Managing E-Waste Using TRIZ

Nikalus Shu Luing Swee, Mum Wai Yip, Chee Sheng Keong, See Chew Tai, and Guat Guan Toh
Tunku Abdul Rahman College, Malaysia
Email: {sweesl, yipmw, keongcs, taisc, tohgg}@mail.tarc.edu.my

***Abstract*—this paper aims to provide a thorough analysis on the application of TRIZ in handling the increasing trend of electronic waste globally. TRIZ tools such as engineering systems analysis, function analysis, cause and effect chain analysis and contraction matrix are applied in order to discover some feasible and elegant solutions to alleviate global e-waste problem. Findings revealed that the e-waste problem is caused by the improving lifestyle, rapid technology advancement versus ineffective recycling management. The root causes and contradictions are solved by applying contradiction matrix, and inventive principles are suggested, i.e., local quality, the other way around, phase transitions and preliminary actions. Therefore, it can be concluded that TRIZ is a powerful tool in inventive problem solving.**

***Index Terms*—contradiction, engineering system analysis, e-waste, TRIZ.**

I. Introduction

In accordance with technology advances, changes in electronic media and cheaper price have resulted in a fast-growing surplus of electronic waste (e-waste) around the globe [1]. E-waste or e-scrap, or waste electrical and electronic equipment ('WEEE) is defined as assembly of electrical or electronic appliances that consist of components such as accumulators, mercury-switches, glass from cathode-ray tubes and other activated glass or polychlorinated biphenyl-capacitors, or contaminated with many harmful metals such as cadmium, mercury, lead, nickel, chromium, copper, lithium, silver, manganese or polychlorinated biphenyl [2].

An estimated 12 million tons of e-waste are produced in Europe by 2015 [3]. The US Environmental Protection Agency estimates that only 15-20% of e-waste is recycled, the rest of these electronics go directly into landfills and incinerators [4]. A shocking 320 tons of gold and more than 7,500 tons of silver are annually used to make PCs, cell phones, tablet computers, and other new electronics and electrical product. Most of those valuable metals will be squandered, however; just 15% or less is recovered from e-waste today in developed and developing countries. Electronic waste contains hazardous materials but also valuable and scarce materials. Electronic waste also contains precious metal "deposits" 40 to 50 times richer than ores mined from the ground [5]. To alleviate the e-waste problem, TRIZ can be applied systematically to derive simple and elegant solutions.

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TRIZ is a Russian acronym for "Teoriya Resheniya Izobreatatelskikh Zadatch", equivalent to "Theory of Inventive Problem Solving" in English. TRIZ methodology was developed in 1940's by Genrich Altshuller, an inventor, a writer and a patent engineer who studied intellectual property contained in approximately 200,000 patents [6]. He discovered and organized his study of 40,000 patents according to innovative patterns of design as well as the inventive principles in these innovative solutions. Findings revealed that problems and solutions, patterns of technical evolution were repeated across industries and sciences, and innovations used scientific effects outside the field where they were developed. Therefore, Genrich Altshuller derived 40 inventive principles [6]-[8]. TRIZ comprises of several essential tools such as engineering systems analysis, function analysis, cause and effect chain analysis, trimming, engineering contradiction, substance-field model and etc. TRIZ uses 40 inventive principles and 39 parameters to help inventors to derive many solutions [7], [9], [10].

II. Problem Statement

Electronic products are not designed for recycling. There is no end-of-life (EOL) management of electronic products. EOL is always not in the loop of consideration for product designers and manufacturers [11]. E-waste contains lots of hazardous metals which can cause serious environmental pollution [1]. Therefore, e-waste causes serious adverse impact to the humanity and all living things on earth. The following are the details on how TRIZ is applied in this circumstance.

III. TRIZ Models and Tools

TRIZ flow process is shown in Fig. 1.1. Primarily, research and brainstorming help indentify the original problem to resolve, and this is followed by function analysis, cause and effect chain analysis and engineering contradiction. Lastly, contradiction matrix is used to retrieve the specific inventive principles, which then lead to generating specific solution(s) [6].

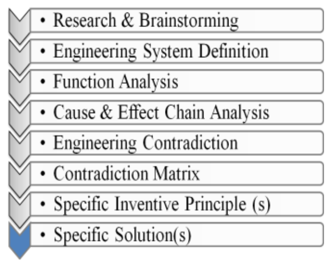

Figure. 1.1 TRIZ flow process [6]

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A. *Engineering System Definition*

An Engineering System comprises of several components that are interacted among each other. These components are commonly accepted as system components (subsystems) that are listed in Table I. Along with subsystems, there are also interactions between engineering system and external entities called supersystems. Supersystems are not designed as part of the Engineering System; however, they can impact the Engineering System. [6], [12].

TABLE I. TABLE ENGINEERING SYSTEM

Sub/System Components	**Raw materials, Electronic Product, Electronic Waste, Recycling factory, E-waste hoarder**
SuperSystems	**Government Policy, Manufacturers, Consumers**

B. *Function Analysis*

Function analysis shows the interactions between two or more subsystems (Engineering System components) which are listed in Fig. 1.2. These interactions are called functions. Functions are simply actions between two components, i.e., a subject and an object in which the subject acts upon and modifies a parameter(s) of the object [6].

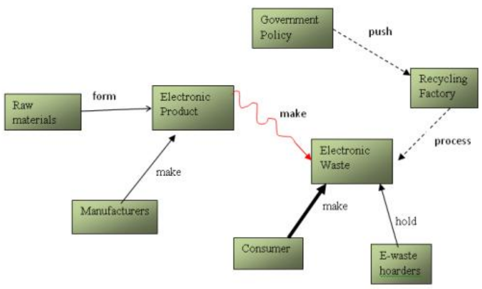

Figure. 1.2 Function model

C. *Cause and Effect Chain Analysis*

The next stage is Cause and effect chain analysis. CECA is an essential tool in the TRIZ methodology. It helps identify the right root cause(s) pertaining to the problem in Fig. 1.3. If we get the wrong root cause, the solution derived may not be effective. Fundamentally, CECA is very similar to "5 Whys". We continue to prompt for causes for the e-waste problem from high level causes to low level causes by asking "the question "why?" [6], [12].

From the CECA, the root causes identified are improving lifestyle of the people, fast changes in electronic technology, electronic product end-of-life management and expensive and complex recycling process.

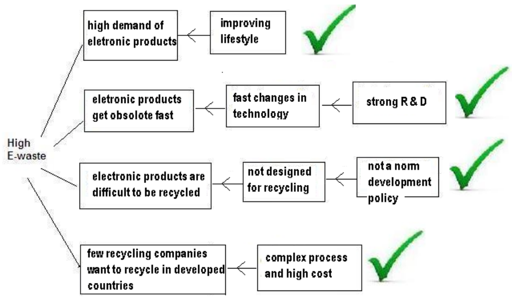

Figure. 1.3 Cause and effect chain analysis diagram

D. *Engineering Contradiction*

Theory of Contradiction had already been applied by George Berkeley in 1710 in the book "A treatise concerning the principles of human knowledge", and F. Engels made use of contradiction in his research of the basic law of dialectics in the late 19 century. Contradiction is always present in our daily life, i.e., plus and minus, differential and integral in mathematics; positive and negative electrical charges in physics and etc. [13].

The most effective solutions are achieved when an inventor solves a technical problem that contains contradiction [10], [12]. Engineering Contradiction means if one characteristic or parameter of the system is to be improved (improving parameter) and causes another characteristic or parameter of the system to deteriorate (worsening parameter). These parameters are translated into one of the 39 engineering parameters in TRIZ. TRIZ approach is to eliminate and solve the contradiction, also better known as engineering contradiction [8]. Engineering contradictions can be formulated based on the cause and effect chain analysis. The contradiction is included in any process of solving the inventive problems. Therefore, contradiction matrix or Altshuller matrix is used to solve the contradiction that developed by Altshuller [8].

Engineering Contradiction 1:

If there were rapid technology advancement and demand, then new electronic products are produced and marketed very quickly, but this will increase electronic waste globally.

	Altshuller's 39 Parameters
Improving parameter: rapid production of new products (momentum)	**#10 Force**
Worsening parameter: generate more electronic waste	**#31 Object-generated harmful factors**

Engineering Contradiction 2:

If e-waste is recycled, then valuable metals like gold and silver can be recovered from the recycling, but the processes are complex and expensive.

	Altshuller's 39 Parameters
Improving parameter: valuable metals (output)	*#39 Productivity*
Worsening parameter: processes are complex and expensive	*#33 Ease of operation*

E. Contradiction Matrix and Inventive Principles

Based on the good and bad parameters in Engineering Contradiction 1 and 2, inventors can then reference the contradiction matrix for the inventive principles.

Recommended Inventive Principle from Engineering Contradiction 1:

Contradiction Matrix	**Inventive Principles**
#10: Force(Improving) X #31: Object-generated harmful factors (Worsening)	*#3 Local quality* *#13 The other way around* *#24 Intermediary* *#36 Phase transitions*

Recommended Inventive Principle from Engineering Contradiction 2:

Contradiction Matrix	**Inventive Principles**
#39: Productivity(Improving) X #33: Ease of Operation (Worsening)	*#1 Segmentation* *#7 Nested doll* *#10 Preliminary Action* *#28 Mechanics substitution*

IV. TRIZ SOLUTIONS AND DISCUSSION

A. Solutions for Engineering Contradiction 1

The recommended TRIZ Inventive Principles are as follow:

#3 (Local Quality), #13 (The other way around),
#24 (Intermediary), #36 (Phase transitions)

After thorough study, in the context of rapid technology advancement in the Engineering Contradiction 1, we found that Inventive Principle #3 (Local quality) and #13 (The other way around) are deemed appropriate for our problem. Other inventive principles are regarded irrelevant or not suitable to our problem. Hence, *Inventive Principle #3, #13 and #36* are adopted**.**

Based on *Inventive Principle #3 (Local quality)* in which it suggests that we can make each part of an object fulfill a useful and different function. Hence, based on our study, we propose to electronic products manufacturers to develop and produce the products that have multi-functionalities. For example, a smartphone could have functions such as MP3, camera, PDA and its main function, which is phone call system. By including multi-functions in a single device, users do not need to purchase other electronic products such as camera and MP3. One of the good examples is Samsung Galaxy Note, the size of Galaxy Note lies between a tablet and a smartphone. It solves the problem of small screen and with the phone call system. Users are not required to purchase and carry two or more separate electronic devices. Therefore, this may help reduce the rise of e-waste.

Next, based on *Inventive Principle #13 (The other way around),* in which the indication is to invert the action used to solve the problem, i.e., e-waste can be recycled effectively. In line with our study, our solution is to urge product engineers and designers to design and produce electronic product in which it has many distinctive product components. Hence, any malfunctioned components can be replaced easily by merely purchasing the right parts or components. Besides that, there is an ongoing need to urge product designers to contemplate for the choices of materials and the implications of the selected materials on recycling [14]. In addition to that, electronics manufacturers are obliged to buy back any used product components to be reconditioned for the market [11]. In addition to that, findings revealed that e-waste can be reused or retransformed to be household items based on three main attributes, i.e., e-waste materials, shapes, and operations [15]. For instance, a used CRT monitor can be transformed into monitor fish tank. Thus, this may apparently prolong the sustainability of the Earth’s resources. It can also alleviate our environmental pollution crisis.

In line with *Inventive Principle #36(Phase transitions),* i.e., use Phenomena occurring during phase transitions (Awareness of market/consumer requirements) [16],[17], our thought is to create awareness to the consumers by educating them to buy electronic products wisely for functionalities needed. We anticipate there is paradigm shift in consumers’ buying behavior. They are advised not to replace electronic products hastily whenever there is a new version with slight new enhancements or features. In addition to that, we appeal to electronics manufacturers to release new products when the new version has at least 50% significant changes as compared to the old version, i.e., improving clock speed of processors by 50% or more. Thus, we believe this may slow down the rise of electronic waste globally.

B. Solutions for Engineering Contradiction 2

The recommended TRIZ Inventive Principles are as follow:

#1 (Segmentation), #7 (Nested doll),
#10 (Preliminary Action),
#28 (Mechanics substitution)

From the study, in the context of complex recycling processes in the Engineering Contradiction 2, we found that Inventive Principle #10 (Preliminary Action) are deemed appropriate for our problem. Inventive Principle #10 (Preliminary Action) suggests that we can perform the required change of an object before it is needed. Hence, based on our research, we would educate all electronic products users to learn how to classify and itemize e-waste in a more detail manner before disposing any electronic products. For example, users should be trained to dismantle an unused personal desktop computer into battery, plastic components, electronic components and etc.. E-waste can also be sorted according to high and low grade material [14]. The recycling companies may save a lot of time and man power to segregate e-waste. This will indeed expedite the recycling processes and also lower the processing cost. Hence, this may be a catalyst to attract many companies to engage in recycling business and also to localize the processing of e-waste.

V. CONCLUSION

In this case study, the problem can be contained and lessened by applying TRIZ tools particularly the inventive principles such as local quality, the other way around, phase transitions and preliminary actions. Triz helps inventors generate more feasible ideas or concepts which may lead to elegant solutions. It is proven that TRIZ is a powerful methodology which can be used in inventive problem solving. It can be concluded that TRIZ is an innovative problem solving methodology.

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N. S. L. Swee is a program supervisor and a senior lecturer at Tunku Abdul Rahman College, Penang Branch Campus, Malaysia. He received BSc (Information & Computer Sciences) from National University of Singapore in 1997, and a MBA from Nottingham Trent University, UK in 2001.
He is specifically interested in application of TRIZ and also provides TRIZ workshop to tertiary students, university lecturers and industry folks.

Mr. Swee is a member of International Association of Computer Science and Information (IACSIT). He is also a member of TRIZ Association of Malaysia. He is a certified TRIZ Level 1 Instructor, Level 1 and II Practitioner. He has received awards from Microsoft (Microsoft Certified Technology Specialist) and IBM (IBM Certified Developer).

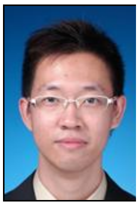
Dr. Yip Mum Wai graduated with a Diploma in Materials Engineering from Tunku Abdul Rahman College in 1997 and a MSc in Manufacturing Systems Engineering from University of Warwick, United Kingdom in 1998. In 2008, he was awarded an Engineering Doctorate in Engineering Business Management(*specialising in Knowledge Management*) from Business Advanced Technology Centre, University Technology Malaysia, Malaysia.

He is the head of mechanical engineering division at Tunku Abdul Rahman College, Malaysia. He is a certified Knowledge Management Facilitator and Practitioner, a certified TRIZ Practitioner, a Senior Member of International Association of Computer Science and Information (IACSIT) and a member of Malaysia TRIZ Innovation Association. He has presented many papers in the field of engineering management especially in KM in many international conferences in China and Indonesia. He is also a reviewer and an Editorial Board Member for International Journals.

Dr. Yip has a lot of experience in research. He has been given a grant by the Ministry of Higher Learning Institution to conduct a research in the implementation of Knowledge Management (KM) in SME in Malaysia.

Dr. Janice Toh Guat Guan holds a degree from University of Malaya, MSc from University of Leicester and a PhD from University of Science Malaysia. She is currently a senior lecturer at the School of Business Studies, Tunku Abdul Rahman College, Penang Branch Campus. She has taught various management and finance courses as well as presented several finance papers at national finance and management conferences. She is also a Certified Triz Level 1 Instructor. Recently in 2009, she has presented a paper entitled "Do Malaysian Investors' Judgment Exhibit Reference Dependence?" in the 8th Asian Academy of Management Conference at Hyatt Resort Hotel in Kuantan, Pahang and has been awarded the "Best Paper Award".

She strongly upholds the life-long learning spirit and has continued to explore her research not only in the area of behavioural finance, but also in learning and thinking skills.



Keong holds a degree in Chemistry and Biology and a master in Environmental Science Majoring in Integrated Water Resource Management and currently pursuing Phd in Education in the area of thinking skill. He is a certified TRIZ Level 1 Instructor, member of Malaysia TRIZ Innovation Association and Malaysian Institute of Chemistry (IKM). He has been actively conducting seminars on leadership, motivation, team building, and study skills for secondary and undergrad students. His passion for innovation in education led him to become a certified level 1 TRIZ trainer. Since then, he has conducted TRIZ training for students in university level and college level. He is presently a chemistry lecturer with Tunku Abdul Rahman College.

Tai holds a degree in Electrical and Electronic and a master in Information Technology. He is a certified TRIZ Level 1 Instructor, member of Malaysia TRIZ Innovation Association. He conducts TRIZ training for students in university level and college level. He is presently a lecturer with Tunku Abdul Rahman College.