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MULTI-CRITERIA DECISION-MAKING MODEL FOR BASIN-WIDE WATER ALLOCATION BASED ON COST-BENEFIT ANALYSIS OF SOCIAL, ECONOMY AND ENVIRONMENT IMPACT DURING WATER SCARCITY

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ABSTRACT

Rapid urbanization and industrial development are two major factors that contribute to the over-population in a river basin. Studies have shown that changes in the land use of a river basin will caused alterations to the basin hydrology thus forcing changes to the natural water and hydrological cycle. The above would lead to the intensification in water scarcity and cause subsequent increase or decrease in potable water demand depending on the types of social and economic activities of the different sectors or region. For a more efficient and effective management of water distribution, some strategies should be carefully devised to fulfil the demand of the various sectors. Klang River Basin is chosen as the study area for its extensive urbanization, dense population, diverse development with complex social and economic activities. This region is experiencing water deficit which is expected to worsen in the near future. Water prioritization and water allocation are key to the basin water resource management to meet the needs of the sectorial water users. Multi-criteria decision-making (MCDM) is used to address the different water allocation constraints. It takes into consideration the economy, environment, social and water availability of the different service areas in the basin. These factors are quantified into normalized indices for easier analysis and comparison. The economic value is determined by factors like GDP, plot ratio, and land value, while social value is based on population concentration in the built-up area. Environmental and water availability values are derived from the proximity of water intakes to the river mouth and the Water Resources Index (WRI), respectively. An aggregated index is calculated for each service area using at set of weightages (social: 0.4, economy: 0.3, environment: 0.2, water availability: 0.1) determined from stakeholder consultation. Areas with higher aggregated index values is given greater water allocation priority, with Bukit Nanas WTP identified as having the highest priority. The study quantifies the economy and social benefits of water allocation using a logistic benefit function curve, which is validated using historical GDP as a function of water use and questionnaire survey of user perception towards water allocation reduction, respectively. Benefit of environmental water use is a polynomial function that follows the Tennant Montana method. Five (5) water allocation options are then evaluated using the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to determine the option which yields the highest basin-wide benefit. The options are further analyzed using cost-benefit analysis to normalize the benefit with the cost, measured in terms of the change in WRI. The study concludes that Option 1 provides the optimal water allocation for the basin, with a benefit-to-cost ratio of 2.25, followed by other options with lower ratios. This model serves as a valuable decision-making tool for authorities during water shortages.

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CHAPTER ONE
INTRODUCTION

1.1 Research Background

Water is fundamental to life, livelihoods, and prosperity, playing a vital role in nearly all types of production, including agriculture, industry, energy, and transport (Grey & Sadoff, 2007). Life cannot exist or survive without water. Earth is likely the only planet in the vast universe that supports life, largely due to its abundance of water (Zakaria et al., 2011). However, about 98% of the world's surface water is salt water found in oceans and seas (Abidin, 2011). According to Chng et al. (2008), only 2% of the world's water is freshwater located in lakes, inland seas, and rivers. Of this freshwater, roughly 99% is trapped in glaciers and ice caps, held as soil moisture, or situated in water tables too deep to access.

As human populations and economies grow, the global demand for freshwater has been rapidly increasing. In recent decades, one of the major challenges has been finding sustainable ways to manage basins suffering from water scarcity (Cetinkaya & Gunacti, 2018). Between 1950 and 2020, the global urban population increased from 0.8 billion (29.6%) to 4.4 billion (56.2%), and it is projected to reach 6.7 billion (68.4‰) by 2050 (UN, 2018). Water scarcity, where demand exceeds availability, is a critical issue for water security, affecting the health and well-being of urban residents, the quality of the urban environment, and socioeconomic development (McDonald, 2011; McDonald, 2014; Garrick et al., 2019; Krueger, 2019a; Krueger, 2019b). Currently, many urban areas worldwide are facing water scarcity (McDonald, 2014). Factors such as population growth, urbanization, and socioeconomic development are expected to increase urban industrial and domestic water demand by 50-80%> over the next thirty years (Garrick et al., 2019; Florke et al., 2018). Consequently, the gap between water supply and demand has become a significant obstacle to economic development, especially in regions experiencing severe water shortages (Xu et al., 2016). Therefore, to avoid current and future conflicts over limited water resources, researchers have been increasingly focused on developing tools and techniques to improve water resource management (Babel et al., 2005; Gebre et al., 2021).