21ST INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED17
21-25 AUGUST 2017, THE UNIVERSITY OF BRITISH COLUMBIA, VANCOUVER, CANADA

AN ECO-INNOVATION METHOD FOR PRODUCTS IN BOTTOM OF THE PYRAMID (BOP)

Chen, Jahau Lewis; Chung, Shih-Hou
National Cheng Kung University, Taiwan, People's Republic of China

Abstract

This paper presents an innovation method for Bottom of the Pyramid (BoP) by integrating BoP case database and TRIZ techniques. This method can help the designer to go through the design processes to produce the innovative concepts for BoP. Improving the education tools in BoP is demonstrated as example to illustrate the capability of this method.

Keywords: Innovation, Sustainability, Ecodesign, Bottom of the Pyramid (BoP), TRIZ

Contact:
Prof. Jahau Lewis Chen
National Cheng Kung University
Department of Mechanical Engineering
Taiwan, Republic of China
jlchen@mail.ncku.edu.tw

Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 21st International Conference on Engineering Design (ICED17), Vol. 1: Resource-Sensitive Design | Design Research Applications and Case Studies, Vancouver, Canada, 21.-25.08.2017.

1 INTRODUCTION

Many people have prosperous life because of technology, but there are still 4 billion people living in poverty now. Professor Prahalad (2004) used the definition "Bottom of the Pyramid (BoP)" to describe them. He thinks that innovations can lead them to the better life and proposed 4A's (Prahald, 2004), such as affordability, awareness, access and availability, as BoP innovative principles. Niti (2009) presents 5D principles (development, design, distribution, demand and dignity) as the design principles for BoP product innovation guidelines. Kirsten and Ian (2012) suggest the concept of frugal innovation which can help designers to break the limitations of resources, finance and institute and to turn them into favorable factors. Crul and Diehl (2010) develops D4S (design for sustainability) approach for BoP innovation. ASME (2014) presented a network platform to propose the E4C (engineering for change) concept for developing different engineering solutions for BoP innovation. It is obviously that PSS concept can play a crucial role for solving problem in Bop area. Chen and Chung (2015) proposed an eco-innovation method for BoP products by using TRIZ and case-based reasoning methods. Chen and Lee (2017) propose a sustainable innovative design method for developing products suitable in the Bottom of the Pyramid (BoP) by integrating biomimetic design concepts, TRIZ techniques, BoP innovative case database and BoP innovative evaluating principles.

This paper will integrate TRIZ theory (Altshuller, 2000) and innovative principles at the bottom of the pyramid, and then collect enough related BoP innovative cases to build an eco-innovative design tool for BoP. The database will help designers to get great ideas by offering innovative cases and related TRIZ principles. The device analysis of Goldfire software (Invention Machine Corporation, 2012) is used in this research to help designers to build product model. By understanding the relations between different components through this product model, designers can get complete innovative solutions for BoP problems.

2 DESIGN CRITERIA AND CASES FOR BOTTOM OF THE PYRAMID

2.1 Innovation design criteria for BoP

The innovation design criteria for BoP are summarized as five items. (1) Low price: affordable by local consumer; (2) Low material & energy consumption: the product uses less resource and energy; (3) Expansibility: the product can increasing the income of local community; (4) Combination: the product can integrated with modern technology; (5) Usability: the product is suitable for using in local community.

2.2 BoP case database

This research will collect different BoP innovations and find associated TRIZ innovative principles to build BoP innovative database. Designer can use keywords to search related innovations and get new product concepts by innovations and TRIZ innovative principles. Each BoP case is recorded in the database with information about this BoP, such as the case number, the name of BoP case, the BoP domain, the 4W scenario, and the TRIZ contradiction parameters, as illustrated in Table 1.

Table 1. Partial list of a BoP case database (Chung, 2015)

Case Number	1	2	3
Concept	Gravity light	Corn shelter device by bike	Deliver drug by existing access
Domain	Energy	Tool	Health
Who	Whole	Farmer	Patient
What	Daily life	Farming	Deliver drug
Where	Indoor	Outdoor	Remote area
When	Night	After harvest corps	Whole day
TRIZ Contradiction Parameters	Brightness	Usability	Shape
	Loss of Energy	Complexity	Adaptability
TRIZ Inventive principles	#12, #25, #28	#1, #5, #6	#4, #5, #7

In Table 1, only a partial list of a BoP case database is shown. A detailed list of all 84 BoP case databases can be found in Reference (Chung, 2015). By matching the same index, the designer can find related BoP cases to get new ideas.

3 TRIZ

3.1 TRIZ contradiction matrix and inventive principles

The TRIZ method (Altshuller, 2000; Kaplan, 1996) is a tool for designers and engineers to handle conflict problems. The method was developed in the former Soviet Union by Altshuller, who had analyzed over 400,000 patents. The most fascinating and amazing part of the TRIZ method is the contradiction matrix constructed through investigating and classifying the patents. The contradiction matrix is composed of 39 engineering parameters and 40 inventive principles. When people face design contradictions, they can search for the appropriate parameters, and then locate 1-4 suitable design principles for resolving the particular problem.

3.2 Device analysis in Goldfire software

A computer aided innovation software (Goldfire) (Invention Machine Corporation, 2012) is used in this study for solving innovative problems. Goldfire software has several special features, such as a semantic search tool for patent and scientific literature, root cause analysis (RCA), device analysis, etc., to support product design processes.

The first step in constructing device analysis model is created function model for components and performed functional analysis. Function model is a visual flowchart that breaks a problem down to its key component features and then links relationships of one feature to other features. The device analysis model is constructed by linking analysis of function models and identifying the type of function as useful function or harmful function. The useful function can be divided as normal function, insufficient function, and excessive function. The designer can use device analysis model on the Goldfire software to analyze every component in problematic systems for understanding the action relationship between components.

The designer can use the “Solution Manager” tool to search the scientific effect database by using solve problem statements that are generated from device analysis model. If the solve problem statement is “insufficient function”, then the semantic search of Goldfire software will add “intensively” into query for searching innovative concepts. As for the solve problem statement is “harmful function”, the semantic search of Goldfire software will add “prevent” into query for searching innovative idea.

4 ECO-INNOVATION METHOD FOR BOP

4.1 Innovative design process

This research presents an innovative design process (Figure 1) to help designers to get BoP innovations. Designers can build life scenario in the local region by "4W scenario" (Sun, 2009), get innovative ideas and targets by understanding similar innovative cases from "BoP innovative database" and use "TRIZ theory" and "Device analysis" to solve BoP problems to achieve the design target.

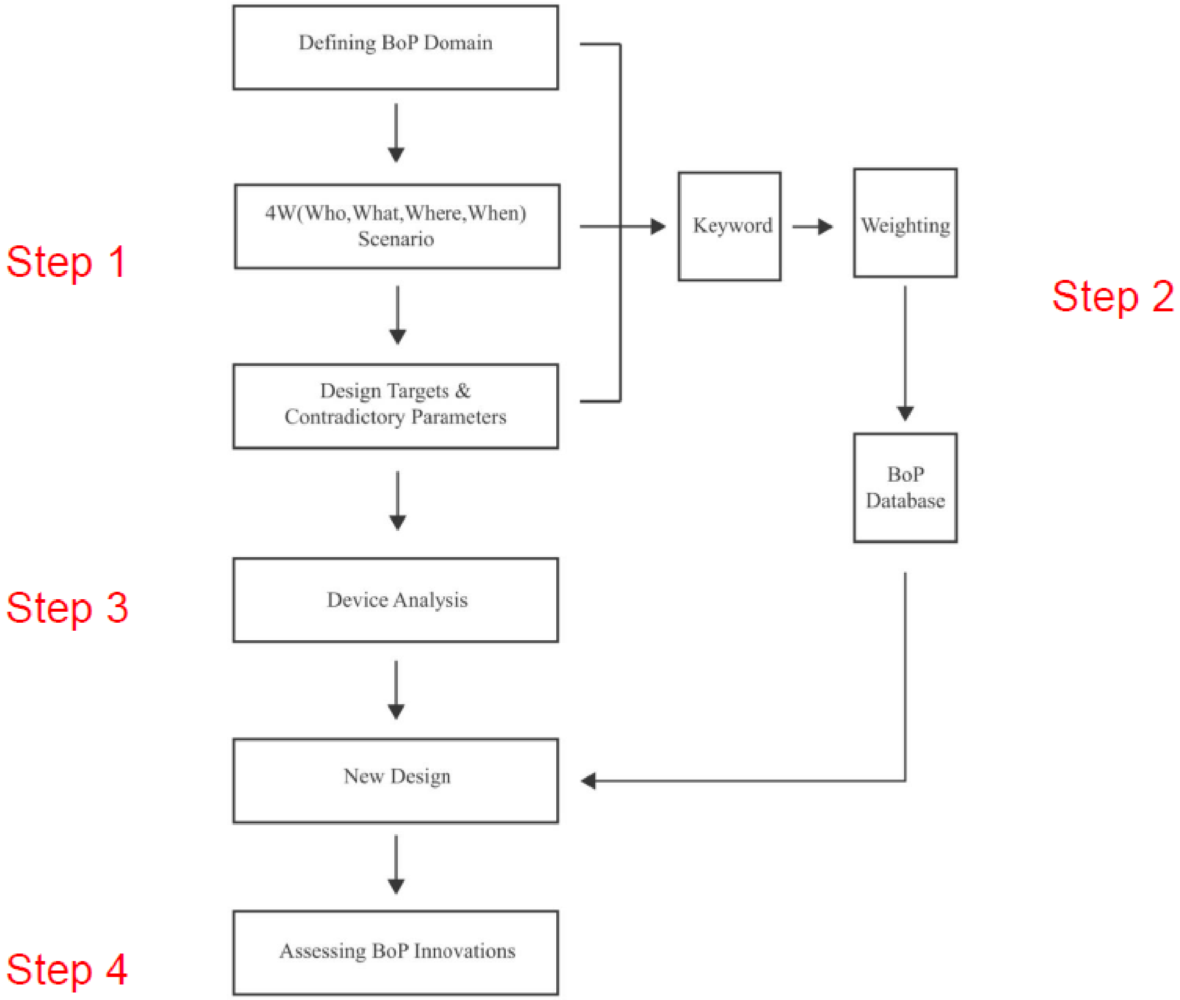

Figure 1. Flowchart of eco-innovation method for BoP

4.2 Step 1: 4W scenario

First, the designer chooses innovative domain, constructs scenario by using "Who", "What", "Where" and "When" and defines design targets and contradictory parameters from scenario.

4.3 Step 2: BoP case capture

Next, the designer uses keywords from the first section and sets the ratio of the main index to sort the BoP innovative cases. Similar cases will give innovative concepts and related TRIZ innovative principles for designers.

To compare the similarity of database's indexes and target system's indexes, the following equation (1) will compute the value of similarity.

$$\text{Similarity} = \sum_{i=1}^{n} w_i \times sim_i(F_i, f_i) / \sum_{i=1}^{n} w_i \quad (1)$$

where i is the number of the index; n is the total amount of indexes; F_i is the index of the target system; f_i is the index of the database; w_i is the weighting; and $sim_i(F_i, f_i)$ is the index's similarity. If the target system's index is the same as the database's index, the value of $sim_i(F_i, f_i)$ is 1, if not, the outcome is 0 instead. The value of similarity will be affected by the weighting of database's indexes, and designer can set the level weighting (1 to 3) depends on the needs.

4.4 Step 3: device analysis and innovation design

The designer uses the device analysis of Goldfire software to build the problem model definitively and get new innovations by simplifying the system and constructing the new system.

4.5 Step 4: evaluation

Finally, the designer uses the BoP principles evaluating diagram to evaluate the new design. Evaluating principles are low price, low energy cost, developing ability, combining ability and usability. These five principles can initially assess the extent of achieving BoP standard for new innovations. Each principle's score has five levels and the score's interval is one. "5" represents the highest level of achieving the criterion. On the contrary, "1" represents the lowest level.

5 EXAMPLE: IMPROVING EDUCATION TOOLS IN BOP

The education is very important developing domain in BoP to increase productivity. Improving education quality and opportunity by minimal resource and cost is the challenge of innovation.

5.1 Step 1: 4W scenario

The innovative domain of this case is defined as "education". The scenario of this case is the teacher needs education tools for teaching students and the students can use the education tools to understanding and learning the contents of teacher's class. The 4W scenario is shown in Table 2.

Table 2. The 4W scenario

Who	Students
What	Learning
Where	Indoor
When	Daytime

The design target is to develop an easy build education tool for teaching many students. This education tool should be simple, low cost and high efficiency function. Therefore, The TRIZ contradiction parameters for this case are "convenience of use" and "productivity".

5.2 Step 2: BoP case capture

Next, the index of this case is shown in Table 3. The weighting ratio of the main index to sort the BoP innovative cases is also shown in Table 3. Three similar cases are captured from case database, as shown in Table 4. The related TRIZ innovative principles (#5 combining, #25 self-service and #27 an inexpensive short-life object instead of an expensive durable one) provide a guideline for designers to innovate new concept.

Table 3. The index value and its associated weighting value of example case

Index	Importance of index	Weighting	Definition
Domain	3	0.231	Education
Who	3	0.231	Students
What	3	0.231	Learning
Where	1	0.077	Indoor
When	1	0.077	Daytime
TRIZ Contradiction Parameters	1	0.077	Convenience of use
	1	0.077	Productivity

In this case, "Domain", "Who", and "What" index is more important than other index and the importance of indexes are assigned as "3". The importance of index of other four indexes is assigned as "1". Therefore, the weighting value of "Domain", "Who", and "What" index is 0.231 (3/(3x3+1x4)). As for the weighting value of other four indexes is 0.077 (1/(3x3+1x4)). Therefore, following equation (1), the calculation of similarity for case number 43 in Table 4 is 1x0.231+1x0.231+1x0.231+0x0.077+0x0.077+0x0.077+1x0.077 = 0.769.

Table 4. Four similar BoP cases capture from BoP case database

Case Number	43	39	28
Similarity	0.769	0.769	0.693
Concept	(Table 5)	(Table 5)	(Table 5)
Domain	Education	Education	Education
Who	Students	Students	Students
What	Learning	Learning	Learning
Where	Power shortage place	Any place	Any place
When	Whole day	Whole day	Whole day
TRIZ Contradiction Parameters	Energy spent by a moving object	Convenience of use	Loss of energy
	Productivity	Complexity of device	Adaptability
TRIZ Inventive Principles	#5 Combining	#27 An inexpensive short-life object instead of an expensive durable one	#11 Cushion in advance, #14 Spheroidality, #25 Self-service

The concept and figure of three similar BoP cases is illustrated in Table 5.

Table 5. The concept of three similar BoP cases

Case Number	Concept
43	Bike type pedal powered machines to generate electricity  (Low-Tech Magazine, 2011)
39	A low-cost small PC with providing learning function which can be adjusting its functions by user.  (TNW, 2013)
28	.A hand-driven electricity generator laptop  (Jsselstein, 2006)

5.3 Step 3: device analysis and innovation design

The designer uses the device analysis of Goldfire software to build the problem model and get new innovations by simplifying the system and constructing the new system, as shown in Figure 2 and Figure 3. As shown in Figure 2, the traditional projector and computer model was used to construct device model in Goldfire software. Computer transfers the data to the projector and then the projector to show images on the projector screen. Projector and computer need power supply to execute projection function. Furthermore, the external environment impacts the quality of projection function. Using the device analysis function in Goldfire software, the old device model (Figure 2) is required to trim device with high energy consumption and to add existing products simultaneously to reflect the limited energy in BoP area. The trimming devices are shown in Figure 3 by grey block flow chart symbols. Traditional projector and computer are replaced by new components. The new device model is only providing energy to new device with cooling function as shown in Figure 3.

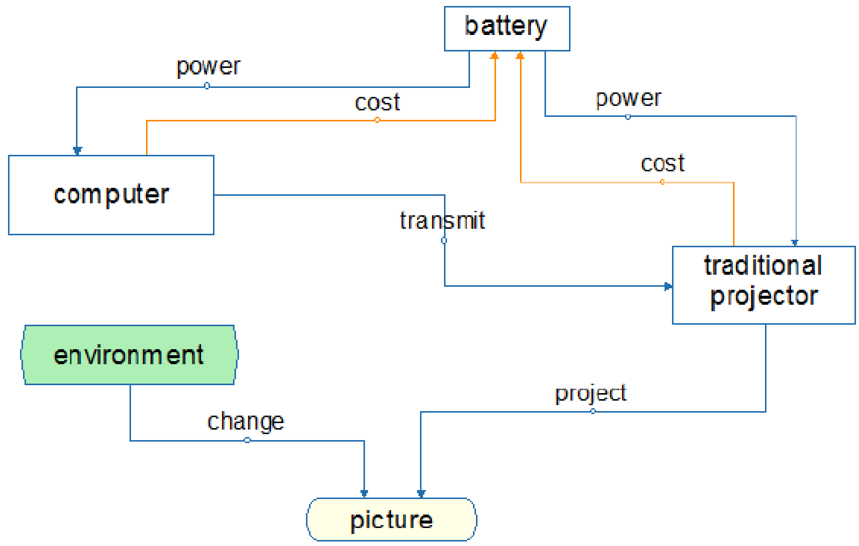

Figure 2. Old device analysis model

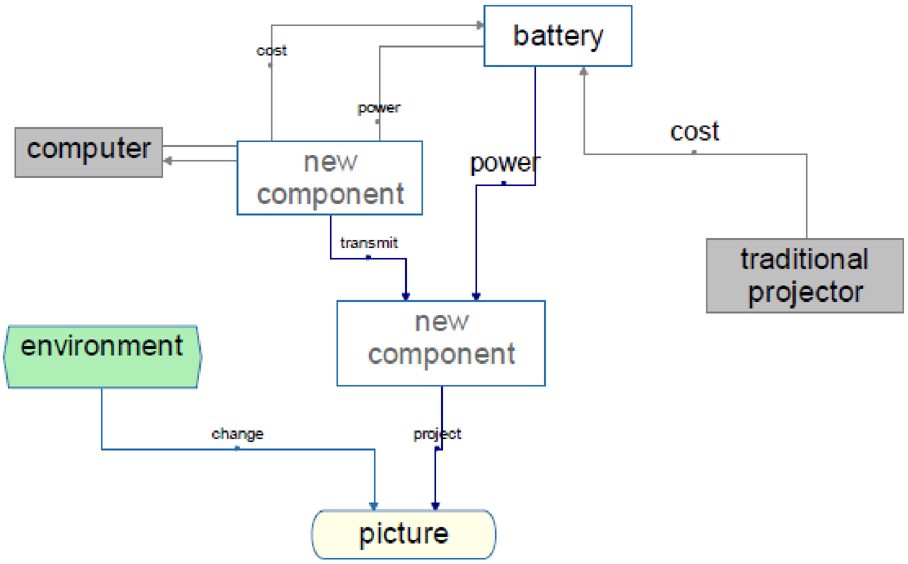

Figure 3. New device analysis model

5.4 Design concept

After whole innovation processes, as shown in Figure 1, are performed, a new design concept is presented. The new innovation design concept is shown in Figure 4. The new innovative concept is integrating current mobile phone with small projector as a new type education tool. In the BoP area, most local communities have basic models of mobile phone. Therefore, replacing computer with mobile phone can reduce the cost of education tool. Furthermore, small projector was a well developing technology and it is easy to combine with the mobile phone to provide data transmission and projection function. The energy source of mobile phone and small projector is from solar panel. Solar energy is local energy and can easily be obtained.

Figure 4. New innovation concept

5.5 Step 4: evaluation

The evaluation diagram for the new innovation concept is illustrated in Figure 5. The main cost of this new concept is small projector since most local communities in BoP have mobile phone in use. However, small projector is less expansive compare with traditional large projector. Therefore, the evaluation score of "low price" is 3 in this new concept. However, energy consumption of small projector is relatively small and solar energy is the resource that can be obtained easily, therefore, the evaluation score of "low energy cost" is 4. The education can increase the productivity of future economics activities. The score of "developing ability" is 5. This new concept is combining exist products (mobile phone and small projector) and can be implemented in local BoP communities. The evaluation score of "combining ability" and "usability" are all equal 4.

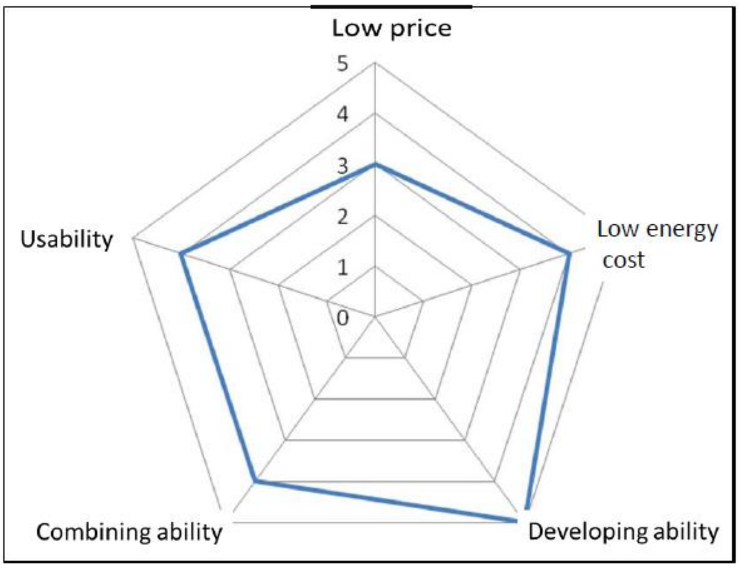

Figure 5. Evaluation diagram of new innovation concept

6 CONCLUSIONS

This paper collected different BoP innovation cases and its associated TRIZ innovative principles to build BoP innovative database. Designer can use keywords to search related innovation cases and get new product concepts by innovation cases and TRIZ innovative principles. Furthermore, the device analysis function in Goldfire software can help the designer to generate innovations for BoP. The capability of the whole innovative design process for BoP was demonstrated by the BoP education tool design case.

REFERENCES

Altshuller, G. (2000), *The Innovation Algorithm: TRIZ, Systematic Innovation and Technical Creativity*, Technical Innovation Center, Inc., Worcester.

ASME (2014), *Engineering for Change*. Available at: https://www.engineeringforchange.org/, (accessed January 25, 2014).

Chen, J.L. and Chung, S.H. (2015), "Integrating innovative principles at the bottom of the pyramid and TRIZ theory to develop sustainable product design method", *9th International Symposium on Environmentally Conscious Design and Inverse Manufacturing, Ecodesign15*, Tokyo, Japan, December 2-December 5.

Chen, J.L. and Lee, C.L. (2017), "Developing sustainable innovative products for the bottom of the pyramid by biomimetic design concepts", *The 24th CIRP Conference on Life Cycle Engineering*, Kamakura, Japan, March 7-9.

Crul, M. and Diehl, J.C. (2010), "Design for sustainability: moving from incremental toward radical design approaches", *Transitions to Sustainability, NZSSES Conference 2010,* Auckland, New Zealand.

Invention Machine Corporation (2012), *Goldfire Version 7.7.0.*

Jsselstein I. (2006), *The 100 Dollar Laptop and the Philippines*. Available at: http://www.bohol.ph/article116.html, (accessed June 6, 2013).

Kaplan, S. (1996), *An Introduction to TRIZ: The Russian Theory of Inventive Problem Solving*, Ideation International Inc., Southfield, MI, USA.

Kirsten, B. and Ian, T. (2012), "Our frugal future: Lessons from india's innovation system". *Nesta*.

Low-Tech. Magazine (2011), Available at: http://www.lowtechmagazine.com/2011/05/pedal-powered-farms-and-factories.html, (accessed October 20, 2012).

Niti, B. (2009), *The 5Ds of BoP Marketing Touchpoints for a Holistic Human-Centered Strategy*. Available at: http://www.core77.com/blog.featured_items/the_5ds_of_bop_marketing_touchpoints_for_a_holistic_human_centered_strategy.12233.asp, (accessed October 22, 2013).

Prahald, C.K. (2004), *The Fortune at the Bottom of Pyramid*, Warton School Publishing.

Sun, K.K. (2009), *Scenario-Based Amorphous Design: A Methodical Approach to Designing System-Oriented Products that are User-Defined*, PhD Dissertation, Stanford University.

TNW (2013), Available at: http://thenextweb.com/gadgets/2013/11/19/kano-99-diy-raspberry-pi-powered-pc-building-kit-lego-style-step-step-instructions/, (accessed June 6, 2013).

ACKNOWLEDGMENTS

This work is supported by the National Science Council, Taiwan, under grant numbers: NSC 102-2621-M-006-004.