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Integration of Green Ergonomics in Robust Decision Making Approach in Water Resources Management in Makassar City

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Abstract. Water resources management has several challenges such as water stress, droughts, human contamination, increasing population, and natural calamities. Therefore, effective strategic planning is critical to minimize these challenges. Water resources for drinking water in Makassar City and other regions in Indonesia are managed by the respective vertical agencies and regional governments. The Regional Drinking Water Company of Makassar City manages the fulfillment of clean water needs for the residents of Makassar City and performs operational activities. In this study, we aimed to integrate the concept of green ergonomics as a guide to propose the basis of interventions, social responsibility, and environmental or ecospheric responsibility in water resources management. Green ergonomics is necessitated for the evaluation and sustainable development and good reciprocal relationship between human and natural systems. In addition, green ergonomics develops an understanding of how a variety of resources such as energy, biological entities, and minerals flow through work systems and integrate with the ecosystems.

Keywords: Environment; Green ergonomics; Robust decision making; Water resource

1. Introduction

Generally, the expansion of flood areas in Makassar City is induced by a decrease in water catchment areas as a result of increased residential areas. This is due to the increasing city population on account of both births and urbanization trends. Simultaneously, due to the lack of clean water supply from two rivers, the Jeneberang River and the Lekopancing River, passing through Makassar City, there is a decrease in the quantity and quality of water. The two rivers originate from different regional government areas and create their own problems in terms of management that could potentially lead to conflicts.

Global climate change has significantly impacted water resources, especially on the water cycle, demand, supply, and quality standards. Furthermore, the availability of clean water sources has been declining over time (Ali et al., 2018). According to (Emanuel, 2005), there are two causes of global climate change: population growth in coastal areas

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and natural events. This finding is in line with studies conducted by (Nelson et al., 2010), who stated that global climate change can trigger an increase in the need for clean water supplies, and (Karl, Melillo, et al., 2009; Kasayanond et al., 2019; Lange-Morales et al., 2014), who concluded that an increase in temperature results in changes in river water discharge, causing humans to need more water to grow and maintain health. Furthermore, Hartono et al. (2010) stated that water quality should be improved to meet clean water standards. To counter these challenges, an effective strategic planning is imperative. Water resources for drinking water in Makassar City and other regions in Indonesia are managed by the respective vertical agencies and regional governments. Regulatory clauses on water resources management rules are distinct, although policy implementation is not optimal when the water resources pass through territorial areas that are administratively under different regional governments.

Green ergonomics includes several principles such as *eco-efficiency*, *eco-effectivity,* and *eco-productivity* (Thatcher et al., 2013). The green ergonomics approach can be applied in evaluating and developing industries to promote sustainable development. In addition, it ensures that human and natural systems maintain a good reciprocal relationship. Green ergonomics with factors of efficiency, effectiveness, and productivity move beyond the specific reference of a work system. Green ergonomics helps develop an understanding of how a variety of resources such as energy, nutrients, biological entities, and minerals flow through work systems and integrate with the ecosystems. This involves understanding the flows of life cycle transformation and their integration and understanding what happens to the "waste" generated by the system (Lange-Morales et al., 2014).

The Regional Drinking Water Company (PDAM) of Makassar City manages the fulfillment of clean water needs for the residents of Makassar City. It also performs operational activities such as managing the distribution and service of drinking water that meets the health requirements of the society in an equitable, orderly, and regular manner and carries out sustainable and environmentally friendly urban development and services. One method that can be employed to analyze environmental problems is the Robust Decision Making (RDM) method, which is reliable in the strategic decision-making for water resources planning policies. Some studies have investigated environmental challenges and water resources management; however, they did not involve decision-making as a key strategy for solving water management challenges (Karl, Melilo, et al., 2009); (Matrosov et al., 2013); (Hidayatno et al., 2015); (Casal-Campos et al., 2015).

This study aimed to integrate the concept of green ergonomics as a guide to propose the basis of interventions, social responsibility, and environmental or ecospheric responsibility in water resources management. Green ergonomics is also important for the evaluation and sustainable development and maintaining a good reciprocal relationship between human and natural systems. In addition, it helps develop an understanding of how a variety of resources such as energy, biological entities, and minerals flow through work systems and integrate with the ecosystems. This involves understanding the flow of the transformation life cycle and its integration (Lange-Morales et al., 2014). Consequently, it is considered necessary to combine ecological or environmental aspects with ergonomic aspects, which, in this case, is the water resources management in a work system.

Furthermore, although several recent studies investigated water resources (Hidayatno et al., 2015; Odume & Wet, 2016; Xie et al., 2017; Knox et al., 2018; Juniati et al., 2019; Sabara et al., 2020), they did not examine the decision making in the water resources management system and did not use an approach that focuses on global environmental and climate issues filled with uncertainty. To our knowledge, this is the first research that integrates the concept of green ergonomics research on water resources management; hence, it is expected that decision-making and strategy identification can lead to efficiency and effectiveness in the work system of water resources management.

2. Methods

This study used the RDM approach for strategic decision-making on water resources management planning for drinking water in Makassar City. In this study, robust is considered as the ability of the system to face decision-making constraints on water resources planning for drinking water. The concept to develop is the concept of ecosystem elasticity that can be improved by upgrading the scale of resistance. This is measured by the magnitude of the disturbance and maximum threat required to determine the resilience or flexibility of the system with the decisions taken (De Bruijn, 2005). Furthermore, the resilience of the economic system and social system is also developed as an integrated material in the interdisciplinary studies, which, in this case, are the green ergonomics and environmental management studies.

2.1. Data Resources

Data collected in this study are primary and secondary data. The primary data was obtained directly through observation, focus group discussions (FGDs), and interviews with resource persons in regards to the questionnaire guide. Meanwhile, the secondary data were regional and national planning documents, Strategic Planning (Renstra) of Makassar City PDAM, Strategic Planning of Water River Central Region-Pompengan Jeneberang (BBWS-PJ), State Electricity Company (PLN), Central Statistics Agency (BPS) of Makassar City, and relevant related research. In addition, the secondary data were used as FGD material by discussing the 2011–2036 Corporate Plan of Makassar City PDAM, long-term plan documents, management of challenges and opportunities, and the BBWS-PJ master plan.

2.2. Data Collection

Data were collected through structured interviews, consumer surveys using questionnaire distribution, which also involved all aspects of human and work systems, and in-depth observation methods on various objects related to water resources planning and management activities. Overall, 125 respondents (61 men and 64 women) from 14 sub-districts in Makassar City participated in this study. The participants were from 10 various professions with an age range between 18 and 65 years. The results of the observations were then combined with the primary and secondary data to conduct an FGD with the entire components involved. In brief, four steps were adopted in data collection to obtain quality data; (1) *participatory scoping*, (2) *case generation and exploration models*, (3) *discovery scenarios*, and (4) *trade-off analysis*. In data collection, FGD was also conducted with environmental and ergonomics experts as one of the integrations of green ergonomics in RDM to obtain scenarios for solving water resources problems in Makassar City.

2.3. Data Analysis Techniques

The analytical technique applied in this study complies with the four-step key RDM process and procedure, as mentioned above. Participatory scoping is a form of focusing attention on issues or challenges that will be studied or resolved through FGDs.

The participants who are expected to attend the event are stakeholders, policymakers, resource persons, environmental ergonomics experts, and water user communities according to their respective capacities. This activity aims to define or limit the scope of objectives and measurements, scope of strategies that can be employed to achieve the objectives, scope of uncertainty that will affect the successful use of the strategy, and scope of relationships that will help demonstrate the process of using the measurement. Thus, the conceptual model of problem-solving is shown in Figure 1.

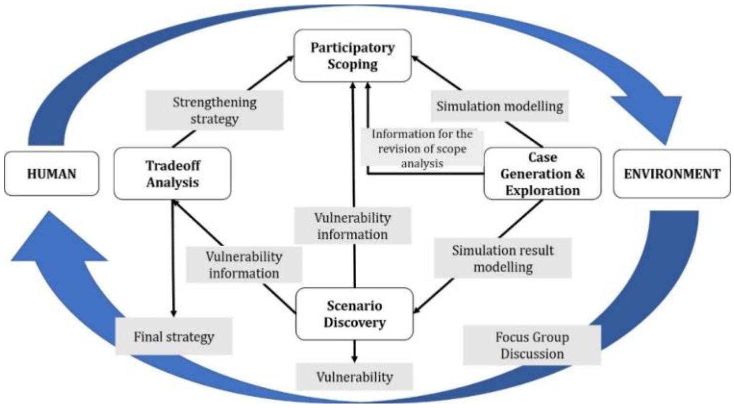

Figure 1 Green ergonomics - RDM conceptual model

To implement the conceptual model shown above, the following steps are implemented as shown in Figure 2.

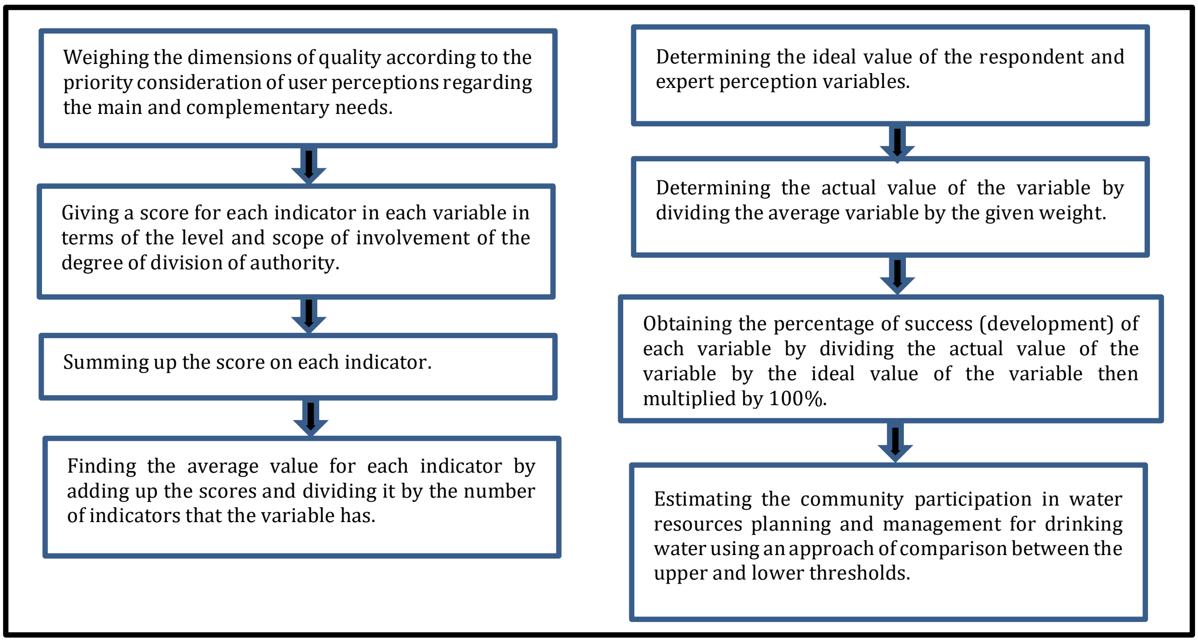

Figure 2 Data analysis stage

3. Results and Discussion

Five main data components were obtained: (1) data on future climate change vulnerability and adaptation strategies, (2) data for Jeneberang River management system planning, (3) data for drinking water management planning of Makassar City PDAM, (4) socio-economic data of PDAM Makassar City customers, and (5) green ergonomics concept in water resources management in Makassar City. The five data were obtained from vulnerability assessment documents, FGDs, interviews, and socio-economic surveys of the people using PDAM water services. The data were analyzed descriptively, and the results were used to answer four key research questions that led to the achievement of research objectives. In this study, vulnerability data were used as the baseline data in exogenous factors or exogenous uncertainties (Xs) while adaptation strategies were used as policy levers (Ls) data. Xs are factors difficult for decision-makers to control; however, they are important in determining the success of the strategy. Meanwhile, Ls are the diversity of combinations of short-term adaptation actions consisting of alternative strategies that will be implemented.

3.1. Climate Vulnerability Data

Historically, floods and strong winds that occur almost every year cause losses and damage to Makassar City. According to BBWS-JP (2014), between 1999 and 2013, there were 26 cases of flooding that damaged 324 houses and impacted 6,476 people. The flood in January 2013 affected 5,763 people and was declared the worst flood in the history of Makassar City. The worst impacted areas were located in the lowlands, with poor drainage and sanitation systems. New housings in the suburb of a former agricultural area became the main flood site in January 2013. Strong winds occurred with an average of two cases per year. Reports on cases of strong winds that damaged around 300 houses and killed around 200 people occurred between 2003 and 2012. In addition, droughts, fires, large sea waves, and endemic diseases were other events that occurred in Makassar City. All these events are attributed to climate change, which is uncertain or difficult to predict and will have different impacts according to the geographical location of the region.

3.2. Jeneberang River System Planning Data

Floods in agricultural and residential areas occur due to the inability of river bodies to accommodate the passing water discharge. Floods occur in the Maros River, Sinjai River, Bialo River, Pappa River, Allo River, Tamanroya River, Calendu River, Pampang River, and Tallo River. Increased erosion and sedimentation in rivers that cause siltation and reduced water storage capacity especially take place in the Maros, Jeneberang (mainly due to large-scale landslide at Mount Bawakaraeng), Pappa, and Tamanroya watersheds. Especially in the Jeneberang watershed, due to the collapse of the slopes of Mount Bawakaraeng, sedimentation into the Jeneberang River was 167.2 million m^3 and sedimentation in the Bilibili Reservoir was 75.2 million m^3. High sedimentation reaches 3,862 tons/year (Tamanroya watershed 342 tons/year, Jeneberang watershed 1,280 tons/year, Kelara-Karaloe watershed 219 tons/year, Maros watershed 233 tons/year, and Pappa watershed 247 tons/year).

3.3. Makassar City PDAM Drinking Water Management Planning Data

Makassar City PDAM revealed that the biggest challenge faced by PDAM Makassar City is the supply of clean drinking water and the service of a clean water supply network. In addition, this network is threatened by increasing demand for water due to the increasing urban population. In Makassar city, the urban clean water system relies heavily on water supply from surrounding districts such as Gowa and Maros. Moreover, urbanization and the lack of proper management of clean water sources put these sources at risk. As a result, the clean water system requires an additional network to meet the increasing demand and regular maintenance. This finding is in line with a study by Tadesse et al. (2013), indicating that one of the major issues of the water source distribution is the lack of proper management in waiting time or queuing of water supply.

3.4. PDAM Customer Condition Data

The survey results show that most of the water sources utilized to meet the needs of clean water use PDAM service water (84%); however, for drinking water, people prefer refilled water (45.6%) to PDAM services (42.4%). The trend of urban people choosing refilled water is for the reasons of convenience and practicality since they no longer need to boil the water for drinking. However, 11.2% of the respondents still use well/artesian well water for bathing and washing needs, and 5.6% who use it as a source of drinking water. The types of PDAM customers that were successfully captured in this study were household customers (88.8%) and the rest were public and business facilities. There were 6.4% of respondents who chose not to answer because they were not PDAM customers or used other water sources.

The survey results show that 61.6% of the respondents found it easy to meet their daily clean water needs, 29.6% very easy, 6.4% moderately difficult, and 2.4% difficult. This indicates that the majority of the people of Makassar City still get easy access to clean water services for their daily needs. In addition, the survey results show that more than 60% of respondents stated that the quality of clean water for drinking water provided by PDAM Makassar City is odorless, tasteless, and colorless, both in the dry and rainy seasons, while 26% stated that it still smells, tastes, and is colored both in the dry season and in the rainy season. The rest chose not to respond, as shown in Table 1.

Table 1. Dry season and rainy season water quality

No.	Response	Climate	Odor	%	Taste	%	Color	%
1	Yes	Dry	14	13.3	9	8.6	14	13.3
		Rainy	20	19.0	9	8.6	27	25.7
2	Not	Dry	89	84.8	88	83.8	82	78.1
		Rainy	83	79.0	87	82.9	69	65.7
3	No Response	Dry	2	1.9	8	7.6	9	8.6
		Rainy	2	1.9	9	8.6	9	8.6
		Dry	105	100	105	100	105	100
		Rainy	105	100	105	100	105	100

3.5. Green Ergonomics Concept in Water Resources Management in Makassar City

An approach that can be employed to examine this problem is green ergonomics. A study on green ergonomics is necessitated to ensure that PDAM as a water resource administrator in Makassar city must be able to carry out its production process ergonomically, cleanly, and efficiently. In this study, the concept of green ergonomics is used to balance water resources management with the role of humans as managers themselves. Green ergonomics currently does not only study the state of a micro work system but also discusses environmental problems more broadly. It is in line with a study by Sarker et al., (2018) that green ergonomics could enhance the sustainable relationship between human well-being and natural resource systems. Green ergonomics experts are deemed necessary to collaborate in environmental management in one area and must be able to overcome global environmental and social problems such as pollution from big cities. Therefore, this study incorporates the concept of green ergonomics as a complement in water resources management.

3.6. Goal Setting, Achievement Strategies, Forms of Uncertainty, and Measurement Results Models

The RDM process begins with FGD activities that bring together the parties and decision-makers to set the goals and consider the severity of the problems found in the decisions, strategies that can be used to achieve goals, uncertainties that will affect the strategies, and the relationships that govern strategic performance related to decision-making considerations (Patterson et al., 2009). This activity uses the XLRM framework, which is used to set up the simulation model. XLRM refers to four factors: (1) Xs, which are factors difficult to control by decision-makers but are important in determining the success of the strategy, which in this research refers to the Makassar City Vulnerability Study Document; (2) Ls are the diversity of combinations of short-term adaptation actions consisting of alternative strategies that will be used, which, in this study, refer to the Strategic Planning documents of PDAM and BBWS-PJ as the buffer institutions; (3) risk and impact measurements (M) or the calculation and evaluation of hazards and risks combined with aspects of vulnerability, exposure, and sensitivity of city system components caused by unpredictable exogenous factors, which in this study refers to the results of the analysis of the level of vulnerability, exposure, sensitivity, and adaptability; and (4) relationships and models (Rs), which represent simulation models that describe the success or failure of adaptation strategies as measured by the impact of risk or the impact of exposure hazard due to X (Table 2).

Table 2. Main Elements of XLRM

Exogenous Uncertainties (Xs)	Policy Levers (Ls)
Hazard related uncertainty: *Increasing rainfall/flood* *Sedimentation* *Drought* *Environmental damage* *Sea level rise* *Beach abrasion* *Strong wind* *Tidal wave* Exposure related uncertainty: *Residential area* *Total population* *Population density* *Poverty* *Economic growth and equity* Vulnerability related uncertainty: *City expansion* *Population growth* *Clean water supply* *Soil erosion* *Floods and puddles* *Long dry season* *Disease outbreak*	BBWS-PJ 1. Integrated upstream-downstream Water Resources Management implementation. 2. Construction/upgrade, operation, and maintenance: • Water source capacity, • Water discharge for raw water facilities/infrastructure services to meet domestic/household, urban and industrial needs (RKI), • Coverage of irrigation and swamp network services, • Coverage of areas protected from the danger of flooding. PDAM 1. Production optimization and capacity building for WTP (Water Treatment Plant) IV and V 2. Construction of New WTP (Tallo River raw water) 3. Development of the main and tertiary distribution of pipeline network in the Eastern Region (II and III) 4. Rehabilitation of old Dutch pipelines for gradual water loss rates of at least 1%–2% per year 5. Plans for adding raw water to support the raw water crisis of WTP II Panaikang by utilizing raw water from the Tallo River during the dry season 6. Service plan in bulk for PDAM Maros Regency customers, which is directly adjacent to the Makassar City PDAM service area
Relations and Models (Rs)	**Impact Measurement (Ms)**
• ArcGIS model: Calculating the impact of the risk and impact damage • SWMM Model • Integrated analytical risk model	Availability of raw water supply: Balance and effectiveness of available budget related to various impacts of natural resource management planning for drinking water

3.7. Adaptive and Robust Strategic Decisions in Water Resources Planning for Drinking Water in Makassar City

Based on the results of this study, the key elements of a robust adaptive strategy are identified as follows:

a) Implementing clear and measurable short-term projects/programs, which, despite the risks, still provide minimal benefits until the occurrence of future climate change and its impacts (near-term no-regret projects);
b) Observing visible signs or indicators of X that requires PDAM and BBWS-PJ to prepare additional investments;
c) Considering and deciding which projects or program activities should be postponed, which in this case are the additional investment to be carried out in the uncertain future conditions;
d) Monitoring and preparing a pessimistic budget for the remaining vulnerabilities, which, in this context, are the project sequence or program activities in the master plan that are projected to fail to achieve the objectives of natural resource management for drinking water in Makassar City.

The results of the study show that the range of river flow conditions and future demand can achieve water reliability. The performance of raw water sources in each region has an identical tendency and has the possibility to achieve water reliability. It is certain, however, that among the planned projects, there will be raw water sources or other types of projects that fail to achieve water reliability.

3.8. Sustainable Water Resources Management with Green Ergonomics Approach

In water resources management, the green ergonomics approach can be employed to support the efficiency of water resources management from raw water to clean water. The application of this concept is a combination of ergonomic and environmental aspects by developing an understanding of how water resources are in line with the work systems and integrating them with the larger ecosystems. This involves understanding the life cycle flows, their transformation and integration, and how the waste generated by these systems are utilized (Véronneau & Cimon, 2007). In green ergonomics, humans play an important role in the implementation of a system. The success of a work system also depends on the ability of workers to implement the system. In water resources management, in the face of uncertainty that becomes a potential risk, ergonomics can be involved in its activities. The involvement of the green ergonomics approach can strengthen the values of the management (Holden, 2012).

In other words, there is a necessity for a reconceptualization of the water resources management system, which otherwise previously focused only on the uncertainty of raw water discharge and its management. Now, however, it requires the integration of humans and the environment in its management. Workers in each production line must be competent in carrying out their work. Workers must know the scope of their work well and create an ergonomic work environment by considering adjustments and flexibility in work (Lange-Morales et al., 2014). It is in line with (Bharti et al., 2020) that there is the need for a paradigmatic in water management to be more integrated and that adaptive management approaches and innovations are key to enhancing urban water management systems. By paying more attention to this, it is possible to demonstrate a more sustainable approach to water resources management as shown in Figure 3.

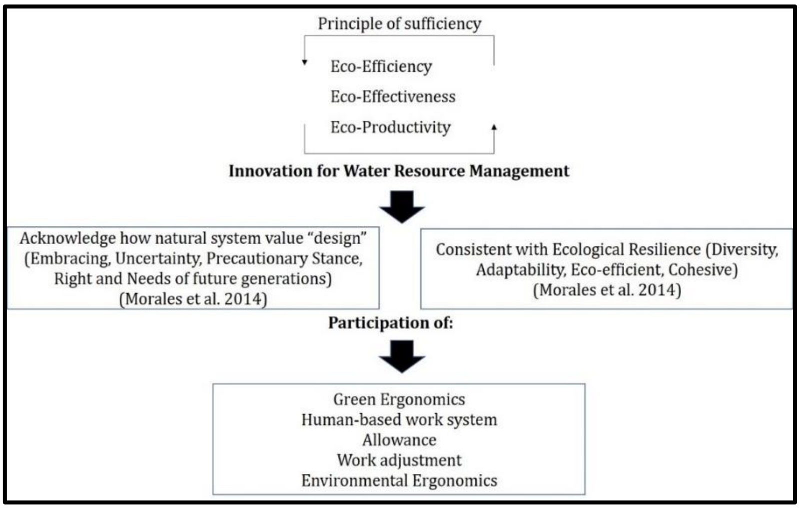

Figure 3 Green ergonomics concept for water resources management

4. Conclusions

In conclusion, the scenario for determining operational policies for natural resource management is influenced by conditions of low, medium, and high economic growth scenarios and political conditions, as well as climate change. It is very important to implement a short-term adaptation strategy plan as the initial basis for long-term climate change adaptation planning and to integrate it into the planning mechanism or management in the form of the PDAM Business Development Plan or RKAP and the city government's annual and medium-term plans. Participatory Ergonomics and Environmental Ergonomics can be considered in the development of Water Resources Management in Makassar City by involving environmental factors, adjustments, and leniency.

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