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Status of Raw Water Management Sustainability Based on Local Wisdom on Rural Water Supply in Bali, Indonesia

I Gusti Ngurah Kerta Arsana[1,*], I Gusti Bagus Sila Dharma[2], Mawiti Infantri Yekti[3], I Putu Gustave Suryantara P[3]

[1]Doctoral Program in Faculty of Engineering, Udayana University, Denpasar City, Indonesia
[2]Faculty of Marine and Fisheries, Udayana University, Badung Regency, Indonesia
[3]Faculty of Engineering, Udayana University, Badung Regency, Indonesia

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Abstract The provision of rural drinking water in Bali Province is mostly managed independently by the community. The rural drinking water supply system is sufficient to contribute to community drinking water services. Preservation of raw water sources and the environment through the application of local wisdom *Tri Hita Karana* greatly determines the sustainability of raw water source management in rural drinking water supply systems in Bali Province. The method of analyzing the sustainability status of raw water management from the social, economic, ecological, technological, and institutional dimensions uses the Multi-Dimensional Scaling (MDS) method. The sustainability index on the analysis results on the ecological dimension is 63.52%, the economic dimension is 51.82%, the social dimension is 55.59%, the technological dimension is 49.30% and the institutional dimension is 51.20%. The status of sustainability with sufficient categories is found in the ecological, economic, social, and institutional dimensions. The lever factor on the sustainability dimension of raw water management in the rural drinking water supply system in Bali Province is 21 attributes of the lever factor. The leverage factor attribute in each sustainability dimension is very sensitive to the sustainability index value. In the dimension of technology sustainability, there are 5 attributes of lever factors that need to be repaired, refined, and improved, including facilities and infrastructure for rural drinking water supply systems for the sustainability of the technological dimension.

Keywords Provision of Rural Drinking Water, Local Wisdom, Sustainability Status

1. Introduction

The sustainable development in the Province of Bali has given its consequences for the development of other sectors in the area and also the provision of supporting facilities and infrastructure. One of them is the need for the availability of raw water sources to serve the clean water needs of the community, industry, and socio-cultural activities. For this reason, the provision of clean water is one part of the regional infrastructure that must continue to be developed to support the development of rural and urban areas.

The development of community-based water resources is carried out by several developing countries to meet the basic needs of the community. The development of a drinking water supply system in Northwest Cameroon is based on community participation [1]. A community participatory assessment approach is needed for sustainability in water resources management [2]. Community-Based Natural Resource Management [3] focuses on collective ecosystem management to improve human well-being and aims to devolve ecosystem management authority to the local (community) level.

The provision of rural drinking water in Bali Province known as Pam Des is currently being maintained to meet rural drinking water services that cannot be reached by Regional Drinking Water Companies (PDAMs) at the sub-district level. The management of rural drinking water supply (Pam Des) is carried out independently by the community. The development of a community-based drinking water supply (Pamsimas) was developed by the central and regional governments to increase the coverage of rural drinking water services.

Based on the report on the planning of the drinking water supply system and regional strategic policies (2018), the management of clean water supply is carried out by the Regional Drinking Water Company (PDAM) and the Provision of Rural Drinking Water (PamDes)/Community-based drinking water supply (Pamsimas). Service areas in the PDAM drinking water supply system are located in each Regency/City in the Province of Bali. The provision of drinking water at the sub-district level in each district that cannot be reached by PDAM, for the provision of drinking water on a small scale is partly managed by the village water supply village institution (PAM Des). Drinking water services in the Denpasar City area are almost entirely served by the Denpasar City PDAM.

The agrarian culture of rural communities in Bali Province is closely related to local wisdom. *Tri Hita Karana* local wisdom as a sustainability concept [4] and the application of *Tri Hita Karana* for sustainability in the "*Subak"* system [5,6,7], and [8]. Through the concept of *Tri Hita Karana* [9], human life is united and identified with nature. An environment that gives human life to be harmonious and vice versa reflects a sustainable environment. Various rituals are also presented to create a balanced and harmonious state between human life and nature [10,11].

This study analyzes 5 (five) dimensions of sustainability, namely; economic, ecological, social, engineering, and management (policy and institutional). For the sustainability dimension of drinking water supply management, it is more to explore the value of local wisdom in rural communities. The values contained in *Tri Hita Karana* are implemented in rural water supply management to achieve sustainability. The ecological and social dimensions explore the local wisdom of *Tri Hita Karana* for economic, technological, and management sustainability. Community economic activities with a philosophy based on *Catur Purusaartha* which includes: *dharma*, *artha*, *kama*, and *moksa*. Human relations and social activities with local wisdom are i, *sagilik saguluk*, *paras paros*, *salulung sabayantaka*. The local wisdom of the Balinese people in efforts to conserve water resources, nature, and the environment will determine the sustainability of raw water management in rural drinking water supply systems.

2. Materials and Methods

2.1. Research Setting

The management of drinking water that is managed independently by the community is carried out by the Village Institute for Village Drinking Water Supply (PAMDes). The provision of rural drinking water that is the scope of the research is PAMDes in Bali Province seen in Figure 1.

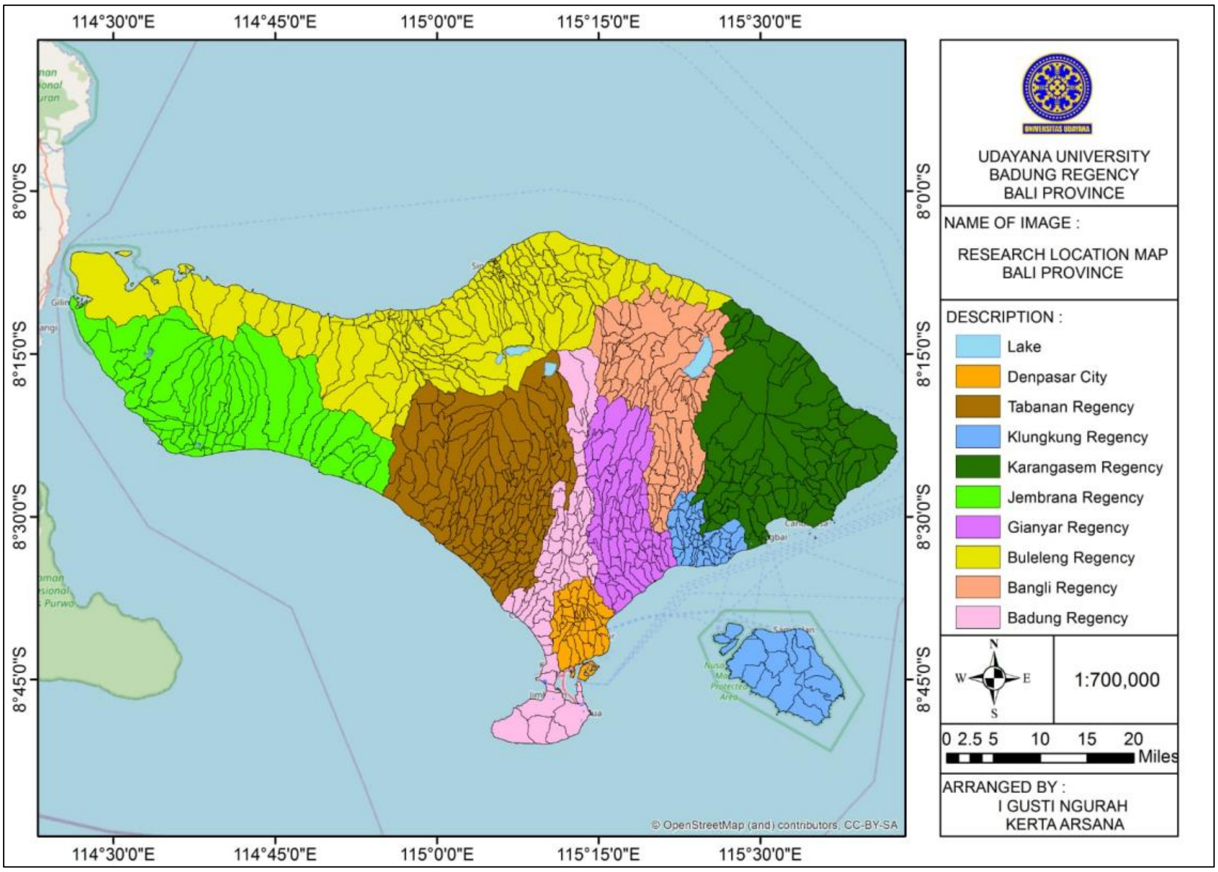

Figure 1. Research Setting

2.2. Data Types and Sources

2.2.1. Primary Data

This research was conducted in the rural water supply service area in Bali Province. The primary data needed in this study include; taking questionnaires, interviews with PAMDes managers, and field surveys. While the criteria for the sample of data sources taken in this study are people who have an understanding of rural drinking water services and provision, so the sample is an appropriate and expert-based data source. The experts/skills according to [12] used in this study are; 1) expert/skill based on knowledge, 2) expertise based on position and 3) expertise based on specialty.

Research respondents are people who have expertise in sustainable raw water management in rural drinking water supply systems. Determination of the location and sample of research data sources in this study using purposive sampling. Purposive sampling is a sampling technique of data sources with certain considerations and objectives. In this particular consideration, for example, the person is considered to know best about what the researcher expects [13].

2.2.2. Secondary Data

According to [13], secondary data is the data taken through intermediaries or parties which have previously collected, in other words, researchers do not directly take their data into the field.

2.3. Data Collection Methods and Techniques

2.3.1. Data Collection

Collecting data through questionnaires, most studies generally use questionnaires as the method chosen to collect data. Questionnaires do have many advantages as a data collection instrument. Procedures for preparing the questionnaire:

1. Develop a question questionnaire to clarify the research objectives needed.
2. Determine the factors that affect the necessary objectives and set accurate questions to measure and evaluate these factors accurately.
3. Describing each variable into more specific and single sub-variables.
4. Determine the type of data to be collected, as well as determine the analysis technique.

2.3.2. Expert Respondent

Filling out the questionnaire on the sustainability status of raw water source management and rural water supply system management policies based on expert judgment.

According to Hora (2009), an expert is a person who has or is suspected of having superior knowledge of data, models, and rules in a particular area or field.

Filling out the questionnaire for the sustainability status of raw water sources at Pam Des involves several experts/experts including: in the field of water resources and socio-cultural science (university), expertise due to position (Head of BWS Bali-Penida, Bali Regional Settlement Infrastructure Center, Head of Provincial Bappeda, Head of Regency/City Bappeda, Head of Provincial PUPR Service, Head of Regency/Municipal PUPR Service), City, Pam Des/Pamsimas Coordinator and expertise due to specialty (Socio-Cultural).

2.3.3. Interview

Data collection through the interview method requires a long time to collect data. Compared to distributing questionnaires to respondents, interviews are very complicated. In conducting interviews, researchers must pay attention to the attitude at the time of arrival, sitting posture, facial brightness, speech, friendliness, patience, and overall appearance, which will greatly affect the content of respondents' answers received by researchers.

2.3.4. Observation

Collecting data through the observation method is the most effective way to complete it with an observation format or blank as an instrument. The compiled format contains items about the events or behaviors that are described as going to happen. The most important role in using the observation method is the observer. Observers must be observant in observing is looking at events, movements, or processes.

2.3.5. Documentation

Documentation method, which is looking for variable data or things in the form of research, books, magazines, and so on. Compared to other methods, this method is somewhat less difficult, in the sense that if there is an error, the data source is still fixed and has not changed.

2.4. Multidimensional Scaling Model Application

Multidimensional scaling [14], is a versatile technique for understanding and displaying multivariate data structures. This technique has been widely applied in behavioral science and has increased the understanding of complex psychological phenomena. MDS has been used to assess cognitive development theory, study interracial relationships among children, determine consumer preferences, and evaluate the dimensional structure and content validity of tests and questionnaires.

Modern multidimensional scaling [15], multidimensional scaling (MDS) is a method that represents the measurement of the similarity (or dissimilarity) between pairs of objects as the distance between points of a low-dimensional multidimensional space. The data for example might be a correlation between an intelligence test, and the MDS representation is a field that shows the test as points getting closer together in a positive way the test is correlated. The graphical display of correlations provided by MDS allows the data analyst to actually see the data and explore its structure visually [16].

Rapfish is a statistical technique for rapid assessment of the relative status of entities (in a fishery), quantitatively assessed against a set of predetermined attributes grouped into an evaluation field or scientific discipline [17]. According to [16] the MDS-Rapfish application in principle can be used as analysis software that can be applied to various fields, so it is known as modified MDS-Rapfish. It is further stated that the estimated score for each attribute is given on a scale from worst to best and the rapfish technique [17,18,19].

Based on Euclidean Distance which is in n-dimensional space, the ordination technique (distance determination) in MDS can be written as follows:

$$d = \sqrt{\{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2 + \cdots\}} \quad (1)$$

The configuration or ordinance of an object or a point in the MDS is then approached by regressing the Euclidean distance (*dij*) from a point *i* to a point *j* whit the origin (*dij*) as the following equation:

$$d_y = a + bd_y + e \quad (2)$$

According to Fauzi and Anna (2002), three techniques can be used to regress equation 2, namely the least squares method (KRYST), an alternative least-squares method based on the root of the Euclidian distance (squared distance), or it can also called the ALSCAL method, and a method based on the Maximum likelihood. Of the three methods, the ALSCAL algorithm is the most suitable method for Rapfish and is easily almost available in each SPSS and SAS statistical software [19]. The ALSCAL method optimizes the squared distance (*dijk*) to the squared data (origin= *Oijk*), which an in a three dimensions is written in a formula called S-*Stress* as follows:

$$S = \sqrt{\frac{1}{m} \sum_{k=1}^{m} \{ \frac{\sum_i \sum_j (d_{ijk}^2 - o_{ijk}^2)^2}{\sum_i \sum_j o_{ijk}^4}} \quad (3)$$

Where the squared distance is the Euclidean distance which is weighted or written:

$$d_{ijk}^2 = \sum_{a=1}^{r} w_{ka} (x_{ia} - x_{ja})^2 \quad (4)$$

When measuring the goodness of fit (metric), it is very important to pay attention to the distance between the estimation point and the origin. Conformity in MDS measures how well (how well) the configuration of a point reflects the original data. This goodness of fit in the MDS is reflected in the magnitude of the S-Stress value which is calculated based on the S value above. A low-stress value indicates a good fit, while a high S value indicates otherwise. In Rapfish a good model is indicated by a stress value that is smaller than 0.25 ($S < 0.25$).

The analytical method that will be used is the software development of the Rap-Fish method through the multi-dimensional scaling (MDS) method to assess the index and sustainability status of raw water management in the catchment area of springs, analyzing leverage to determine the responsive attributes that affect the sustainability index in each dimension, and analysis of Monte Carlo was used for estimating the error effect on the 95% confidence interval. The index of Monte Carlo value will be compared with the MDS index value determinationtion of the value of Stress and the R^2 serves to determine the presence or absence of additional attributes and reflect the accuracy of the dimensions studied with the actual situation.

2.5. Method and Analysis Techniques

2.5.1. Research Method

This research uses mixed methods by combining qualitative and quantitative research methods. This mixed study uses a sequential exploratory strategy. Mixed research is a procedure to analyzing analyze, and mix quantitative and qualitative in a study or research to understand a problem [21].

The mixed-methods analysis approach [22] used in this study is mixed methods exploratory sequential design. The sequential approach starts with a qualitative stage first followed by a quantitative stage and has the audience of exapproachesy approaches. The exploratory sequential mixed method is a design in which the researcher starts first bloring with the data, then analyzes qualitatively and the findings are used for the second quantitative stage.

2.5.2. Determining the Dimension of Sustainability

This study by analyzing 5 (five) dimensions of sustainability, namely; economic, ecological, social, technical, and institutional (policy and institutional). For the attributes of the economic, ecological, and social dimensions, they will explore the local wisdom values of rural communities. The implementation of Tri Hita Karana and the local wisdom of the Balinese Hindu community affect the management of rural drinking water the determination nation of the attributes of the sustainability dimension of PAM Des is based on the development of the implementation of Tri Hita Karana and the need for sustainable management. Community economic activities with philosophy are based on Catur Purusaartha which includes: dharma, arthand a, kama, and moksa. Social life is related to human relations and social activities with local wisdom menyame *braya, sagilik saguluk, paras paros, salulung sabayantaka*.

Data related to variables in the MDS-RAPS analysis are known as attributes. Attributes or variables are interpreted as characteristics of observations that have variations in value. There are three important things related to attributes in the Rapfish application [18], namely; 1) Attributes that are not related to sustainability should be eliminated at the beginning, and attributes related to sustainability are used. 2) The number of attributes for each dimension is usually 6 to 12 attributes. 3) The score of each attribute can be in the form of ordinal or ratio data or a binary mix.

According to [16], the determination of variables/attributes in each dimension of sustainability must meet the principles in the application of the MDS-RAPS (Rapid Appraisal for Sustainability) method, which requires various scientific approaches in its preparation, including; 1) literature studies or can do specific ones through scientific reviews based on literature or scientific publications. 2) brainstorm with experts. If the attributes that are built are deemed less reasonable, then it is better to do brainstorming with experts or ask an expert directly for the assessment of the object being studied. The attributes for each of the resulting dimensions and the research design with the MDS application are presented in Figure 2.

2.5.3. Rapfish MDS Analysis Flow

MDS analysis is used to determine the status of sustainability Raw Water Management in the Rural Drinking Water Supply System carried out through several stages:

1) The stage of determining the attributes of the sustainability status assessment for each dimension (Ecological, economic, social, technical, and institutional),
2) The attribute assessment stage is on an ordinal scale or according to the attribute character referring to the literature/sustainability criteria for each dimension, and
3) The stage of preparing the index and sustainability status (supported by normalization test of model feasibility, leverage analysis, and Monte Carlo simulation)

The results of the MDS analysis will be obtained: status or index of each dimension and sensitive attributes or influential attributes based on Root Mean Square (RMS).

The implementation of Tri Hita Karana is contained in the sustainability dimension in Pam Des management and the model diagram with the MDS application is presented in Figure 3.

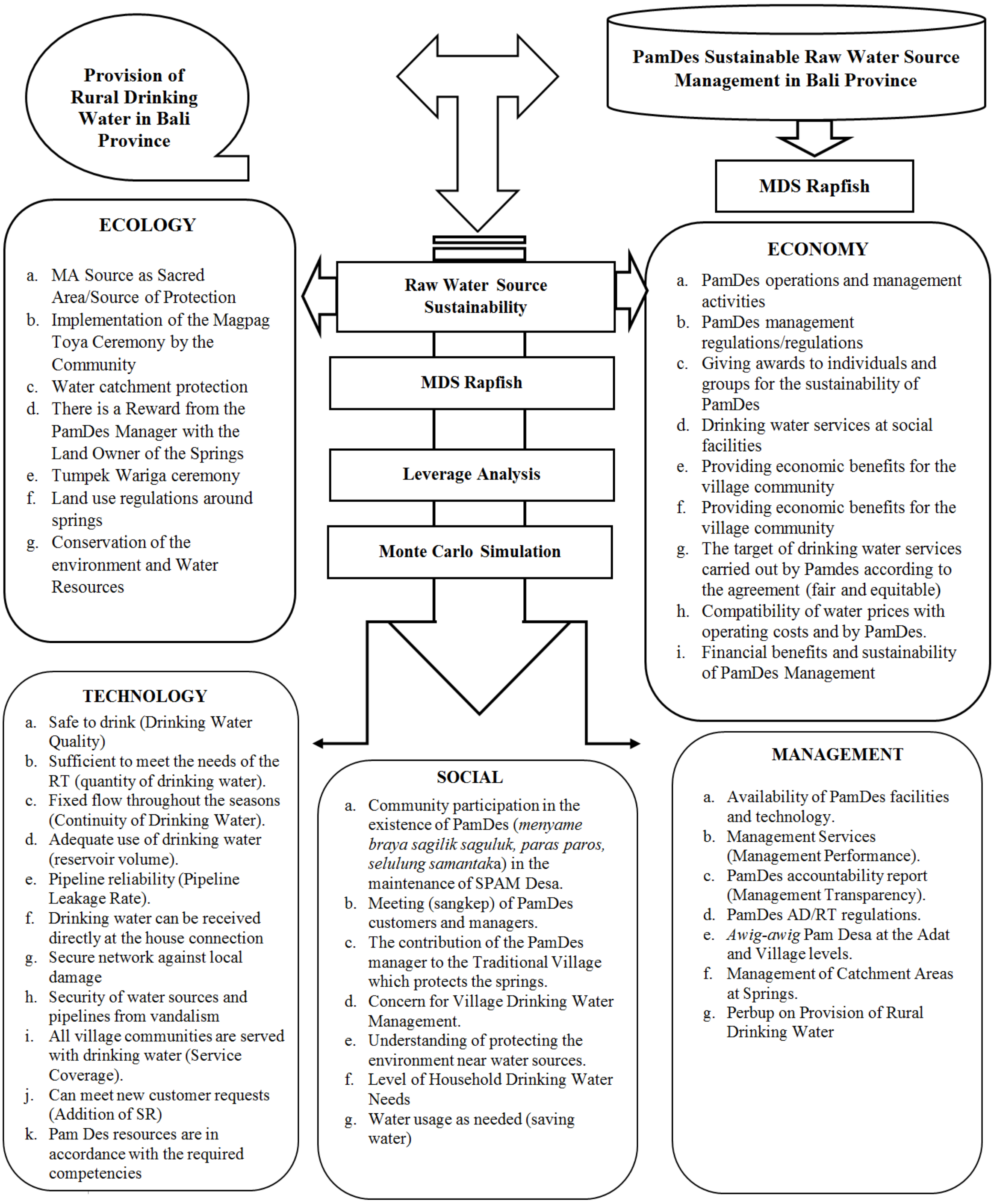

Figure 2. Research Design of Sustainability Dimensions with MDS (Nurhayati, 2014) and Modifications

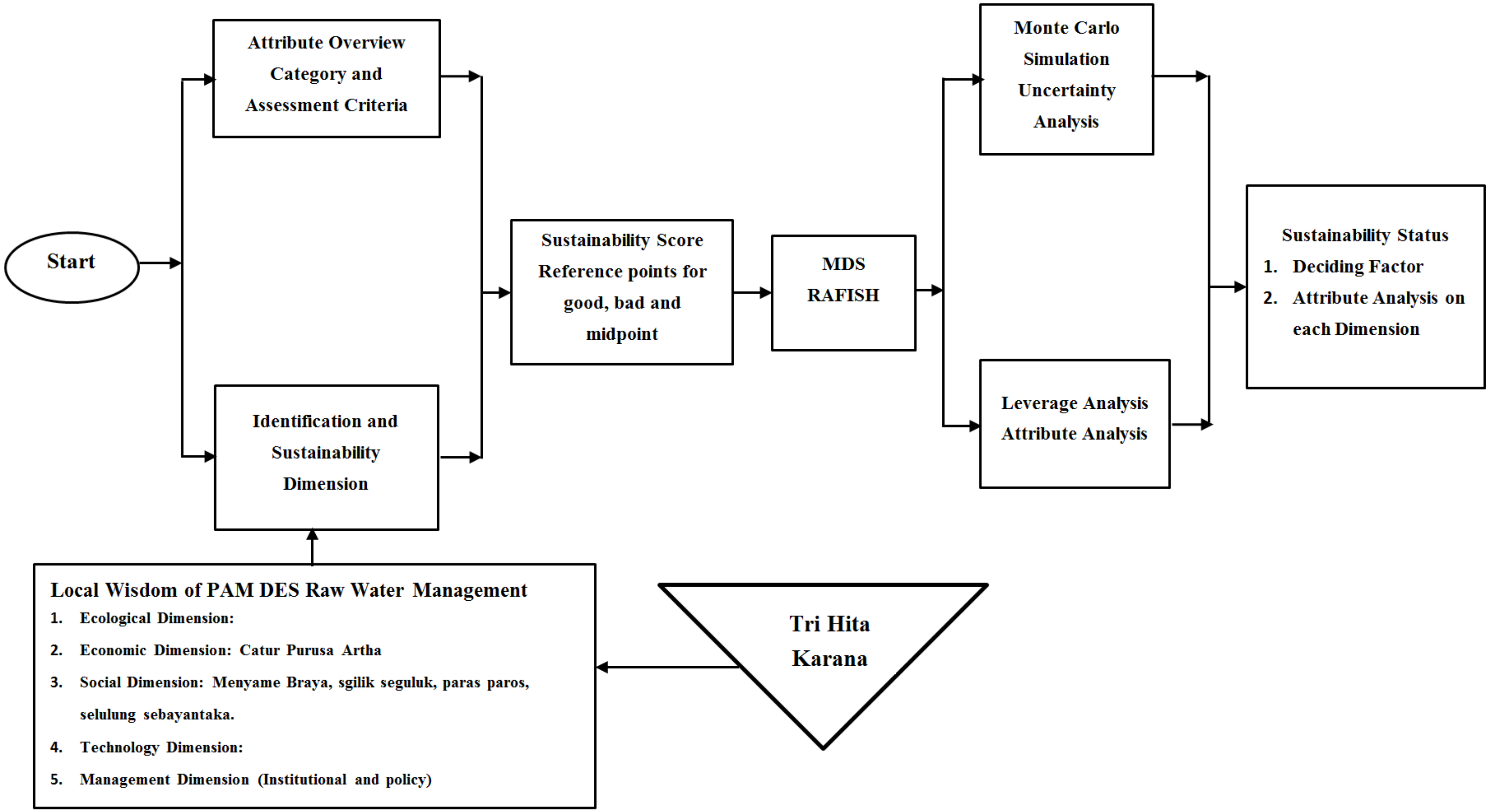

Figure 3. Model Flowcharts Using MDS Applications (Alder, 2000) and Modifications

3. Result and Discussions

3.1. Bali Province Drinking Water Supply System

3.1.1. Drinking-Water Management

The provision of drinking water in the Province of Bali is managed by PDAM and the provision of clean water on a small scale is partially managed by village institutions (PamDes) and Pamsimas. Village residents/village institutions manage to meet drinking water needs independently. To meet the drinking water needs of the community in each district, piped and non-piped systems are used. The piping system is carried out by PDAM and PamDes.

The drinking water supply in Bali Province is managed by PDAM and currently, each management unit already exists at the sub-district level. The provision of clean water for PDAMs in the Regency/City utilizes springs, groundwater, and surface water. The administrative population is the total population in the administrative area of the regency/city, while the technical population or service area population is the total population in the area served by the relevant district/city PDAM. Based on the PDAM technical report (2020), the technical population of PDAMs in Bali Province in 2019 was 3,490,903 people and the number of people served was 2,431,838 people.

Rural drinking water services, both PamDes and Pamsimas, currently exist in some areas of the Province of Bali, the entire community mostly uses PDAM services. However, for people who are not PDAM customers, clean water services use springs, dug wells, or drilled wells as access to clean water needs for daily needs.

3.1.2. Drinking-Water Service Coverage

Minimum Service Standard (SPM) achievement for drinking water in Bali Province reached 58.73% with the highest drinking water service at 86.15% in Klungkung Regency, while the lowest was in Jembrana Regency at 45.90%. The coverage of drinking water services in each regency/city in the province of Bali is presented in Table 1. For more details, the achievement of drinking water service coverage in each Regency/City in the Province of Bali is presented in Figure 4.

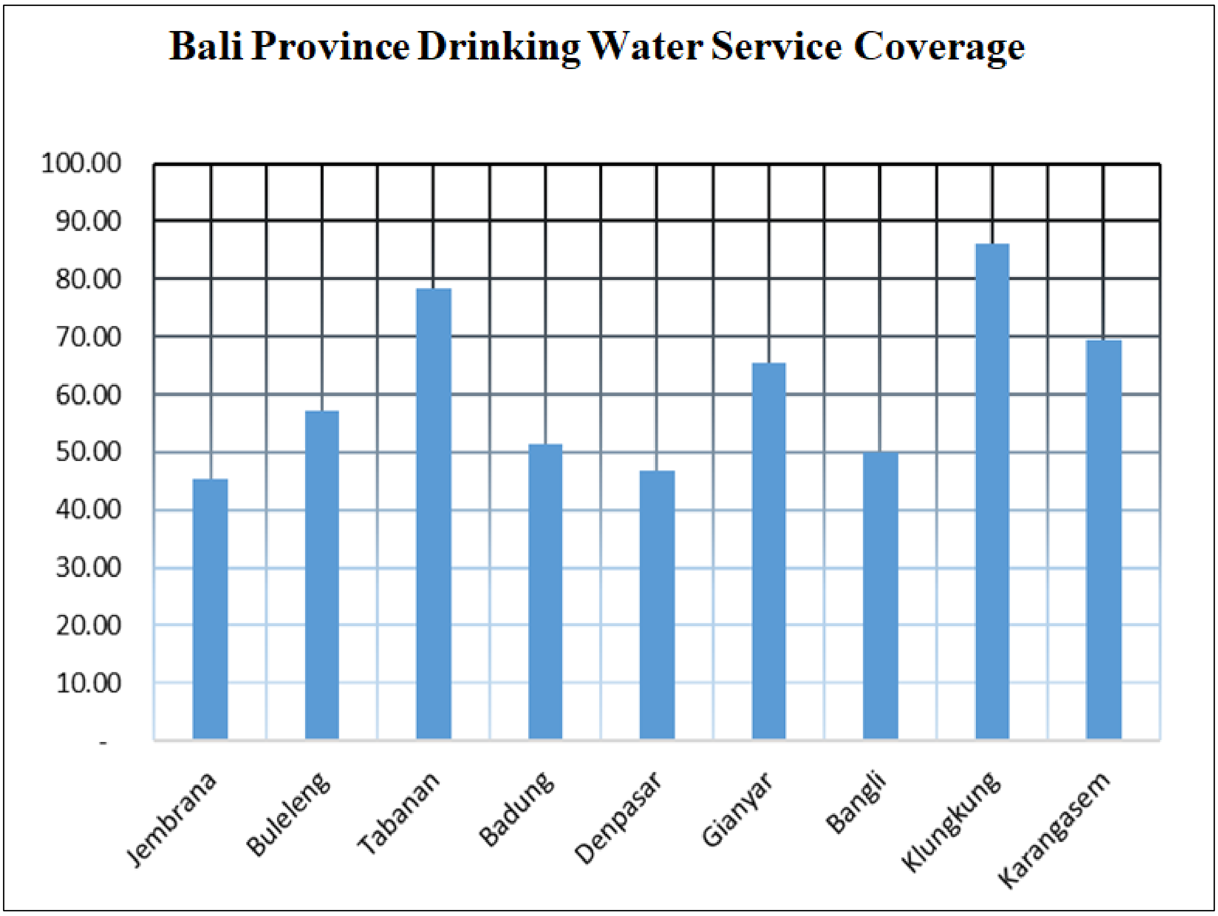

Figure 4. Bali Province Drinking Water Service Coverage

Table 1. Coverage of Drinking Water Services in the each Regency/City of Bali Province

No.	Kabupaten	Number of KK	Total number	Number of SR or KK			Total population	Service Coverage (%)
				PDAM	PamDes	PamSimas		
1	Jembrana	55,620	278,100	19,622	-	5,908	25,530	45.90
2	Buleleng	139,052	660,600	55,341	7,900	16,259	79,500	57.17
3	Tabanan	99,044	445,700	58,339	12,987	6,286	77,612	78.36
4	Badung	146,310	670,200	74,089	1,133	-	75,222	51.41
5	Denpasar	189,420	947,100	88,491	-	-	88,491	46.72
6	Gianyar	113,822	512,200	60,157	11,048	3,176	74,381	65.35
7	Bangli	47,394	227,300	19,547	0,343	3,811	23,701	50.01
8	Klungkung	39,800	179,100	33,012	1,274	-	34,286	86.15
9	Karangasem	83,320	416,600	38,611	15,482	3,808	57,901	69.49
		913,782	4336,900	447,209	50,167	39,248	536,624	58.73

Source: Analysis Results, 2022.

The number of drinking water customers managed by PDAM is 447,209 house connections and those managed by rural drinking water supply (PamDes) are 89,415 house connections. The contribution of drinking water services in the Province of Bali by PDAM is 83.34% and PamDes is 16.66%.

3.2. Sustainability Dimensions and Attributes

The local wisdom of Tri Hita Karana (THK) as a sustainability concept is applied in the management of drinking water supply systems through a participatory approach. The values contained in Tri Hita Karana are implemented in rural drinking water management for the sustainability of the socio-cultural subsystem which includes social, environmental, and economic aspects. Meanwhile, the technology subsystem and the management of rural drinking water supply are adjusted to the needs of participatory drinking water management. The implementation of Tri Hita Karana strongly supports the sustainability of rural drinking water supply and contributes to the coverage of drinking water services in the province of Bali.

Sustainable raw water management in rural drinking water supply analyzes 5 (five) dimensions, namely; ecological, economic, social, technological, and institutional. Each Dimension is determined in its explored attributes based on the value of local wisdom of rural communities in rural drinking water management.

1. Ecological Dimension

This dimension is a reflection of the good and bad quality of the environment near the springs so that the sustainability of raw water sources in the rural drinking water supply system can be maintained. In the ecological dimension, there are 7 (seven) attributes that will be analyzed for sustainability.

2. Economic Dimension

This dimension is a reflection of whether or not a rural water supply management activity can provide economic benefits and can run in the long term and sustainably.

The definition of this dimension in the management of sustainable drinking water supply is then translated into nine attributes, which operationally can describe the overall condition of rural drinking water supply which is analyzed in terms of the economic dimension.

3. Social Dimension

This dimension describes social life that relates human relations and social activities to local wisdom, namely *menyame braya, sagilik saguluk, paras paros, salulung sabayantaka*.

There are seven social dimensions in the management of sustainable drinking water supply, all of which operationally can describe the condition of rural water supply which is analyzed from the social dimension.

4. Technology Dimension

This dimension includes the existence of a drinking water supply system unit which includes; raw water units, production units, distribution, and service units. The application of technology in the rural water supply is very supportive of long-term and sustainable drinking water supply.

In the technology dimension in the management of sustainable drinking water supply, there are eleven attributes, which operationally can describe the overall condition of rural drinking water supply which is analyzed from the technological dimension.

5. Institutional Dimension

The institutional dimension of rural water supply includes institutional regulations, PamDes *awig-awig*, PamDes regulations, and management. The better the degree of regulation that is carried out, the more it can guarantee that every economic activity carried out in the management of rural drinking water supply can run in the long term and sustainably. In the institutional dimension there are 7 (seven) attributes to make it happen. The regulation of PamDes activities must be based on environmental ethics and accompanied by considerations for the creation of the sustainability of environmental functions, their existence, and natural resources in it.

The total number of attributes from the five dimensions of sustainability is 41 attributes. The attributes of each sustainability dimension are shown in Figure 2. Research Design for Sustainability Dimensions with MDS.

3.3. Status of Sustainability of Raw Water Management for Rural Water Supply

3.3.1. Sustainability Status

1. Ecological Dimension Sustainability Status

The results of data analysis using Rap analysis show that the development index value of 63.52% means it is quite sustainable (the index lies between 50% - 75%). A good index value indicates the ecological condition in Bali Province. This shows that the ecological capacity of the area to support activities in the area is quite sustainable. The following Figure 5 Output ordinance index from the Raps application with the Rapfish software.

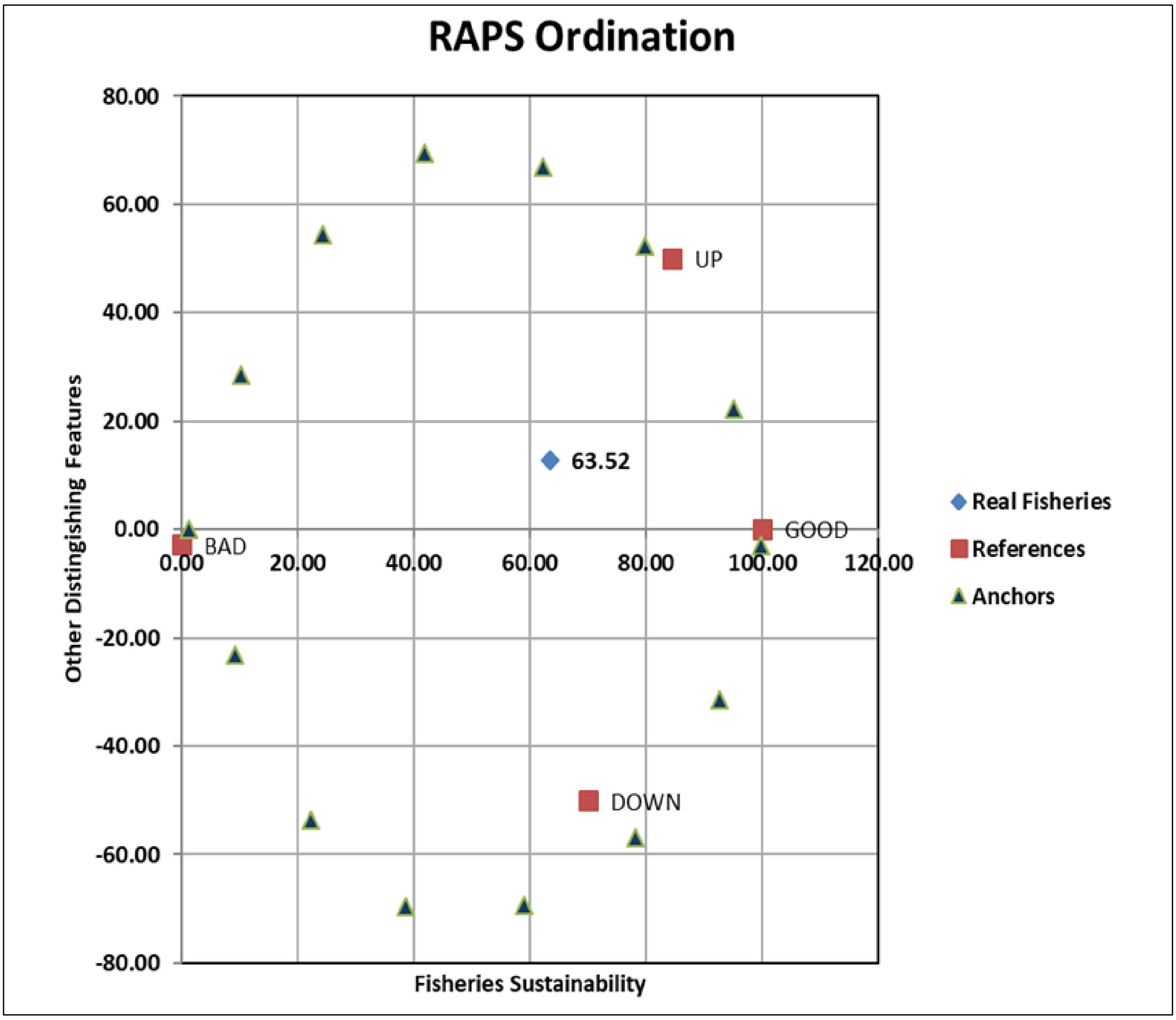

Figure 5. Description of the ordinance index on the Ecological Dimension

The leverage of Attributes is a description of the attribute lever. The attribute of leverage is an attribute whose presence is responsive to changes in the sustainability index, the higher the root mean square (RMS) value, the greater the role of the attribute on sustainability sensitivity.

The determination of the main lever attribute is based on the RMS coefficient value of each attribute. The root means square (RMS) value is the root of the average value of a function squared. To determine the attributes of the main lever in this analysis, the Pareto optimum law approach is used. Pareto's law states that something or a system always has the smallest percent (20%) of value or the greatest impact (80%). In other words, there are 20% of main causes that can affect 80% of the impacts. Obtained five attributes that are considered sensitive to the sustainability of the economic dimension are based on leverage analysis.

a. There is a reward from the PamDes manager with the landowner

The springs used by PamDes managers are in other villages and the location of the springs is on someone else's land. The use of springs and the location of *bronkaptering* placement must obtain permission from the landowner by making an agreement and fulfilling obligations so that the use of the spring's water can be used for the long termThetainably.

The analysis of attribute assessment on an ordinal scale shows that there is a payoff from PamDes managers and landowners that has a significant influence on the sustainability status of the ecological dimension with a value of 5.40. This condition illustrates that the sustainability of PamDes raw water sources by providing compensation from PamDes managers to landowners is still being carried out.

b. Implementation of the *Mapag Toya* ceremonya

Mapag Toya is a form of expression of gratitude to the ruler of water (God). This ritual also asks for permission to be given abundant water for the fertility of agricultural crops. The implementation of the Magpag Toya ceremony is carried out every six months by the adat that manages ruraTheng water.

The results of attribute analysis on an ordinal scale, it shows that the implementation of the Magpag Toya ceremony has a significant effect on the status of the ecological dimension with a value of 4.63. This condition illustrates that the implementation of the Magpag Toya ceremony in agrarian areas is still ongoing as a form of gratitude to Ida Shang Widhi for the abundant water provided.

c. Protection of catchment areas near the spring

The vegetative conditions in the catchment area near the springs determine the potential of the springs. To maintain the existence of springs in terms of quantity, quality, and continuity, vegetative functions are needed that function as conservation plants around the catchment area.

The results of the attribute assessment analysis on an ordinal scale show that the protection of the catchment area near the spring has a significant effect on the ecological sustainability status of 4.56. This condition illustrates that the protection of water catchment areas near springs is very necessary for structuring and regulating land use through customary *awig-awig* or village regulations.

d. Protection of Springs

In general, at every point of the spring, there is Beji Temple which is also a sacred area. Beji is a sacred garden located in the temple area as a place of purification for Ida Bethara. Beji is also often used for melukat as a spiritual cleansing of the mind and soul.

The results of the attribute assessment analysis on an ordinal scale indicate that the protection of springs has a significant effect on the ecological sustainability status of 4.22. This condition illustrates that the protection of springs is maintained as a sacred and conservation area.

e. Implementation of *Tumpek Wariga*

Tumpek Wariga or *Tumpek Bubuh* every 6 months on *Saniscara* (Saturday) *Kliwon, Wuku Wariga*, exactly 25 days before *Galungan* Day. The worship of Tumpek Uduh is a manifestation of God as *Sangkara*, the ruler of plants. The *Tumpek Wariga* ceremony is a type of ceremony held to ask for the safety of the environment, especially plants.

The results of attribute analysis on an ordinal scale indicate that the implementation of *Tumpek Wariga* has a significant effect on the ecological status of 4.04. The implementation of *tumpek wariga* by rural communities will give more meaning to the environment, especially plants.

2. Economic Dimension Sustainability Status

This dimension in raw water management in the rural drinking water supply system is then translated into nine attributes, which operationally can describe the condition of PamDes raw water management which is analyzed from the economic dimension.

The results of data analysis using Rap analysis show that the economic dimension sustainability index value of 51.82% means it is quite sustainable (the index lies between 50% - 75%).

Obtained five attributes that are considered sensitive to the sustainability of the economic dimension are based on leverage analysis. Changes to these four leverage factors will easily affect the increase or decrease in the value index of sustainability of the economic dimension.

a. Providing Economic Benefit for The Village Community

The provision of drinking water for rural communities is very beneficial to meet the needs of household (domestic) and non-domestic drinking water. The need for drinking water will increase according to the activities carried out by the community and will certainly provide economic benefits for rural communities.

The results of the attribute assessment on an ordinal scale indicate that the provision of rural drinking water can provide significant economic benefits for the village community towards economic sustainability of 4.14. Fulfillment of raw water for rural drinking water supply is very important to support rural community activities and economic sustainability.

b. Improvement of Customer Welfare

The use of rural drinking water is not only focused on the use of domestic drinking water and non-domestic needs are now growing. The need for drinking water for non-domestic alone does not support the activities of home industries and has also begun to be used for livestock.

The results of attribute analysis on an ordinal scale show that increasing customer welfare has a significant effect on the economy of 1,7, a crease in the coverage of drinking water services coupled with an increase in system capacity can fulfill drinking water services fairly and equitably.

c. Financial Benefits and Sustainability of PamDes

The management of rural drinking water is carried out independently by the community. In PamDes, villagers/village institutions manage to meet drinking water needs independently, management of drinking water produced is fully implemented by each village/community group, starting from use, development, and maintenance. From the results obtained by PamDes from withdrawing the water account, it is only able to carry out minor maintenance that is carried out routinely.

d. The suitability of water prices with operating and maintenance costs by PamDes

The water price agreement is made based on the price agreed by the community with the PamDes manager. The current water price is still social in nature and is only able to finance the operation and maintenance of the routine drinking water supply system and has not been able to meet the system capacity.

3. Social Dimension Sustainability Status

This dimension describes how the community's social system in raw water management in rural drinking water supply systems can support the sustainability of PamDes. Community participation in the maintenance of PamDes facilities and infrastructure is closely related to the concept of *menyame braya, sagilik saguluk paras paros, selulung seenantaka*.

The results of data analysis using Rap analysis show that the social dimension index value of 55.59% means it is quite sustainable (the index lies between 50% - 75%).

Based on leverage analysis onur attributes are attributes that are considered sensitive from the social dimension. The decrease or increase in the value of the social index can be influenced by changes in the attribute value of the leverage factor.

a. The level of drinking water needed in rural households

The need for drinking water for household (domestic) and non-domestic purposes is adjusted to community activities. The existing PamDes facilities are equipped with water meters for each household. To avoid fraudulent use of water by the community, the PamDes manager places a water meter in front of the house's yard.

The results of the attribute analysis on an ordinal scale show that the level of rural drinking water needs has a significant social impact of 3.38. The current condition of PamDes facilities and infrastructure has a limited system capacity and community water use control is maintained for the social dimension.

b. Community concern for the provision of village drinking water infrastructure

The community's concern for PamDes infrastructure by participating in maintaining and maintaining the infrastructure is very helpful in the management of PamDes. Improved facilities and infrastructure, increased maintenance to maintain drinking water production capacity.

c. The contribution of the PamDes manager to the Traditional Village that protects springs

The income derived from the amount of the customer's drinking water levy is currently unable to contribute to the Traditional Village because the drinking water tariff imposed is very small. In the future, it is necessary to increase the tariff for rural drinking water with the agreement of the community. This increased contribution is intended for the costs of routine operations and maintenance carried out by PamDes.

d. Community participation in Pam Des (menyame braya, sagilik saguluk paras paros, selulung seenantaka)

The source of raw water used for the provision of drinking water in rural areas uses springs. The location of the eye source is at the lower elevation and the flow is in the transmission pipe by gravity. Transmission pipelines are usually mostly located on cliffs and during the rainy season landslides often occur. Repair and maintenance of transmission pipelines on this line are carried out in mutual cooperation by the community to reduce operating and maintenance costs. Increasing community participation in Pamdes for its sustainability.

4. Technology Dimension Sustainability Status

The results of the analysis show that the technology sustainability index has an ordinance value of 49.30% or is categorized as less sustainable. This ordinance value illustrates that the management of raw water in rural drinking water supply in the Province of Bali is experiencing pressure on the technological aspect.

The results of the analysis of leverage on technology attributes through the Pareto optimum approach obtained five attributes that are considered responsive to the level of sustainability of the technological dimension, namely; adequacy of drinking water ususenbyhe required competencies, which can meet the demands of new customers, all village communities reserved drink water, and security of water sources and pipelines from vandalism. The decrease or increase in the value of the sustainability index on the technology dimension will be easily affected by changes in the five leverage attributes.

a. Adequate use of drinking water (reservoir tank volume)

The capacity of the PamDes system which has been built for moreseveralars has several problems in the raw water unit, including; the use of limited raw water sources (1-3) liters/second, the capacity of the transmission unit by the current drinking water needs, the application of water distribution in each service area contained in the transmission pipeline and the capacity of the distribution reservoir is not capable of serving drinking water needs at peak hours.

The results of the attribute analysis on an ordinal scale show that the adequacy of air use has a significant effect on technology by 0.54. The condition of the capacity of the PamDes system needs to be improved, especially in the raw water and production units for the technological dimension.

b. Paby in accordance with the required competencies

The drinking water supply system for rural systems is mostly managed by the community and is self-managed using a simple organizational system. PamDes management resources are very limited in terms of number and competence. Utilization of air sources PamDes uses more air sources and gravity flow towards reservoir distribution. The management of PamDes that utilizes springs and gravity drainage in operation and maintenance is not a problem, but technical assistance for PamDes managers is still needed so that the functioning of the drinking water supply system can be optimal. PamDes which manages raw water with the help of pumps usually has difficulties in maintaining pumps and supporting installations. Conditions like this require resources according to their competence so that the drinking water supply system can work optimally.

The results of the attribute analysis on an ordinal scale indicate that the PamDes resources according to the required needs have a significant influence on technology by 0.19. To improve the competence of PamDes managers, training or technical guidance is needed from the District Public Works and Spatial Planning Office.

c. New customer requests can be met (adding SR to PamDes)

The capacity of the drinking water supply system built through the Pamsimas program has met the aspects of quantity, quality, and continuity. The development and expansion of the customer network are still possible. Meanwhile, the capacity of PamDes that has been built is very limited, it is very difficult to meet drinking water needs according to standards. With the condition of PamDes with a limited system, more rural communities use water for bathing and washing by utilizing the nearest spring.

Increasing the capacity of the PamDes system is necessary for the sustainability of the technology. Increasing the capacity of the drinking water supply system which includes; raw water units, production, nits, distribution, and service units.

d. All village communities are served with drinking water (coverage of PamDes services)

The limited capacity of the PamDes system greatly affects the community's drinking water needs. The condition of PamDesa with limited raw water sources greatly affects community activities and when there are traditional ceremonial activities, it is often a turn to use air.

The distribution capacity of the reservoir cannot meet the water demand during peak hours. There are several problems in the transmission network where there is air intake on the line to meet customer needs so that the filling of raw water in the distribution reservoir is disrupted and cannot fulfill drinking water services. The results of the attribute analysis of all communities served by water with an ordinal scale of 0.14 can have a significant influence on technology. Efforts to increase the capacity of raw water sources and technical guidance on water supply need to be carried out for PamDes management.

e. Security of water sources and pipelines from vandalism

The security of air sources in the piping network of the rural drinking water supply system has been carried out with community particip,atactionnd of course supported by regulations regarding sanctions if there are activities that damage the PamDes network. The security of air sources in the pipeline from raw water units to services must be guaranteed so that PamDes technology can be achieved. The social life of rural communities today is so strong that vandalism can be threatened.

The results of the analysis of the security attributes of air sources and pipelines from vandalism with an ordinal scale of 0.11 are sufficient to have a significant effect on technology. Socialization activities are very necessary regarding the importance of joint supervision by the community on the PamDes pipeline network that has been installed.

5. Sustainability Status Institutional Dimension

The institutional aspect sustainability index obtained an ordinance value of 51.20% or quite sustainable. The ordinance value illustrates that the management of rural drinking water supply is quite sustainable in the management aspect.

Based on the leverage analysis on institutional attributes through the Pareto optimum law approach, five attributes are found that are considered responsive to the sustainability level of the institutional dimension.

a. PamDes *awig-awig* at the Customary and Village levels

Awig-awig is a rule made by the customary village community and/or Banjar adat community which serves as a guide in the implementation of *Tri Hita Karana* in the sustainability of raw water management in rural drinking water supply systems. *Awig-awig* regarding PamDes at the customary village level is very necessary for institutional sustainability because currently not all Pamdes are not equipped with *awig-awig*.

Management of dribased only the basis of harmony and togetherness is based on the concept of *Tri Hita Karana* and on that basis the sustainability of PamDes management can be achieved. The sustainability of rural drinking water supply institutions will provide the fulfillment of community drinking water according to the aspects of quantity, quality, and continuity.

b. Management of Catchment Areas at Springs source (springs source used by PamDes)

The raw water used by PamDes comes from springs and the location of the springs is in another village area with gravity flflowingondition of the water catchment area at the springs is currently with good vegetation and is located in the valley as the base flow in the river. Generally, the location of the springs is Beji Temple which is a sacred area.

To maintain the condition of the catchment area, it is necessary to arrange the catchment area by making regulations that strengthen the conservation area. Management of water catchment areas near the source is very necessary because this attribute is very sensitive to institutional sustainability.

c. PamDes accountability report (management transparency)

The accountability report carried out by PamDes every year is a form of management transparency. Transparency is one of the principles in the realization of good management. The existence of transparency can guarantee access or freedom for every community to obtain information about the implementation of PamDes management, namely information about policies for carrying out management, and their implementation as well as the results achieved.

The results of the analysis of the attributes of the PamDes accountability report with an ordinal scale of 0.40 are sufficient to have a significant effect on institutional sustainability. Financial transparency by PamDes managers is very useful for increasing public trust and institutional sustainability.

3.3.2. Output Interpretation

1. Sustainability Index

The sustainability index is obtained from the sustainability ordinance value which is a description of the coefficient or sustainability index of each dimension. The results of data analysis using Rap analysis showed that the highest sustainability index value was obtained from the ecological dimension of 63.52% and the lowest technological dimension of 49.30%. The sustainability index value of the ecological, economic, social, and institutional dimensions with a value above 50% means it is quite sustainable. The value index of sustainability the technological dimension in raw water management for rural water supply is less sustainable. Improvement of facilities and infrastructure for rural drinking water supply in Bali Province is very necessary for its sustainability.

Stress value to indicate the size of the discrepancy. The results are close to the actual situation or cannot be seen from the stress value. The actual situation is interpreted if the number is getting closer to 0. The tolerable stress value is less than 20%.

The value of the R^2 to assess the accuracy (goodness of fit). The value of R^2 is to find out the proximity between the data and the perception map and whether the data is mapped properly or not. R^2 value > 80% indicates that the sustainability index estimation model is good and adequate to use. The value of sustainability, pressure and coefficient of determination on the sustainability dimension are listed in Table 2.

6. Leverage of Attributes

The leverage of Attributes is a description of the attributes of the lever, where this attribute is responsive to changes in the sustainability index. The determination of the leverage attribute is based on the RMS value of each attribute. The number of attributes in each dimension of sustainability is based on the Pareto optimum law approach. The total number of lever attributes on the five sustainability dimensions is 21 attributes. The number of lever attributes in each sustainability dimension is presented in Table 3.

Table 2. Sustainable va,lues, Stress values, and R^2 values

No.	Sustainable dimension	Sustainable values	Stress values	Coefficient of Determination Value (R2 values)
1	Ecology	63.52	0.16	0.89
2	Economy	51.82	0.15	0.94
3	Social	55.59	0.15	0.94
4	Technology	49.30	0.15	0.94
5	Institutional	51.20	0.17	0.94

Source: Analysis Results, 2022

Table 3. Attribute Levers on Each Sustainability Dimension.

No.	Sustainable dimension	Leverage factor	RMS
1	Ecology	There is a reward from the PamDes manager and the owner of the spring land	5.40
		The implementation of the Magpag Toya ceremony by the community	4.63
		Community protection of catchment areas near springs	4.56
		Protection of water sources carried out by the community,	The
		The implementation of the tumpek wariga ceremony	4.04
2	Economy	Provide economic benefits to the village community	4.14
		Improve customer welfare	1.67
		Financial benefits and sustainability of PamDes	1.17
		Compatibility of water prices with operating and maintenance costs by PamDes.	1.02
3	Social	The level of drinking needed needs in rural households	3.38
		Public concern for PamDes infrastructure	2.12
		The contribution of PamDes managers to the Traditional Village	1.92
		Community participation in PamDes	1.73
4	Technology	Adequate use of drinking water	0.54
		PamDes resource with the required competencies	0.19
		Can meet new customer's request	0.18
		All village communities are served drinking water	0.14
		Security of water sources and pipelines from vandalism	0.11
5	Institutional	PamDesa *awig-awig* at the adat and village levels	1.33
		Management of water catchment areas at springs,	0.46
		PamDes accountability report	0.44

Source: Analysis Results, 2022

Table 4. Difference of value of Monte Carlo with the Sustainability Ordinance.

No.	Sustainable dimension	Sustainable index value (%)		Difference	Category
		MDS	Monte Carlo		
1	Ecology	63.52	62.04	1.48	Valid
2	Economy	51.82	51.47	0.35	Valid
3	Social	55.59	55.51	0.08	Valid
4	Technology	49.30	49.32	0.02	Valid
5	Institutional	51.20	51.204	0.004	Valid

Source: Analysis Results, 2022.

7. Monte Carlo

Analysis of Monte Carlo is used as a method of simulation to assess the impact of random error in the analysis of statistics. This analysis is in rapfish software as a validation tool for the resulting model. Validity confidence is obtained from the Diffinence of the value of Monte Carlo with the Sustainability Ordinance, where the maximum acceptable difference iThe differenceerence between the value of Monte Carlo with the Sustainability Ordinance is presented in Table 4.

3.4. Conclusions

The implementation of Tri Hita Karana strongly supports sustainability in raw water management in rural drinking water supply systems. The local wisdom of the Balinese people in efforts to conserve water resources, nature, and the environment will determine the sustainability status with sufficient categories in the ecological, economic, social, and institutional dimensions. The results of the analysis show that the value index of sustainability on the ecological dimension is 63.52%, the economic dimension is 51.82%, the social dimension is 55.59%, the technological dimension is 49.30% and the institutional dimension is 51.20%.

The lever factor on the sustainability dimension of raw water management in the rural drinking water supply system in Bali Province is 21 attributes the lever factor. To increase the index value of each dimension of sustainability in the rural water supply system in the future, it is necessary to mathe maintain good performance of lever factors and make improvements nts to poor performance of lever factors. In the dimension of technology sustainability, there are 5 attributes of lever factors that need to be improved, improved facilities and infrastructure for rural drinking water supply systems for the sustainability of the technological dimension.

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