Effective New Product Development by Using Inventive Problem Solving Tools in Systematic Innovation Method

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Abstract

The research addresses a real-world problem about handicaps of plastic bottles when the hot liquid is filled in the plastic bottle and cooling with the closed cap. Idea screening and concept design are the core parts of the New Product Development. The paper provides the alternative approach for these core stages by using Systematic Innovation methods. The principles and concepts are discussed based on Systematic Innovation methodologies. The method has been already applied several practical applications and gives the guidelines to be adapted into new product development innovatively. The design of the new bottle system demonstrates effectiveness and significance by applying the systematic innovation method for generating innovative idea.

Keywords: Bottle design, New product development, Product manufacturing, Systematic innovation, TRIZ, TIPS

1. Introduction

A PET (Poly-Ethylene Terephthalate) bottle is reusable and reduces amount of waste that goes into landfills. PET was commercially introduced by Coca-Cola in 1979 as their soft drink bottles which were promoted as unbreakable form of bottles. Eventually, it has been also used by all other beverage companies for their beverages. Although a glass bottle is most reusable, it uses heaviest materials commercially. Regarding the environmental perspective, glass is best choice for companies because they want to be eco-friendly. On the other hand, PET materials would be a better option due to its lightness of weight that could minimize shipping loads in terms of operations and manufacturing factors. Although typical plastic bottles cannot be reused in the same way as glass bottles can, the material composition makes possible to dump into landfills and allows to be reused as cheaper recycled plastic products. As it mentioned, the main reason to choose PET bottles is the weight difference between them. A glass bottle weighs around 6000 grams per a liter but a plastic bottle weighs only 33 grams per a liter (Isaac, 2012). This weight difference gives huge impacts for transportation of beverage products in the view point of logistics costs.

Recently, one of startup companies for beverages in Philippines has been using a plastic (PET) bottle for their packaging. Although this material is cheap and light, there are some problem for a hot (temperature) beverage packaging:

- Hot tea is poured directly in the bottle.
- Present design evolved through continuous changes in consultation with the manufacturer.
- Present design dents on the top portion of the bottle giving it unaesthetic appearance.
- Bottle cost is half the cost of the product.
- The cost of a mold for new bottle is around 67K USD in Philippines.

Because of the above reasons, the bottle design had been improved and a new bottle has been developed for pouring of the hot liquid into the bottle. The company had used the different design of the bottle in the past (Foodmarks, 2013) and it has been modified (Bayani, 2014). Both bottles (new and old designed) has been used for beverage packaging but the problems of hot liquid packaging are still remained. In addition, the company could not change the design frequently because the molding cost for new design is expensive. Even though, the company has tried to improve the design (Figure 1), denting the bottle is still one of the major problems. This project is targeted to deliver another new design of the plastic bottle which compromises the denting problem.

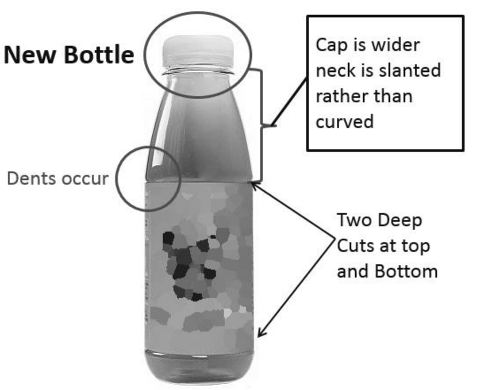

Fig 1. Current improved plastic bottle

New Product Development (NPD) is the complete process of bringing a new product into the market. Idea Screening and Concept Development in the NPD stage are the core parts (Koen, 2007; Ulrich and Eppinger, 2004). On the other hand, Systematic Innovation (Terninko, 1998) is a structured process and the set of practical tools to provide the guidelines for idea generations. It could be applied to create (or improve) products, process or services that delivers the new values to customers. Systematic Innovation tools (TRIZ) have been widely used for technical breakthrough and system improvements (Petkovic, 2013). The knowledge search based on the patents has been adapted for the innovative product design but it has not been targeted for wider range of new future product planning (Li, 2013). The systematic innovation contains the sets of the innovative problems solving tools (TRIZ) including the patent based knowledge search with the technology evolution patterns which could be adapted not only into wider range of the new product planning but also into the specific targeted product design to solve the current problems by technical breakthrough during the product development phase (Chen, 2009 and Howard, 2011).

The systematic innovation method suggests three general steps; Problem Identification is the step to identify the core problem and it is similar with the value identification in Lean Thinking (Womack and Jones, 1996). ENV model in OTSM-TRIZ (Mirakyan, 2009 and Khomenko, 2010) and RCA (Root Cause Analysis) are typical inventive problem solving (TRIZ) tools during Problem Identification step. Second step, most of TRIZ tools such as 40 inventive principles, Substance-Field model with 76 Standards (Domb, 2003) and ARIZ (Altshuller, 1989) are applied in Problems Solving step. Selection of the candidate solution and actual implementation is the last step as Concept Design Evolution step (Figure 2).

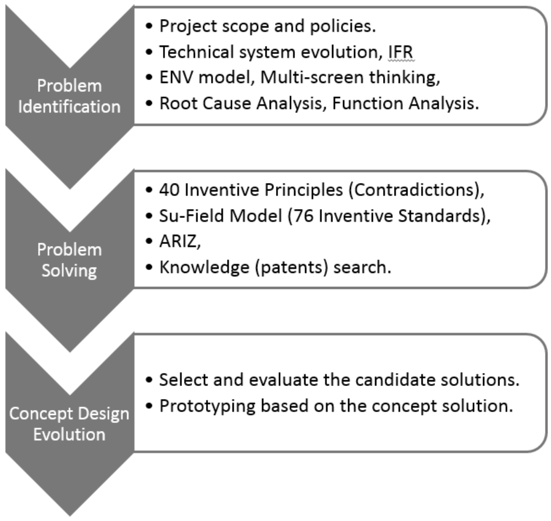

Fig 2. General process of the systematic innovation method

The systematic innovation method could be the recursive process and it is also a set of continuous evolving tools that will improve ability to solve the problems. TRIZ (TIPS; Theory of Inventive Problem Solving) is the most powerful tool set for systematic innovation (Domb, 1999 and Grace, 2001). Recently, the inventive problem solving techniques (TRIZ) are applied in management area (Jafari, 2013 and Lin, 2011) but the usage of TRIZ tools have been very limited. Most using TRIZ tool is 40 Inventive Principles which is relatively simple to use but the systematic innovation approach requires the combination of appropriate tools for each step. The tools should be applied on the right spot and it is hard to generate the practical new idea if the tools are applied independently without any sequence of the systematic innovation process. ARIZ (Algorithm for Inventive Problem Solving) provides the sequence (or process) of usage for the inventive problem solving tools (TRIZ). Even though ARIZ provides the most powerful framework to properly use TRIZ tools (Bukhman, 2012), it is rarely used for solving the problems (less than 10 percent) because of difficulties and complexity of this problem solving algorithm (Ilevbare, 2013). The sequence of the systematic innovation method (Figure 2) is the simplified process that helps to use the inventive problem solving tools (TRIZ) effectively.

In this paper, the design of the new bottle system as a product development example illustrates the systematic innovation application for getting innovative concept design idea. It also demonstrates the practical application to design the new products to overcome the problems which appear in a current product. Even though, actual development of the product has not been completed in this paper, the paper gives the guideline of New Product Development (NPD) by adapting the systematic innovation and good practices for developing the critical thinking skills even for non-engineering majored people.

2. New Product Development Based on Systematic Innovations

Systematic Innovation process (Terninko, 1998) contains the sequence (Figure 2) to provide the guidelines for using the appropriate inventive problem solving tools (TRIZ). In this research, the tools of the systematic innovation method in this particular research are as follows:

. *Problem Identification:*
- ENV Model*
- Function Analysis
- Root Cause Analysis

. *Problem Solving:*
- 40 Inventive Principles
- Substance-Field Model**

. *Concept Design Evolution:*
- Prototyping (design drawing only)

*) OTSM-TRIZ created by Khomenko (2010),
**) Enhanced Su-Field model created by Kim (2011)

The tool set (mostly part of TRIZ) for the systematic innovation method is targeted to support anyone who wants to create (or improve) products, process or services that deliver new value to customers. It is designed for improving the ability to solve the problems as out-of-box thinking. As it mentioned, TRIZ is the most common tool in the systematic innovation method (Rantanen, and Domb, 2002). Regarding this project, Root Cause Analysis and Function Analysis which both are the most popular TRIZ tools are applied in Problem Identification step. 40 Inventive Principles and the substance-field model with 76 Inventive Standards (Mao, 2007 and Terninko, 2000) are used in Problem Solving step even though these are old and conceptualized by Genrich Altshuller (1989, 1996, 1997,1999) who is the founding father of TRIZ.

2.1 Problem Identification

The sequence of Problem Identification is (1) ENV model (for the problem description), (2) Function Analysis, (3) Root Cause Analysis and (4) ENV model (for the solution descriptions). To analyze the problem more clearly, transforming the current problem to ENV model is a starter. ENV (Element-Name-Value) model describes the problem as Elements, the feature Name of the elements and Value of the feature. ENV model is the core part of OTSM-TRIZ (General Theory of Powerful Thinking) which has been created by Nikolai Khomenko (2010). OTSM is a Russian acronym which describes the next evolution of the classical TRIZ (Khomenko, 2010). ENV model helps to formulate the problem which makes it easy to adapt the classical TRIZ tools and allow to using various knowledge (Mirakyan and et. al., 2009). The problem of the current bottle is denting which means that the shape of the bottle is changed. This problem could be described by ENV model as follow:

Problems: The shape (volume) of the bottle is decreased;

. Element: Plastic bottle,
. Name of Feature: shape (volume of bottle),
. Value: decrease.

Both Function Analysis (also called Function Model) and Root Cause Analysis (RCA) could be the next procedure after ENV model and Function Analysis is applied before RCA for this time. Function model is the diagram that describe the system with functions and components (or elements). It is originally developed in systems engineering but it has been widely used as the TRIZ tool to describe the system. Bottle system instead of the bottle itself is considered for the function analysis. In the view point of the system, the bottle is not only elements to make the system (Figure 3) and there are more elements to build up the bottle system.

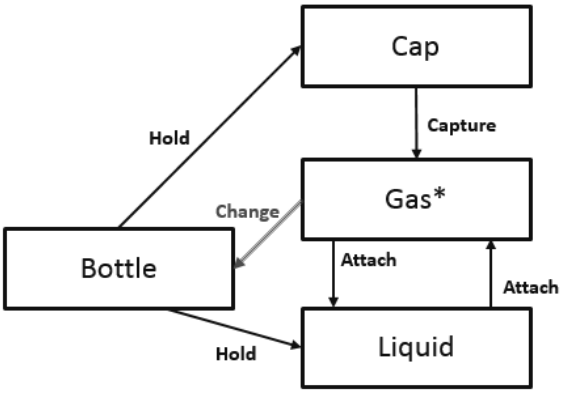

Fig 3. Function model of the bottle system

The function model (see Figure 3) reveals which element is the actual problem. According to Ideal Gas Law (Halliday and et. al., 2010), the volume of gas changed by the temperature. Since the beverage is relatively hot (around 80 Celsius degree) and it affects the volume of the air inside of the bottle when the bottle is sealed and naturally cooling down around 28 degree. Basically, the plastic bottle is not strong enough to sustain the volume changes of the air during naturally cooling the beverages.

RCA (Root Cause Analysis) is targeted to find the core problem from the original problem and expanding the RCA would reveal hidden problems.

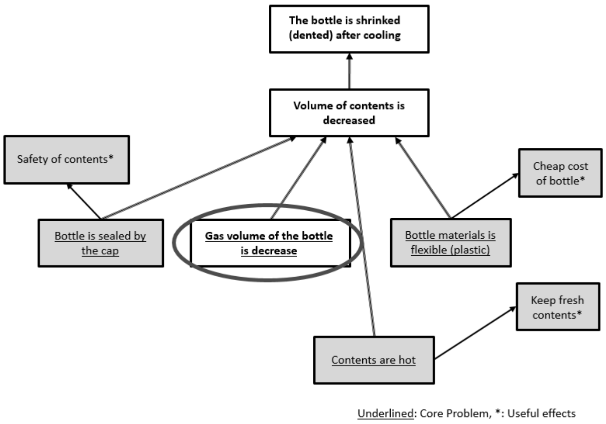

Fig 4. Root Cause Analysis

Even though, there are several root causes (underlined contents) on RCA (Figure 4), one root cause which is about the volume of gas in the bottle could be addressed as the core problem because other causes have the useful effects and their own purposes with the reasons.

Based on the function analysis (or function model) and RCA (Root Cause Analysis), the problem could be defined based on ENV model for describing the potential solution of the problem. ENV model provides the system relationships by using its capability to change the value (V) of one (or more) features (N; Name of feature) of the element (E) that changes it from Object to the desired Product (Khomenko, 2010). According to ENV model, the formulated statements of discomfort are identified from What-I-Want (WIW) stage. In this case, the object of the system is the plastic bottle and the element that affects the current object is the air in the bottle after cooling (see Figure 5).

Element	Name of Feature	Value of Feature	
		Current	Desired
Air (in the bottle)	Volume	< a (after cooling)	> a (after cooling)

Fig 5. ENV model for the solution

From WIW (problem) stage, the air should be kept as the certain amount of volume (a) after cooling down which means the temperature changes from 80 degree to 28 degree. The procedure to transform from WIW (problem) to ENV model gives the different view of the problems. Regarding this project, the problem has been changed to gas (or air) in the bottle instead of bottle problem.

2.2 Problem Solving by Inventive Principles

TRIZ provides the sets of 40 inventive principles and 39 system features. The system that has the technical contradiction could be clarified based on the feature for improve and the feature for remove within a set of system features (Altshuller, 1997). Originally, Altshuller reviewed patents in order to find out what kind of contradictions were resolved or dissolved by benchmarking the patents that had been achieved. Regarding this project, the contradiction matrix is applied as the parameter to improve and amount of substance as undesired result. The contradiction of the system is that the gas in the bottle is shrinking (i.e., volume is decreased) after the liquid is sealed in high temperature but the bottle is not strong enough to keep the same shape of the bottle. If the density of air is heavier, the bottle is dent and it means that the bottle is not strong enough to keep the shape before and after cooling down. The technical parameters and the recommendations from the contradiction matrix (Altshuller, 1997) are as follows:

Improving Feature:
Volume of stationary object (#8)
Worsening Features:
Strength (#14)
Responding Inventive Principles:
No. 9: Preliminary anti-action,
No. 14: Spherical shapes,
No. 17: Moving to another dimension,
No. 15: Dynamism,

The Inventive Principle number 9 is chosen to remove the harmful effects and incorporate the current bottle to develop new types of bottle system.

3. Concept Design of Bottle System

Based on Inventive Principle #9 from the previous session, several idea of concept design could be proposed. One design idea would be the modification or re-design of the bottle for preliminary anti-action (filling more gas before sealing the bottle). But, again, the design change of a bottle is very expensive and it is equally hard to apply the rapid prototyping approach. Instead of modifying a bottle, other elements could be considered for the preliminary anti-action. This situation could be described as the substance-field (Su-Field) model. The new type of the substance-field model without using the inventive standards is applied for this project. Even though the original substance-field model with Inventive Standards (76 Standard Solutions) is well defined and organized (Rantanen and Domb, 2002), it is still difficult to learn and complicated even for TRIZ specialists. More importantly, the 76 Inventive Standards are not intuitive (Soderlin, 2003). Enhanced Su-Field model provides the intuitive concept solution instantly once the problem is described by the proper notation (Kim, 2011). Users could deploy candidate solutions based on the enhanced su-field models without knowing full knowledge of 76 Inventive Standards. Object (S1) is the plastic bottle and Tool (S2) is the gas in the bottle. According to the enhanced Su-Field Model, it is *Problem Type-2* (Kim, 2011) that contains the harmful action and the candidate solution is basically removing the harmful function:

$$2/S/F\{/0\} \rightarrow \begin{cases} 2/S^*/F, & S^* = S^+ \ or\ S' \\ 2/S/F,^+ & \\ 2/S/F/a, & 0 < a < 1 \end{cases} \tag{1}$$

Even the above formula (1) shows the concept solution by adding a new substance ($S^*=S^+$) or modifying the substance ($S^*=S'$), but possible solutions are not limited. Actually, the candidate attribute of substance for Type-2 solution could be:

$$S^*=\{S^*: S', S^+, S^2, S^\infty, S^n\}.$$

The final recommendation of the concept solution for the enhanced new bottle design is:

$$2/S/F\{/0\} \rightarrow 2/S^+/F \tag{2}$$

where S^+ which indicates that the substance that added for preventing the distortion of a bottle. The additional substance for the solution is a modified cap to seal a bottle. The concept solution is modifying the cap which is an element of the bottle system, instead of changing the bottle by itself. The final recommendation, as demonstrated in Figure 6, is to come up with the new cap that has the elastic film (same materials as the cap but made it thinner) inside to capture more air when the bottle is sealed in hot temperature. Once beverage is cooling down, the elastic film is moved to fill the gap of volume decreasing in the bottle. It is noted that the air inside of the cap do not need to be vacuumed and it does not be required to have any specific gases because of Idle Gas Law (Halliday and et. al., 2010) which could be applied for any gases in the world. The mechanism for working in the cap only depends on the volume reduction by changing the temperatures from 80 Celsius degree to the room temperature (around 28 Celsius degree in Philippines). The air inside the cap reduces around 14 percent when the temperature is changed from 80 degree to 28 degree.

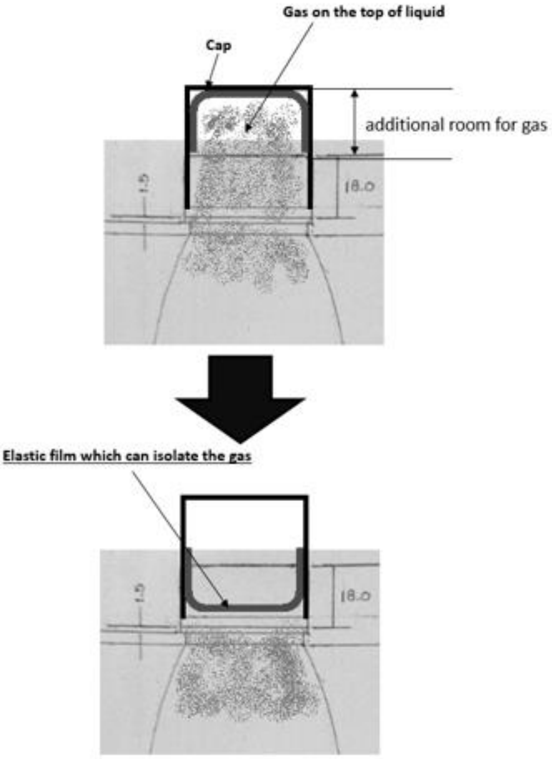

Fig 6. Prototype design of the new cap on the bottle

4. Conclusions

Systematic Innovation could be widely applied in the various area such as environmental engineering (Kim, 2013), helipad construction of the military airport (Cruz and et. al., 2013). It also has been partially applied in the high-tech industry problems, especially targeted for the institutive user experience design (Kim, 2010 and 2012). The major target of this project is demonstrating the new concept of product development sequences based on Systematic Innovations. The pattern of Systematic Innovation approach could be expanded to other industries on the top of the various cases mentioned above even though the research is dedicated with new product development. It is the good study case that gives the guidelines for whom wants to create the new things innovatively. As it mentioned, this research has been only targeted to develop the concept design and an actual product is not covered at this moment. The consumer 3D printing technology has been evolved rapidly (Kim, 2016) and making a proto-type of a new cap by using a 3D printer could be considered as the part of future research.

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