Study on Rooftop Rainwater Harvesting System in Existing Building of Taiwan

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Abstract

This paper would focus on reuse mechanism of rainwater drainage system in existing building of Taiwan. The current design methodology of roof construction for rainwater plumbing system would be reviewed. Furthermore, we investigate circumstances and survey the conditions of typical buildings in Taiwan to find out the applicable reuse mechanism of rainwater system in existing building. In this study, some influence factors including financial and technical issues must be considered. In order to clarify the practicable performance, we would conclude some practicable models for existing buildings, which can integrate the existing roof construction for rainwater plumbing system.

Keywords
rainwater use, water conservation, guideline, design standard, evaluation system

1. Introduction

Many metropolitan areas in Taiwan have experienced water shortages in recent years, due partly to droughts, economic development and rapid urbanization. These water shortages have resulted in an anxious public consciousness to existing water supplies and created an economic barrier to development. Consequently, it is clear that alternative water resources must be investigated to alleviate the water shortage problem in urban areas. Rainwater use as a supplement to the potable water supply in Taiwan has been demonstrated a practical and promising alternative where traditional groundwater or surface water is limited.

To implement rooftop rainwater harvesting systems for domestic water-use, the Water Resources Bureau, Ministry of Economic Affair, has published the “Rainfall Catchments and Dual Water Supply System-Handbook” to provide a reference for engineers in preliminary building design. A new rainwater use guideline that had been linked to building code offers an easy approach to the evaluation of water conservation and a rainwater use system for architectural planning in Taiwan currently. However, these rainwater use system guideline mostly were conducted for new constructions and rare to mention about the large number of existing buildings.

This paper would focus on reuse mechanism of rainwater drainage system in existing building of Taiwan. The current design methodology of roof construction for rainwater plumbing system would be reviewed. Furthermore, we investigate circumstances and survey the conditions of typical buildings in Taiwan to find out the applicable reuse mechanism of rainwater system in existing building. In this study, some influence factors including financial and technical issues must be considered. In order to clarify the practicable performance, we would conclude some practicable models for existing buildings, which can integrate the existing roof construction for rainwater plumbing system. Finally, this paper would also perform a case study and simulation as the verification.

2. Calculation And Evaluation Mechanism

The calculation method and procedure of rainwater use system had been conducted in our previous research. As a new aspect, this report would focus on the rainwater utility for existing building. It is necessary to consider the integration of existing conditions and practicability. However, the calculation and evaluation mechanism are basically in similar consideration. First of all, we need to know the quantity of rainwater from collection and for usage. According to the basic balance concept of input and output, it can be concluded as four parameters to calculate the rainwater use system. Those are rainwater from collection device and replenish from tap water system in the side for input, and the others are consumption quantity for user and overflow from storage device. We can indicate this concept as the diagram shown in figure 1[10].

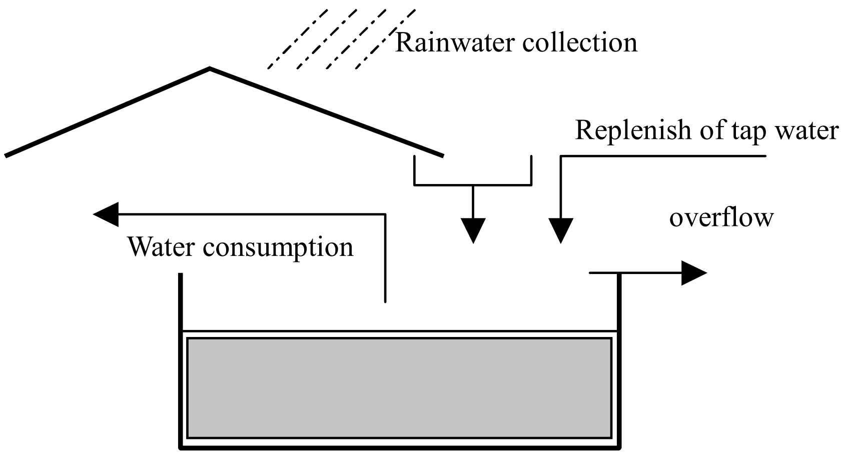


Figure 1. Balance of input and output for rainwater utilization

According to the daily precipitation database, at first, we must conform the location of design object (for example: in Taipei) and the meteorological precipitation data for simulation object or assessment as the calculation process of utilization quantity of rainwater. Then, we have to decide the area of collection device, object character of water utilization as the condition for simulation and assessment. The calculation process is as the following:

(1) The collection quantity (CRW) from daily precipitation (Rd) and collection area(CA).

$$CRW(m^3) = CA(m^2) \times Rd\ (mm/day) \times \gamma \times 10^{-3}$$

(γ is the flow out coefficient, according to the character of collection location, it is usually adopted 0.85-0.95 as general roof.)

(2) The overflow quantity (OFV) from collection quantity (CRW), volumes of storage

tank (SV) and remains quantity in storage tanks (RSV).

When CRW + RSV > SV(m^3), then OFV = CRW + RSV - SV

When CRW + RSV < SV(m^3), then OFV = 0

(3) The first remains quantity in storage tank (RSV') after above calculation.

When CRW + RSV > SV, then RSV' = SV

When CRW + RSV < SV, then RSV' = CRW + RSV

(4) The quantity replenish water (CW) from the remains quantity in storage tank (RSV') and consumption quantity for user (UW).

When RSV’ - UW < 0, then CW = - (RSV’ - UW)

When RSV’ - UW > 0, then CW = 0

(5) The second remains quantity in storage tank (RSV'') after above calculation.

When RSV’ - UW < 0, then RSV'' = 0

When RSV’ - UW > 0, then RSV'' = RSV’ - UW

(6) We adopt the second remains quantity in storage tank (RSV'') as the initial data of RSV for next day's data to add up all parameters and yearly utilization by looping calculation.

(7) According to the above add-up calculation, we can get the yearly rainwater utilization quantity (YRU), yearly rainwater collection quantity (YRC) and yearly consumption quantity (YTU).

$YRU = \Sigma (UW - CW)$, $YRC = \Sigma CRW$, $YTU = \Sigma UW$

(8) The rainwater utilization rate (PRU%) and substitution rate of tap water (PCW%) can be calculated as following:

$$PRU(\%) = YRU \div YRC \times 100, \quad PCW(\%) = YRU \div YTC \times 100$$

The above calculation procedure of rainwater assessment had been written into the computer program, and we can get the simulation results very rapidly. The program flowchart is shown in the figure 2. This calculation method offers quantity information for evaluation of rainwater utilization and help primary decision making for designer. However, we need further information about the situation of existing circumstance and conditions of existing building. Then, the practicability of rainwater use system for existing building could be arranged. Therefore, we performed an investigation and interview to verify the practical conditions and inference factors.

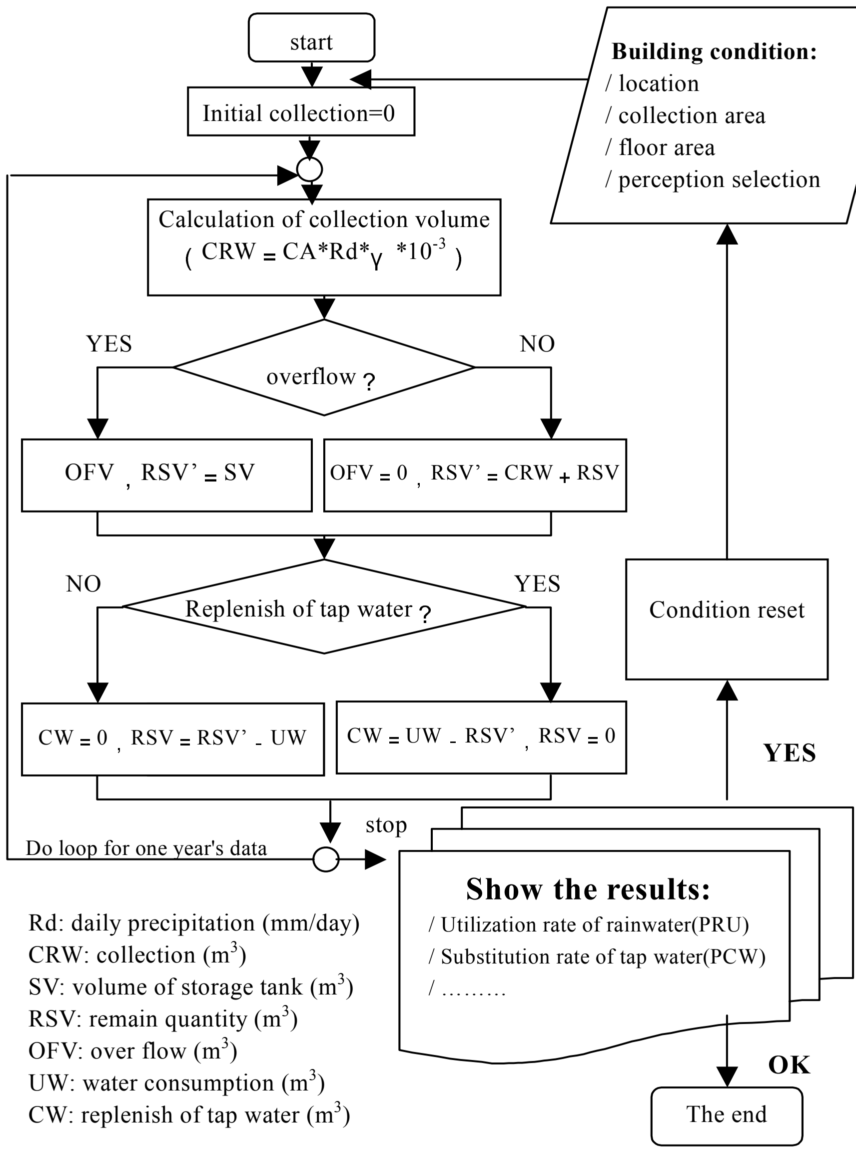


Figure 2. Flow chart of rainwater utilization simulation

3. Investigation for Existing Building

City is always constructed by infrastructure and buildings and simultaneously with high-density population. In order to figure out the existing conditions for rainwater utility, we choice the Taipei City as the study object. Figure 3 shows the urban planning map of Taipei City. Firstly, we focus on the potential rainwater utilization in Taipei City. There is about 271.8 kilometer square and about 2641000 populations in this city and its tap water availability rate is 99.49%. The precipitation is about 2400mm/year, then the total rainwater for one year is theoretically approximate 6.52 hundred million ton. On the other hand, the annual tap water supply is about 10.93 hundred million ton due to tap water authority's report. It shows the high potential of rainwater utilization for Taipei City. In fact, rainwater always becomes the burden of the city drainage or treatment device. On other words, there are high potential of rainwater utilization in Taipei City or many other place of Taiwan.

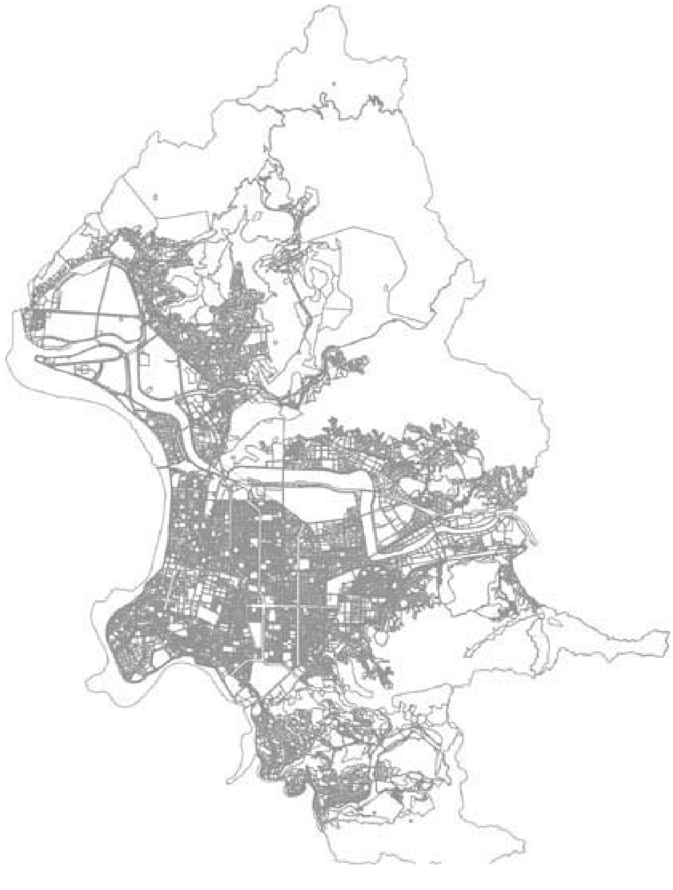


Figure 3. The urban planning map of Taipei City

As observed object, investigation take samples randomly by grid method and GIS information system. According to the city map coordinates system in 1/1000 scale, we select the intersect point building as observed object. Figure 4 is a performance example for object decision in this investigation and Figure 5 shows the whole observed objects distribution in this investigation.

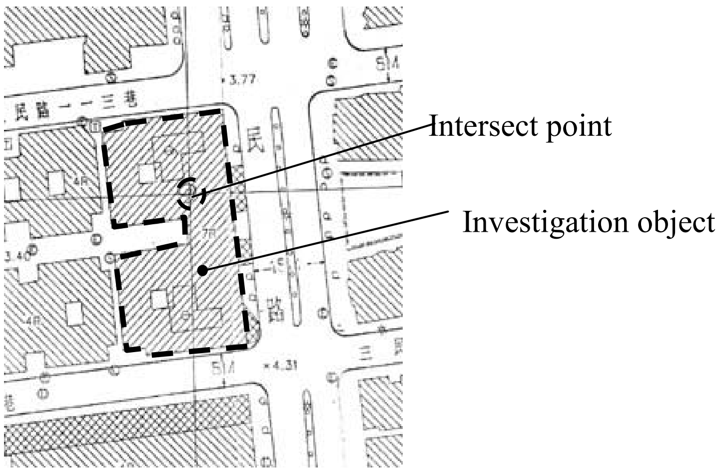


Figure 4. Performance example for object decision

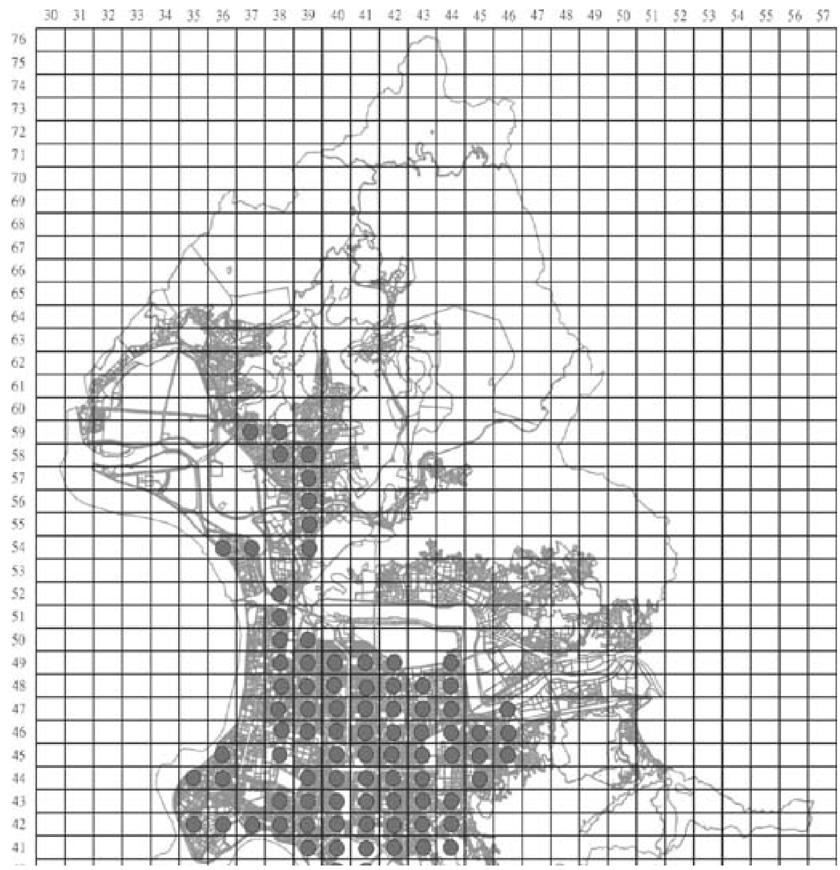


Figure 5. The whole observed objects distribution in this investigation

As the initial observation for these investigation objects, there are 97 cases were selected. Figure 6 shows that the building age is in 20~30 years at the most cases. The cases that are under 10 years or over 30 years occupy less percentage in this investigation.

Building age (year)	Case numbers	Percentage %
5~10	6	6.19%
10~15	12	12.37%
15~20	22	22.68%
20~25	24	24.74%
25~30	24	24.74%
>30	9	9.28%
Total	97	

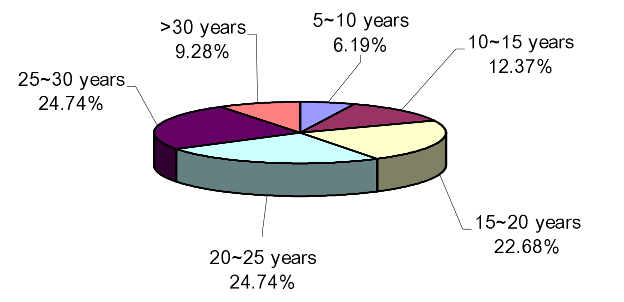


Figure 6. Building age and distribution of observed objects

Figure 7 shows that the building floors height is in 1~5 floors at the most cases with 67%. The cases above 16 floors occupy less percentage merely with 2% in this investigation.

Building floors	Case numbers	Percentage %
1-5	65	67.0
6-10	13	13.4
10-15	17	17.5
>16	2	2.1
Total	97	100

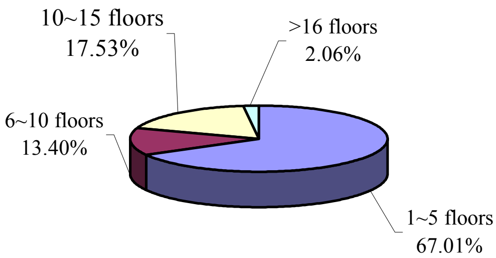


Figure 7. Building floors height and distribution of observed objects

4. Condition analyses and issues identification

As the results of investigation, this report concluded 3 issues of existing rooftop rainwater harvesting system for evaluating the practicability.

(1) Rooftop

Reinforce concrete structure buildings which are with flat rooftop occupy the most cases in this investigation. The typical building roof has two conditions, one is flat concrete roof and the other is with additional steel roof frame as shown in Figure 8 and Figure 9. The numbers of these two kinds of rooftop are very similar.

Figure 8. Reinforce concrete structure building with flat concrete roof

Figure 9. Reinforce concrete structure building with additional steel roof frame

(2) Plumbing and piping work

Drainage piping work for rainwater is also typically two types, one is conceal piping buried into structure and the other is show off piping with clear system on building envelope. Conceal piping work always has the problems of maintenance and duration. Figure 10 shows the view of existing show off piping case in this investigation.

Figure 10. View of existing show off piping case

(3) Drainage system and details

According to the observation, drainage system for rainwater generally collects from rooftop and through piping work then flows out to outside urban drainage system. Most individual cases under 5 floor height directly flow out the rainwater through simple piping work, and some building with larger scale and more complex function collect rainwater into basement structure once before driving out. Figure 11 shows the most popular driving out type and Figure 12 is some details of collection installations.

Figure 11 View of the most popular driving out type

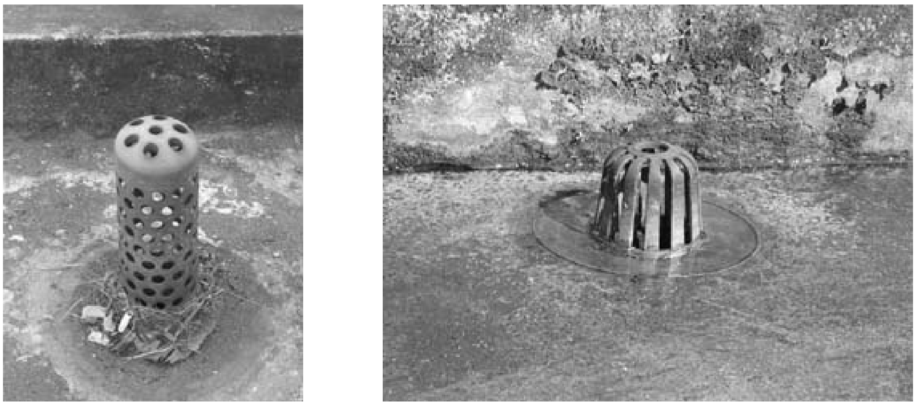
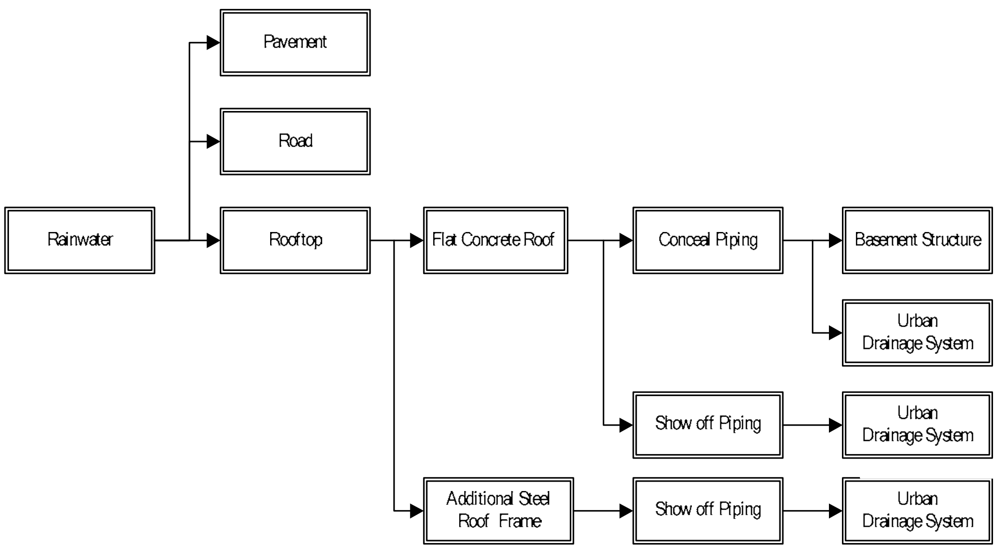


Figure 12. Details of collection installations

According to the understanding of existing building condition, the practical performance of existing rooftop rainwater harvesting system could be considered as the following diagrams as shown in Figure 13.


Pavement
Road
Rainwater
Rooftop
Flat Concrete Roof
Conceal Piping
Basement Structure
Urban Drainage System
Show off Piping
Urban Drainage System
Additional Steel Roof Frame
Show off Piping
Urban Drainage System

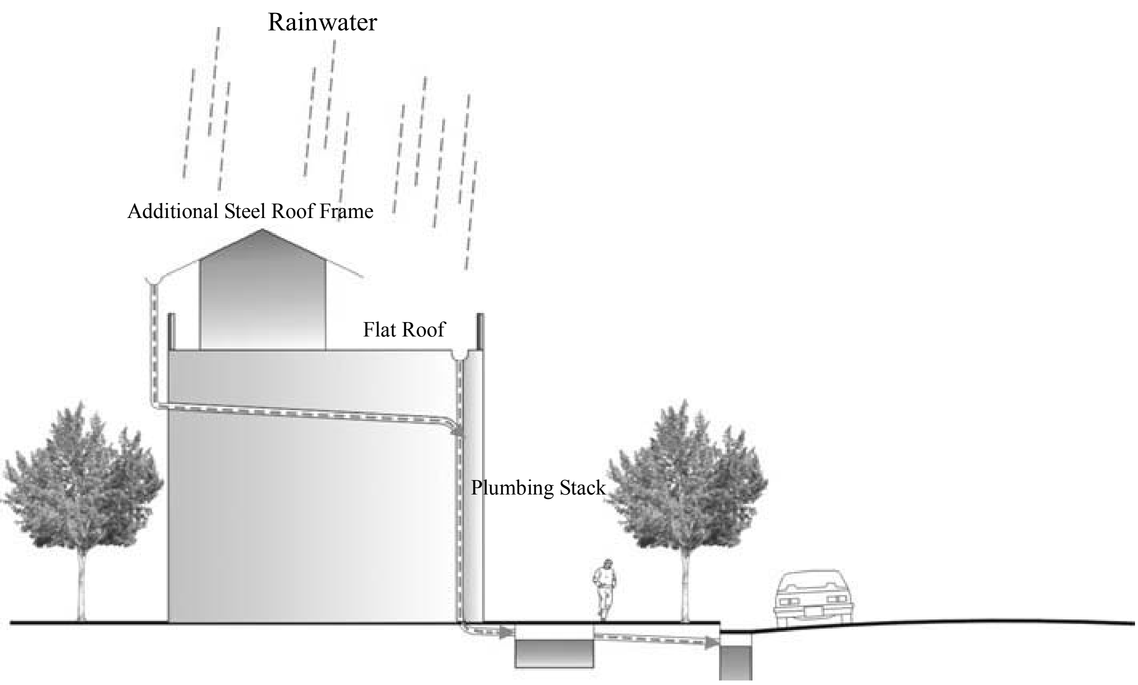

Rainwater
Additional Steel Roof Frame
Flat Roof
Plumbing Stack

Figure 13. Existing rooftop rainwater harvesting system frame

5. Evaluation Tool

Existing rooftop rainwater harvesting system is an acceptable solution for alleviating the water shortage problem in urban areas. However, practical performance need functional tool to make the real progress for the publics. Herein, we developed a practical evaluation tool in the research. By using system dynamic theory, we transfer the calculation to be dynamic simulation through commercial software STELLA. The transformation flows and the object treatment are as shown as Figure 14.

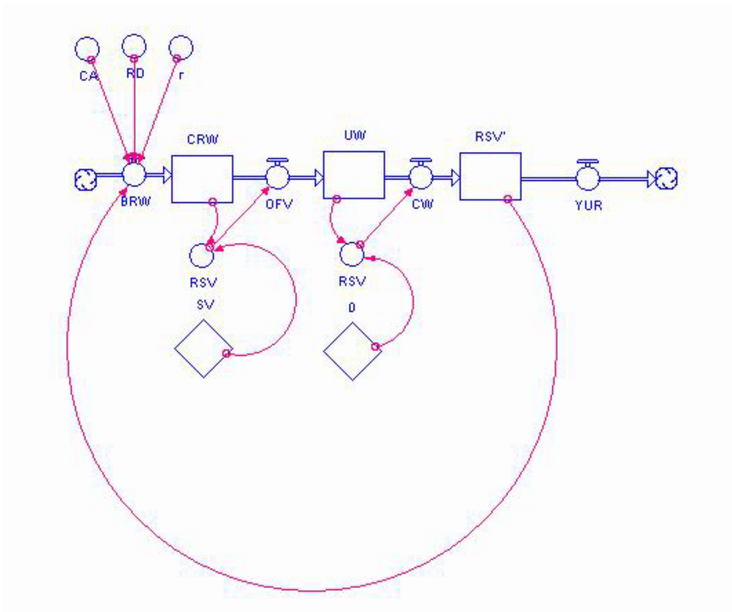


Figure 14 Transformation flows and the object treatment of dynamic simulation

The performance of this dynamic simulation is still conducting. The partial results and the application are offered in network at present. Figure 15 shows the entrance page of the dynamic simulation for practical evaluation of existing rooftop rainwater harvesting system.

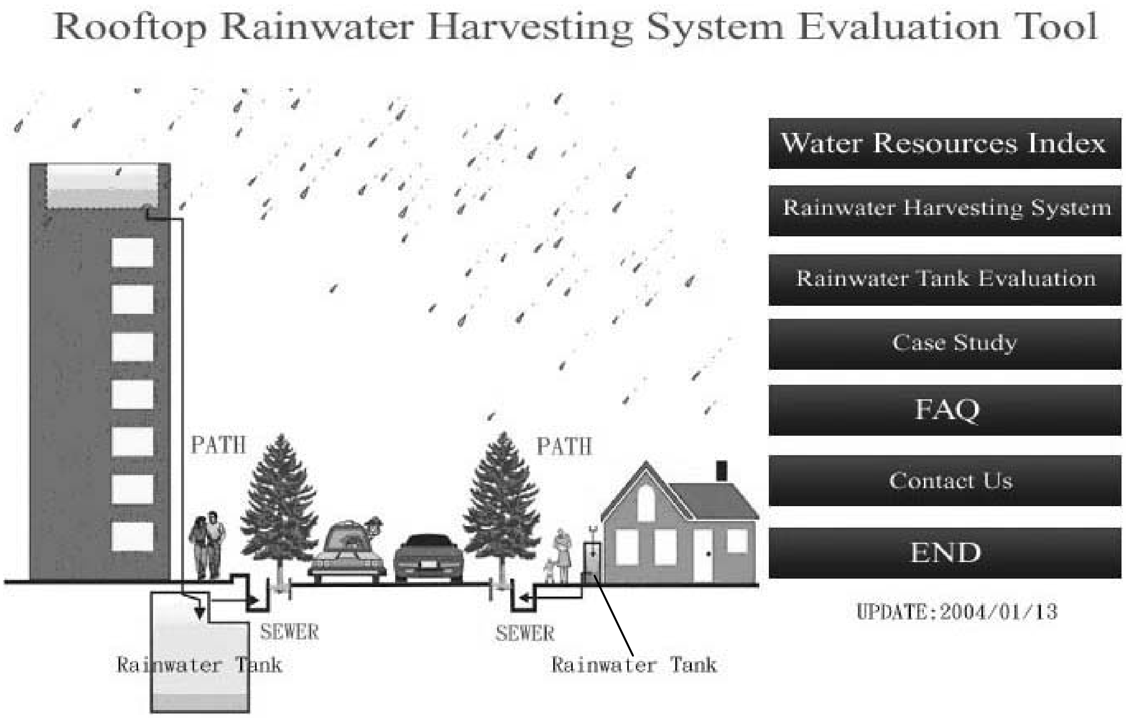


Figure 15 Entrance page of the dynamic simulation tool

6. Conclusion

This paper focuses on existing rooftop rainwater harvesting system of Taiwan. The current design methodology of roof construction for rainwater plumbing system had been reviewed. We investigated circumstances and survey the conditions of typical buildings in Taiwan to find out the applicable reuse mechanism of rainwater system in existing building. We also arrange the categories of existing building rainwater drainage conditions including rooftop, piping work and drainage system. In order to clarify the practicable performance, we concluded some practicable models for existing buildings, which can integrate the existing roof construction for rainwater plumbing system. Finally, this paper also offered dynamic simulation tool information of existing rooftop rainwater harvesting system for practical application.

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Main author presentation

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