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The Development of a Device for Draining Floodwater and Incrementing Groundwater or Collected Water Based on TRIZ Contradiction Matrix

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Abstract

Taiwan is often visited by spells of drought and flood, problems which are not in the least helped by global climate change and the greenhouse effect and which adversely affect industrial development in the island. They threaten danger to life and limb and damage to property, and in general impair the quality of life. The related important issues are how to efficiently drain floodwater emanating from rainstorms, reduce land subsidence and increment the reserves of usable water. This research aims to provide a solution by using contradiction matrix (CM) to design a new device to cope with draining such floodwaters, reduce land subsidence, and increment water resources. The method uses CM to identify two inventive principles (IPs): IP22 (harm to benefit) and IP2 (taking out). Moreover, transferring floodwater during a typhoon to water reserves of use against drought is based on a time separated principle. Based on the above principles, the design of the device is innovative. It comprises sets of vertical parallel pipes lowermost and a fence uppermost, separated by a net. It solves the above-mentioned problems and helps achieve the research aim. The device has obtained a Taiwanese patent, and it was awarded the Bronze Medal in the Taipei International Invention Show & Technomart invention contest in September, 2008.

Keywords: contradiction matrix, draining floodwater, increasing water resources, innovative device design, reduce land subsidence.

1. Introduction

Serious land subsidence along the southwest coastal region of Taiwan, caused by pumping groundwater beyond reasonable limits, has been a long term problem. One consequence of the practice is the structural damage caused to buildings in the locations affected. Government has allocated considerable funding to deal with the matter but with no clear signs of amelioration, rather the opposite. Adding to and closely linked to the difficulties are the frequent alternating spells of flooding and drought that Taiwan suffers in the train of global climate change and the

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greenhouse effect, all of which also have a harmful impact on industrial development. As well as the threats to life and limb and the damage to property there is a general deleterious effect on the quality of life. The important issues relating to this problem are how to efficiently drain floodwater resulting from rainstorms, reduce land subsidence and increment usable water resources.

Groundwater accumulates from rainfall filtering through the soil surface over the long term, the essential nature of the process being that it is continuous and gradual. Imprudent excesses of pumping groundwater have harmful consequences that are not easily or quickly remedied. Extraction beyond reasonable limits can lead directly to land subsidence with damage to built structures. The main method of countering such threats is to increment groundwater by recharge. At the same time, because of flood and drought spells, measures must also be taken to efficiently drain floodwaters and increment reserves of usable water. Hence, the aim of this study is to address these three issues together by presenting a device that uses the CM (contradiction matrix) method to drain flood water and to increment groundwater or the collected usable water reserves.

2. Literature Review

2.1 Flooding

Recent decades of intense economic development and demographic change have made Taiwan one of world's most densely populated areas. Urbanization increases the extent of impermeable paving, which is an important causal factor in flooding. Because the plains area occupies only a quarter of Taiwan's surface, there is a scarcity of land suitable for development and a consequent pressure to expand into hilly areas. But, not enough consideration has been given to water conservation work on hillsides and as a result there has been considerable run-off of water and soil that has placed strains, at times overload, on flood drainage structures (Tsai and Chang, 2004).

According to official hydrology data, the density of a 2-hour period of rainfall in Taiwan is the highest in the world, as is the regional ratio of daily rainfall in excess of 1000 mm (Water Resource Agency, Taiwan Ministry of Economic Affairs, 1996). Despite these special conditions, the design of drainage capacity in Taiwan cities is almost the same as that found in cities elsewhere that do not face such conditions. Moreover, land subsidence and flooding during typhoons restricts industrial and commercial development and threatens life and property. Added to that, Taiwan like the rest of the world has its share of problems arising from global climate change and the greenhouse effect, namely heat waves, flooding, drought, and windstorms (Lin, 1999).

2.2 Drought

Global climate change brings not only extremes of water excess in the shape of rainstorms but also extremes of water shortage. Taiwan experiences frequent, damaging spells of drought. A typhoon might well produce a large amount of water, but water that is not usable if it is polluted by soil. In Taoyuan, for example, a growing population means a growing demand for water, but Typhoon Aere in 2004 was followed by 21 days of drastic water shortage in that city, during which performance for 350 companies was badly affected, to the tune of 43 hundred million NTD.

2.3 TRIZ (Theory of Inventive Problem Solving)

Genrich Altshuler (1926~1998) developed the Theory of Inventive Problem Solving (TIPS/TRIZ) including CM and 40 Inventive Principles (IP). TRIZ is a problem-solving method that can be used to analyze problems, find contradictions, and then offer solutions. CM is the tool of frequent use.

Systematic contradiction solving is frequently employed by engineers to deal with engineering problems. While one Engineering Parameter (EP) may provide a beneficial result, that is, an improvement, another may provide an adverse result, that is, a worsening. TRIZ can help solve the problem of systematic contradictions. The first step is to locate the contradictions in the system. The second is to identify the corresponding Altshuller EP. The third and final one is to use CM to identify the corresponding IP with which to solve the problem (Mann, 2007).

(1) Engineering Parameter

Altshuller compiles a list of 39 frequently occurring systematic characteristics in technology. He terms them Engineering Parameters (EPs) and notes that some may contradict one another (Domb et al., 1998). One purposeful use of EPs is to transform real engineering design contradictions into general or standard technology contradictions.

(2) Inventive Principle

There are 40 IPs used to solve similar contradiction problems repeatedly in different time periods, backgrounds, and fields (Joglekar, 2007; Retseptor, 2008a; Retseptor, 2008b).

(3) Contradiction Matrix

CM is a 40-row multiple 40-column matrix. The procedure for its application is as follows: First, identify which EP worsens a product or process and which improves it. Then, find the corresponding EP numbers in the row and column. Finally, find the intersecting matrix elements in the corresponding row and column. These elements give the numbers of the recommend IPs. For example, Figure 1 shows that the EP that improves is 2 (Weight of stationary object), while the one that worsens is 39 (Productivity). So, find the intersecting matrix element in corresponding row 2 and column 39. This gives 1, 28, 15, and 35, which are the numbers of the recommended IPs.

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Parameter that Worsen / Parameter that Improve	1.Weight of moving object	2.Weight of stationary object	……	39.Productivity
1.Weight of moving object				35,3,24,37
2.Weight of stationary object				1,28,15,35
:			:	
39. Productivity	35,26,24,37	28,27,15,3		

Suggested Inventive Principles

Figure 1. Contradiction Matrix.

3. Selection of Inventive Principles for an Innovative Device to Drain Floodwater and Increase Groundwater or Collected Water

Groundwater accumulates from rainfall filtering through the soil surface over the long term. The EPs of this research are as follows:

(1) The parameter of improvement is EP30 (Harmful factors acting on an object). Flooding brings into a location a large amount of water that threatens life and property.
(2) In situation 1, the parameter of impairment is EP22 (Waste of energy): draining the floodwater requires a motor to pump, which is an undesired waste of energy. In situation 2, the parameter of impairment is EP23 (Waste of substance): draining the floodwater is an undesired waste of substance.

Table 1 shows the IPs selected by CM. Table 2 indicates that situation 1 uses CM to identify IP22 (harm to benefit); in this situation, a great amount of water is transferred underground to charge the groundwater and thus reduce the likelihood of land subsidence, an overall benefit to the location. Situation 2 uses CM to identify IP 2 (taking out), by which the surface floodwater is taken out and used to form groundwater.

Table 1. Device's Inventive Principles Selected by Contradiction Matrix

Parameter that Worsen / Parameter that Improve		EP22	EP23
		Waste of energy	Waste of substance
EP 30	Harmful factors acting on object	21,22, 35,2	33,22 19,40

Table 2. The device's selected Inventive Principles for Draining floodwater and Incrementing Groundwater or Collected Water

Improve demand	Design principle	Corresponding solution
EP30 Harmful factors acting on object	IP22 Harm to benefit IP2 Taking out	Transfer harm (ground level floodwater) to benefit (underground groundwater)

The following describes the design concept. In situations 1 and 2, this research identified IP22 (harm to benefit) and IP2 (taking out). The design of the device based on the above principles is innovative. Its threefold aim and function is to drain floodwater, increment groundwater [and thus by incrementing groundwater, reduce subsidence] and increment reserves of collected water. Draining floodwater takes water out of the system. Draining floodwater into soil increments groundwater and thus reduces subsidence, which is to say that harm is exchanged for benefit. An equal exchange of harm for benefit also occurs when floodwater is drained into soil and thus increments the reserves of collected water.

4. Designing an Innovative Device for Draining Floodwater and Incrementing Groundwater or Collected Water

The device is designed in two versions of the basic unit: a primary structure and a box structure. Given the versions, there are four types of application: (I) a structure used at ground level with plants; (II) a structure used on pavement; (III) a structure used for watershed (in an area for water collection); and (IV) a structure used on rooftops with plants. The details are explained in the following sections.

4.1 Basic structure unit

Primary Structure Unit

Figure 2 shows the primary structure of the device. This comprises a large number of vertical parallel pipes lowermost with a fence uppermost, separated by a layer of net. The device can be installed in the ground for the purpose of draining floodwater and incrementing either or both groundwater and collected water. The sets of hollow pipes is placed in a suitably large excavation in the ground and covered with the separating net and fence. The soil layer spread above the fence forms the ground surface. As surface water filters through the soil layer it can quickly escape, reach and flow through the vertical pipes, which is the main function of the device.

Box Structure

Figure 3 shows that this version of the device is constructed as an all-in-one box structure. This structure comprises a set of vertical rectangular hollows, a fence above those, and an intervening layer of net. This structure helps water flow through the provided hollows, and at the base of the box structure there is a side channel that directs the flow into the local drainage system.

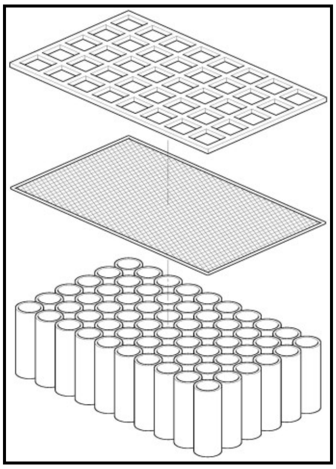

Figure 2. Primary structure

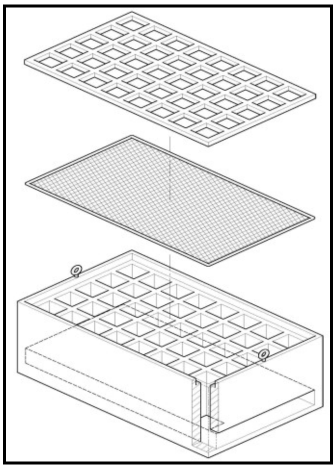

Figure 3. Box structure

<u>Installing the Structure Below Ground</u>

Figure 4 shows how to install the structure below ground. The first step is to excavate a hole in the ground big enough to take the vertical parallel pipes. Second, place the pipes in the hole. Third, a separating net is placed above the pipes and above that a fence. Finally, a layer of soil is spread above the fence, and leveled to form the ground surface. In this way, collecting water is made easy. Vegetation can be planted in surface soil as desired. When surface water filters through the soil, it can easily flow through the fence and separating net to reach the vertical pipes, and then quickly downwards to reach deeper soil levels. Floodwater is thus drained and groundwater incremented.

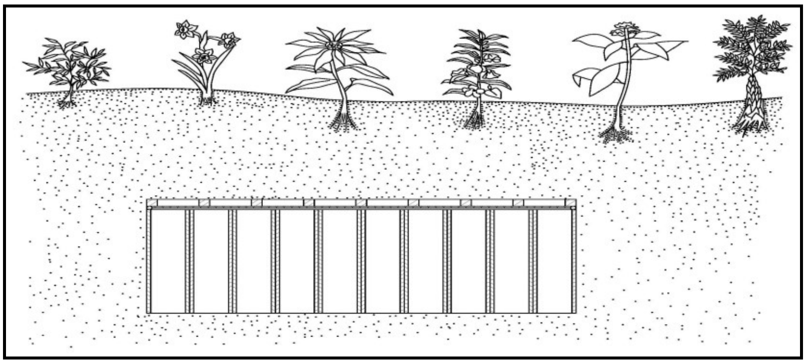

Figure 4. Installing the structure below ground

4.2 Application types

<u>Type I: a structure used at ground level with plants</u>

Figure 4 shows a structure installed in a single place while Figure 5 shows a structure in a continuous ground space with plants. First, excavate a suitably sized space to take one or more structures (No. 6 in Figure 5). Second, place the required numbers of structures side by side in the excavation to form a water flow path. Then spread and level the required layer of soil (No.4 in Figure 5) above the structures. Finally, plant the surface soil layer with vegetation as desired

(No.5 in Figure 5). When rainfall reaches the surface above the structures, most of the water will flow through the plants and into the fence (No.3 in Figure 5) and separating net (No.2 in Figure 5). It will next flow into the vertical parallel pipes (No.62 in Figure 5) of the structures and penetrate from there rapidly to deeper soil (No.44 in Figure 5). In this way, the groundwater under the continuous ground space is incremented. The increment in continuous ground space is much more than in any single place.

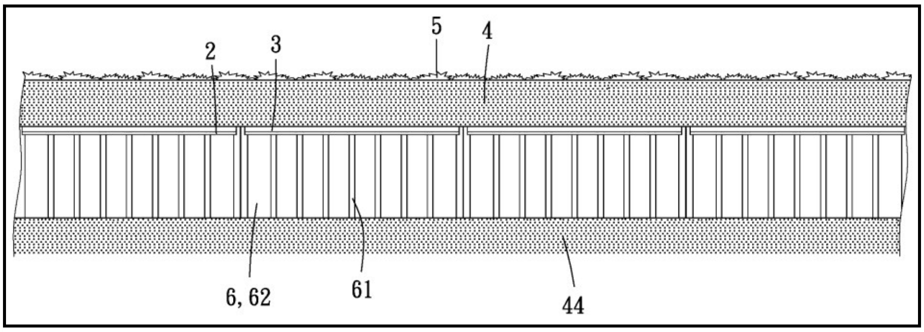

Figure 5. Type I: Structure used at ground level with plants

<u>Type II: a structure used on paving</u>

Water accumulation on a footpath is usually avoided by laying down a layer of gravel on the surface. Figure 6 shows the pavement structure for such as a scenic area footpath. First, excavate a suitably sized space to take one or more of the device structures (No. 6 in Figure 6). Second, install a suitable number of structures side by side into the excavation to form a water flow path. Spread a layer of soil (No.4 in Figure 6) above the structures and level off. Finally, add the gravel layer (No. 41 in Figure 6) above the continuous structure. The rainfall gathers in the excavated space above the structure, with most of the water flowing through the gravel and then into the fence (No.3 in Figure 6) and the separating net (No.2 in Figure 6). It then flows into the vertical parallel pipes (No.62 in Figure 6) of the structure and is carried rapidly downwards to the deeper soil (No.44 in Figure 6) below the pipes. In this way, groundwater is incremented in continuous ground space. The increment in continuous ground space is much greater than in any single place.

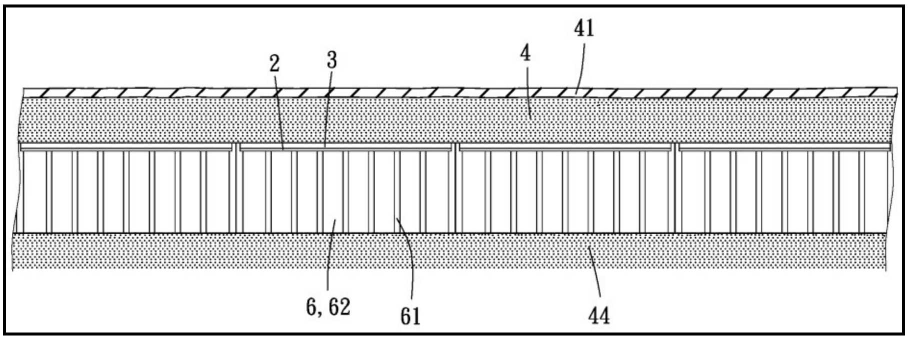

Figure 6. Type II: Structure used on pavement

<u>Type III: a structure used for watershed (an area for water collection)</u>

Figure 7 shows a structure constructed on a watershed in continuous ground space. A side channel (No. 64 in Figure 7) is established at the base of the box structure (No.6 in Figure 7).

This channel collects the water flowing from the vertical parallel pipes (No. 62 in Figure 7). The structure is installed near an area for water collection, such as a reservoir or pool, so the water flow is directed to the watershed. A layer of soil (No. 4 in Figure 7) is spread above the structure and leveled. When the rainfall reaches the surface above the structure, most of the water flows into the fence (No.3 in Figure 7) and separating net (No.2 in Figure 7). It then flows into the vertical parallel pipes of the structure, and from there is quickly carried via the side channel towards the watershed. In this way, the amount of usable water in the continuous ground space is incremented.

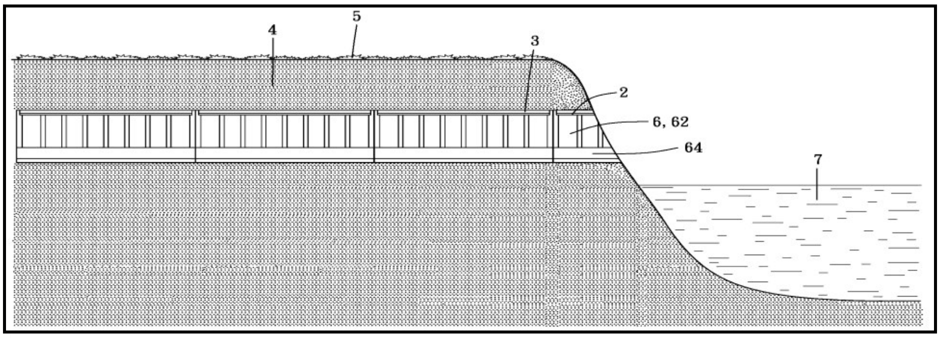

Figure 7. Type III: Structure used for watershed

Type IV: a structure used on rooftop with plants

Here the device can be used not only on the ground, but also on buildings. For example, it can be installed on a rooftop or balcony, or in a parking lot. Fig. 8 shows a rooftop structure (No.81 in Figure 8) with plants in a continuous space – on a concrete surface (No.8 in Figure 8). Soil (No.4 in Figure 8) is spread above the structure and the desired vegetation (No.5 in Figure 8) planted. A side channel (No. 64 in Figure 8) established at the base of the box structure (No.6 in Figure 8) is connected to the drain pipes (No.82 in Figure 8) of the buildings which in turn are connected to a collection space, such as a tank or pool. When rainfall reaches the surface of the space above the structure, it filters through the soil and then flows through the fence and separating net to reach the vertical parallel pipes. From there, it flows into the side channel and drain pipes, and then to the collection space. In this way, usable water resources are incremented in continuous ground space and possible mishaps of slipping on wet concrete floors are averted.

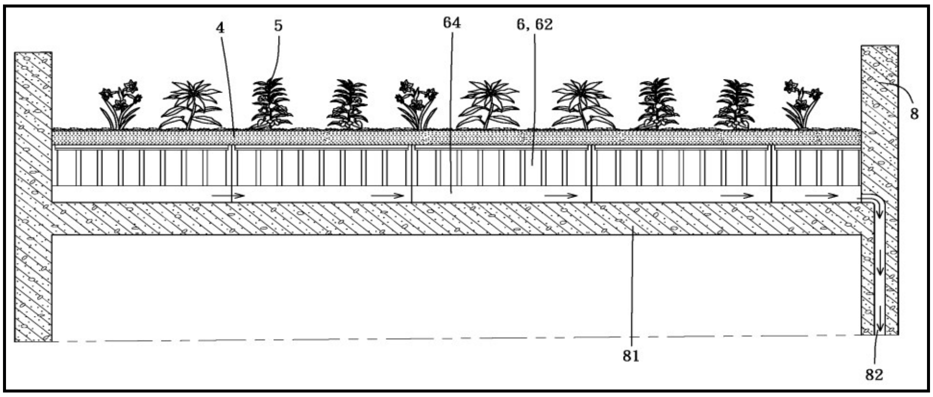

Figure 8. Type IV: Structure used on rooftop with plants

5. Conclusions and Suggestions

The device gained a Taiwanese patent and has featured in many exhibitions. It was also awarded the Bronze Medal at the Taipei International Invention Show & Technomart invention contest in September, 2008.

This research used contradiction matrix (CM) to identify two IPs (inventive principle): IP22 (harm to benefit) and IP2 (taking out), which were instrumental in designing the device for controlling the draining of rainstorm floodwater, for incrementing groundwater, thereby reducing land subsidence, and for incrementing reserves of collected water.

Situation 1 used CM to find IP22 (harm to benefit); effective in transferring large amounts of water (surface flooding) to below ground, i.e., in incrementing groundwater and thereby reducing land subsidence, and thus transforming harm (flood) into benefit (groundwater) in the region. Situation 2 used CM to find IP2 (taking out): effective in using surface floodwater to increment groundwater. In addition, transferring floodwater during a typhoon into water reserves against a spell of drought is based on a time separated principle.

The aim of this research has been to employ the IPs obtained from CM to design the device. It comprises sets of vertical parallel pipes lowermost and a fence uppermost, separated by a net. There are two versions of the structure: a primary structure and a box structure. These can be used in four ways: (I) ground–level structure with plants; (II) structure on paving; (III) structure for a watershed (for water collection); and (IV) rooftop structure with plants.

The research demonstrates that TRIZ can help solve systematic contradiction problems in engineering. It is altogether likely that other researchers will find it useful for designing devices to solve problems in quite different fields.

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Youn-Jan Lin is an Associate Professor of Ming Hsin University of Science & Technology in Taiwan since 1996. He earned his PhD degree from the Department of Civil Engineering, National Taiwan University in 1995. He has licenses of PE in Hydraulic Engineering, Tour Leader of Chinese language, and etc. He is currently the Director of Center for Intelligent Living Technology Development and he is teaching in Department of Hotel Management. His areas of interests include Systematic Innovation including TRIZ, Damage Mitigation, Hot spring hotel. He received the "Greatest Teacher's Award", the highest honor recognizing the national most outstanding faculty from the Private Education Association in 2006. He got 27 patents and his inventive devices have featured in many exhibitions and gained awards, for example, as follows: 1. Shown at "2006 Taipei International Invention Show and Technomart". Awarded the most popular query prize among factory owners in the National Science Council Exhibition Hall. 2. Shown at "2008 Taipei International Invention Show & Technomart". Gained Bronze Medal at the 2008 Taipei International Invention Show & Technomart invention contest. He was awarded "Lifetime Achievement of Invention" and "Pride of the Nation Inventor" that are co-awarded from Taiwan International Invention Award Winners Association and Golden State University of USA in 2009.

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