Application of TRIZ in Resolving Water Crisis

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Abstract
This paper applies the TRIZ systematic approach in resolving the water crisis in Malaysia. The TRIZ tools used in this study are engineering system analysis, function analysis, cause and effect chain analysis, engineering contradiction and physical contradiction. The purpose of this study is to discover and develop some feasible and elegant solutions in order to mitigate the problem. Findings revealed that people’s attitude is the most critical disadvantage among the man-made phenomena. The root cause and contradictions are then resolved by applying Contraction Matrix and Separation Principles. The recommended inventive principles are #1 Segmentation, #3 Local quality, #10 Preliminary action, #24 Intermediary, #32 Color change and #34 Discarding and recovering. Therefore, it can be concluded that TRIZ is a powerful tool in solving inventive problem.

Keywords: Engineering Contradiction, Physical Contradiction, Inventive Principles, Water Crisis, Water Sustainability Index.
1. Introduction

Originally, water is a transparent substance that forms the streams, lakes, and oceans in the world. However, 2 million tons of sewage, industrial and agricultural waste are discharged into the world’s water daily (UNESCO, 2003). This has contaminated the water that exists in most of the rivers of the world. Nevertheless, water continues to play an important role in the global economy. It is one of the essential resources that is widely used in human activities. For domestic purposes, water is used for drinking, food preparation, bathing, washing, flushing toilets as well as watering lawns and gardens. In industries, water facilitates processing, cleaning, transportation, dilution and cooling manufacturing facilities. For commercial purposes, motels, hotels, restaurants, office buildings and other commercial facilities require water to run their business operations. In the agricultural sector, water is applied to farm, orchard, pasture and horticultural crops. Besides, water is also used in the production of electric power generated with heat. Without sufficient supply of water, human activities will be disrupted and eventually, economic growth will deteriorate.

Malaysia has been blessed with abundant rainfall, averaging 3,000mm annually, which amounts to 990 billion cubic meters of water over the country due to its strategic location in the equatorial region (Department of Water Supply, 2006). Therefore, Malaysia has a tropical rainforest climate. Besides its strategic location, it has an extensive river system consisting of more than 150 rivers that provide the country with more than 25,000 cubic meters of renewable water per capita per year according to an Edge report in June 2002. The amount of renewable water that Malaysia receives far exceeds that of many other parts of the world. Despite all these privileges, the usually drenched country is now facing water crisis. However, water crisis we are facing now is not just a national problem. Take a look at the world around us; we will notice a similar echo of water woes spanning the globe. Water crisis is not just happening in the third world countries but also in some developed countries like Japan, Australia and the United States. Thus, we need to take concrete measures to secure the future of our water resources. TRIZ; a systematic way of solving problem may be of help in battling the looming water shortages in Malaysia.

TRIZ is a Russian acronym for “Teoriya Resheniya Izobreatatelskikh Zadatch”. In English, it means “Theory of Inventive Problem Solving”. In the 1940’s, Genrich Altshuller and his teammates had developed the TRIZ methodology. He was a Soviet engineer, an inventor, a scientist, a journalist and also, a writer. He analyzed over 200,000 patents and managed to identify 40 common inventive principles with his vast knowledge [(Guin et al, 2009), (Mann; 2003, 2007), (Shulyak and Rodman; 2000, 2002), (Smith, 2000) (Terninko et al, 2010), and (Yeoh et al, 2009)]. From his extensive study, there were three main discoveries. First, problems and solutions were repeated across industries and sciences. Next, patterns of technical evolution recurred across industries and sciences too. Lastly, scientific effects outside their original field were used to innovate products, services and processes of different disciplines (Barry et al). In the application of TRIZ, the process will be initiated by performing Function Analysis and Cause & Effect Chain Analysis. If possible, Trimming will be carried out to decrease and eliminate the disadvantages or harmful functions of the trimmed components. The process will then be followed with the use of various TRIZ tools. These TRIZ tools start off with the Model of Problem (such as Engineering Contraction, Physical Contraction, Function Model, Substance-Field Model),
followed by the Tool (such as Contraction Matrix, Separation/Satisfaction/Bypass, Scientific Effects, System of Standard Inventive Solutions), and lastly the Model of Solution (such as 40 Inventive Principles, Specific Scientific Effect, 76 Specific Standard Inventive Solutions) (Yeoh et al, 2009).

2. Problem Statement

Starting from February 2014, Selangor has been experiencing water crisis; caused by the extended hot and dry season due to the El Nino phenomenon. This is the worst water crisis since the 1998 Klang Valley water crisis. At the initial stage, various districts in Selangor including Gombak, Petaling Jaya, Klang, Shah Alam, Kuala Selangor, Hulu Selangor and Kuala Lumpur started to impose water rationing to avoid rapid depletion of water supplies. This water rationing affects the daily lives of 722,032 households, which roughly equals to about 3.6 million people (Cruez, 2014). It has then spilled over to two other states namely Negeri Sembilan and Johore. Undeniably, water rationing is cumbersome; and indefinite water cuts defeats its purpose because consumers resolve into filling up buckets and buckets of water; so that they can carry out daily activities without much disruption when there is no water supply. At the end of the day, the net water saved is too little to help solve this scarcity. Based on news that was reported by Charles Santiago on the 10th April 2014, only seven percent of total water consumption is saved after implementing water rationing for a month (Santiago, 2014). In conclusion, this government strategy is dysfunctional. Therefore, a more radical solution is needed to resolve the water deficits; and ensure continuous clean water supply for the current and future generations of this world.

3. TRIZ Models and Tools

In this study, we apply the TRIZ process flow that is shown in Figure 1.1. First and foremost, the original problem is identified. It is then followed by function analysis, cause and effect chain analysis, engineering contradiction and physical contraction. Finally, contradiction matrix and separation/satisfaction/bypass are used to locate the specific inventive principles, which will subsequently lead to specific solution(s) [(Guin et al, 2009) and (Yeoh et al, 2009)].
3.1. Engineering System

An Engineering System consists of several components that are interacting among each other. These components are commonly known as subsystems, which are listed in Table 1.1. Besides, the subsystems are also affected by external factors, which are called supersystems. Supersystems are not designed as part of the Engineering System; however, they have an impact on the Engineering System too [(Guin et al, 2009) and (Yeoh et al, 2009)].

Table 1.1 Engineering System Analysis

<table>
<thead>
<tr>
<th>Subsystems</th>
<th>Raw Water, Dam, Treatment Plant, Service Reservoir, Water Reticulation Main, Pipe, Particles.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supersystems</td>
<td>Rain, Dry Weather, River, Industrial / Commercial Users, Households</td>
</tr>
</tbody>
</table>

3.2. Function Analysis

Function analysis describes the interaction between two or more subsystems as shown in Figure 1.2. The interactions between subsystems are called functions. Functions are actions that one component acting upon another component to modify parameter(s) of that component. The functions can either be useful or harmful. Useful functions comprise of “normal”, “insufficient”, or “excessive” functions [(Guin et al, 2009) and (Yeoh et al, 2009)].
3.3. Cause and Effect Chain Analysis

Cause and effect chain analysis (CECA) helps to identify the fundamental root cause(s) pertaining to the problem. The CECA is shown in Figure 1.3. This is a very crucial stage. If we diagnose the root cause wrongly, the solution derived may not be effective and the actual problem will not be resolved. At this stage, a series of “why” questions will be asked until the last “why” question cannot be answered. By doing so, high order root cause for the original problem will be distilled to next lower order root cause until the nth order root cause. The next step is to review each of the fundamental root causes. They are then discarded if not plausible, or considered as potential root cause to the original problem. Each of these potential root causes is then considered as the revised problem, which needs to be resolved (Yeoh et al, 2009).

From the CECA, there are many potential root causes. Some are natural phenomenon while others are man-made phenomenon. However, in this study, we would focus mainly on man-made phenomenon i.e. people’s attitude as it is the most critical disadvantage. The result of our finding is corroborated with the statement given by the secretary-general of Water and Energy Consumer Association of Malaysia (WECAM), Mr Foon Weng Lian that wastage and shortage of water is the result of the low level of awareness and apathetic attitude among Malaysians. He reported the result of a survey conducted in 2012 that water consumption in Malaysia was 212 litres per person per day. This was one of the highest in the region, compared to 151 litres in Singapore and 150 litres as recommended by the United Nations (Voon, 2014).
Currently, effort is only focused at identifying more water sources to meet the demand and little effort is directed to look at ways on how to control the resources and its usage for long term benefits. Just like Foon’s belief, it is timely for Malaysians to reflect on their bad water habits. Not only consumers are required to change their behaviour, policy makers are also required to design policies to ensure sustainability of the water resources.

3.4. Engineering Contradiction
The concept of contradiction is not the contradiction between two things external to one another, however it is in fact at the essence of one thing. Furthermore, this is inevitable in our daily life (Savransky and Stephan, 1996). Based on the work of V.I. Lenin, he has described the universality of mutually contradictory phenomena such as plus and minus, differential and integral in mathematics, combination and dissociation of atoms in chemistry, offense and defense, victory and fault in war and etc. TRIZ states that the most effective inventive solution of a problem is solution that overcomes the contradiction. Engineering Contradiction occurs when we are trying to improve one characteristic or parameter of an Engineering System (i.e. improving parameter), the other characteristic or parameter of the system is deteriorating (i.e. worsening parameter). These parameters are translated into one of the 39 engineering parameters in TRIZ. TRIZ approach is to eliminate and solve the contradiction, which is better known as engineering contradiction. 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 is used to solve the contradiction that developed by Altshuller (Shulyak and Rodman; 2000, 2002).

In this study, the Engineering Contradiction can be formulated as follows:
If water main pressure is high, then it provides convenience to people, but it will cause wastage of water. The manipulative variable is the water main pressure. While, the responding variables are shown in Table 1.2.
Table 1.2 Responding Variables

| Improving parameter: Provides convenience | Ease of operation (#33) |
| Worsening parameter: Cause wastage of water | Loss of substances (#23) |

Based on the improving and worsening parameters in Engineering Contradiction, we can then refer to the contradiction matrix to search for the suggested inventive principles, which is shown in Figure 1.4. The inventive principles are:

#2 Taking out  
#24 Intermediary -- selected  
#28 Mechanic substitution -- selected  
#32 Color change – selected

They are derived from the 40 inventive principles developed by Genrich Altshuller (Shulyak and Rodman, 2000).

Figure 1.4 Extract of the Contradiction Matrix

3.5. Physical Contradiction

Physical contradiction can be applied as we are dealing with contradictions with a single parameter i.e. the water main pressure. This is also known as “control parameter” (Yeoh et al, 2009). Thus, we can develop the following physical contradictions:

PC1: The water main pressure needs to be high to ensure convenience to people.  
PC2: The water main pressure needs to be low to ensure water is conserved.

The physical contradictions can be solved through the methods given under separation in space as well as separation in time. The suggested inventive principles under separation in space are
4. Proposed Triz Solutions

Based on the suggested inventive principles given in the contradiction matrix, separation in space and time, we would like to propose the following solutions to resolve the water crisis.

4.1. Inventive principle #1 Segmentation, #3 Local quality, #28 Mechanic substitution and #24 Intermediary

By incorporating these principles, Department of Water Supply can design water plan with different packages that allow users to have access to different fixed amount of water just like the telecommunication services. Consumers are then required to subscribe to the water plans. By doing so, consumers are encouraged to manage their water usage within the stipulated plan. Water plans can be charged at different tariffs to curb excessive water usage. This was exemplified in Hungary when its government increased water prices from 0.20 euro to 0.50 euro per cu m from 1992 onwards; this has resulted in a decrease in the country’s water consumption by about one-third in 1996 (Biswas and Kirchherr, 2013).

A mechanical device can be installed on all households’ water reader to detect the level of water consumed. Once the reader shows that the water consumed hit certain pre-determined level based on the water plan subscribed, the intermediary will then reduce the water pressure. When the water pressure is reduced, water will continue to be supplied to households but with lesser water due to the lower water pressure.

Below are the suggested steps:
1. A water pressure reducing valve (which is shown in Figure 1.5) is installed in series directly after the PBA (Department of Water Supply) water meter at home.
2. PBA personnel will check and record the total amount of water usage and compare with the water plan subscribed by the consumer.
3. If the total amount of water consumed is more than the water plan subscribed, the PBA personnel will reduce the water pressure into the house by adjusting the knob on the water pressure reducing valve. The valve will reduce the water pressure from the main supply to a lower pressure.

4. The amount of water pressure could be reduced by 10%, 20%, 30%, or more, depending on how much would be water consumed in excess of the water plan subscribed.

5. After adjusting the water pressure reducing valve, the PBA personnel will lock the knob of the water pressure reducing valve with special seal from PBA. This is to prevent the consumer from turning back the knob back to maximum pressure setting of the valve.

6. The level of water pressure dropped at the outlet of water pressure reducing valve will be made known to consumer through the water bill printing in different color.

7. If consumer manages to reduce the water usage within the stipulated level stated in the plan, PBA personnel will set the water pressure reducing valve back to the maximum pressure during the next visit for the bill recording.

Figure 1.5. Water Pressure Reducing Valve

4.2. Inventive principle #10 Preliminary action

Water conservation awareness campaign can be organized to educate citizens on the importance of water. This campaign is important, as availability of water will directly affect the sustainability of water resources and ultimately, the country’s overall sustainable development. If water is not managed effectively, it will cause water depletion. The Water Sustainability Index showed a decrease from 64% in 1992 to 33% in 2002, reflecting that Malaysia’s water resources are depleting rapidly and have not been managed properly (WWF-Malaysia). Thus, there is an urgent need to organize more water conservation awareness campaign to disseminate information pertaining to water usage and water problems. This may help to improve water management. There are two good examples in this context. First, Arizona’s Department of Water Resources has announced that April is the state’s water awareness month. Second, Singapore’s Public Utilities Board has run conservation campaigns since early 1970s. A few events were organized by PUB for example meter reading contests and public water fora. In addition, PUB has established a Water Conservation Centre with interactive exhibitions. In 1995, PUB has also launched a remarkable awareness strategy where water supplies to 30,000 randomly selected households were withheld for as long as 14 hours per day for a week. Such campaign has fostered long-lasting behavioral changes among Singaporeans and has reduced water consumption from 172 litres per day in 1995 to 153 litres per day in
4.3. Inventive principle #34 Discarding and recovering

Wastewater can be sent from households or businesses through a pipeline system to a treatment plant, where it is treated to a level consistent with its intended use. The water is then routed directly to a recycled water system for uses such as irrigation, industrial cooling or drinking. There are several communities in the world have been using the recycled water for many years. These include US, Singapore, Australia and Namibia.

4.4. Inventive principle #32 Color Change

The idea of color change can be applied in water bill. Water bills will be printed in different color to inform and alert consumers of their water usage. For example, red bill indicates high usage, green bill for moderate usage and white bill for low usage. This serves as a reminder to consumers so that they can manage their water usage more efficiently and effectively in order to conserve water.

5. Conclusion

Not many people would believe that Malaysia is facing water shortage because it has always been blessed with abundant rainfalls and an extensive river system. For most Malaysians, they seem to care less about how much water they have been using because they can access to water so easily and it is very cheap. On average, Malaysian family’s water bill is only about 10% of its electricity bill. In this study, applying TRIZ tools particularly the inventive principles such as segmentation, local quality, preliminary action, mechanic substitution, intermediary and color change as well as discarding and recovering can help to reduce water wastage and eventually conserve water for the use of the current and future generations. Therefore, it is proven that TRIZ is a powerful innovative methodology, which can be used to resolve inventive problem.
References


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