not discuss in the research. In performing transformation, no matter what we introduce the new component, link multiple Su-Field triangles, extend the field or make use of the intermediary matter, by integrating extension of matter-element with Su-field model, the efficiency of developing creative concept will be improved effectively. Therefore, in this article, we will try to apply and integrate extension of matter-element with Su-field modeling, the corresponding procedures and properties are presented as follows.

First of all, as for the characteristics of product concept design, such as creativity, complexity, multi-objects, multi-scheme and uncertainty of the design inference, we will use theory and method of "extenics" to set up matter-element models and knowledge extensible expressions for proceeding the divergence and transformation of matter-elements. According to the advantage of extensibility, the possible solutions for design problems based on the proposed modeling method will be extended more widely and feasibly.

Savransky proposed five most important properties of Su-fields, as stated in property 1 and property 2, a subsystem as an incomplete Su-Field component, any of its characteristics can be changed or by adding a new component to get a complete Su-field model. Relatively, different actions, which are applied to a Su-Field component, will cause transformation of other components. As proposed in basic transformation 1, to solve a problem, the missing component is introduced to the incomplete Su-field to make it complete. In basic transformation 2, in order to increase the efficiency of an existing Su-Field, its substantial component, since it is a tool, can be expanded into an independent Su-Field, connected to the initial one. (the obtained Su-Field is referred to as a chain one) As for basic transformation 4, it is advised that the most efficient way to destroy harmful, unwanted, or unneeded Su-Fields is to introduce a third substantial component that is a modification of one or both substantial components composing the given Su-Field. Obviously, by introducing the concept of matter-element and matter-element with multi-characteristics and regarding a substance of Su-field model as a matter-element, it will assist the creative thinking and innovation for problem solving. Matter-element and matter-element with multi-characteristics are defined as follows,

matter-element

$$R = (N(t), c, v(t)) \quad (1)$$

matter-element with multi-characteristics

$$R(t) = \begin{bmatrix} N(t) & c_1 & v_1(t) \\ & c_2 & v_2(t) \\ & \vdots & \vdots \\ & c_n & v_n(t) \end{bmatrix} = (N(t), C, V(t)) \quad (2)$$

Based on the divergence of matter-element, matter-element $R_0(N_0, c_0, v_0)$ can be diverged from one or two of $N_0$, $c_0$, $v_0$ to synthesizing different

matter-elements, to build a extending tree. Extending tree is a method for matter to extend outwards to provide multi-orientated, organizational and structural considerations.
An event is the interaction of matters and described as event-element. Basic elements for describing a event-element are constructed by verb (d), name of verb characteristic (b) and u, the corresponding measure about (b).
Event-element

$$\mathrm{I}(t) = (\mathrm{d}(t), \mathrm{b}, \mathrm{u}(t)) \quad (3)$$

Multi-dimensional event-element

$$\mathrm{I}(t) = (\mathrm{d}(t), \mathrm{B}, \mathrm{U}(t)) \quad (4)$$

There may be different relations among a certain matter, event and other matters, events; there is interaction between these relations, influence each other. The corresponding matter-element, event-element and other matter-elements, event-elements can be used to describe these relationships and interactions. Relationship-element is form by relationship name s(t), characteristics $a_1, a_2, \cdots, a_n$ and corresponding measure values $w_1(t), w_2(t), \cdots, w_n(t)$:

$$Q(t) = \begin{bmatrix} S(t) & a_1 & w_1(t) \\ & a_2 & w_2(t) \\ & \vdots & \vdots \\ & a_n & w_n(t) \end{bmatrix} = (S(t), A, W(t)) \quad (5)$$

The extensible properties of matter-element, event-element and relationship-element, comprising: divergence, expansibility, relevance and implication. While solving design problems based on Su-field model, diversity and creativity, the advantages of “extenics” method will be imported by implementing the extensibility of matter-element, event-element and relationship-element. Thus, the solution will not be limited by standard solutions but be inspired. A patent successfully demonstrate that the proposed innovative design process is feasible and flexible.

## 3.5 Transformation of Matter-Element

The processes of transform matter-element $R_0(N_0, c_0, v_0)$ into $R(N, c, v)$ or $R_1(N_1, c_1, v_1)$, $R_2(N_2, c_2, v_2)$, $R_n(N_n, c_n, v_n)$ are defined as the transformation of matter-element $R_0$, denotes as $TR_0 = R$. Replacement, decomposition, addition/deletion and expansion/ contraction are four basic methods for transformation of matter-element and to be conducive to exchanging or to synthesizing different matter-element.

### 3.5.1 Replacement

The name (N), characteristic(C) and value(V) of the matter-element can be replace by another one. It should be noted that replacement has to be employed according to the extensibility of matter-element.
Ask the question:
*“Is there any part can be replaced?”*
and think about any substituting part of your product/process for something else. ( such as: materials, components, etc.)

### 3.5.2 Addition or Deletion

Addition is to integrate two different matter-elements into a new one and denoted as $TR_0=R_0 \oplus R_1$, where symbol $\oplus$ is presented to integrate different matter-elements. Deletion is to remove some matter-elements and denote as $TR_0=R_0 \ominus R_1$ contrary.
Ask the question:
*“What principle, function, ideas, methods, modules, materials can be added or combined?”*
*“What would happen if I removed a component or part of it?”*
and think about relative matter-elements.

### 3.5.3 Expansion or Contraction

Expansion and contraction transformation is often used to modify the corresponding values of matter-elements.
Ask the question:
*“What happens if I diminish or exaggerate a feature or component?”*
And think about changing part or all of the current situation, or to distort it in an unusual way.

### 3.5.4 Decomposition

By decomposition transformation, the major matter-element can be decomposed into subordinate matter-elements.
Ask the question:
*“What would happen if I rearrange the existing order, location, composition, scheduling, element, type, character and effect?”*
And think about how to rearrange.
As shown in figure 3

## 3.6 Flowchart of Extensible Innovative Design Processes

Proposed extensible innovative design process is shown in figure 3. The major steps proposed in this paper is to utilize the transformation methods of matter-element. With the help of asking questions about replacement, decomposition, addition/deletion and expansion/contraction, designers can exchange or to synthesize different matter-element conveniently.

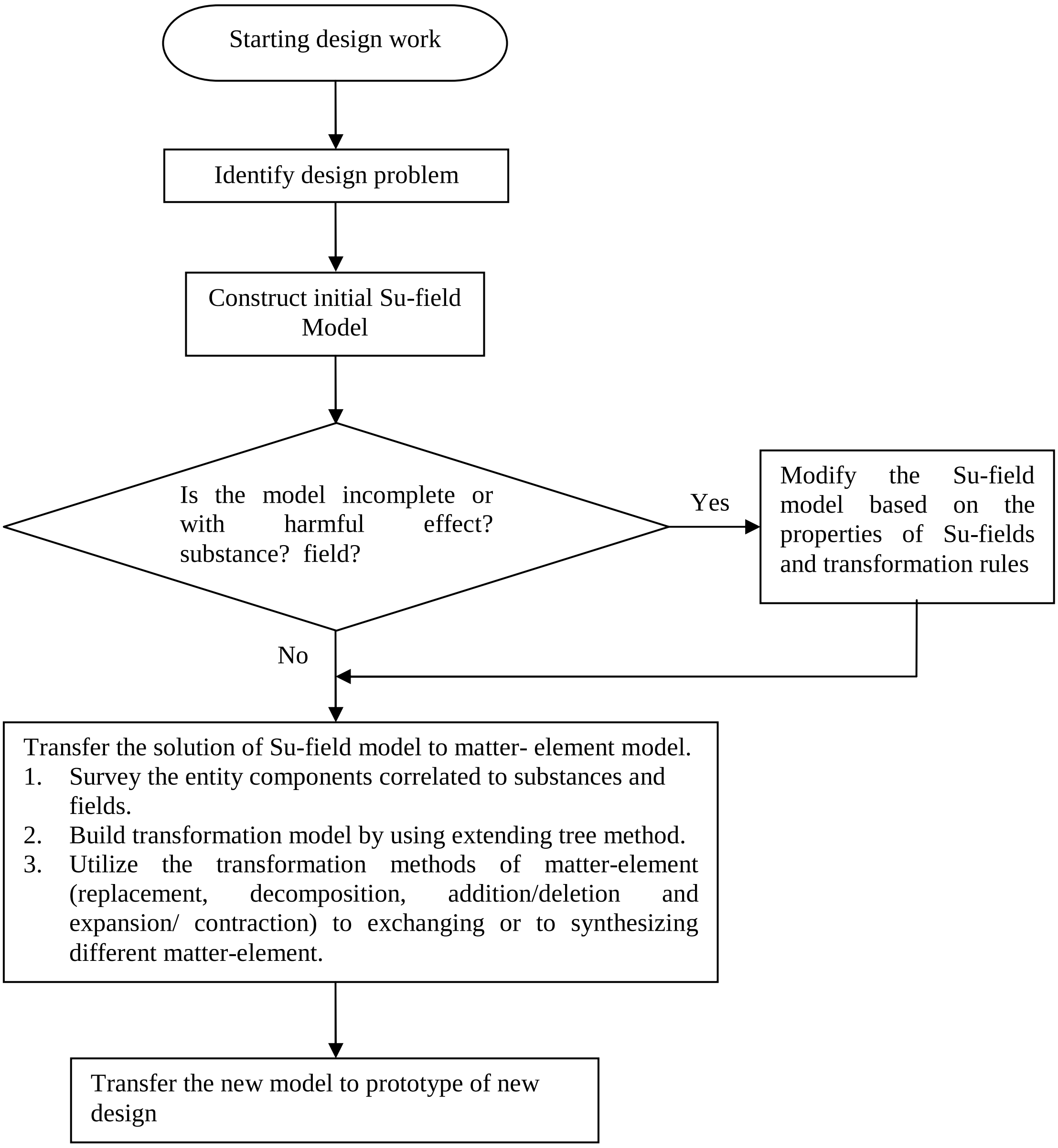


Fig.3 Flowchart of extensible innovative design process

## 4 Illustrative Design Case

In this research, two design cases "Staple free stapler" and "manpower-drive vehicles", are adapt to explain and verify feasibility of the proposed design procedure. Traditional staplers use metal staples to bind papers. However, metal staples have inconspicuous but serious impact to environment. Thus, it is imperious to develop a "Staple free stapler". Design problem: "How to dispel the use of the staple under the principle of not influencing the function --binding"

### 4.1 Su-field model related to design problem of Stapleless Stapler

At first, we construct initial Su-field model according to operation situation and function of the traditional stapler and the course correlated to staples. Su-field model of the traditional stapler can be illustrated at least 3 types. It is essential that the present Su-field model should be conformed to the design problem. It should be avoided to illustrating a Su-field model that is irrelevant to the design problem. Inadequate model will confuse designer and make the solution procedures too complicated.

In this case, the design purpose is green design, tending to reduce consumption of resources. Design problem, problem core wanted to break through is "How to dispel the use of the staple under the principle of not influencing the function—binding". Among the illustrated Su-field models, the model as shown in Fig.4 seems to be the most suitable one. As shown in Fig.4, $S_1$ represents the metal staple, $S_2$ represents the punch of stapler, and $F_{ME}$ represents a mechanical pressure. This description of Su-field model is that the punch ($S_2$) transmits mechanical pressure force ($F_{ME}$) to the metal staple ($S_1$).[13]

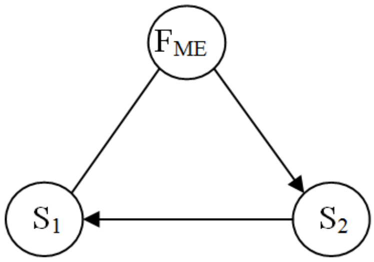

Fig.4 Su-field model (I) of the traditional stapler

The metal staple ($S_1$) is considered as the material component that harmful to environment. After eliminating it, this Su-field model becomes incomplete. Then, refer to 1st transformation rule, introduce a substance component (represent with $S_1$* here, in order to avoid confuse with the original material $S_1$) to fill up the vacancy of model, make it keep function that bind. Similarly, the substance S1' should bear the mechanical pressure ($F_{ME}$) force by the punch ($S_2$) on the stapler. After performing transformation, Su-field model is illustrated as Fig.5.

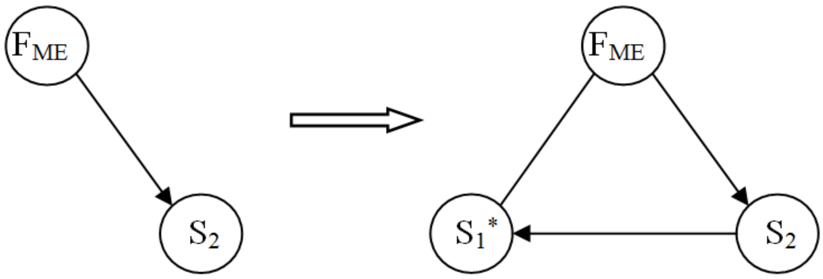

Fig.5 Add new substance to complete Su-field model

### 4.2 Integrated with Extension of Matter-Element

The following steps are to transfer Su-field model to design prototype:

1. Survey the entity component correlated to S1'. Besides the metal staple, we search for the replaceable subject by using the divergence of matter-element.
2. Use extending tree method to build the transformation model for staple: A matter refers to multi- characteristics, a characteristic also mapped by matters. Thus, “one matter with multi-characteristics”, “one characteristic maps to multi-matters” , “one value maps to multi-matters”, “one matter, one value vs. multi- characteristics”, “one matter, one characteristic vs. multi-values” are the extending propositions of matter-element to resolve contradiction. The extension of matter-element, staple, can be expressed as,

$R_1$ = ( N, $c_1$, $v_n$)
= (staple，material，plastic)
= (staple，material，rope)
= (staple，material，glue) ......etc.
$R_2$ = (N, $c_2$, $v_n$)
= (staple，binding method，staple binding)
= (staple，binding method，rope binding)
= (staple，binding method，glue binding)
......etc.

The extension of event-element,

$I_1$ = ( d, $b_1$, $u_n$)

= (binding，binder，plastic)
= (binding，binder，rope)
= (binding，binder，glue) ......etc.
$I_2$ = (d, $b_2$, $u_n$)
= (binding，objective，papers) ...... etc.
$I_3$ = (d, $b_3$, $u_n$)
= (binding，tighten effect，tight) ...... etc.
$I_4$ = (d, $b_4$, $u_n$)
= (binding，method，rope) ...... etc.

The extension of relationship-element (relationship-element could be the binder, objective, imposer, effect, structure,etc.)

$$Q=\begin{bmatrix} binding & binder & staple \\ & objective & papers \\ & imposer & punch \\ & structure & \cdots \end{bmatrix}=(s,A,W)$$

3. Utilizing the transformation methods, devises the new extensible model, and found the new concept: Once the extending tree set up, the matter-element obtained from the 1st level of extending tree should be evaluated whether it meets the demand of the new Su-field model or not. If the components, corresponding to matter-elements obtained from extending tree, cannot meet the design demands, design processes should proceed with the help of performing extension of event-element or relationship-element. Relatively, a new concept has occurred that we try to let the interaction "bind" to be carried out by the objective (sheets).

Using replacement, basic transformation, as we ask the question: *"Is there any part can be replaced?"*we can obtain that

$$R_0=\begin{bmatrix} staple & effect & binding \\ & impact\ to\ environment & great \end{bmatrix}$$

$$TR_0=\begin{bmatrix} rope & effect & binding \\ & impact\ to\ environment & great \end{bmatrix}$$

$$TR_0=\begin{bmatrix} glue & effect & binding \\ & impact\ to\ environment & slight \end{bmatrix}$$

$$TR_0=\begin{bmatrix} stapleless & effect & binding \\ & impact\ to\ environment & slight \end{bmatrix}$$

The new matter-element, stapleless, can also be transformed as "fastener", "magnetic fastener", "clamp"…

4. Draws out the new design problems based on the new concept and repeat the extending processes: After having this concept, we consider making the paper play the role of metal staple and then, design problem becomes "How to complete binding without using glue?" Therefore, restart the extending processes by taking a new matter "paper staple" and a new characteristic "binding method" to set up matter-element, event-element, relationship-element and extending tree. By the achievement, we obtain an idea, may consider that uses "fold-up type" the way to replace "binds".

5. Determine the processes of using "fold-up type" to realize the proposed idea. Finally, we have to solve the key problem induced by "fold-up binding" method to complete design. The key problem becomes "How to complete "fold-up binding" the movement at a time, in the stapler consecutive action." We may observe from the traditional stapler's operating process to describe the actions related to "field" as follows.

a. Forward impulsive force of the paper while putting into the port of the stapler.
b. Depresses the downward impulsive force which punch produces.
c. Stop pressing, the resilience that the punch acts.
d. The pulling force that the paper pulls out outward to the stapler.

So, the new design of the stapler can refer to these four actions; avoid adding too many extra new components. In these four actions, also by (b) to (d) maneuverability is great and easy to control. May treats as action (b) and (c) for makes "paper staple" the process and action (d) transforms to the action "fold paper staple".

6. Su-field of the new design is illustrated as Fig.6, the added field $F_2$ represents the force to fold-up paper staple and $S_3$ represents the sheets to be bound.

1. Put the sheets into the punch and press downward the level arm.

2. The punch makes some arrow-shaped crevices and the arrow-shaped papers will be pulled out the sheets while the level arm is lifting up.

3. The part of arrow-shaped papers will be folded and attached to the sheets.

4. However, pure fold-up, the chucking power is obviously insufficient to clamp the document, but as falls off the risk. Repeat the extenics design procedures, such as "addition", the transformation method. Ask the question: *"What function, methods, modules, materials can be added or combined?"*

A new field $F_3$ and substance $S_3$ can be added to the models to solve this problems. As shown in Fig. 8, front end rear area of the arrow shape will wear out the sheet, surrounding the sheet to fasten tightly.

Actually, the similar idea has been put into practice, the prototype drawings are shown in Fig.7, [14]

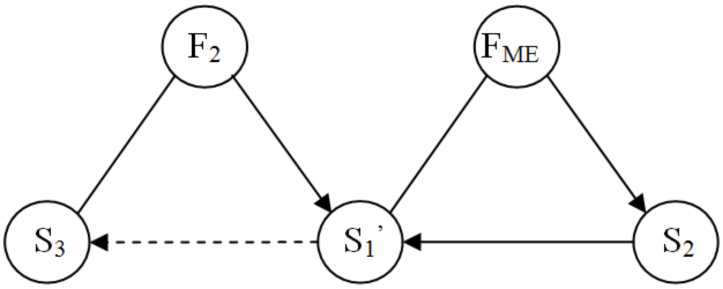


Fig.6 Su-field of the new design

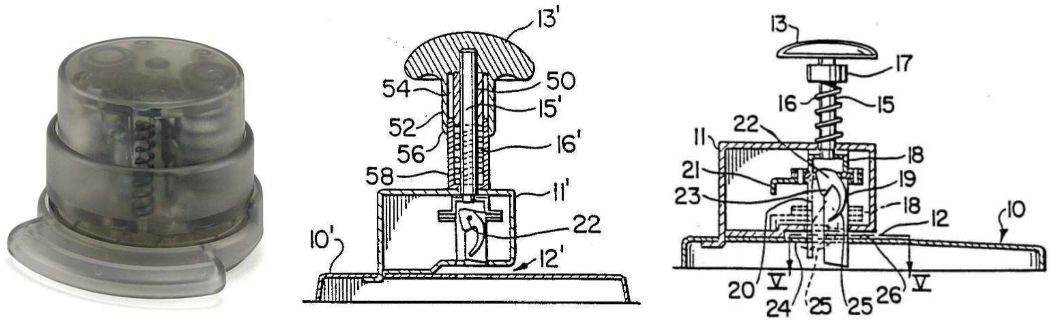

Fig.7 Prototype drawings of the staple free stapler

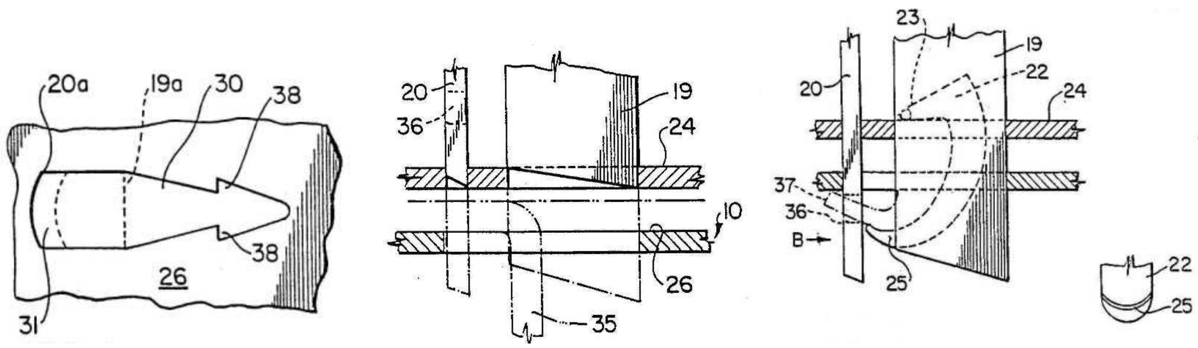

Fig.8 "staple free stapler" schematic drawing of the fold-up process

## 4.3 Transformation Application of Concept Design of Manpower-Drive Vehicle

The transmission system of manpower-drive vehicles always plays an important role in promotion of riding performance and enjoyment. We try to design the transmission system of the manpower-drive vehicles with the help of the proposed extensilbe innovative procedure. Because of length relations, the Su-field model will not present. Bicycle is adopted as the initial case to develop matter-element model.

Implication products of manpower-drive vehicles are: fitness equipment, movement equipment, manpower machines and tools, leisure electrical appliances and toy.

$R_1$ = ( N, $c_1$, $v_n$)
= (movement equipment, exercise, Swing)
= (movement equipment, exercise, Torsion)
= (movement equipment, exercise, Compression)
= (movement equipment, exercise, Pull)
= (movement equipment, exercise, Thrust)
......etc.

Abbreviation the detailed discussion procedure, we transfer the concept of transmission system of train to the exercise equipment. Schematic drawing is shown in Fig. 9. While we expand the concept to the front wheel and adopt the "Swing" transmission type, the new design will also be obtained as shown in Fig. 10.

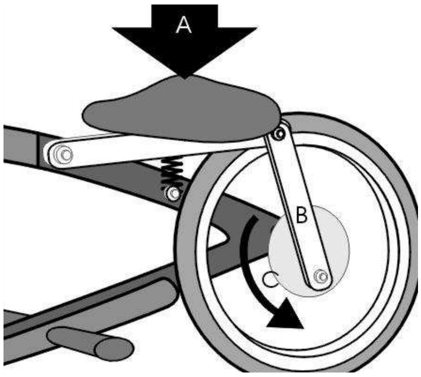


Fig.9 Concept of "Compression" transmission system of exercise equipment

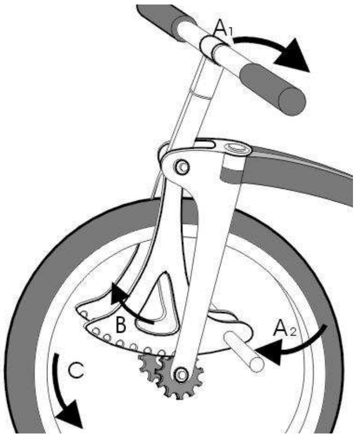


Fig.10 Concept of "Swing" transmission type of exercise equipment

## 5 Conclusion

In this research, we will introduce the matter-element analysis model to formalize and clarify Su-field model (substance or field) which is difficult to understand. The extension method can help people resolve problems separately by decomposing them, recombining the problems, and then searching for the feasible solutions, assist the Su-field model to extend and deduce concepts widely. Su-field analysis is able to not only model a system in a simple graphical approach and identify problems, but also offer standard solutions to improve the system. While using the Su-Field method to realize innovative design, expansibility of matter-element can give extending design based on the advised solution providing by 76 standard solutions. Through the transformation, designers can conceive of other substituting matter-element models effectively and quickly to obtain various innovative design plans. In this research, some interrogative sentences are proposed to provide the designer facilitate tools while operating transformation methods. We make use of extensibility of matter-element to exchange the descriptions of design problems and solutions into creative fields. The concrete result includes,

1. Proposed the flowchart of extensible innovative design process. The differences and

benefits between Su-Field modeling procedure and matter-element modeling procedure are also evaluated.

2. Assess possibility and advantage to combine construction of symbolic system in Su-Field model and the transformation and extension of matter-elements.

3. Introducing concept extension of matter-element into symbolic developments to derive out more creative solutions.

4. Some interrogative sentences are proposed to provide the designer facilitate tools while operating transformation methods.

Two design cases "Staple free stapler" and "manpower-drive vehicles", successfully demonstrates that the proposed design process is feasible and efficient.

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