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Solving the Problem of ARIZ Using ARIZ (Algorithm of Inventive Problem Solving): Case Study on Pipeline Maintenance System Design

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Abstract

ARIZ (Algorithm of Inventive Problem Solving) is known as one of the most powerful innovation tools. However, it is too complicated to understand and apply. Various versions of extended and modified ARIZ have been proposed in the past with little success. The aim of this research is to simplify ARIZ by analyzing the problem of ARIZ and solving the key problems using ARIZ itself. As the result, a new version of ARIZ is presented in this paper. It helps facilitate the understanding and usage of problem solvers by integrating the 40 Inventive Principles and the MAR (Modify, Add, Replace) Operator into Part 1 of ARIZ. This makes ARIZ more user-friendly for solving general problems. This new version of ARIZ is effectively demonstrated by using the problem of industrial pipeline maintenance system as a case study in which many practical ideas come up during Part 1 of ARIZ and more ideal solution concept is attained at the latter parts.

Keywords: TRIZ, ARIZ, innovation tools, residual magnetic field, arc welding

1. Introduction

Nowadays, innovation is one of the most frequently quoted keywords in both the world of business and technology. Unfortunately, most of the quots are more concerned with "What is" innovation rather than "How to". There are not so many tools or methods that guide people how to reach innovation. Among them, ARIZ (Algorithm of Inventive Problem Solving) is known as one of the most powerful innovation tools which is logical and scientific in problem solving and idea generation. ARIZ is a step-by-step method of analyzing a problem for the purpose of revealing, formulating, and resolving contradictions. ARIZ was developed by Genrikh Altshuller (1926-1998), the founder of TRIZ (Theory of Inventive Problem Solving) (Altshuller, Zlotin, Zusman, & Philatov, 1998). ARIZ itself is problematic and has evolved into many versions and variants. The last version of ARIZ is ARIZ-85C which contains 9 parts and totally 40 steps which are complicated and difficult to understand and apply, especially for TRIZ beginners. The author investigates into the development of ARIZ and attempts to propose a new version that will facilitate understanding and usage of problem solvers while preserving the essence and originality of ARIZ-85C by identifying the key problems of ARIZ and solving them by using the process of ARIZ itself. The new version of ARIZ is effectively demonstrated by using the problem of industrial pipeline maintenance system.

1.1. Evolution of ARIZ

The first version of ARIZ was developed in the year 1956 and was named ARIZ-56 according to the year it was developed. ARIZ-56 contains 3 parts and 10 steps after which it has evolved into many versions with more parts and steps (Petrov, 2006) as shown in Fig. 1.

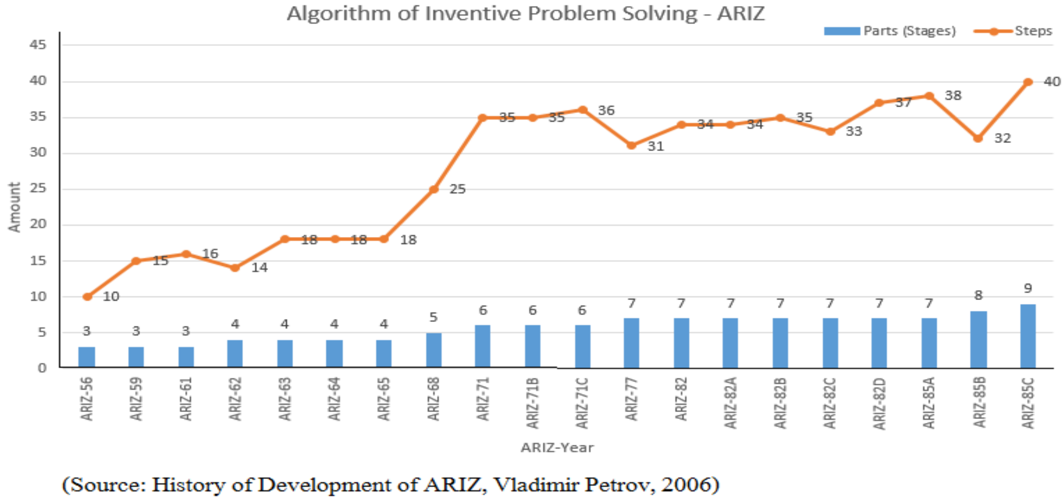

Fig.1. History of Development of ARIZ

It is noticeable that the first Table of Inventive Principles was developed in ARIZ-64 and evolved into 39x39 Contradiction Matrix Table with 40 Inventive Principles in ARIZ-71. But as a result of TRIZ's evolution, the method of 40 Inventive Principles with Contradiction Matrix Table was removed and replaced with System of Standard Solutions and Substance Field Analysis in ARIZ-71B. Altshuller considered System of Standard Solutions to be much more efficient and powerful for idea generation than 40 Inventive Principles and recommended to TRIZ community to stop using the 40 Inventive Principles and Contradiction Matrix Table, and to start using the System of Standard Solutions and Substance Field Analysis instead. But for TRIZ beginners, especially for those outside the borders of Soviet Union, however, the 40 Inventive Principles with Contradiction Matrix Table is easier to understand and apply than the System of Standard Solutions.

The last version of ARIZ developed by Altshuller is ARIZ-85C in the year 1985 after which he retired himself from involving in ARIZ development and concentrated his efforts in the area of the Theory of Development of a Strong Creative Personality (TRTL) (Zlotin & Zusman, 1999). Many TRIZ practitioners have attempted to simplify ARIZ by extending or modifying it into many versions and variants as shown in Fig. 2.

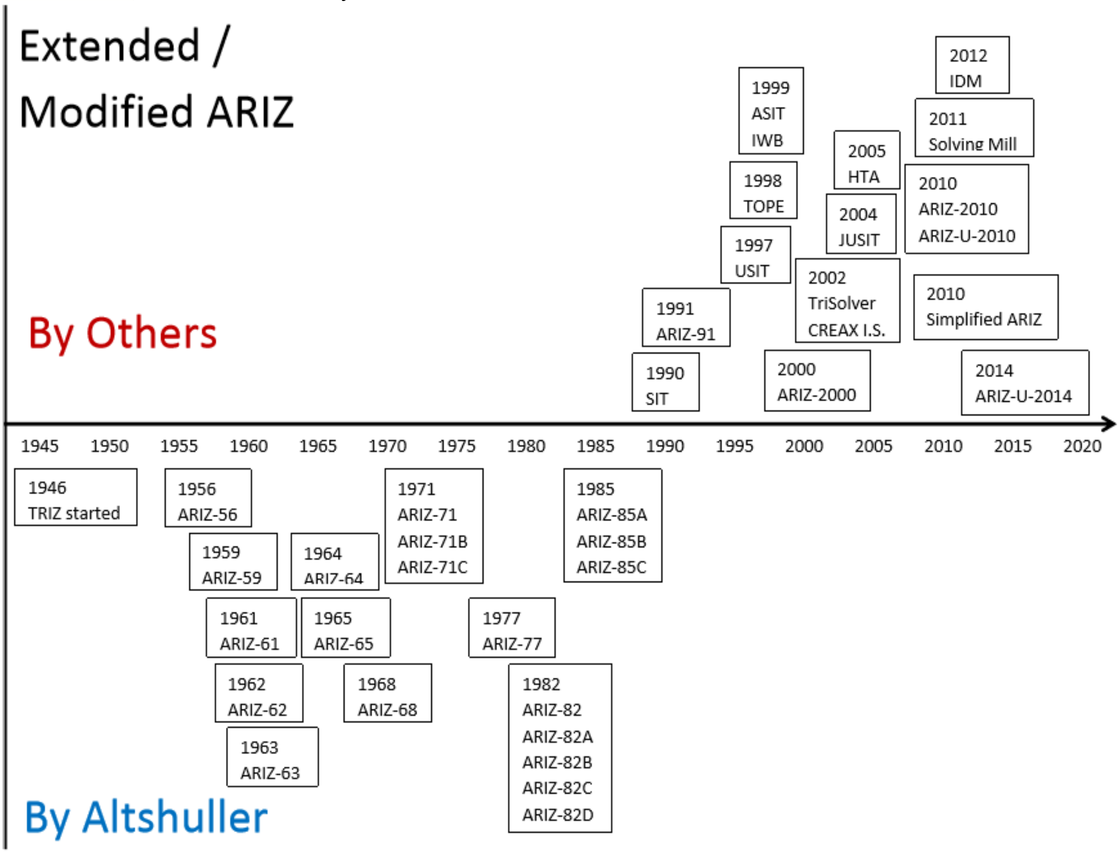

Fig. 2. Extended/Modified ARIZ

The commonly known extended or modified ARIZ which are found in many literatures and websites includes ARIZ-91, ARIZ-SMVA, ARIZ-2000, ARIZ-2010, ARIZ-U-2010, ARIZ-U-2014, SIT (Systematic Inventive Thinking), ASIT (Advanced Systematic Inventive Thinking), USIT (Unified Structured Inventive Thinking), JUSIT (Japanese version of Unified Structured Inventive Thinking), TOPE (TechOptimizer), IWB (Innovation WorkBench), Creax.I.S (CREAX Innovation Suite), HTA (Hierarchical TRIZ Algorithms), TriSolver, Solving Mill, IDM (Inventive Design Method), and Simplified ARIZ (Ball, 2005; Cameron, 2010; Horowitz, 1999; Ideation International Inc., n.d.; Invention Machine Corp., n.d.; Mann, 2002; Nakagawa, 2008; Petrov, 2009; Rubin, 2012, 2014; Sickafus, 1997; Soderlin, 2003; Systematic Inventive Thinking, n.d.; TriS Europe Innovation Academy, n.d.; Target Invention Ltd., n.d.; Time To Innovate, n.d.; Zlotin, Zusman, Litvin, Petrov, et al., 1997).

Among them, ARIZ-91 and ARIZ-SMVA are considered to be the best versions with many enhancements while trying to keep the originality of ARIZ-85C, but the System of Standard Solutions is still applied in Step 1.7 to verify the possibility of solving the problem model created by Step 1.6 which makes it still difficult for TRIZ beginners to apply.

ARIZ-2000 clarifies where the problem statement and refinement ends, and where the actual problem solving or idea creation phase starts, and rearranges problem solving or idea creation phase into 4 routes with different TRIZ tools after which Substance Field Resources are deployed to generate ideas (Soderlin, 2003).

ARIZ-2010 is modular and adaptive to variety of problem classes. It supports various degrees of time/depth work scope per user needs. While comprehending existing ARIZ versions, it also adds a new stage for choosing the initial problem to start work on (Petrov, 2009).

ARIZ-U-2010 andARIZ-U-2014 is based on a set of models for functions (useful, insufficient and harmful). It automates the process of formulating requirement contradictions, IFR, selecting standards for inventive problem solving and formulating other ARIZ steps (Rubin, 2012, 2014).

SIT/ASIT/USIT/JUSIT are variants of problem solving tools which have different approach and structure from ARIZ, but are deeply rooted in TRIZ. They are mentioned here for reference with the original ARIZ (Horowitz, 1999; Nakagawa, 2008; Sickafus, 1997; Systematic Inventive Thinking, n.d.).

Hierarchical TRIZ Algorithms is a how-to TRIZ book designed vividly with animated pictures to assist both beginning and advanced users in solving technical problems (Ball, 2005).

Simplified ARIZ is an algorithm describes the process for contradiction problem solving in a TRIZ book called TRIZICS. It is divided into 4 phases with totally 18 steps (Cameron, 2010).

Innovation WorkBench, Solving Mill, TechOptimizer, Creax.I.S (CREAX Innovation Suite), TriSolver, Solving Mill, and IDM (Inventive Design Method) are extended or modified versions of ARIZ which are computerized as TRIZ software tools (Invention Machine Corp., n.d.; Ideation International Inc., n.d.; Mann, 2002; TriS Europe Innovation Academy, n.d.; Target Invention Ltd., n.d.; Time To Innovate., n.d.).

1.2. Problems of ARIZ

Although there are many versions and variants of ARIZ after ARIZ-85C in which many of them are advanced and sophisticated with computer software support, the only accepted version is still ARIZ-85C as listed in TRIZ Body of Knowledge of TRIZ Developers Summit (Litvin, Petrov, and Rubin, 2007) and problem solving using ARIZ-85C is required as a compulsory TRIZ project for TRIZ Specialist certification program at the International TRIZ Association (MATRIZ) (The International TRIZ Association (MATRIZ), n.d.).

Altshuller was quoted as saying that "ARIZ is a complicated tool. Do not apply it to solve new practical problem without at least 80 academic hours of preliminary study" (Altshuller, Zlotin, Zusman, & Philatov, 1998; TRIZ Korea Inc., 2002). According to the research of Altshuller, less than 5 % of the problems encountered in daily engineering activities are problems which are truly unique and cost-effective enough for ARIZ (Zlotin & Zusman, 1999). This is emphasized by further claim that only 1 % of the problems required the use of ARIZ (Savransky, 2000).

Although ARIZ is widely known as an innovation tool, it is used just only by a few TRIZ specialists, and even though ARIZ is the main tool of TRIZ which integrates all other tools and knowledge base, it is not as popular as other stand-alone tools.

With respect to the spirit of Altshuller who has devoted his life to the development of TRIZ as a science for mankind (Altshuller, 1984), the author attempts to identify the key problems of ARIZ and proposes a new version that will facilitate understanding and usage of problem solvers while preserving the essence and originality of ARIZ-85C which from now on will be referred as ARIZ.

2. Method

The problem of ARIZ is first analyzed by using the method of FA (Function Analysis) and CECA (Cause-Effect Chains Analysis) to identify the key problem after which ARIZ is deployed to solve the key problems and search for ideal solutions.

2.1. Function Analysis and Cause-Effect Chains Analysis

ARIZ itself can be considered as a technological system which evolves in accordance with TRIZ's Laws of Technological System Evolution. The main useful function of ARIZ is to guide problem solvers through creative thinking process in solving problems and to attain innovative solution concepts. The system of ARIZ comprises 9 parts and 40 steps for analysis and idea generation incorporated with TRIZ tools, knowledge base, resources, scientific effects and Solution Park where solution concepts generated during the process are parked. The function model of ARIZ-85C can be described as in Fig. 3 and the functions of each part can be broken down into the functions of steps as in Fig. 4.

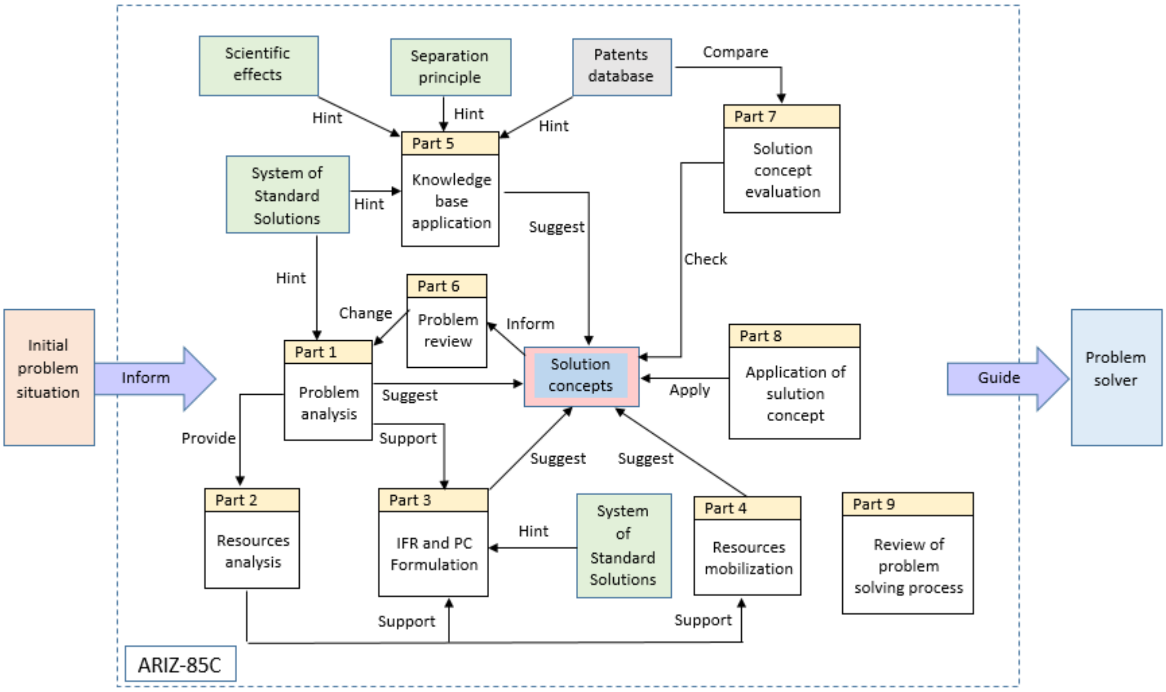

Fig. 3. Function Model of ARIZ-85C

Part 1. Analyzing the problem	Part 2. Analyzing the problem model	Part 3. Formulating the ideal final result and physical contradiction	Part 4. Mobilizing and utilizing substance-field resources	Part 5. Applying the knowledge base to solve physical problem	Part 6. Changing or substituting the problem : If the problem is not solved	Part 7. Analyzing the method for resolving the physical contradiction	Part 8. Capitalizing on the solution concept	Part 9. Analyzing the problem-solving process
Step 1.1. Formulate the mini-problem	Step 2.1. Define the operational zone	Step 3.1. Identify the formula for ideal final result (IFR) 1	Step 4.1. Simulation with smart little people	Step 5.1. Applying the system of standard solutions	Step 6.1. Transfer the theoretical solution into a practical one	Step 7.1. Check the solution concept	Step 8.1 Define how the super-system that encompasses the changed system should be changed	Step 9.1. Compare the real process of problem solving with the theoretical one
Step 1.2. Define the conflicting elements	Step 2.2. Define the operational time	Step 3.2. Intensify the formula for ideal final result 1	Step 4.2. "Stepping back" from the IFR	Step 5.2. Applying solution concepts to non-standard problems that have already been solved using ARIZ	Step 6.2. Check to see whether the description in step 1.1 represents a combination of several problems	Step 7.2. Preliminary estimate of the solution concept	Step 8.2. Check whether the changed system or super-system can be applied in a new fashion	Step 9.2. Compare the solution concept to the information in the TRIZ knowledge base
Step 1.3. Build graphical models for the Technical Contradictions	Step 2.3. Define substance and field resources	Step 3.3. Formulate the physical contradiction for the macro-level	Step 4.3. Using a mixture of substance resources	Step 5.3. Solving physical contradiction by Utilizing the separation principles	Step 6.3. Change the problem by selecting another technical contradiction in step 1.4	Step 7.3. Check the novelty of the solution concept via patents search	Step 8.3. Apply the solution concept for solving other problems	
Step 1.4. Select a graphical model for further analysis		Step 3.4. Formulate the physical contradiction for the micro-level	Step 4.4. Using empty space	Step 5.4. Solving physical contradiction by Utilizing the library of natural effects and phenomena	Step 6.4. Return to step 1.1 and reformulate the mini-problem with respect to the super-system	Step 7.4. Note possible sub-problem which might require invention, design, calculations, etc.		
Step 1.5. Intensify the conflict		Step 3.5. Formulate the ideal final result 2	Step 4.5. Using derived resources					
Step 1.6. Formulate the problem model		Step 3.6. Consider solving for the new physical problem	Step 4.6. Using an electric field					
Step 1.7. Apply the system of standard solutions			Step 4.7. Using a field and field-sensitive substance					

Fig. 4. Parts and Steps of ARIZ-85C

The function analysis of ARIZ-85C shows no undesirable effects such as insufficient or excessive useful function or harmful function, as long as the problem solver is well trained and specializes in using ARIZ. For the general problem solver with little experience however, ARIZ is difficult to understand and apply which makes ARIZ not so popular among them.

With the Cause Effect Chains Analysis as shown in Fig. 5, the key disadvantages or key problems of ARIZ are identified as follows,

1) ARIZ is not suitable for the general problems
2) ARIZ takes too much time to learn
3) ARIZ is mostly used in business consulting service

Note: By the general problems, the author means the problems encountered by general problem solvers who are either TRIZ experts or TRIZ beginners. The characteristics of the problem can be either complex (advanced) or less complex (basic).

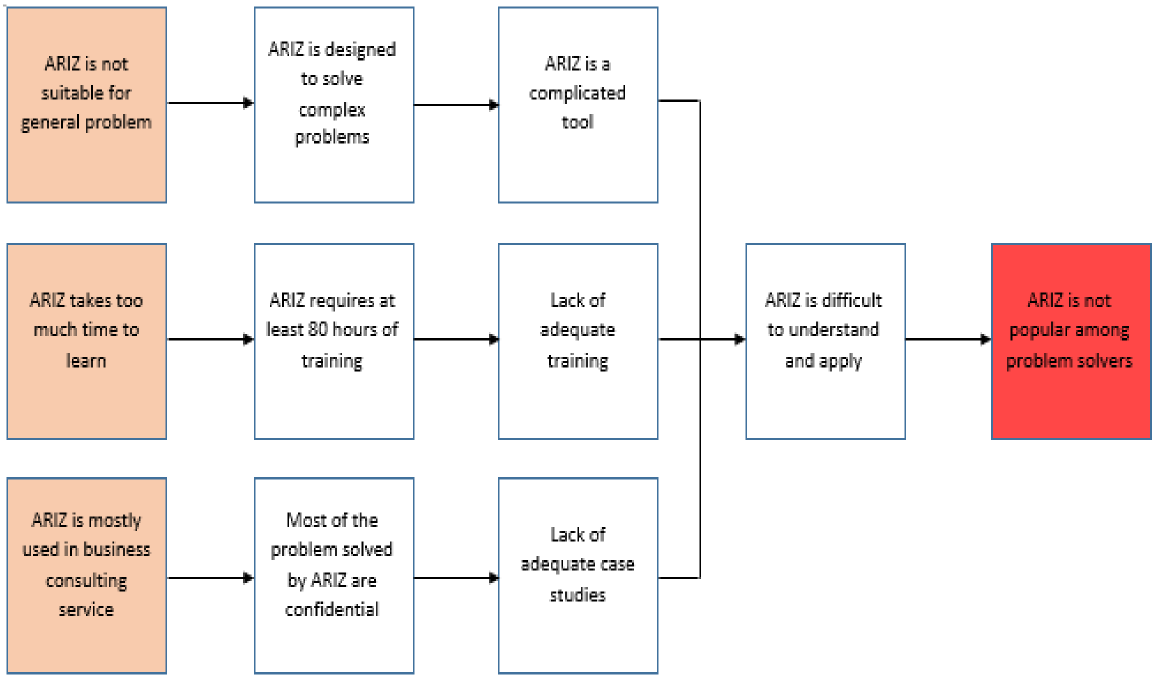

Fig. 5 Cause Effect Chains Analysis of ARIZ

In order to make ARIZ more popular among general problem solvers, the author aims to solve the key problems of how to make ARIZ also suitable for general problems (besides its strong points for solving complex problems), how to shorten the learning curve of ARIZ with more supporting resources, and how to make ARIZ widely adopted by both the industries and the academic world (not just only by consulting firms) so that there will be more disclosed application of ARIZ to be referred to as case studies.

The algorithm of ARIZ-85C is deployed to solve the problem of ARIZ. The process and results are explained in the following chapter.

3. Results

Due to the page limit, only some important steps will be explained as follows,

3.1. Part 1. Analyzing the Problem

Step 1.1 Formulate the Mini-Problem

The mini-problem of ARIZ is formulated as follows. The technical system for guiding problem solver includes initial problem situation, parts and steps of ARIZ, TRIZ tools, knowledge base, resources, scientific effects and solution concepts.

It is necessary, with minimum changes to the system, to facilitate the understanding and usage (of problem solver) without lessening the essence and originality (of ARIZ-85C).

Technical Contradiction 1 (TC-1): If modification is extensive, then it facilitates the understanding and usage, but it lessens the essence and originality.

Technical Contradiction 2 (TC-2): If modification is mild, then it preserves the essence and originality, but it insufficiently facilitates the understanding and usage

Step 1.2 Define the Conflicting Elements

The Conflicting Elements includes Product and Tool which, are defined as follows,

Products: 1.Understanding and Usage and
2. Essence and Originality
Tool: Modified ARIZ

Step 1.3 Build Graphical Models for the Technical Contradictions

Graphical Models for the Technical Contradictions are built as shown in Fig. 6.

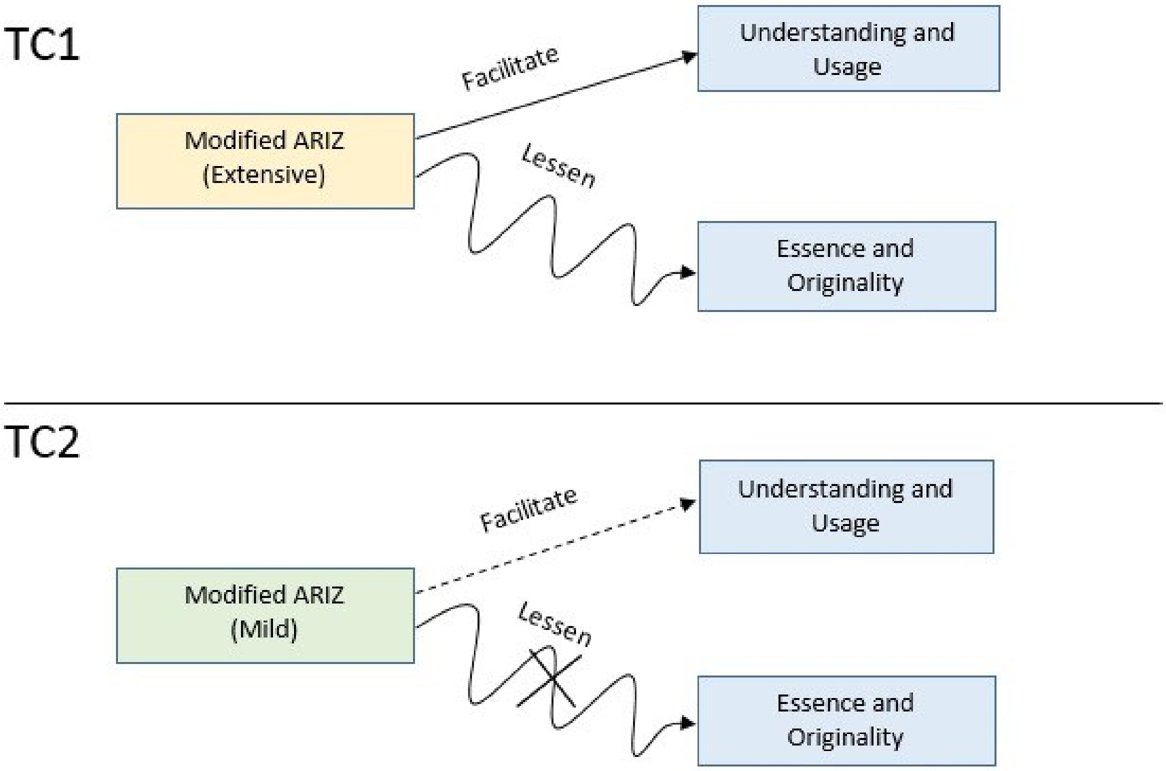

Fig. 6. Graphical Models for the Technical Contradictions

Step 1.4 Select a Graphical Model for Further Analysis

Since the main function of the ARIZ system is to guide problem solver with good quality of algorithm, the Essence and Originality must not be lessened by the Modification. Thus, we select TC-2 which states that if modification is mild, then it preserves the essence and originality, but it insufficiently facilitates the understanding and usage.

Step 1.5 Intensify the Conflict

In order not to compromise (trade off) useful function with harmful effect, we intensify the conflict by considering that instead of "Mildly Modified ARIZ", it is replaced by a "No Modified ARIZ" in TC-2 as shown in Fig. 7.

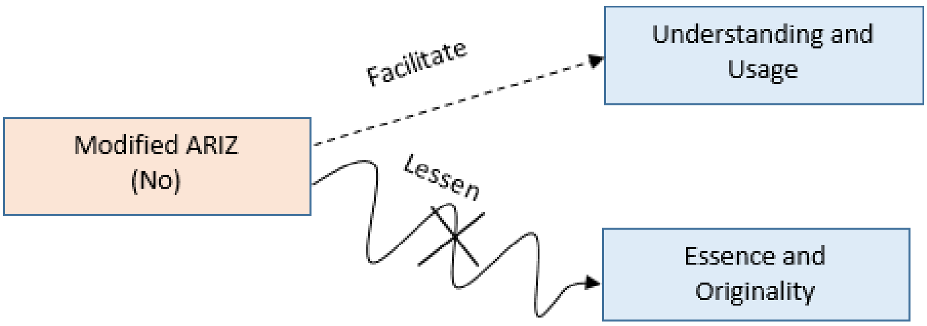

Fig. 7. Intensified Graphical Model

Step 1.6 Formulate the Problem Model

Find an element "X" that maintains the feature of No Modified ARIZ for preserving the essence and originality while also facilitating the understanding and usage as shown in Fig. 8.

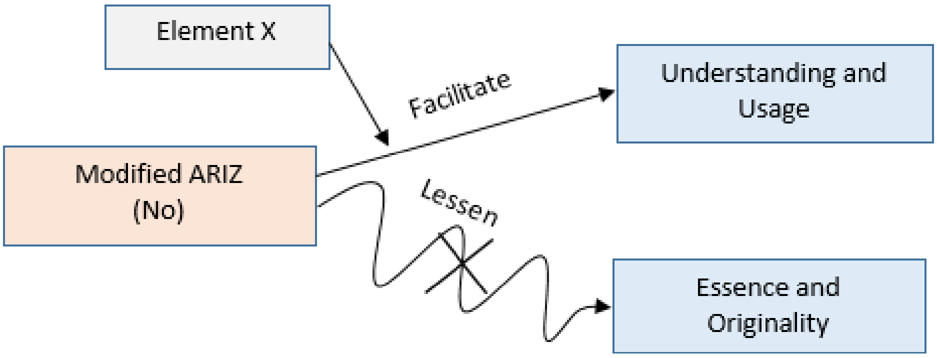

Fig. 8. New Problem Model

Step 1.7 Apply the System of Standard Solutions

In this step the graphical model is analyzed using Substance-Field Modeling and Analysis (Belski, 2007) along with System of Standard Solutions (Altshuller,1985) to find element "X" as follows.

The initial Substance-Field Model is created with S1(object) as Understanding and Usage, S2(tool) as No Modified ARIZ, F1 as Human Intelligence or Biological Field. While solving problem, problem solver exerts Human Intelligence on No Modified ARIZ to insufficiently facilitate the Understanding and Usage as shown in Fig. 9(a).

In order to improve the efficiency of the system, the standard solution which best corresponds to the above initial model is standard solution 2.1.2 which states as follows.

Standard solution 2.1.2 "Synthesis of a Dual Substance Field System"

If it is necessary to improve the efficiency of substance-field system and the replacement of substance-field system element is not allowed, the problem can be solved by the synthesis of a dual substance-field system through introducing a second field which is easy to control.

Idea 1: Use optical field through computer software (F2) to improve the efficiency of facilitating the understanding and usage for problem solver. The computer software helps to create a double substance field system and can be easily controlled as shown in Fig. 9(b).

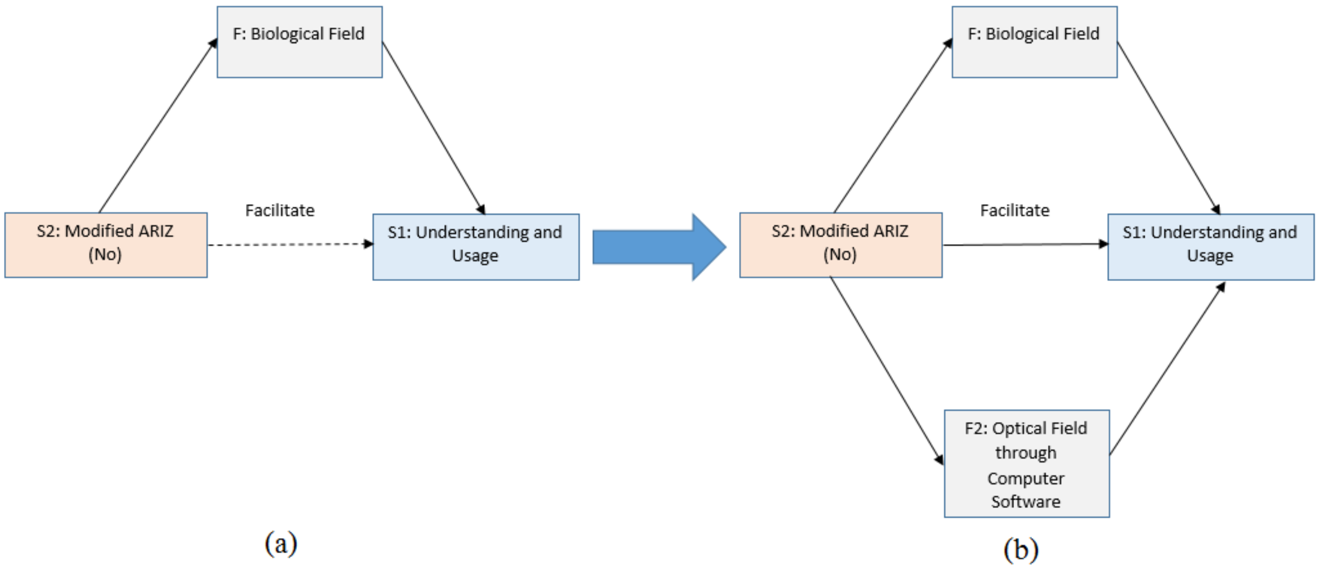

Fig. 9. Substance-Field Modeling and Analysis

Although nowadays computer is a cheap resource which can be easily acquired, it is preferable to consider internal resources inside the system and environment to utilize and generate more ideal solution concepts, so we move on to Part 2 Resources Analysis and Part 3 Formulation of the Ideal Final Result and Physical Contradiction.

3.2. Part 2. Resources Analysis

If the problem is easily solved within Part 1, there is no need to go further into Part 2.

Part 2 and other Parts that follow will deal with solving complex problem as in the following steps.

Step 2.1 Define the Operational Zone (OZ)

In the problem of using ARIZ, the Operational Zone is defined to be the ARIZ system and its interface with problem solver.

Step 2.2 Define the Operational Time (OT)

In the problem of using ARIZ, the Operational Time is defined to be the period of time during using ARIZ.

Step 2.3 Define the Substance Field Resources

A list of Substance-Field Resources with their parameters is created as in Table 1.

Table 1. Substance-Field Resources (Bukhman, 2012)

Source	Substance-Field Resources	Type	Parameter
Internal Resources	Parts of ARIZ	Substance	Amount, Level
	Steps of ARIZ	Substance	Amount, Level
	40 Inventive Principles	Substance	Amount
	Contradiction Matrix Table	Substance	Size
	System of Standard Solutions	Substance	Amount, Level
External Resources	Computer	Substance	Speed, Space
	Internet Access	Field	Speed, Bandwidth

3.3. Part 3. Formulatiion of the Ideal Final Result and Physical Contradiction

Step 3.1 Identify the Formula for IFR-1

Ideal Final Result (IFR) (Domb, 1998) is used to define the problem to be solved. The Ideal Final Result by introducing the element "X" is defined as follows,

While neither complicating the system nor causing harmful effects, element "X" improves the useful function of the no modified ARIZ to facilitate the understanding and usage during operational time (the period of using ARIZ) within the conflict zone (the ARIZ system and its interface with problem solver) while preserving the essence and originality of ARIZ.

Step 3.2 Intensify the Formula for IFR-1

We intensify the formula of IFR-1 by introducing an additional requirement that the element "X" comes from substance field resources. In this case, "Parts of ARIZ" is considered to replace the element "X".

Step 3.3 Formulate the Physical Contradiction for the Macro-Level

The Physical Contradiction (Kaplan, 1969) for the Macro-Level is formulated as follows,

Parts of ARIZ in the the ARIZ system and its interface with problem solver during the period of using ARIZ, has to be simple in order to perform facilitating the understanding and usage, and has to be complicated (advanced) to perform preserving the essence and originality.

Idea 2: Use Principle of Separation in Space

Part 1 which concerns with problem analysis should be made simple to analyze and generate ideas for the general problem. If the problem is too complicated and the generated ideas are not satisfactory, then the problem can be moved forward to the latter parts of ARIZ which deals with complex problem.

Step 3.4 Formulate the Physical Contradiction for the Micro-Level

In this case, Steps of ARIZ of each part can be considered as the micro-structure of ARIZ. The Physical Contradiction for the Micro-Level is formulated as follows.

There should be Steps of ARIZ that is simple in the the ARIZ system and its interface with problem solver in order to provide simple Parts of ARIZ, and Steps of ARIZ should be complicated in order to provide complicated (advanced) Parts of ARIZ.

Idea 3: Use Principle of Separation in Structure

Some Steps of ARIZ should be made simple for TRIZ beginner, but ARIZ as a whole still preserves its essence and originality to deals with complex problem.

Since, from Idea 2, Part 1 should be made simple, therefore the steps of ARIZ to be made simple should come from Part 1. Steps of Part 1 are analyzed and simplified using the existing resources. The author has come up with more ideas as follows,

Idea 4: Use the Contradiction Matrix Table and 40 Inventive Principles which are the existing resources to generate ideas for resolving the technical contradiction selected in Step 1.4

Although the user-friendly Contradiction Matrix Table and 40 Inventive Principles (Altshuller, 1997) are removed from ARIZ and replaced with System of Standard Solutions, most TRIZ practitioners consider them to be complementary to each other. Therefore, the author simplifies Step 1.4 by using 40 Inventive Principles and leaves the complicated (advanced) System of Standard Solutions to be used in the latter Parts of ARIZ (Step 3.6 of Part 3 and Step 5.1 of Part 5). But the System of Standard Solutions is also required in Step 1.7 of Part 1 which makes Part 1 too complicated for TRIZ beginners. The author has come up with some ideas to simplify the System of Standard Solutions at this step as follows,

Idea 5: Instead of using the full scale of the System of Standard Solutions, some minimum set of the System of Standard Solutions might be prepared to facilitate the understanding and usage of the problem solver.

As most of the problems in Substance-Field Model are typically concerned with the insufficient useful function or undesirable effects of the system, the solution standards in subclass 1.1, 2.1 and 2.2 which deal with improving the useful function and subclass 1.2 which deal with eliminating harmful interaction are frequently used and can be prepared according to Idea 5. But it is still difficult for the TRIZ beginners who might be unfamiliar with the contents and technical terms used in each standard solution.

Since the System of Standard Solutions is concerned with manipulating components in the system and its environment for the purpose of transforming the initial Substance-Field Model into a problem-free model, the author tried to look into the contents of each standard solutions in subclass 1.1, 1.2, 2.1 and 2.2 which consist of totally 21 solutions, to analyze the frequently used actions and the components that are manipulated.

The result is shown in Table 2.

Table 2. Actions and Components of System of Standard Solutions

Solution	Standard Solution	Action			Component	
Number	Name	Modify	Add	Replace	Substance	Field
1.1.1	Building of Substance-Field Model		X		X	X
1.1.2	Improving interactions by introducing additives into the objects		X		X	
1.1.3	Improving interactions by introducing additives into a system		X		X	
1.1.4	Use of environment to improve interactions		X		X	X
1.1.5	Modification of environment to improve interactions	X	X		X	X
1.1.6	Providing minimum effect of action		X		X	X
1.1.7	Providing maximum of effect of action		X		X	
1.1.8(a)	Providing selective effect by maximum field and Protective substance		X		X	
1.1.8(b)	Providing selective effect by minimal field and active substance		X		X	
1.2.1	Elimination of harmful interaction by a foreign substance		X		X	
1.2.2	Elimination of harmful interaction by modification of an existing substance	X			X	
1.2.3	Elimination of a harmful effect of a field		X		X	
1.2.4	Elimination of a harmful effect by a new field		X			X
1.2.5	Elimination of a harmful effect caused by magnetic field		X			X
2.1.1	Synthesis of a Chain Substance-Field System		X		X	X
2.1.2	Synthesis of a Dual Substance-Field System		X			X
2.2.1	Replacing poorly controlled field with a well controlled			X		X
2.2.2	Increasing a degree of fragmentation of substance components	X			X	
2.2.3	Transition to capillary porous objects			X	X	
2.2.4	Increasing a degree of system dynamics		X		X	
2.2.5	Changing structure of a field			X		X
2.2.6	Changing structure of a substance object			X	X	

As shown in Table 2, the actions of each standard solution in subclass 1.1, 1.2, 2.1 and 2.2 can be categorized into 3 types namely, Modify, Add and Replace which act on the components (substance and/or field) of the initial Substance-Field Model and/or its environment. The author has summarized it into a table called the MAR Operator as shown in Table 3.

Table 3. The MAR Operator

Number	Operator Name	Description
1	M: Modify	Modify the existing substance and/or field in the initial Substance-Field Model and/or its environment.
2	A: Add	Add new substance and/or field into the initial Substance-Field Model.
3	R: Replace	Replace the existing substance and/or field in the initial Substance-Field Model with new substance and/or field.

In summary, the problem of ARIZ has been analyzed and solution concepts have been attained for facilitating the understanding and usage of the problem solvers without lessening the essence and originality of ARIZ. Principle of Separation in Space and in Structure have been used to resolved the Physical Contradictions in Macro and Micro Level by Separating Parts and Steps of ARIZ to be simple (basic) and at the same time, complicated (advanced). Originally, Part 1 of ARIZ is deemed to test the complexity of the problem. If the problem is easily solved at the end of Part 1, then it is considered to be non-complex and not necessary to move on to the latter parts of ARIZ. However, there is no easy tool in Part 1 to help TRIZ beginners to generate ideas as the user-friendly 40 Inventive Principles has been removed from ARIZ-85C and replaced with the complicated System of Standard Solutions.

The author attempts to revitalize the Contradiction Matrix Table and 40 Inventive Principles which can be considered as internal resource by incorporating them into Step 1.4 of Part 1 to resolve the Technical Contradiction selected for further analysis, and has simplified the subclass 1.1, 1.2, 2.1 and 2.2 of System of Standard Solutions which deal with improving the useful function and eliminating harmful interaction by grouping them into 3 types of actions e.g. Modify, Add and Replace which is named MAR Operator. The MAR Operator is suggested to solve the problem model in Step 1.7 of Part 1 instead of using the System of Standard Solutions as shown in Fig. 10.

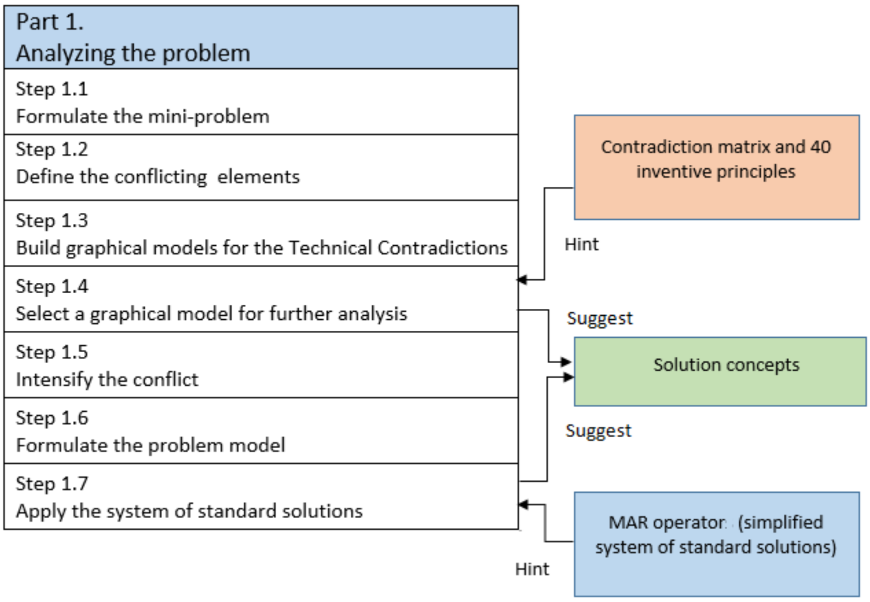

Fig. 10. The Proposed Algorithm of Part 1

The individual operator or the combination of operator can help the problem solvers to generate ideas for solving their problem and relieves them from the burdens of looking into the details of the complicated System of Standard Solutions. However, when the problem solvers have more confidence, they can come back to look at the detailed situations and conditions described in each standard solution and refine their solution concepts using full scale of the System of Standard Solutions as deployed in Step 3.6 and Step 5.1 of ARIZ.

4. Case Study

The previously solved complex problem of low quality arc welding on industrial pipeline maintenance system (Benjaboonyazit, 2014) is used to test the effectiveness of the proposed algorithm. Some of the related steps are described as follows,

4.1. Initial Problem Situation

In pipelines maintenance system, a Magnetic Flux Leakage (MFL) device with strong magnetic field is used to magnetize the pipe wall to nearly saturation level while traveling through the pipelines. Magnetic field leakage at the corrosion part will be detected by magnetic sensors on the MFL device. After corrosion part of the pipeline is located, the damaged segment is cut off and replaced with the new one by welding it to the existing pipeline, the problem occurs with the welding rod and arc column subjected to the magnetic force that causes it to deviate from the right position, thus render the low quality of arc welding.

Step 1.3 Build graphical models for the technical contradictions.

Technical Contradictions (TC) are formulated as follows:

TC-1: If the Residual magnetic field is strong, it is easy to detect corrosion part. On the other hand, the arc column will be deviated.

TC-2: If the Residual magnetic field is weak, the arc column can be positioned correctly. However, it is difficult to detect corrosion part.

The Graphical Models for the Technical Contradictions are built as shown in Fig. 11.

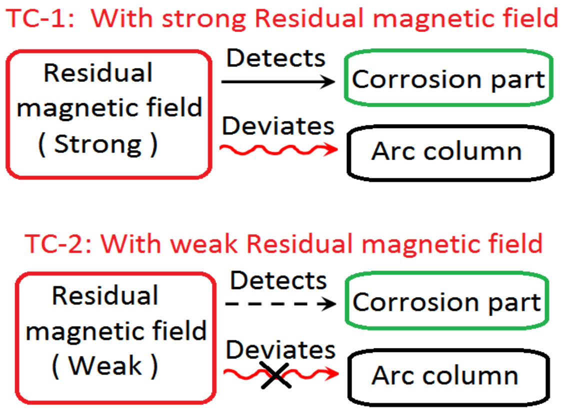

Fig. 11. Graphical models for the technical contradictions.

TC-1 is selected as Graphical Model for further analysis. In this case, with strong Residual magnetic field, it is easy to detect corrosion part. However, the arc column will be deviated. So we try to solve the technical contradiction at Step 1.4 with 40 Inventive Principles and eliminate harmful effect of Residual magnetic field at Step 1.7 with the MAR Operator in the proposed algorithm.

In Step 1.4, the Contradicting Parameters can be viewed as 21.Power VS 31.Object-generated Harmful Factors and 28.Measurement Accuracy VS 31.Object-generated Harmful Factors, the ideas generated with the suggested Inventive Principles are shown in Table 4.

Table 4. Contradiction Matrix Table with 40 Inventive Principles and Ideas generated

Contradicting Parameters	Inventive Principles	Ideas generated
21.Power VS 31.Object-generated Harmful Factors	2. Taking out	Demagnetize the residual magnetic field
	35. Parameter changes	-
	18. Mechanical vibration	Vibrate the pipeline to disalign magnetic domains
28.Measurement Accuracy VS 31.Object-generated Harmful Factors	3. Local quality	Demagnetize only the welding zone, no need to demagnetize the entire pipeline
	33. Homogeneity	-
	39. Inert atmosphere	-
	10. Preliminary action	Demagnetize the pipeline before the welding process

In Step 1.7, the initial Substance-Field Model is constructed with S1 (object) as Pipeline, S2 (tool) as Arc column, F1 as Residual magnetic field and F2 as Welding current. While welding Pipeline with Welding current (F2) through Arc column, Residual magnetic field (F1) causes a harmful function by exerting force through the pipeline to deviate the arc column. The useful function (weld) becomes insufficient (Dashed line) as shown in Fig. 12.

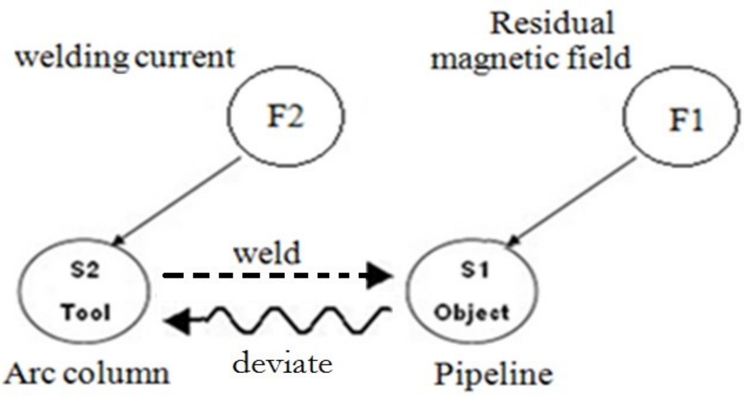

Fig. 12. Substance-Field Model of industrial pipeline maintenance problem

Instead of using the complicated System of Standard Solutions to find the solution for the above Substance-Field Model, the MAR Operator are deployed to manipulated the components in the system and its environment and the ideas are generated as in Table 5.

Table 5. The MAR Operator and Ideas generated

The MAR Operator	Component manipulated	Ideas generated
Modify	Field	Use Alternating Current instead of Direct Current for welding
	Substance	-
Add	Field2	Heat (thermal Field) or strike (mechanical Field) the pipeline to disalign magnetic domains
	Substance	-
Replace	Substance and Field	Replace electric welding machine with torch welding machine

The ideas generated in Step 1.4 and Step 1.7 can be combined to form solution concepts that are practical enough to solve the problem such as “burn or strike the pipeline locally at the welding zone before welding to disalign magnetic domains” or “Replace DC electric welding machine with other welding machine”. Unfortunately, sometimes the situation or condition of the problem might not allow the problem solver to change components freely or the solution concepts might not be ideal enough. That is why ARIZ emphasizes on the necessity of formulating “Mini-Problem” on the first Part and analyzing the resources in the system and its environment in the second Part that might be used to solve the problem internally without introducing external resources.

The following steps show how this problem can be solved ideally with the latter parts of ARIZ.

Step 3.4 Formulate the Physical Contradiction for the Micro-Level

The Physical Contradiction for the Micro-Level is formulated as follows,

“Free electrons” should flow around the pipe in the welding zone to create proper intensity and direction of magnetic field during welding time to eliminate the harmful effect of the very strong residual magnetic field, and should not flow around the pipe in the welding zone during pre-welding time to preserve the ability of the very strong residual magnetic field to detect corrosion part as shown in Fig. 13.

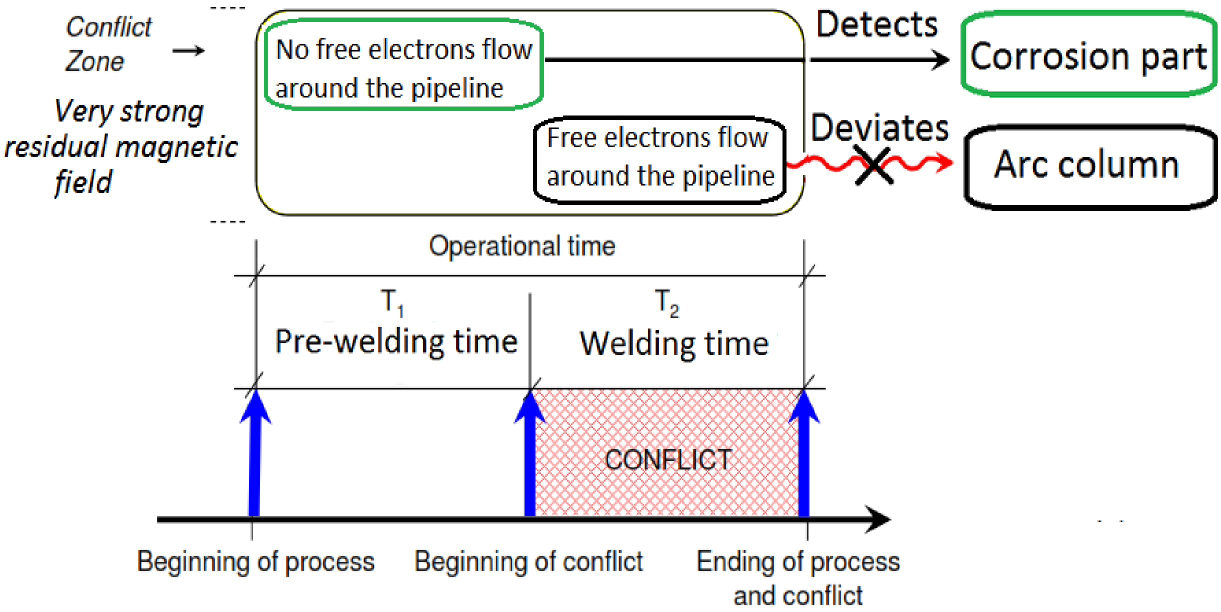

Fig. 13. Physical Contradiction for Micro-Level

Step 3.5 Formulate the Ideal Final Result (IFR-2)

The Ideal Final Result (IFR-2) from the Physical Contradiction for the Micro-Level is formulated as follows,

IFR-2: "Free electrons" should, on their own, flow around the pipe in the welding zone to create proper intensity and direction of magnetic field during welding time to eliminate the harmful effect of the very strong residual magnetic field, and should be, on their own, neutralized during pre-welding time to preserve the ability of the very strong residual magnetic field to detect corrosion part.

Step 3.6 Consider Solving the New Problem using the System of Standard Solutions

Consider Solving the New Problem in step 3.5 using Standard solution 1.2.5 with magnetic field from welding current as resource to generate ideas. Standard solution 1.2.5 "Switching Off" a Magnetic Influence: which states that If it is necessary to eliminate the harmful effect of a magnetic field in a Substance-Field Model, the problem can be solved by applying the physical effects which are capable of "switching off" the ferromagnetic properties of substances, for example, by demagnetizing during an impact or during heating above the Curie point.

Potential solution: Use "Magnetic field from welding current".

Magnetic field from welding current is a derived resource in the system and can be utilized to counteract the residual magnetic field in the pipeline locally at the welding zone during the welding time. By winding the electrode lead and grounding wire around the pipe near the welding zone with proper amount of turns and direction, the free electrons will, on their own, flow around the pipe in the welding zone to create proper intensity and direction of magnetic field during welding time as soon as the arc column is initiated, and during the non-destructive inspection process before the welding time, no free electron is flowing around the pipe, thus, the ability of the residual magnetic field to detect corrosion part can be preserved as shown in Fig 14.

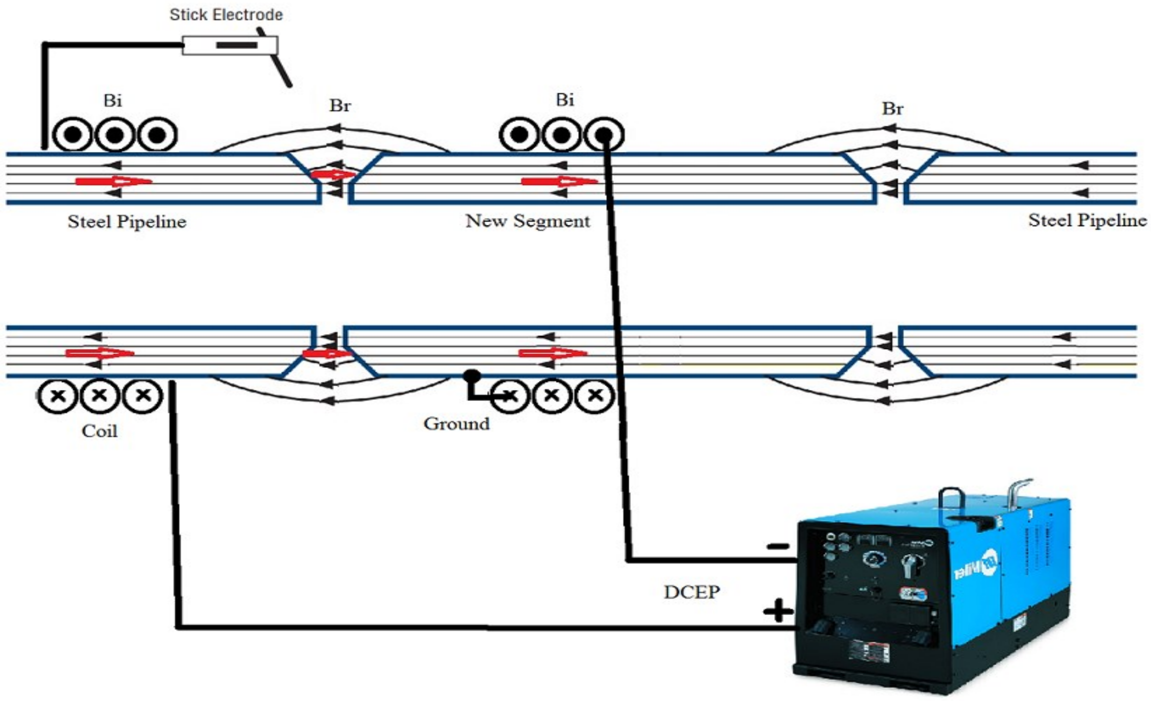

Fig. 14. Potential solution

5. Discussion

The case study above shows that even the complex problem like the low quality arc welding problem during pipeline maintenance can be easily solved at the first part of ARIZ in the proposed algorithm. The Contradiction Matrix Table and 40 Inventive Principles, though maybe simple, are still useful in idea generation for resolving technical contradiction in Step 1.4. Moreover, the proposed MAR Operator in Step 1.7 is also very effective in manipulating components of the substance field system and its environment in order to improve the useful function or eliminating the harmful interaction without the burden of going into the details of System of Standard Solution.

As for the general problems from the general problem solvers, especially from TRIZ beginners, the proposed algorithm is sufficiently effective enough to solve general problems with Part 1 of ARIZ after which Part 7 can be reached for evaluating the solution concepts attained in Part 1. This help make ARIZ more user-friendly and can be more popular among problem solver. ARIZ will be adopted more widely in industries and the academic world as well. This new version of ARIZ proposed here is easy to understand and applied by the general problem solvers, especially from TRIZ beginners. In this aspect, the new method solves the problem addressed in this paper. Besides, when people are encouraged to learn and get more acquainted with ARIZ, it will be easy for them to start solving complex problem ideally by exploring system resources and formulating Ideal Final Result and Physical Contradiction in the latter parts of ARIZ process.

And when compared with other variants of ARIZ, in general, this new method required shorter learning curve from problem solvers. More importantly, with minimum changes to the system, this new method preserves the essence and originality of ARIZ-85C which is the last version developed by Altshuller while facilitating the problem solvers to solve technical problem with less burden.

6. Conclusions

A new version of ARIZ is proposed to facilitate the understanding and usage of problem solvers by integrating the 40 Inventive Principles and the MAR Operator into Part 1 of ARIZ without lessening the essence and originality of ARIZ-85C. A case study of industrial pipeline maintenance problem is used to test the effectiveness of the proposed version and comes out with satisfactory result. The new version is expected to be used widely and can be easily extended to cover the problem in the business and management area.

In addition, a computer software called “ARIZ-85C+” which supports this version of ARIZ, is under development. More rigorous testing and quantitative evaluation of the proposed version can be conducted with more cases in the near future.

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Development of Systematic Business Model Innovation Software Prototype for Teaching Assistance and Cases Accumulation

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Abstract

The book "Business Model Generation" provides a tool to help people quickly see the key points of establishment (innovation) plans, which can be updated easily and continuously, thus, responding to rapid global changes. This new tool is the "Business Model Canvas", which divides a business establishment system into nine key blocks (factors); customer segments, value propositions, channel, customer relationships, revenue streams, key resources, key activities, key partnerships, and cost structure, and this elaborate visual design enables the reader to see their relationships on sight. The reader can obtain the revenue source from the customer segments, value propositions, customer relationships, and channel strategies, and then, the key resources, key production activities, and key partnerships can be confirmed, allowing the reader to understand the cost structure. The profit model is obtained by subtracting the cost from the revenue. However, this book is not software, it cannot make the content into files for saving and transfer. This study composes a program, where the required data are entered step by step, displayed on a Business Model Canvas on the computer screen, and nine key blocks can be listed. When the input content in the nine key blocks omits choosing/filling data, the system reminds the user, and every item must be completed to complete the entire Business Model Canvas. This software can be used by teachers for teaching, and features convenient file save and transfer.
Keywords: systematic; business model innovation; nine factors; teaching material; software

1. Introduction

1.1 Research background

In order to distinguish business opportunities with profit potential and seek a more original business model, the "Business Model Generation" team completed the "Business Model Generation" book. This book has been used by over 100 thousand people around the world. To create a good business model is to master future profitable opportunities, and business model innovation is not a new subject. From the first credit card issued in 1950 to the first iPhone released by Apple Inc. in 2007, new business model innovations have rapidly and drastically changed the industry environment and our life style. In the past, business establishers and innovators spent much investigation time preparing thick business plans written in three to six months; however, sometimes, upon implementation, their assumptions were found to mismatch reality, because the world is alive, whereas the business plan is dead. In this increasingly changing world, any "plan" must be alive, and able to change with the ever changing world. It is difficult to revise a business plan, sometimes the anterior part is revised, but the posterior part is omitted, and a slight change may affect the situation as a whole. In addition, some business plans have the severe defect of a lacking "global" view. Therefore, we need a new business planning tool to help people quickly identify the key points of business establishment (innovation) plans, which can be easily updated and continuously respond to the rapid changes in the world. This new tool is the "Business Model Canvas", as created in this book. The Business Model Canvas splits a business establishment system into nine key blocks (factors), and uses visual design to quickly enable one to master their relationships. Revenue sources can be obtained from the customer segments, value propositions, customer relationships, and channel strategies, and when the key resources, key production activities, and key partnerships are confirmed, the cost structure can be worked out. The profit model is obtained by subtracting the cost from the revenue.

1.2 Research purposes

As mentioned earlier, the book "Business Model Generation" divides the business model into nine key blocks, which are integrated into a Business Model Canvas. This study composes a program, where the required data are entered step by step, displayed in a Business Model Canvas on a computer screen, and nine key blocks can be printed. When the input content in the nine key blocks omits selecting/filling data, the system reminds the user, thus, the items are completed one by one to complete the entire Business Model Canvas. This software can be used by teachers for teaching, and after case accumulation and multiple trials, it can be used for directing medium and small enterprises to collect consultant fees.

2. Literature Review

While business models have been discussed and studied in Taiwan for a few decades, the concept of the business model has existed in the western society for a long time, and was used to describe the correlation and structure of data and processes as early as 1970 (Konczal, 1975). In the mid-1990s, the business model developed rapidly via the internet, and the concept of business model continuously appeared in various learned periodicals and practical journals (Ghaziani and Ventresca, 2005). For example, Value Migration (Slywotzky, 1995) and Profit Patterns (Slywotzky, 1999), which systematically expounded the business model.

The business model involves many domains, such as food and beverage, marketing, logistics, etc. However, the core of the business model remains focused on customer value. The business model is an architecture of product, service, and information flow, and describes the various enterprise participants and their roles, potential profit, and revenue sources (Timmers, 1998). Enterprises use business opportunities to design a transaction to create value, and the business model describes the specific content and structure of the transaction. The business model is a script that explains how the enterprise works. A good business model must be able to answer "who is the customer", "what is the customer value", "how to make profit for the enterprise", and "what is the economic principle of transferring value to the customer at an appropriate cost" (Magretta, 2002). To be brief, the business model is the means and method to describe how an organization creates, transfers, and obtains value, as shown by the pattern in Figure 1 (Osterwalder et al., 2012). It is extended by Miki (2014), and several easy steps and cases enable readers to rapidly comprehend this technique.

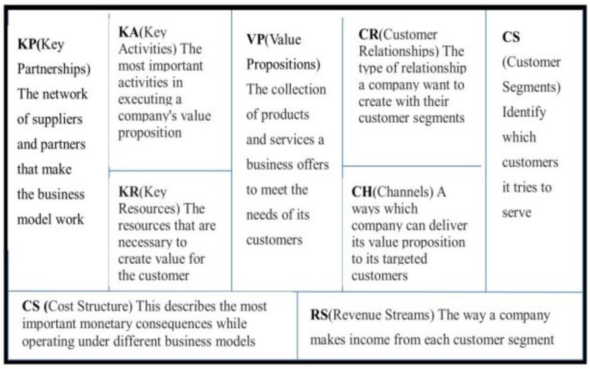

Fig. 1 Business Model Canvas (Source: Business Model Generation, 2012).

3. Nine Key Blocks of the Business Model

The nine key blocks are briefly described, as follows (content is extracted from Osterwalder et al., 2012, please refer to the book for details).

(1) Customer segments

1. Definition: an enterprise targeted individual or organization group to be contacted or served.

(2) Value propositions

1. Definition: entire product sets and services that can create value for specific customer segments.

(3) Channels

1. Definition: how a company communicates with and contacts the customer segments to convey its value propositions.

(4) Customer relationships

1. Definition: the relationship type built by a company with specific customer segments.

(5) Key activities

1. Definition: the most important proceedings of a company for running its business model.

(6) Key resources

1. Definition: the required most important assets for running a business model.

(7) Key partnerships

1. Definition: the required supplier and partner networks for running a business model.

(8) Cost structure

1. Definition: all the costs generated by running a business model.

(9) Revenue streams

1. Definition: the cash of a company derived from every customer segment (the cost must be deducted from revenue to obtain the profit).

4. Process of Software Prototype Development

This study uses C# software in development environment of visual studio to development the business model program software. C# (pronounced "C sharp") is a simple, powerful, type-safe and

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object-oriented programming languages.. ıt will immediately be familiar to C and C++ programmers. C# combines the high productivity of Rapid Application Development (RAD) languages and the raw power of C++. Visual C# .NET is Microsoft's C# development tool. It includes an interactive development environment, visual designers for building Windows and Web applications, a compiler, and a debugger. Visual C# .NET is part of a suite of products, called Visual Studio .NET, that also includes Visual Basic .NET, Visual C++ .NET, and the JScript scripting language. All of these languages provide access to the Microsoft .NET Framework, which includes a common execution engine and a rich class library. The .NET Framework defines a "Common Language Specification" (CLS), a sort of lingua franca that ensures seamless interoperability between CLS-compliant languages and class libraries. For C# developers, this means that even though C# is a new language, it has complete access to the same rich class libraries that are used by seasoned tools such as Visual Basic .NET and Visual C++ .NET. C# itself does not include a class library. Please refer to associated books for details.

5. Results and Discussion

This study composes the business model PC program. The nine factors of the business model can be completed step by step to complete the overall Business Model Canvas, which can be displayed on a computer screen or printed. The program execution procedure is described, as follows:

Fig. 2 Input Customer Segments.

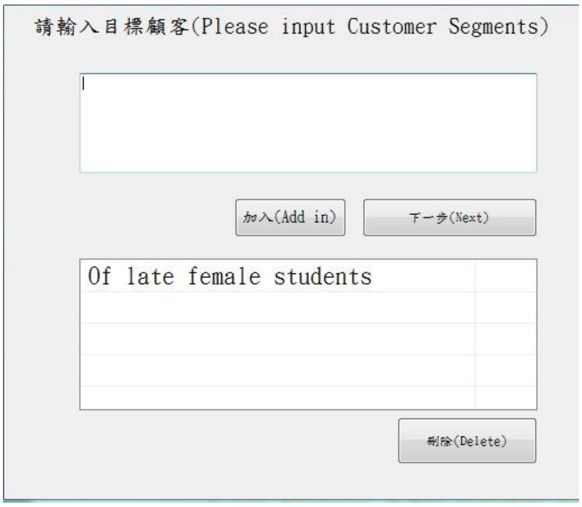

Fig. 3 Customer Segments has been input.

Fig. 4 Input Value Propositions.

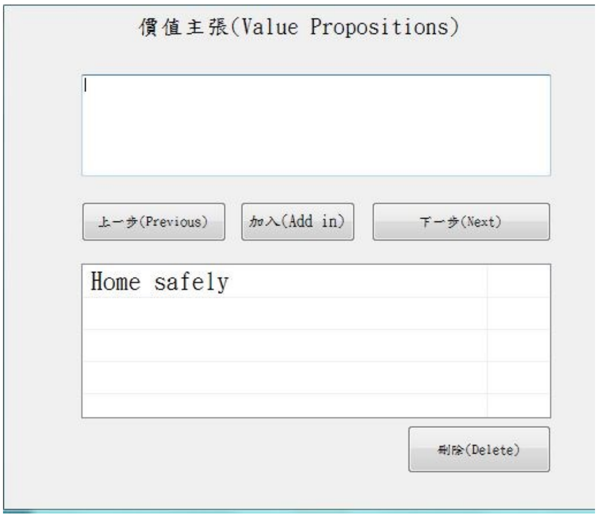

Fig. 5 Value Propositions has been input.

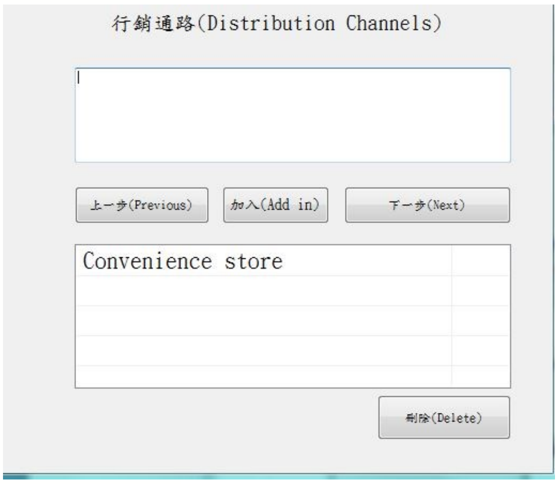

Fig. 6 Distribution channels have been input.

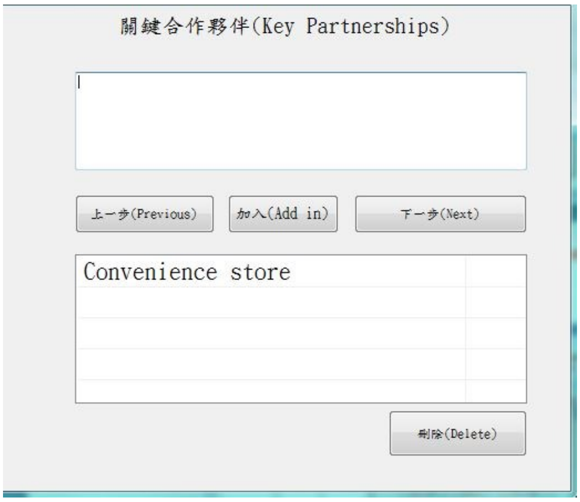

Fig. 9 Key Partnerships has been input.

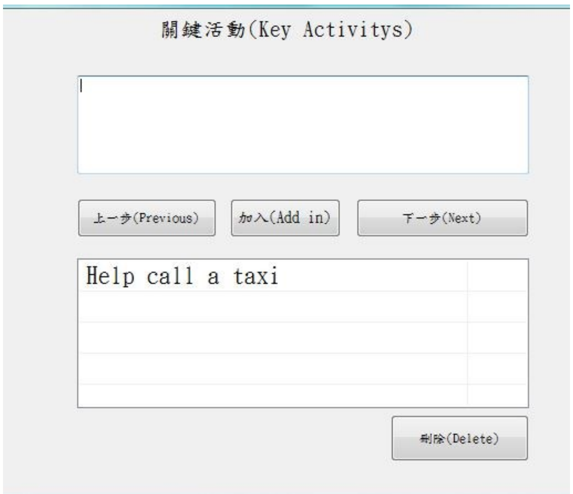

Fig. 7 Key Activity has been input.

Fig. 10 Cost structure has been input.

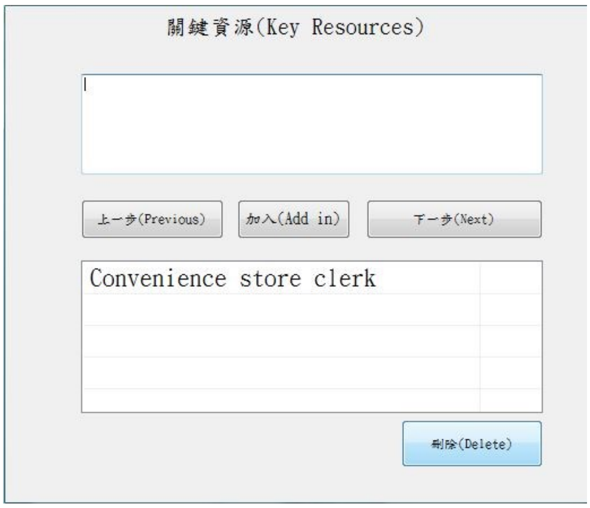

Fig. 8 Key Resources have been input.

Fig. 11 Revenue Streams has been input.

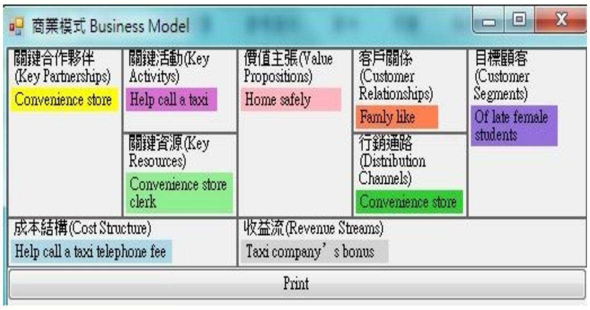

Fig. 12 Screen display of Business Model input complete.

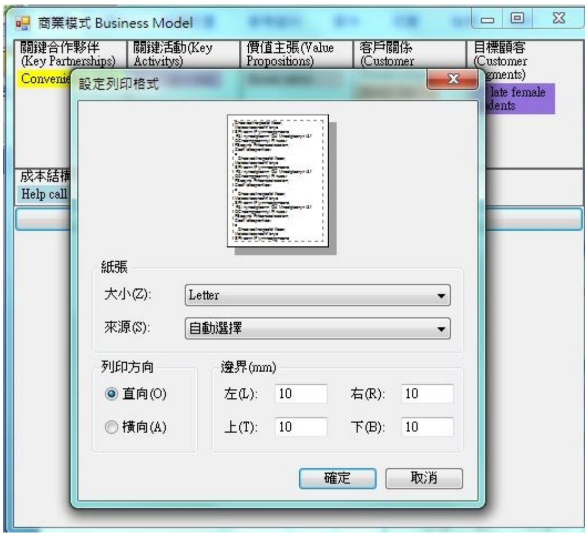

Fig. 13 Screen display of Business Model waiting for printing.

The computer-based systematic filling, additions, and deletions of items are more esthetic than handwriting, and the results can be placed in report files.

6. Conclusion and Suggestions

(1) Conclusion

The book "Business Model Generation" provides a tool, namely the "Business Model Canvas", to help people quickly see the key points of business establishment (innovation) plans; it can be updated easily and continuously to respond to the rapidly changing world; it is used by enterprises all over the world. However, as this book is not software, it cannot make the content into files for saving or transmission. This study composes a "systematic business model innovation" software program, where the required data are entered step by step to complete nine key blocks, which can be printed or displayed as a Business Model Canvas on a computer screen. When the input content in the nine key blocks omits selecting/filling data, the system reminds the user. The overall Business Model Canvas is completed by completing every item.

(2) Suggestions

The "systematic business model innovation" software program of this study can be used by teachers for teaching, and after case accumulation and multiple trials, it can be used to direct medium and small enterprises to collect advisory fees.

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Author Biographies

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Uber, a Disruptive Business Model of a Taxi Service

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Abstract

Uber is an on-demand non-conventional taxi business since it owns no cabs and has no cab drivers as employees. Instead, it sends a driver to a user when they ping a mobile app. It is a technology company that matches consumers to car services in many cities around the globe and takes a slice of the fair for the service.

Uber started as a luxury black-car service in San Francisco in 2009 that went on to be valued at $17 billion by June 2014. It has disrupted the monopoly of taxi cab transportation and has reinvented the experience completely. Previously, there were several payment difficulties when you arrived at your destination. Uber has solved all these touch points, creating a "WoW" (enjoyable) experience by giving the customers "peace of mind" and sparking an avalanche of word of mouth and press.

Uber's Business Model has come under attack from regulatory authorities in many Countries, from China to France. However, we see it as teething problems as on the S-curve, it is still at the birth stage and will have to solve the "ifs and buts" in the paradigm shifting innovation journey to reach its ideal.

Taking Customer Evolution Trend, Uber has positioned itself in the Experience Quadrant of the trend by reimagining the customer's entire experience and making it seamless across all the touch points.

Keywords: 4 Pillars of Systematic Innovation, Business Model, Disruptive, S-Curves

1. **Introduction**

Uber is a taxi service that is currently disrupting the taxi market worldwide. Unlike any other taxi companies out there, it is non-conventional since it owns no cabs, and the taxi drivers aren't their employees. However, a better label to give Uber would be a "technology company", since what they do is they use a mobile app to match consumers to cars. They send a driver to a user when they ping the mobile app and take a small slice (20%) of the fair for providing the service. Basically what Uber is doing is they're *selling the taxi service differently.*

2. **History and Exponential Expansion**

Uber started in 2009 and was launched in 2010 in San Francisco, ever since then their growth as a company has been exponential. (See Figure 1 and Figure 2)

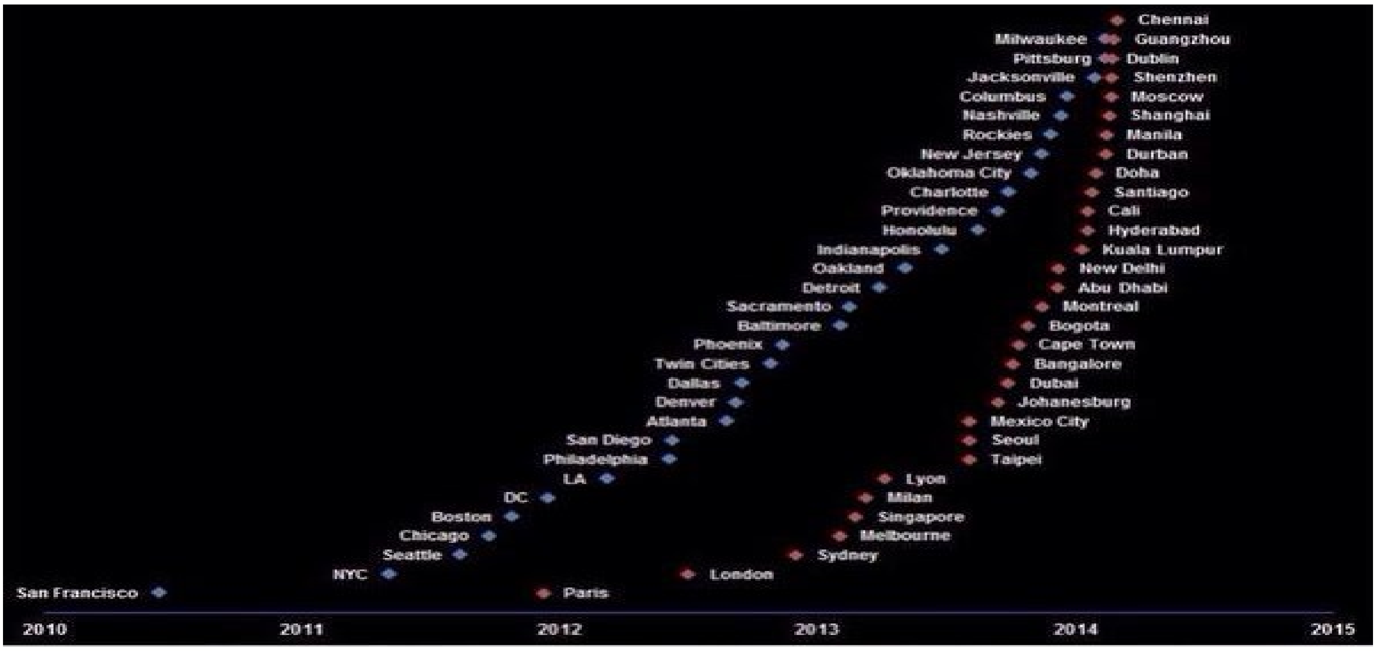

Fig. 1 Uber's city expansion.

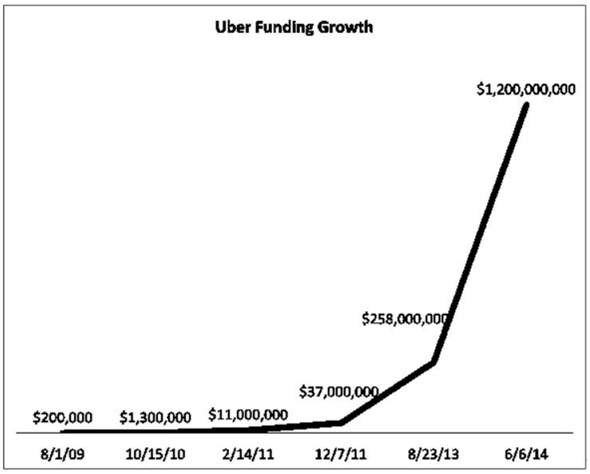

Fig. 2 Uber's funding growth (Ferenstein, G., 2014).

- Uber now runs in 250 cities up from 12 in 2012
- Grew from 75 staff in August 2012 to over 300 staff in August 2013
- Ever since 2013 their revenue has been growing by 18% every month
- BBC stated that it will create over 50,000 jobs in Europe
- By June 2014 its valuation was $40 billion and some say it will be the next $100 billion company

Since Uber's launch, the firm has been under attack from regulatory authorities in several cities around the globe:

- **France:** ban from Jan 2015 for fraudulent business practice & improper competition – fine €100,000, Oct 2014
- **India:** Dec 2014 banned in Delhi as one of the driver arrested on rape charges
- **Netherlands:** banned as it lacked a special license required by the country's law
- **Portland USA:** sued for not having for-hire vehicle licence
- **Thailand:** ordered to stop services as it went against the laws of the country
- **Other Countries:** China, Taiwan, Germany, UK

We as innovators simply see these issues as teething problems. Uber are currently at the bottom of their S-curve (Figure 3) and so they will be prone to problems such as these. Innovation is (Figure 4) defining what ideal is for the customer, and reaching that ideal by solving all the "*ifs and buts*" along the way. This can already be observed as in London, a new sharing economy body has been created to allow the government and businesses similar to Uber and Airbnb to find common ground and establish some baseline rules to move forward.

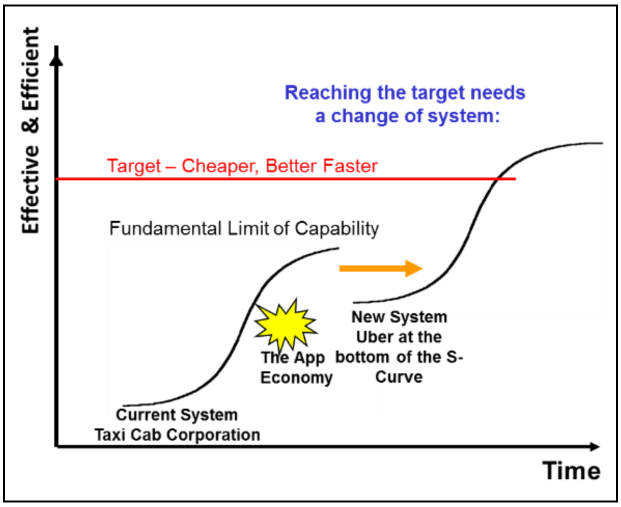

Fig. 3 S-Curves (Mann, D. L., 2008).

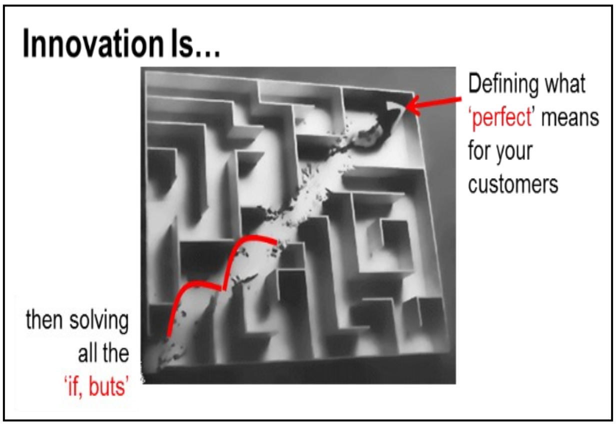

Fig. 4 Innovation Definition (Mann, D. L., 2007).

3. What is Business Model?

The factor that makes a good business model is when the company is organised differently, which allows them to sell their products differently.

A very well-known example of this would be Nespresso, a company owned by Nestle that make coffee machines and coffee pods to be used in the machines. The company almost failed in 1987 when they first launched their Nespresso system due to their poor business model. They had a joint venture with the manufacturer of their machines to target and sell to offices. This failed because offices weren't very interested and even when they did make sales, the majority of the money would go to the machine manufacturers.

Nespresso then changed their business model. They began selling their machines through retailer channels. They sold their coffee pods through their own channels, the repetitive pod sales are what allowed their revenue to increase. They also set up multiple distribution channels to sell the pods, such as online, mail order, call centres and Nespresso stores. Ever since this change in business model, Nespresso has been growing by 30% each year for the past 10 years.

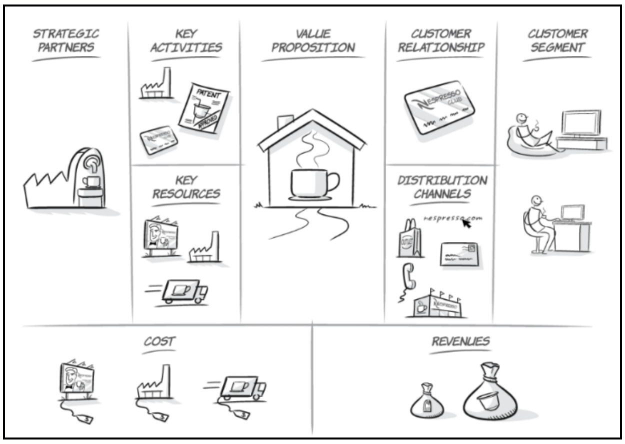

Fig. 5 Nespresso Business Model canvas (Pijl, Patrick Van der, 2009).

Another great example would be Google. They receive revenue by selling adverts on their search engine as well as YouTube and use this revenue to provide their end users with a free perfect now service (the search engine).

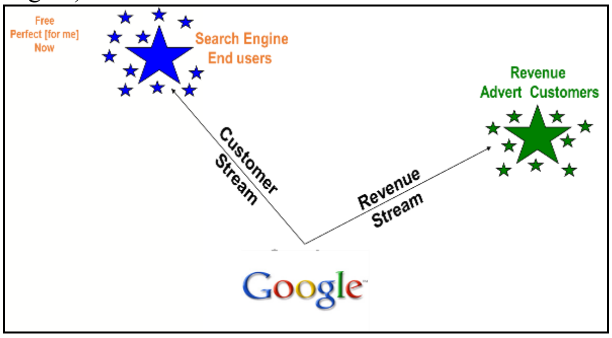

Fig. 6 Google Business Model (Walji, J. & Mann, D. L.,2007).

Grameen Bank. They are a bank that sell microloans, however unlike any conventional bank, their loans don't require any collaterals. The borrowers don't have to sign any legal documents and it's owned by poor women. The amount of loan one receives is based on the potential one has. As a result, 58% of borrowers (20 million people in the last 20 years) have been lifted out of poverty. The bank also has a return rate of about 98.5%, which is higher than any conventional bank, thanks to the unique peer pressure and peer support system they utilise.

Semco in Brazil is yet another brilliant example. Their main business is making biscuit machines. The majority of the company also relies on peer pressure. They have a workplace democracy. Managers set their own wages, Workers choose their own bosses, set their own time, and so there is no need for things such as a HR department or employee contracts, thus saving cost without losing the HR function. As soon as this business model was applied, Semco's revenue went through the roof. Ricardo Semler has now replicated this business model in primary schools where students choose their own teachers, set the rules of the schools and choose the days they take off etc.

4. Four Pillars of Systematic Innovation

The four pillars of systematic innovation are *Ideality, Functionality, Contradictions and Resources.* These can significantly be found in Uber's business model.

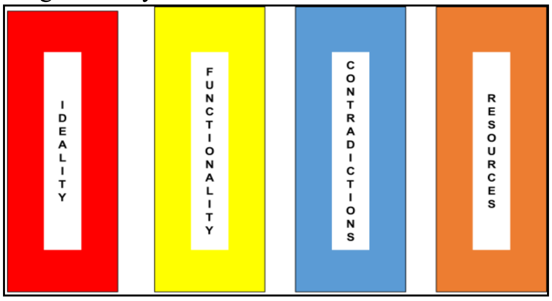

Fig. 7 Four Pillars of Breakthrough Innovation (Walji, J. & Mann, D. L.,2007).

Ideality: Also known as *Customer Value* is simply increasing the good and decreasing the payment factors. Therefore it can also be represented by the formula in Figure 8.

$$CV = \frac{\text{Benefit (tangable + intangable)}}{\text{(Cost + Harm)}}$$

Fig. 8 Customer Value Formula.

The aim with customer value is to reduce the cost and harm as much as possible to provide a service that includes all three of the value parameters: *Cheaper, Better and Faster*, and the ideal of that would be a service that is *Free, Perfect, and Now.*
Traditional taxi services fail to do this, they usually provide one of these parameters. Uber on the other hand has managed to provide all three of the value parameters and that is why it's disrupting the taxi market so severely.

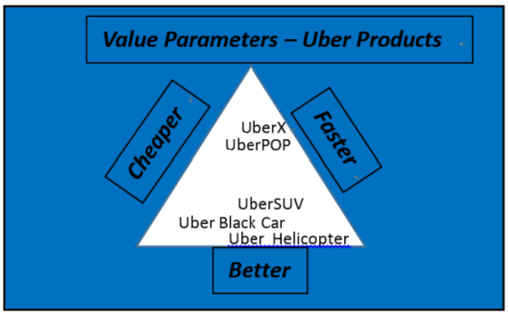

Fig. 9 Uber's Value Parameters (Ownyang, J., 2014).

- **Functionality:** The second is functionality. Functionality states that the function stays the same, but the solution changes. An example would be washing clothes. It started with hand washing, then moved to washing machines that use soap powder, then Sanyo came out with a washing machine that uses no soap powder, then a washing machine that uses no soap powder and virtually no water was invented, and then air washing, and finally a perfect shirt (released in 2006) that doesn't get dirty (nanotechnology). The outcome of all of these is a clean shirt (Figure 10).

Fig. 10 Function stays the same Solution changes (Walji, J. Mann, D. L., 2007).

Uber's function is to provide transport. The traditional taxi system has evolved to produce this new system that is efficient, as the car reaches your house in under 10 minutes, and the app charges your credit card at the end of the ride. This also makes the experience more enjoyable for the customer since they don't have to deal with cash, change, tips, or receipts. The outcome of all of this is; the customer has peace of mind, which is an intangible value, and Uber has provided this intangible value via tangibles, which all companies should aim to do.

"Intangibles are non-physical factors that contribute to or are **used** in producing goods or providing services, or that are **expected** to generate future productive benefits for the individuals or firms that control the use of those factors."

Additionally, another thing that makes Uber really efficient is their capacity utilization. Capacity utilization is a major problem with traditional taxi companies because they fail to match supply to demand, and as a result you get taxis cruising empty. To compensate for these empty rides traditional taxi companies have to charge higher fares. However, Uber matches supply to demand almost perfectly, which allows them to be more profitable and offer lower fares on certain routes.

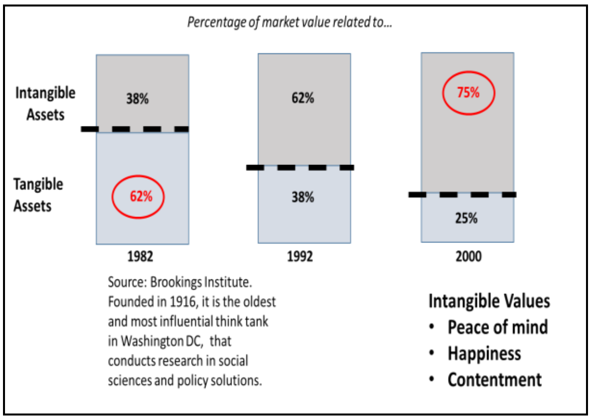

Fig. 11 Source of value has shifted (Brookings Institution, 2007).

- **Contradiction:** The third pillar. All systems contain contradiction. What people and companies do is they try and solve a contradiction by coming up with a compromise. This often involves opportunity cost. They do this because they believe that compromise is the only way to deal with contradictions. But we know that all powerful and ideal solutions are ones that solve the contradiction, and thus eliminate the opportunity cost within these compromises.

Example: The bicycle saddle. An ideal saddle must be wide to provide comfortable support, AND the saddle must also be able to permit pedalling action. Because this design contradiction could not be solved, they came up with a compromise where the back of the seat is wide and the front of the seat is narrow, where the opportunity at cost is the comfort. But in innovation we try and eliminate opportunity cost. ABS sports came up with a solution called the "dual action seat" that is wide to provide comfort, and allows you to pedal despite the width.

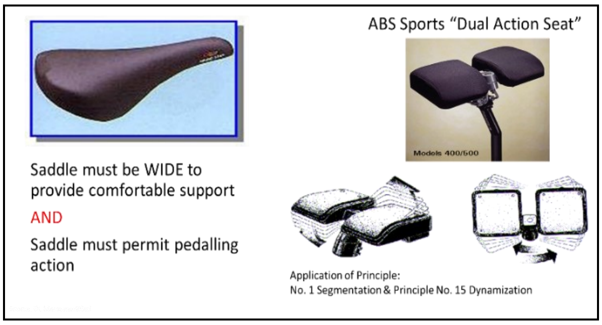

Fig. 12 Typical design compromises - The bicycle saddle (Robinson, C. & Mann, D.L., (2006).

Uber has successfully solved the contradiction of providing a cheaper AND better AND faster taxi service. Traditional taxi services have given into opportunity cost, which is to offer one of the three value parameters, rather than solving the contradiction itself, and this once again, is why Uber has been so successful and disrupted the taxi market so effectively.

- **Resources:** The fourth pillar. Uber has effectively used the whole city as a resource and as a result, they have managed to turn all of the fixed costs that traditional taxi companies have, into variable costs, this is what allows them to charge cheaper fares on certain routes. They don't require large parking lots to park their taxis (e.g. Dubai and Doha) because they don't own any taxis, drivers use their own personal parking space in their homes. They don't have to worry about maintenance of the cars because once again the cars are owned by the drivers. Even for insurance, the drivers are responsible. Anyone who owns a car can become an Uber driver. What Uber has done is, it has defined the whole city as a system, and used everything in it as a resource. This is the uniqueness of their business model that is *selling the taxi service differently by using the whole city as a resource.*

5. Economic Evolution Trend (customer expectation evolution trend)

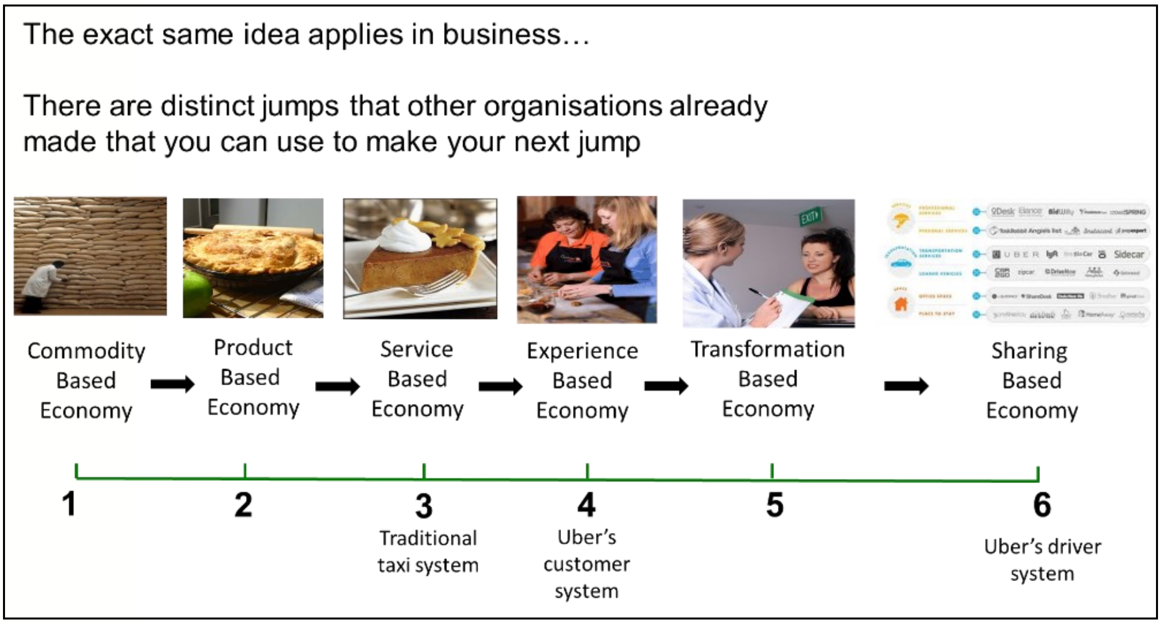

Fig. 13 Non-linear customer expectation evolution trend.

Fig 13 is one of many non-linear trends in Systematic Innovation. What it shows that things go from a commodity based economy (wheat in this case) to a product based economy (pie) to a service based economy (restaurant) to experience (learning how to cook) to transformation (nutritionist changing your life style) to a sharing economy and finally in 2050 and beyond a caring economy due to the ageing global population.
Traditional taxis are in the service economy or customer expectation box. Uber however has jumped into the experienced based economy quadrant by providing its customer with a peace of mind (intangible value) through a seamless enjoyable experience going from point A to point B.
On the other hand Uber has also leap frogged into the sharing economy quadrant, similar to Airbnb, by sharing the revenue with the taxi drivers (80% to the drivers and 20% to Uber). This is how Uber has disrupted the traditional taxi business.

6. Uber's Business Model

Fig 14 shows the Uber business model in a nut shell.

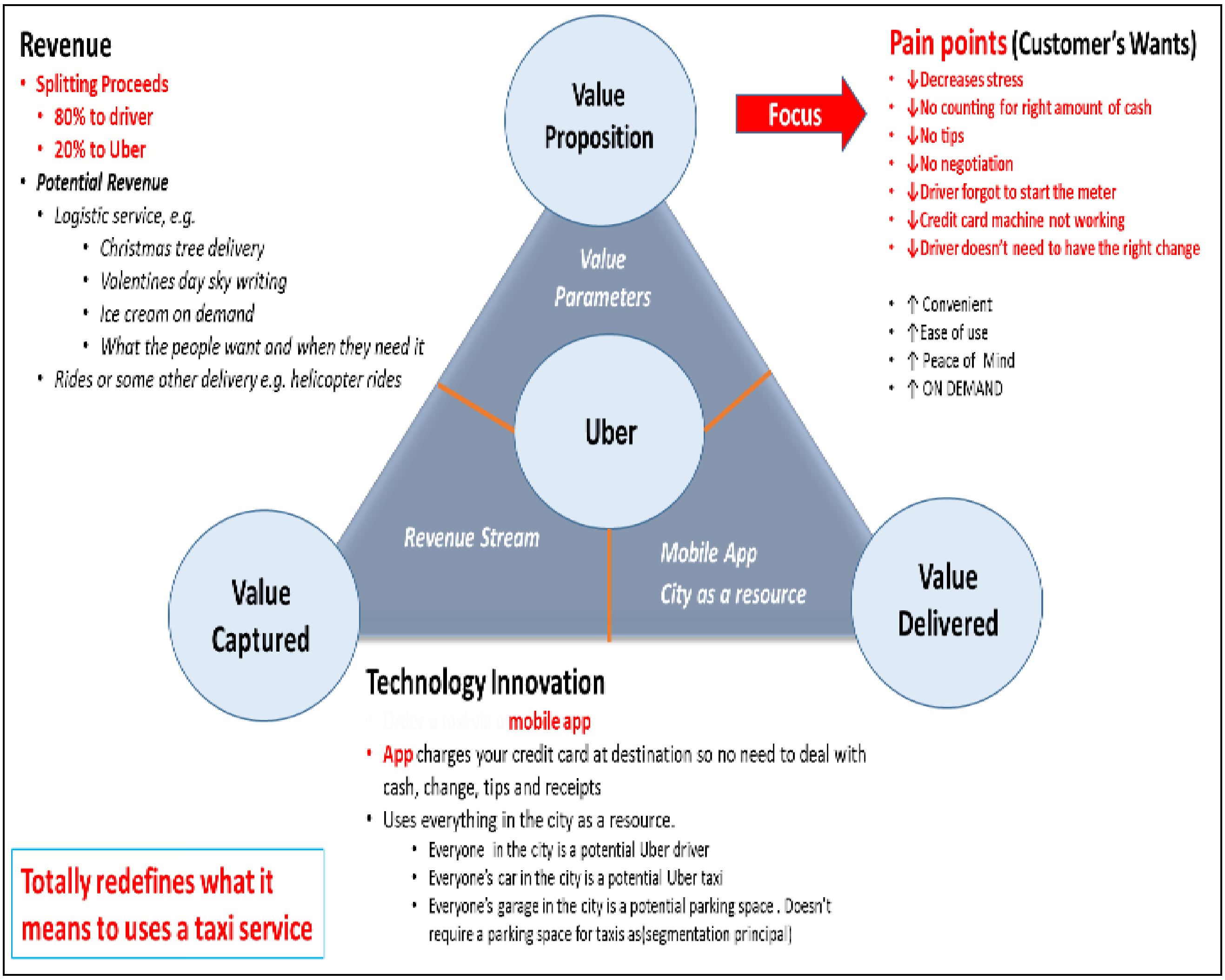

Fig. 14 Uber's Business Model.

Uber's value proposition is made of many value parameters as shown in the fig 14. What Uber does is provide convenience, ease of use, peace of mind and an On Demand service. This has eliminated all the pain points of the customer as shown above. For example, the customer does not have to negotiate with the driver, does not have to give him a tip, etc.

The said value is delivered through a Mobile App and using the whole of the city as a resource as explained earlier.

The value is captured through a revenue split of 80% to the drivers and 20% to Uber. However, the reason Uber is at present, valued at $40 billion, and people are saying that soon it will be the first $100 billion company; is because it is a logistic company and not a taxi company anymore. They deliver Christmas trees, ice cream on demand and helicopter services. It could be that in the next five years courier companies like FedEx or DHL will use Uber to deliver their documents and parcels. Amazon.com may also use Uber for its logistics as it probably won't require warehouses to store their goods. They will order Uber to collect say a book, CD, etc. from the publisher and deliver it to an amazon customer. So, one can now see why Uber is valued at $ 40 billion and heading towards $100 Billion.

What the four pillars of Systematic Innovation are saying, is, look at what resources are already available in the system, whether that is in a city, nationally, internationally or globally to resolve a contradiction that provides a function, which is ideal for the customer.

This is what Uber has done with its Experience & Sharing Economy Business Model.

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Application of TRIZ in Inventive Product Design: A Case Study on Baking Tray Rack

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Abstract

Innovation is an important weapon for enterprises to achieve sustainable development in the market. In the large number of product markets featuring dramatic changes today, the products that attract consumers and win their heart must be manufactured to create business opportunities. Therefore, it is more vital to create opportunities of product innovation than to determine consumer needs. Taking the baking tray racks produced by an enterprise for an example, this study innovated the product with the skills and knowledge of TRIZ, a systematic innovation tool, according to consumer needs. In this study, function analysis was adopted to analyze the components and interaction of baking tray racks, and create a function model graph. The causal contradiction chain was analyzed to explore diverse consumer needs for baking tray racks, all the problems were analyzed one by one, and then, interlinked to determine the roots of the problems and identify contradictions. After analysis, 39 engineering parameters were introduced regarding all factors, and the engineering contradiction matrix was employed to seek the inventive principles for innovative ideas. Moreover, the design of the baking tray racks was simplified according to the concept of simplistic design. Eventually, the assumed improved baking tray rack was endowed with three innovative functions: (1) it could be stored away; (2) baking trays of various sizes could be placed on it at the same time; (3) it enabled enterprises to meet consumer needs and be innovative.

Keywords: systematic innovative, TRIZ, baking tray rack

1. Introduction

1.1 Research motives

Western-styled bakeries are scattered across Taiwan and play an essential part in people's daily life. Around 1940, the concepts and skills of various food, such as breads and cakes, were introduced from the West. To date, small traditional stores have developed into central kitchens of mass production, which shows the great need for bread in the Taiwanese diet. The Taiwanese people lead a busy and hasty life, and bread is sold in all convenience stores, which has led to an increasing number of people who buy take-away food to eat on-the-go. Nowadays, there are over 10,000 bakeries in Taiwan, creating an annual sales volume of NTD 60 billion, which accounts for merely one tenth of the annual output of Taiwan's food industry (China Productivity Center, 2016). Although the amount is not too large, this industry plays a significant role in Taiwanese market.

The use of space is particularly important in bread making. All bread-making locations, big or small, feature three steps for bread placement: handmade dough is placed for fermentation; frozen dough is placed for unfreezing; finished bread is placed for cooling after baking. As such placement requires both time and space, the need for space is a big problem; therefore, a vertical structure was adopted as the main architecture of earlier baking tray racks, which allowed many baking trays to be placed, and limited space to be fully used.

In addition to the basic function of wheel installation, a transparent cover could be added or a customized closed baking tray rack could be made according to consumer needs. However, there remain two unaddressed needs and problems in the use of baking tray racks according to the suggestions for manufactures: the baking tray rack occupies too much space; there is limited placement for baking trays of different sizes.

1.2 Research purposes

A baking tray rack is used for storing baking trays; however, traditional baking tray racks were limited by the mainstream design, meaning that all baking trays must be the same size to fit the racks. All commercial spaces represent both an asset and a cost to investors, thus, attention must be paid to how such spaces are used, such as the placement of baking tray racks. According to two problems inherent in the traditional baking tray rack, this study focuses on creative thinking in the design of existing products, and seeks to maximize the use of the space required for baking tray racks.

1.3 Research method and procedure

This study collected the problematic issues of products available on the market in order to identify the shortcomings of the functions of the products, and then, adopted TRIZ, a systematic innovation tool, to design an improved product for the market.

The architecture and procedures of this study are, as follows:

1. Introduction: This section elaborates on the research background, motives, research objectives, problem definition, and research method and procedures.

2. TRIZ: This section illustrates the analytic tool adopted in this study, examines how the solution is proposed according to the contradiction matrix of TRIZ, and offers 40 inventive principles, thus, displaying the ability of the analytic tools of TRIZ, and how it is used in this study.

3. Development procedure: In this section, a series of TRIZ tools are employed to analyze and design the products of the case study.

4. Conclusion and suggestions: The development procedure in this study is described, and suggestions and future directions for product development are proposed.

2. Analytic tools of TRIZ

2.1 Development of TRIZ

TRIZ is an abbreviation consisting of the initial letters of four English words transliterated from Russian, namely, Teoriya, Resheniya, Izobreatatelskikh, and Zadatch, literally meaning the "Theory of the Inventive Problems Solving". It is a systematic method of thought proposed by Genrich Altshuller, a Russian patent attorney and inventor (Savransky, 2000).

In addition to product design, TRIZ is applied to business, society, quality management, finance, marketing, and architecture (Yan et al., 2014). Savranky (2000) stated that only TRIZ could effectively solve some problems, including unknown reasons or directions. Additionally, some Top 500 enterprises succeeded in enhancing their productivity and quality through TRIZ, which demonstrates its great importance for enterprises. One of the features of TRIZ is that it can convert harmful resources into useful resources, eliminate contradictions, and replace the original compromise (Mann & Winkless, 2001; Su & Lin, 2008).

2.2 Functional analysis

Function analysis (FA) is helpful in detecting negative functions and the most fundamental problems of a system. When distinguishing the relations among the functions of systematic and definition components, function analysis can be divided into four types: useful, harmful, excessive, and insufficient, which are represented by the arrows shown in Fig 1.

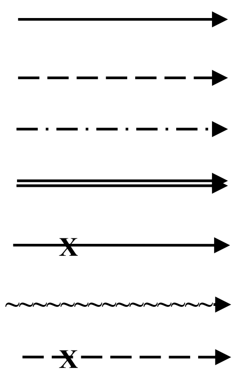

Fig. 1 Function signs (Savransky, 2000)

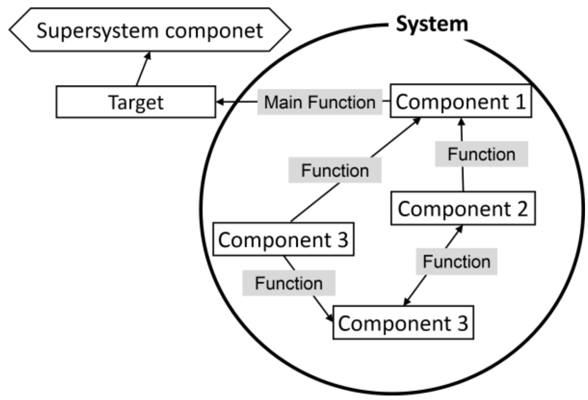

Fig. 2 Function analysis example

In function analysis, a supporting tool can enhance the FA -- functional hierarchies, whose architecture includes the constituents and functions between the system and the subsystem. Its strength is that it can simplify the system (see Fig. 2).

2.3 Engineering contradiction

Contradiction is one of core concepts in TRIZ. Among over 150,000 patents across the world, Altshuller identified contradictions among the 39 engineering parameters and the 40 inventive principles to put forward the contradiction matrix, in order to obtain a standard solution for thinking within a short time. Engineering contradiction occurs in causal analysis, where a reason can improve one result, while worsening another.

There are core problems in contradiction, thus, the 40 inventive principles of TRIZ are intended to help enterprises determine the causes for problems, and seek improvements.

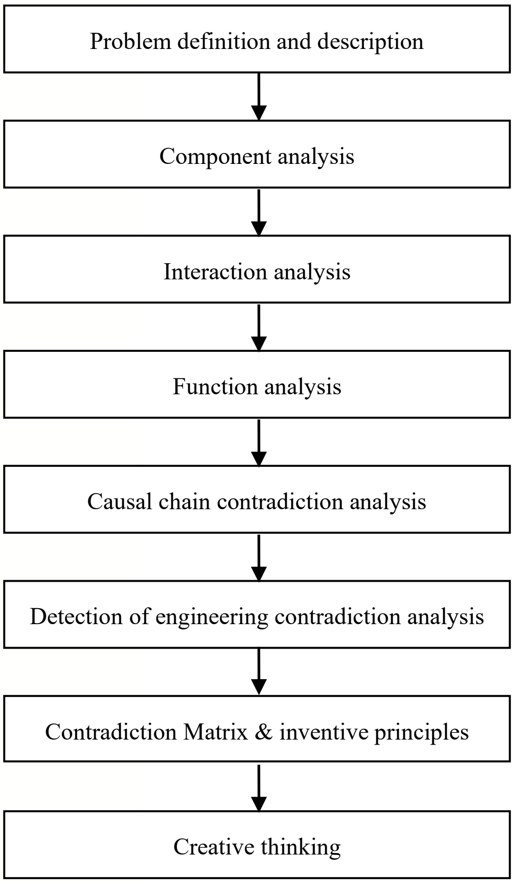

Fig. 3 Development procedure

3. Development procedure

The overall product development and design procedure is as shown in Fig. 3. First and foremost, problem definition is conducted to determine needs and problems. Then, the analytic tools of TRIZ are adopted for improvement until the inventive principles are obtained to assess and define feasible approaches.

3.1 Problem definition and description

Currently, there are limitations on the framework breadth of baking tray racks, and there is no universal standard for breadth in the market. Meanwhile, as the breadth of supporting sheets affects heat radiation, baking trays of the same breadth cannot be placed on a rack. Due to the mainstream design, baking tray racks cannot be stored away, thus, the use of space for baking tray racks is limited.

Therefore, two problems are defined in this study: **baking trays of different sizes cannot be placed on the baking tray rack** and **baking tray racks cannot be hidden**. These two problems are analyzed in the following sections.

3.2 Component analysis, interaction analysis, function analysis, and cause effect chain analysis

In component analysis, a rack can be divided into several components which include X framework (horizontal breath), Y framework (horizontal depth), Z (vertical height), supporting sheet, weld, shaft, brake, wheel, big backing tray, medium baking tray and small backing tray (see Fig. 4 and 5).

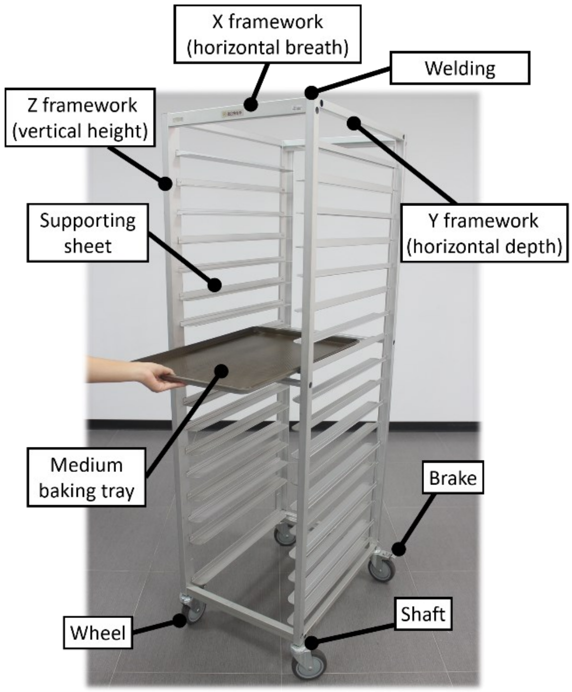

Fig. 4 The component analysis of the backing tray rack

Fig. 5 The component analysis of three different sizes of backing trays

All the components are analyzed the interaction between components. The symbol "+" is marked if there is interaction, while the symbol "-" is marked if there is no interaction (see Table 1). Then, function analysis is employed to define the contents and importance of functions according to the existing interaction among the components It helps identify useful and harmful functions, and categorize useful functions into three levels, basic, auxiliary and additional functions, and three degrees, normal, insufficient and excessive (see Table 2).

The function analysis table is converted into a function model (see Fig.6), which shows that excessive and insufficient "placement function" exists among large and small baking trays on the supporting sheets. The same problem could be found in the capacity of the X framework. According to the component analysis of the capacity among baking tray racks, the framework was divided into X, Y, and Z framework, and two paralleled baking tray racks would touch each other. According to the problem, the supporting sheets and framework require improvements.

Table 1 Interaction analysis

	1.X framework	2.Y framework	3.Z framework	4.Supporting sheet	5.Weld	6.Shaft	7.Brake	8.Wheel	9.Big baking tray	10.Medium baking tray	11.Small baking tray
1		+	+	-	+	+	-	+	-	-	-
2	+		+	-	+	+	-	+	-	-	-
3	+	+		+	+	+	-	+	+	-	-
4	-	-	+		-	-	-	-	-	+	-
5	+	+	+	-		+	-	-	-	-	-
6	+	+	+	-	+		+	+	-	-	-
7	-	-	-	-	-	+		+	-	-	-
8	+	+	+	-	-	+	+		-	-	-
9	-	-	+	-	-	-	-	-		-	-
10	-	-	-	+	-	-	-	-	-		-
11	-	-	-	-	-	-	-	-	-	-	

Table 2 Function analysis

Function	Objective	Classification	Level	Degree
Brake				
Stop	Wheel	Useful	Auxiliary	Normal
Shaft				
Support	X framework	Useful	Auxiliary	Normal
Support	Y framework	Useful	Auxiliary	Normal
Support	Z framework	Useful	Auxiliary	Normal
Rotate	Wheel	Useful	Auxiliary	Normal
Wheel				
Support	Shaft	Useful	Auxiliary	Normal
Welding				
Fix	X framework	Useful	Auxiliary	Normal
Fix	Y framework	Useful	Auxiliary	Normal
Fix	Z framework	Useful	Auxiliary	Normal
Fix	Supporting sheet	Useful	Auxiliary	Normal
Fix	Shaft	Useful	Auxiliary	Normal
Supporting sheet				
Support	Medium baking tray	Useful	Basic	Normal
Z framework				
Locate	Supporting sheet	Useful	Auxiliary	Normal
Support	X framework	Useful	Auxiliary	Normal
Support	Y framework	Useful	Auxiliary	Normal
Block	Big backing tray	Harmful	n/a	n/a
Y framework				
Support	X framework	Useful	Auxiliary	Normal
Support	Z framework	Useful	Auxiliary	Normal
X framework				

Function	Objective	Classification	Level	Degree
Support	Y framework	Useful	Auxiliary	Normal
Support	Z framework	Useful	Auxiliary	Normal

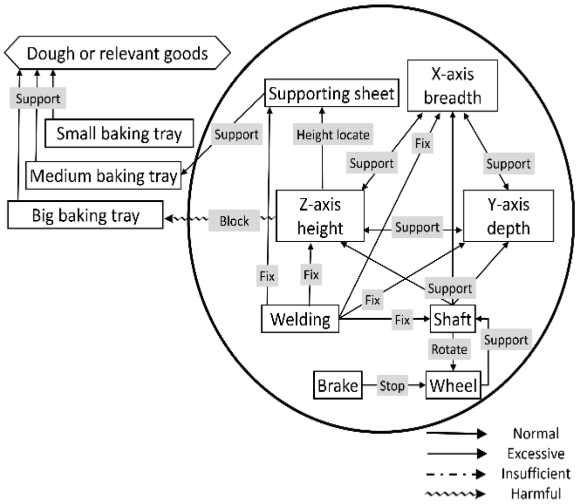

Fig. 6 The function model of baking tray rack

Eventually, according to the defined problems, these 2 issues were taken for causal chain contradiction analysis (See Fig. 7 and 8). The engineering parameters were retrieved, and the deteriorating and improving parameters were defined one by one. Regarding placement, the reasons for the problems in supporting sheets and frameworks were analyzed: the breadth of supporting sheets was medium; the framework could not be extended or adjusted. Each of these two reasons formed an engineering contradiction, thus, forming the 40 inventive principles consistent with the contradiction matrix.

3.3 Contradiction matrix

In the causal contradiction analysis, the engineering parameters marked with "+" presents as improving features, while those marked with "-" denote the worsening features, as caused by providing a certain parameters. These features were classified as 39 engineering parameters and based on the principles of high-quality patents concludes 40 inventive. Therefore the contradiction matrix was used to determine the corresponding 40 inventive principles which and helped us to deal with these contradiction (Savransky, 2000). The first issue of current backing tray rack is that it is designed to hold a unique size of trays. However, there are usually many different sizes of trays in the working environment (see Fig. 9). Secondly, there are usually more than one backing tray rack which cause a problem when being stored (see Fig. 10).

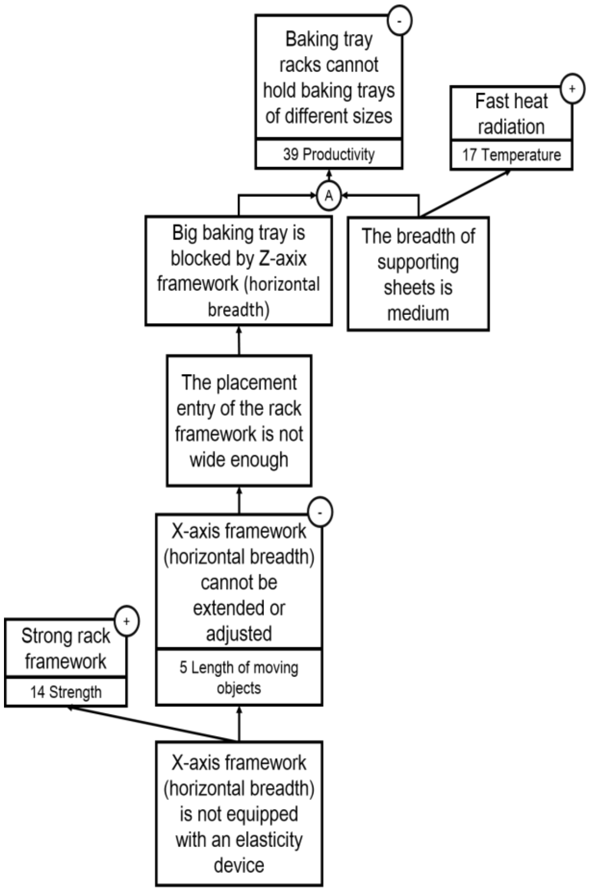

Fig. 7 Causal contradiction analysis (first issue)

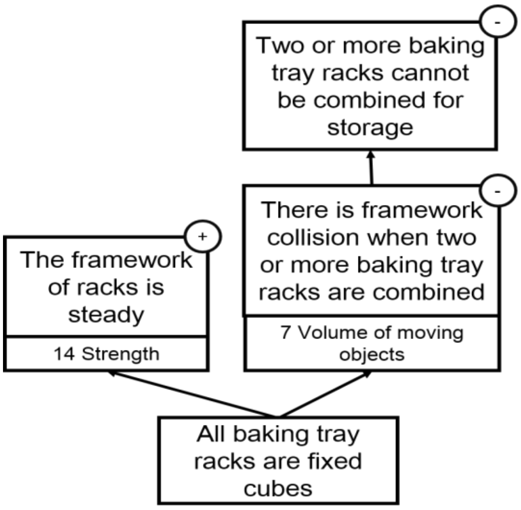

Fig. 8 Causal contradiction analysis (second issue)

Fig. 9 The first issue of the current backing tray rack

Fig. 10 The second issue of the current backing tray rack

While using cause-effect-chain analysis, we find that the root causes of these problems are the contradiction between 'strong rack framework' and 'X framework cannot be extended or adjusted' and the contradiction between 'the framework of racks is steady' and 'there is framework collision when two or more backing tray racks are combined' (see Tables 3 and 4).

Table 3 Engineering Matrix of the Contradiction Between Strength and the Length of Moving Objects

Worsening Parameter / Improving Parameter	5. Length of Moving Objects
14. Strength	1. Segmentation
	15. Dynamization
	8. Anti-weight
	35. Parameter changes

Table 4 Engineering Contradiction Matrix of Strength and the Volume of Moving Objects

Worsening Parameter / Improving Parameter	7. Volume of Moving Objects
14. Strength	10. Preliminary action
	15. Dynamization
	14. Sphere Shape
	7.Nested doll

When considering the approach how to apply the listed inventive principles to products; each inventive principle provides a solution direction rather than an absolute solution; therefore, it is necessary to take countermeasures most suitable for the products, according to the features and functions of the products. The inventive principles, showing in the contradiction matrix, are presented in order of decreasing frequency of their use in past patents (Savransky, 2000). In this study, the inventive principles of "Parameter changes" and "Nested doll" are chosen for generating inventive solution for new products.

3.4 Innovative thinking and procedure of inventive principles

Following is an interpretation of inventive principle 35, "Parameter changes": Change physical states or change measurable parameters (Savransky, 2000). Therefore, the general solution is used to consider certain solutions. By focusing on the supporting sheets, the original mutually paralleled supporting sheets were developed into five angle-based change combinations (see Fig. 11).

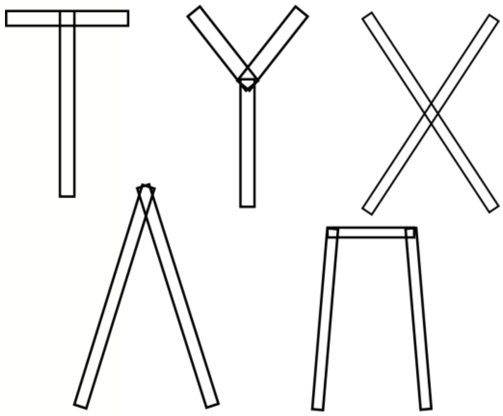

Fig. 11 Angle-based Change Combinations of Supporting Sheets (Top View)

Following is an interpretation of inventive principle 7, "Nested doll": An object or system is placed in another object or system (Savransky, 2000). This inventive principle shows that shopping carts are among the existing products that share the same concept (see Fig. 12). This product can be stored away in the nesting position due to its horizontal angle of elevation and the vertical supporting structure on one side.

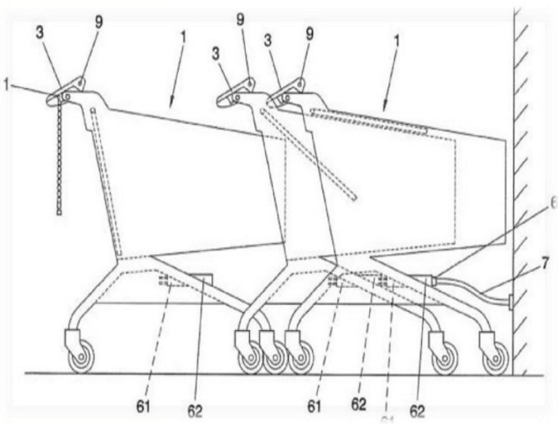

Fig. 12 Side View of Shopping Cart
Source: Gomera Rincon, Jose Antonio Perez Robles, Judith, Spanish patent NO. U201030810 (July 29, 2010.)

Following is a description of the best solutions to the two above-mentioned problems, placement and storage, are listed as the below:

1. The number of Z frameworks (vertical) is reduced from 4 to 2.

2. The supporting function of supporting sheets is merged into an XY framework (horizontal) to create "a framework that supports baking trays".

3. Trapezium is adopted for the angle combination of the XY framework (horizontal).

4. The angle of elevation of the XY framework (horizontal) is 15°.

According to the above-mentioned proposals, an "innovative baking tray rack" was designed in this study. In addition to maintaining a simplistic design and avoiding making products more sophisticated, this study developed the following functions:

1. The overall form of the innovative baking tray rack is similar to a shopping cart. It can be stored away and save space (see Fig. 13 and 14), thus, reducing wasted space when the rack is left unused.

2. The trapezium-shaped XY framework (horizontal) allows the placement of baking trays of different sizes, which diversifies the use of the baking tray rack (see Fig. 15).

3. The angle at which baking trays are placed increases from one to many, which enhance the efficiency of use.

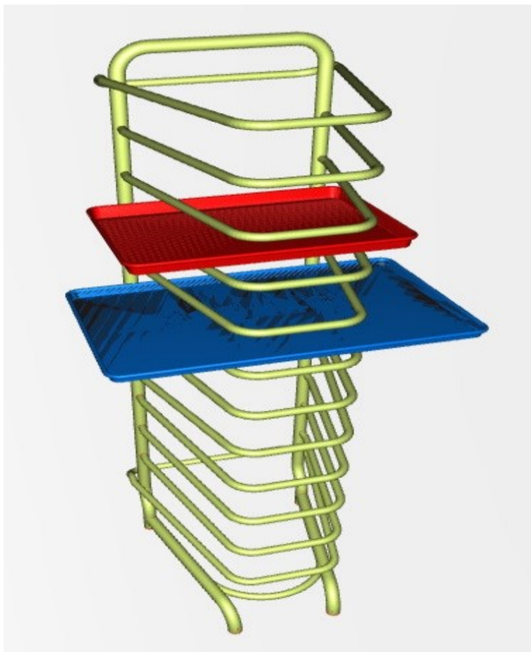

Fig. 13 Storage of the Innovative Baking Tray Rack (Top View)

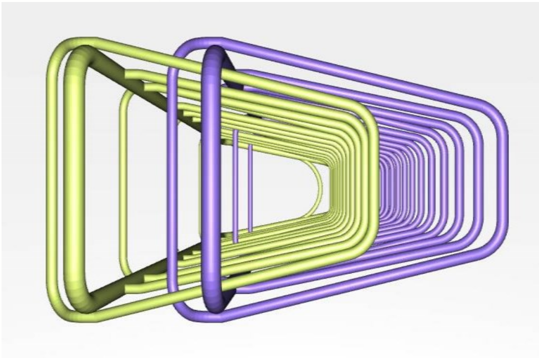

Fig. 14 Storage of the Innovative Baking Tray Rack (Side View)

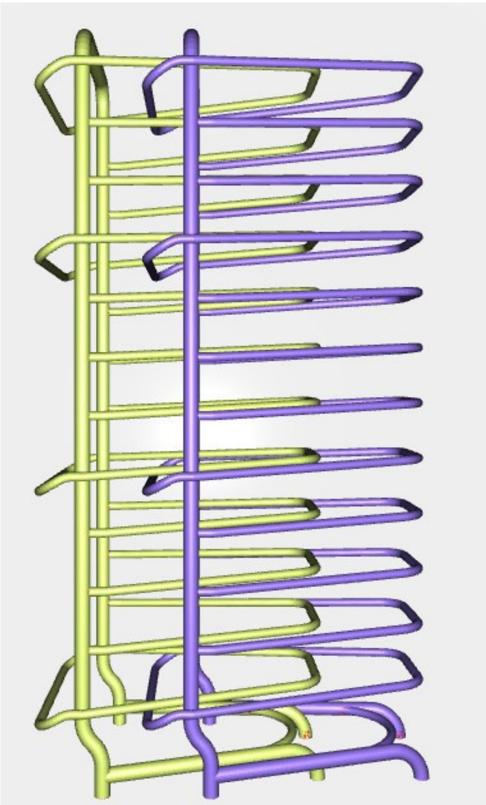

Fig. 15 Placement of Baking Trays of Different Sizes

4. Conclusion and suggestions

Three innovative functions are combined in this innovative product: baking trays of different sizes can be placed at the same time; baking trays can be placed at different angles; the rack can be stored away, which are functions best demonstrated in a central kitchen featuring mass production. Usually, a large number of baking tray racks are needed in a central kitchen for the placement of baked foods. In addition to diversifying the movements of bakers and the placement of baking trays, this innovative baking tray rack can hold baking trays of different sizes. Hence, the innovative product has great value.

In addition to a large central kitchen, this innovative product is applicable to small and medium sized baking rooms. In consideration of limited assets, small and medium bakers often choose a small area for production, thus, this innovative product will contribute to flexible utilization of space according to the production demands of these bakers. Moreover, when baking trays are renewed, the new ones would likely be different from the old ones in size, thus, this innovative product can well meet renewal needs and maximize the use of limited space.

However, there are still some problems to be solved in innovative baking tray racks. For instance, it remains unknown whether there will be a safety problem regarding space when there is excessive space caused by the placement of large baking trays. These problems require further discussion in future studies.

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