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Exploring the environmental impact assessment commissioners' perspectives on the development of the seawater desalination project

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ABSTRACT

In recent years, extreme climate conditions have resulted in uneven precipitations in Taiwan. The development of traditional water resources frequently suffers from protests of environmental groups, potential dam sites being hard-to-find, and other factors. The development of new water sources has been increasingly difficult. Sea water desalination has the advantages of a short construction time and easy expansion flexibility, making it an important alternative as a new water resource. In this study, the current proposal of Tainan's desalination plant was used as an example. Qualitative interviews and Analytic Hierarchy Process (AHP) were used to explore the environmental impact assessment (EIA) commissioner's perceptions of the impact from the development of the desalination project. The results of the qualitative interview indicate that the main concerns of the EIA commissioners are whether the development could damage the marine ecological environment and its fishery resources, which may have adverse socioeconomic consequences. The AHP results show that the commissioners' priority of environmental impact is ecological environmental impact 36.9%, social impact 29.7%, economic impact 23.7%, and physical and chemical environmental impact 9.7%. The main concerns in each impact category are, respectively, marine ecological environment, land and ocean utilisation, fisheries, and air quality.

1. Introduction

In terms of the global water resource distribution on Earth, nearly 97.5% of the water is in the ocean, and the freshwater resources only account for 2.5%. Most of the freshwater resources are in the glaciers and groundwater, only 0.4% of the freshwater is available to human beings and other terrestrial animals [1]. Global warming is making these available freshwater fluctuate temporarily and spatially, making it difficult to satisfy the demands [2,3]. Seawater desalination is an emerging water resource [4–6]. With the advantage of being un-exhaustible and climate independent, countries with water shortage problems, such as Australia, Japan, Spain, China, and the USA, have already developed this new water resource [7]. Australia has been through several flooding and drought years due to climate change, so the government built 17 desalination plants from 2013–2014. Half of the domestic water is supplied using desalination technologies in the cities of Adelaide, Brisbane, and Perth in Australia [8–10]. According to the International Desalination Association (IDA), there are 150 countries with a total of 18,426 desalination plants operated worldwide, as of 2015, producing 86.8 million cubic meters per day, providing water for 300 million people. In terms of the plants under operation, the daily production of desalinated water is 85,000 tons. Half of these plants are located in the Middle East [11,12].

The impact on the terrestrial environment caused by seawater desalination includes construction, piping, removal of vegetation, excavations, as well as the noise from the construction activities [13–15]. The impact on the marine environment includes seabed digging and piping, long-term pumping, discharge of brine with pre- and post-treatment chemical additives, waste heat, and heavy metals, resulting in changes of salinity and pH [16–18], eutrophication, and the accumulation of heavy metals and chemicals that affects the coastal ecology [19–22].

Due to the foreseeable water shortages in Tainan City, Taiwan's Water Resource Agency (WRA) has started to plan a seawater desalination plant in this area [23]. However, there are no full-scale desalination plants on the main island of Taiwan and such a development also requires a stringent EIA to evaluate its impact and feasibility. According to Taiwan's Environmental Impact Assessment Act, the EIA commissioners are the final decision makers for the development projects, unlike in other countries where the commissioners serve as consultants or advisors whose sole role is making recommendations [24]. EIA commissioners in Taiwan are typically well-respected scholars, distinguished scientists, or knowledgeable experts who make decision based on sound science. Therefore, their perceptions and opinions

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towards the development of the desalination project is crucially important. In this study, the proposed Tainan's desalination plant was used as an example to explore the EIA commissioners' perspectives on the environmental impact of the development. The potential environmental, economic, and social impact and their consequences during the development were discussed in order to provide recommendations for promoting the seawater desalination projects.

2. Methods

2.1. Study site

In 2009, Typhoon Morakot brought the worst-ever recorded rainfall in Taiwan that many weather stations registered the precipitation intensity over a flood frequency of 2000 years [25]. This event caused severe siltation in the main reservoirs in the Tainan area, resulting in the reduction of the storage volume to 170 million cubic meters. The WRA predicts an even greater water shortage along with other regional water resource management problems, so that the Tainan desalination plant was proposed as a potential alternative new water resource [26]. The Tainan seawater desalination plant is located in abandoned coastal salt pans. Based on the cost effective considerations, reverse osmosis technology with a recovery of 36% was adopted in the proposed plant. The production in the early stage is 50,000 CMD with an expansion capacity to 100,000 CMD in the future [27]. The goal for this desalination plant is to provide the domestic water supply in the coastal area.

2.2. Semi-structured interview

In order to understand the EIA commissioners' opinions towards the environmental impact of the Tainan desalination plant, semi-structured interviews were employed to explore the views of the commissioners who are familiar with Tainan's environment. In the semi-structured interview, the perceptions and opinions of the EIA commissioners towards the proposed Tainan desalination plant were explored [28]. The entire interview process was conducted in a relaxed and easy manner. The flexibility of the questions was maintained to encourage the commissioners to fully express their personal opinions, share their personal experiences, and elaborate their interpretation of the controversial issues [29]. The interview framework of the themes intended to be explored is presented in Table 1. The interviews first sought to understand the positions of the interviewed EIA commissioners regarding the promotion of the desalination plant and explore their opinions on the overall situation of water use in Tainan, the environmental impact of the desalination plant and the development of EIA procedures to analyse the reasons behind the respondents' support for or opposition to the establishment of the desalination plant.

2.3. Analytic Hierarchy Process (AHP)

Because the evaluation factors for the environmental impact of the desalination plant are wide-ranging and diverse, the relative importance of each evaluation factor cannot be understood via qualitative interviews. Therefore, in this study, an AHP questionnaire survey was given to EIA commissioners to quantify their views on the relative importance of the environmental impact factors involved in the development of the desalination plant. AHP is capable of systematising complex questions and can simultaneously capture the opinions of multiple experts and decision-makers to indicate coherence and logicality of the experts' opinions by comparing various dimensions via consistency testing [30]. AHP breaks down the problems to be researched into clear hierarchical structures. In this study, Taiwan EPA's scoping guidelines in the “EIA Manual for Development Activities” [31], the United Nations Environment Program's “UNEP Resource and Guidance Manual for EIAs” [32], and our team's previous environmental impact framework under ICZM [33] were utilized to establish a hierarchical structure of the impact from desalination development (See Fig. 1).

In AHP, the relative importance of objectives is determined and an appropriate set of weights derived. The relative importance of each objective is determined through a series of pairwise comparisons. The subjective judgments are translated into a quantitative score using a discrete 9-point scale as suggested by Saaty [30]. The results of the pairwise comparison of different criteria can be developed in matrix A as follows:

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \quad a_{ii} = 1,\ a_{ji} = 1/a_{ij},\ a_{ii} > 0 \tag{1}$$

$$\sum_{j=1}^{n} a_{ij} w_j = \lambda_{max} w_i \tag{2}$$

where w is the normalized weight and λ_{max} is the largest eigenvalue. Each criterion a_{ij} is the relative importance of i_{th} items to the j_{th} items. The higher values of a_{ij} means stronger preference of criteria a_i over a_j. Eigenvector method is used to calculate normalized principal eigenvector which is actually the priority weight of each criterion against the system's objectives.

When distributing AHP questionnaires to EIA commissioners, the

Table 1
The theme and question for semi-structured interview in this study.

Theme	Questions explored
Position of promoting desalination plant	• Support, neutrality, or opposition to the development of desalination plant, and rationale for making such decision. • Opinions on whether the desalination plant is an important source of water. • Opinions on the desalination plant in operation. • How the respondents obtained information to establish a position on the desalination plant.
Water resources demand and supply	• Explore the views on solving the problem of water shortages. • The effect of desalination plant on regional water supply. • Opinions on Water conservation. • Position on water price adjustment and its related issues.
Environmental impact of desalination plant and its assessment procedure	• Opinions of Impact of seawater desalination on the environment. • Opinions on the environmental impact assessment procedure for desalination plants. • Effects of brine discharge from the desalination plant on the environment and local economy. • Opinions on the most direct impact from the seawater desalination plant.
Public participation during the development of desalination plant	• Influence of desalination plant on the stakeholders. • Effect of public involvement on the development of desalination plant • Local community residents' role in the development of desalination plant.
Other issues	• Recommendations on whether the current EIA process has room for improvement • The relevance of the water quality of desalination plants to the needs of users