Analyzing Public Cognition and Attitudes toward Water Infrastructure in Taiwan

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Abstract. The purpose of this study is to understand public cognition and attitudes toward water infrastructure in Taiwan through survey responses and to further explore the relationship between the two. Results show that among the cognition variables, the percentage of correct answers given by the participants for the factor related to water infrastructure and it can impact the environment and society was the highest. As for the attitude variables, such as the exploitation of water sources and the construction of reservoirs, while the majority of the public stated that the environmental impact should be considered first, they do not agree with the government collecting additional fees from the public for the maintenance of facilities such as sewage treatment plants and pipelines. The correlation analysis shows that the correlation coefficient between the cognition and attitude variables is very low, indicating that attitudes cannot be influenced by either high or low conceptual knowledge of water infrastructure.

1. Introduction

According to a United Nations’ report on water development and climate, global water consumption has increased sixfold in the past 100 years, and continues to increase at a rate of about 1% per year due to factors such as population growth, economic development, and changes in consumption patterns. Climate change coupled with a more unstable water supply will accelerate the formation of water-scarce areas [1]. By 2050, the water shortage crisis caused by the demand for food and the continuous growth in agriculture and animal husbandry activities will affect about 25% of the world’s population. Water is a major factor in conflict in many countries [2]. It is necessary for countries to include the construction of more water infrastructure in future plans in order to solve the water resource crisis. For example, water reuse is a reliable alternative to conventional water resources, provided that it is safely handled and utilized. The supply of fresh water can also be increased through the desalination of seawater [1].

The types of water infrastructure are numerous and wide-ranging, and may include dams, hydropower, water supply, sanitation, and irrigation. [3]. In response to the water resource problem, many countries had begun investing large sums of money in the construction, maintenance, and management of water resource infrastructure; however, the funding gap is another major challenge [3,4]. For example, in the United States, although their reservoirs provide drinking water, irrigation, hydroelectric power generation, flood control, and a venue for tourist activities, there are about 90,580 reservoirs nationwide, with an average age of about 56 years. Statistics show that as of 2016, 15,500 potentially dangerous reservoirs would need to be repaired, and an estimated investment of US$45
billions would be required for their maintenance in the future [5]. Drinking water is delivered through one million miles of pipes across the U.S. Many of those pipes were laid in the early- to mid-20th century with a lifespan of 75 to 100 years. According to the American Water Works Association, an estimated $1 trillion is necessary to maintain and expand services to meet demands over the next 25 years [6].

Besides relying on government budgets to support their construction and maintenance, these types of water infrastructure are often improved by charging the public taxes. For example, in the state of Washington, the water utilities conducted a survey on consumers’ attitudes toward and willingness to engage with paid maintenance with regard to three plans proposed by the residents, namely water quality improvement, pinhole leak damage insurance, and replacing aged water distribution infrastructure. It was found that 17% of the respondents chose to support the water quality improvement plan, 9% favored the leak damage insurance plan, and 29% favored the public infrastructure program. Among the three plans, although residents were relatively more supportive of the public infrastructure improvement program, about 44% of the respondents still did not support paid improvement plans. This result shows that although the public was relatively concerned about the construction of water infrastructure, most of the residents were unwilling to pay additional fees to fund it out of their own pocket [7].

Taiwan receives abundant rainfall, with an average annual rainfall of about 2500 mm—2.6 times the global average. There are frequent rains and typhoons every spring and summer to replenish water sources. The annual rainfall is about 90.5 billion tons, and there is frequent flooding. Even so, due to the steep terrain, concentrated rainfall, and short rivers, most of the rainwater quickly flows into the ocean. Furthermore, climate change caused by global warming results in an increasing frequency of floods and droughts. Now, Taiwan already has a water crisis [8]. There are currently about 95 reservoirs in Taiwan. In 50 years, many reservoirs will become unusable due to heavy sedimentation. For example, Taiwan’s current largest capacity Tseng-Wen Reservoir is widely used for flood control, water supply, and power generation, with a design capacity of 713 million cubic meters. Sediments transported by heavy rainfall result from frequent typhoons in the Tseng-Wen Reservoir, which now comprise one-third of the capacity of the reservoir [9]. Besides, not only is the installation of sewage projects necessary for ecological protection, but they are also a modern water infrastructure. In the past, Taiwanese governments invested extensively on the construction of sewerage systems. Statistics show that as of 2013, the overall sewage treatment rate is 66.62%, with the sewage treatment rates of Taipei City and New Taipei City being the highest at 100%, but with that of Taitung County being the lowest at only 13.14%. Due to Taiwan’s late start in sewage treatment system construction—despite the increase in the system’s penetration rate over the years—Taiwan’s overall sewage treatment rate not only lags far behind countries in the Americas and Europe, but also lags considerably behind other neighboring locations in Asia such as Hong Kong (93.00%), South Korea (90.10%), and Japan (75.80%). In order for Taiwan to keep up, it is imperative that construction be accelerated [10].

Due to the low price of water, people in Taiwan had thought that water was readily available. However, due to frequent droughts in recent years, they have gradually realized the daily inconvenience likely to be brought about by a lack of water resources, and hence have also begun to attach importance to water conservation [11]. However, the public generally consider the construction of water infrastructure, such as the maintenance of water quality, the dredging of reservoirs, river improvement, and the utilization of reclaimed water to be the government or responsible agencies’ business, not theirs [12]. In order to maintain the stability of water prices, these maintenance costs are all covered by the government’s separate budget [13]. In order to solve the water crisis, Taiwan has launched the Forward-looking Infrastructure Development Program (FIDP) in recent years. The first phase had an investment of US$93.3 million for the construction and running of the water resources-related FIDP between 2017 and 2018, including water quality improvement, reservoir dredging, stable water supply, and hydroelectric power generation. In the future, more funds will be invested to improve the overall water environment, to provide people with a safe and livable environment away from flooding, and to make water available to every person and every industry [14].

Therefore, in order for water resources to be sustainable and for water to be available for everyone, management through legal restrictions, construction, or related water infrastructure maintenance is
required. These management policies often incur backlash from developers or the local population. It is believed that the promotion of correct understanding and good attitudes toward the policies among the public through effective publicity and communication, and further inclusion of the public will be beneficial to the subsequent construction and maintenance of water infrastructure [15]. The main purpose of this study is to develop the “Public Cognition and Attitudes to Water Infrastructure in Taiwan” survey scale, to understand the public cognition and attitudes to water infrastructure in Taiwan through analysis of the collected data, and to further explore the relationship between the two.

2. Materials and Methods
The information obtained from the reference literature in this study is used as a basis for developing the survey questions of the questionnaire, resulting in our own compilation of the “Public Cognition and Attitudes to Water Infrastructure in Taiwan” questionnaire. The questionnaire is divided into 3 parts: the first part, basic personal information; the second part, questions regarding the “cognition” variables, where each question is a multiple choice question with 4 options; and the third part, questions regarding the “attitude” variables, where each questionnaire item is divided into 7 levels, from “strongly agree” to “strongly disagree.” Three experts who had some relation to this study topic assisted in the revision and semantics of the questionnaire items. These experts were people such as the staff responsible for the public water resources development in government agencies, university professors, and lecturers promoting environmental education in the Kaohsiung Science Museum. The questionnaire survey was conducted in two stages. A pre-test of the rating scale questionnaire was carried out during the first stage in April 2020, with people over 18 years of age visiting the Kaohsiung Science Museum as participants. A total of 167 valid questionnaires were collected for pre-test analysis. Data were analyzed by using statistical techniques (item discrimination, exploratory factor analysis, and reliability analysis) with SPSS. The official survey using the rating scale questionnaire was carried out during the second stage between July and September 2020 at science museums in Northern, Central, and Southern Taiwan. The participants were over 18 years of age and visiting the Kaohsiung Science Museum. A total of 809 valid questionnaires were received during the survey. Data were analyzed by using statistical techniques (descriptive statistics, Compare Means, one-way Repeated Measurement ANOVA, and correlation analysis) with SPSS.

3. Results and Discussion

3.1 Analysis of the Pre-test of the Rating Scale Questionnaire
During the pre-test period, a total of 172 questionnaires were received, 5 of which were invalid or answered inaccurately and hence removed from analysis. Pre-test analysis was ultimately carried out on a total of 167 valid questionnaires.

3.1.1. Public Cognition: Item Discrimination
The cognition subscale was developed primarily using discriminant analysis. A total of 13 questions were used for item analysis, of which two, namely “What is Taiwan’s largest reservoir?” and “Why do we need to carry out watershed conservation projects?” were deleted, as the 2 items difficulty index was larger than 0.8 and was too simple. The remaining 11 questions had difficulty indices between 0.548 and 0.776, and discrimination indices between 0.351 and 0.740, indicating that these remaining questionnaire items were of moderate difficulty, had good discrimination, and could be directly adopted.

3.1.2. Public Attitudes: Exploratory Factor Analysis
Public attitudes were divided into two factors, including concern about water infrastructure issues and positive attitudes and values. The 11 items were entered into a principal axis factor analysis with varimax rotation (KMO=0.852; Bartlett’s χ², 55 df = 849.007, p < 0.001). Two questions, namely “In the future, there may be wars due to the seizing of water resources” and “I think the government should demonstrate the construction of or encourage people to build rainwater storage facilities”, were removed.
as their factor loading was too low (< 0.4). These items were removed, and the factor analysis was recalculated (KMO= 0.819; Bartlett’s $\chi^2$, 36 df = 625.035, p < 0.001). Two factors were extracted with eigenvalues greater than 1, together accounting for 61.8% of the variance (see Table 1).

Table 1. Rotated factor matrix - public attitudes (loading < 0.40 suppressed).

| Items                                                                 | Factor 1 | Factor 2 |
|-----------------------------------------------------------------------|----------|----------|
| Local residents should participate in or care about the construction of water infrastructure. | 0.873    |          |
| When developing water sources or constructing reservoirs, one should care about and consider the impact on the local environment. | 0.838    |          |
| I think deforestation and vegetable cultivation in the catchment area will result in water pollution. | 0.773    |          |
| In recent years, floods and droughts in Taiwan became very frequent.  | 0.677    |          |
| I think the government should allocate more funds for river improvement to avoid river flooding. |          | 0.834    |
| I agree with the imposition of additional usage fees by the government to maintain water quality and for sewage treatment plant maintenance. |          | 0.750    |
| The practice of discharging wastewater treated by the sewage treatment plant to the ocean after meeting the standards is in line with sustainable principles. |          | 0.672    |
| To enable sewage sewer construction projects, I am willing to bear with the inconvenience caused by related projects. |          | 0.653    |
| I agree that the government should implement stricter land restrictions in order to gain better water sources. |          | 0.588    |

3.1.3 Reliability Analysis

After revising the questionnaire following the removal of the questionnaire items, the K-R reliability and Cronbach $\alpha$ internal consistency were used to test the reliability of each aspect. The result was a K-R reliability coefficient of 0.773 in the 11 questionnaire items belonging to the “cognition” aspect, and a Cronbach $\alpha$ of 0.914 in the internal consistency test on the nine questions belonging to the “attitude” aspect. All questionnaire items were within acceptable limits and had good reliability.

3.2 Data Analysis

After the aforementioned pre-test analysis on the rating scale questionnaire was conducted and unsuitable questionnaire items were removed, official questionnaire data analysis was carried out. In this study as shown in Table 2, 886 copies of the questionnaire were issued and 853 were retrieved. After eliminating the invalid samples, there were 809 valid samples, with a valid return rate of 94.8%. In terms of gender, there are 558 females (69.0%), while males account for 30.7%. Most of the respondents were aged 40–49 years (n=300, 37.1%), followed by 30–39 years (n=265, 32.8%). About 591 (73%) of the people participating in the survey had installed water filtration equipment in their homes, indicating that the public was not very confident in the quality of drinking water provided by the government. In the flooding experience part of the survey, only 150 people (about 18.5%) responded that they had experienced flooding in their homes. As the survey locations were large cities in Northern, Central, and Southern Taiwan, this shows that the drainage facilities in these cities had served their function. When posed with the question as to whether they had experienced water use restrictions, as many as 516 people (about 63.8%) answered in the affirmative. This shows that the Taiwanese people were indeed already feeling the inconvenience to daily life due to frequent promotion of water conservation and partial domestic water restrictions by the government as a result of frequent droughts in recent years.
Table 2. Characteristics of Samples (n= 809).

| Item                          | Category | Number of samples |
|-------------------------------|----------|-------------------|
| Gender                        | Male     | 248 (30.7%)       |
|                               | Female   | 558 (69.0%)       |
| Age                           | 18-29    | 144 (17.8%)       |
|                               | 30-39    | 265 (32.8%)       |
|                               | 40-49    | 300 (37.1%)       |
|                               | Above 50 | 100 (12.4%)       |
| Install water filtration equipment | Yes    | 591 (73.1%)       |
|                               | No       | 218 (26.9%)       |
| Flooding experience           | Yes      | 150 (18.5%)       |
|                               | No       | 658 (81.3%)       |
| Water restriction experience  | Yes      | 516 (63.8%)       |
|                               | No       | 293 (36.2%)       |

3.2.1 Analysis of Public Cognition Variables
The cognitive variables of water infrastructure were divided into two factors, namely “knowledge of water infrastructure construction goals and use” and “understanding of the impact water infrastructure use can have on the environment and society.” Table 3 compares the percentage of correct answers to various factors in the public cognition of water infrastructure. Among them, the overall percentage of correct answers for the factor “understanding of the impact water infrastructure use can have on the environment and society” was the highest at 81%, showing that the general public had a high awareness of the impact water infrastructure would have on the overall environment and society. Within this factor was the questionnaire item “excessive hillside development destroys soil and water conservation and will cause flooding,” with the percentage of correct answers reaching 91%. This indicates that the Taiwanese are very knowledgeable about water and soil conservation issues and disaster prevention on the whole. As for their understanding on the use of water infrastructure, the percentage of correct answers to the question “What kind of facilities can generally be built on Taiwan’s outlying islands to increase fresh water for residents’ use?” was the lowest, at only 63%. This shows that the residents living on the main island of Taiwan did not know much about the current use of seawater desalination facilities to replenish fresh water on outlying islands. In addition, for the people’s understanding of the use of water infrastructure, the percentage of correct answers to one of its questionnaire items, “Why do we need to build many reservoirs in Taiwan?” was only 64%. This shows that the general public lacked understanding of the knowledge and concepts regarding the necessity to build a reservoir despite frequent rainfall in Taiwan, as the topography makes rainwater retention difficult.

Table 3. Answer accuracy of cognition variables and analysis of covariance between factors.

| Cognition                          | Mean | No. of Items | Answer Accuracy | F     | Post hoc Result |
|------------------------------------|------|--------------|-----------------|-------|-----------------|
| 1. Construction goals and use      | 3.88 | 5            | 78%             | 14.169*** | 2>1             |
| 2. Impact on the environment and society | 4.83 | 6            | 81%             |       |                 |

***p< 0.001

3.2.2 Analysis of Public Attitude Variables
The public attitudes in this questionnaire survey were divided into two factors: “concern about water infrastructure” and “positive attitudes and values.” In order to understand the public’s level of connection to each factor, a comparative analysis of the means was carried out. As shown in Table 4,
questions belonging to the “concern about water infrastructure” factor had a mean of 6.39 per question, which was significantly higher than that of the “positive attitudes and values” factor. This shows that the general public was very concerned about water infrastructure construction issues, such as the development of water sources or the construction of reservoirs, with most people indicating that the impact on the environment should be considered first. However, there was a lack of positive attitudes toward matters such as maintaining sewage treatment plants, pipelines, and other infrastructure, indicating that the people did not really agree with the government charging the people.

Table 4. Attitude analysis of covariance between factors.

| Attitude                  | Mean | No. of items | Mean of each item | F      | Post hoc result |
|---------------------------|------|--------------|-------------------|--------|-----------------|
| 1. Concern about water infrastructure issue | 25.57 | 4            | 6.39              | 123.816*** | 1>2             |
| 2. Positive attitudes and values                     | 30.50 | 5            | 6.10              |        |                 |

***p<0.001

3.2.3 Correlation Analysis Between the Public Cognition and Attitude Variables
We obtained a correlation coefficient of $r = 0.099$ (p <0.01) between the two variables (public cognition and attitude) by the point-biserial correlation method. Despite the significant relationship between the variables, their correlation was very low, with a coefficient of determination ($r^2$) of just 0.9%. This shows that the public cognition and attitudes toward water infrastructure were not related.

4. Conclusions
The main purpose of this study was to develop a rating scale questionnaire on public cognition and attitudes toward water infrastructure in Taiwan, and to further explore the performance of each variable. In terms of the development of the rating scale questionnaire, after obtaining the results of pre-tests such as item discrimination, exploratory factor analysis, and reliability analysis, and the removal of unsuitable questionnaire items, the rating scale exhibited good reliability and validity. In terms of basic data survey and analysis, only about 18% of the people had experienced flooding in their homes. As the surveys in this study were all conducted in larger cities in Northern, Central, and Southern Taiwan, this showed that the drainage and flood control facilities of the cities had served their function. The addition of a comparative analysis among regions such as urban, suburban, and rural areas in the next survey is suggested.

In terms of water restriction experience, since the dry season in Taiwan runs six consecutive months from November to April every year, this survey found that most people had experienced water use restrictions, and that the Taiwanese people were indeed already feeling the inconvenience caused to daily life. Therefore, besides appealing to everybody to save water in recent years, dredging reservoirs and increasing water storage are also important strategies to maintain a stable water supply. In addition, about 73% of people had water filtering equipment installed in their homes, indicating that people lack confidence in tap water as drinking water. In fact, Taiwan’s tap water undergoes several stages of treatment before being sent to homes through the supply system, and hence is a clean source of drinking water. Activities involving drinking tap water directly had also been promoted before; however, because people still do not drink tap water directly, they are still willing to spend extra money to improve the quality of drinking water. It is recommended that the competent authorities further strengthen publicity in the future, replace aging pipelines to improve water quality, and gradually increase the confidence of the people in Taiwan.

In terms of cognitive variable analysis, most people believed that the construction of water infrastructure would affect Taiwan’s entire social and environmental development. In particular, there
was a high level of awareness about the fact that good soil and water conservation can reduce flood disasters. This shows that the government had achieved good results in their promotion of disaster prevention awareness. However, it appears that awareness regarding desalination facilities, the construction of new reservoirs, and the causes of reservoir siltation need to be strengthened, in particular, the construction of seawater desalination plants. Seawater desalination plants are currently a very important type of water infrastructure and an important source of fresh water in Taiwan’s outlying islands such as Penghu, Kinmen, and Matsu. However, the cost of construction and maintenance of these facilities and the impact of the desalination process on the ecological environment are significantly higher than the cost incurred by the treatment process in typical water plants on the main island. The government needs to publicize the water scarcity problem on outlying islands, so as to promote understanding among the public and to remind the general public to save water.

As for the attitude variables, most people were very concerned about the government’s construction of water infrastructure and believed that local residents should participate in or care about the management and decision-making process of public water resources projects (projects such as reservoirs, water source protection areas, flood detention ponds). This shows that if the government could directly communicate with and explain to the public—as well as let them participate in and understand the impact of these projects on their own living environment—obstacles in the future promotion of the planning and implementation of related projects would be reduced, and the needs of the public would be met by such projects. As for attitudes toward the construction of sewage sewers and the maintenance of related pipeline facilities, the questionnaire analysis showed that most people did not really agree with increasing water prices or paying additional usage fees. Relevant units are recommended to explain to the public and clarify the necessity of fee collection more frequently, such as the function of sewage systems and the purpose of their construction. They should also let the public understand the concept of construction cost-effectiveness in order to avoid subsequent disputes over charges. Although there was a significant correlation between the cognition and attitude variables toward water infrastructure, the correlation coefficient was very low. This shows that the level of conceptual knowledge of water infrastructure could not affect attitudes.

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