Journal of Natural Resources and Environmental Management
12(3): 555-569. http://dx.doi.org/10.29244/jpsl.12.3.555-569
E-ISSN: 2460-5824
http://journal.ipb.ac.id/index.php/jpsl

Key attributes in the clean water supply program in Soppeng Regency, South Sulawesi

Emil Azmanajaya[a], Chaterina A. Paulus[b], Hadi Hermansyah[c], Ezra H. Pongtuluran[a], Ishak Jumarang[d], Tuatul Mahfud[e]

[a] Department of Civil Engineering, Balikpapan State Polytechnic, Balikpapan, 76129, Indonesia
[b] Department of Aquatic Resource Management, Nusa Cendana University, Kupang, 85142, Indonesia
[c] Department Heavy Machine Equipment Engineering, Balikpapan State Polytechnic, Balikpapan, 76129, Indonesia
[d] Department of Physic, University of Tanjungpura, Pontianak, 78124, Indonesia
[e] Department of Hospitality, Balikpapan State Polytechnic, Balikpapan, 76129, Indonesia

Article Info:
Received: 19 - 05 - 2022
Accepted: 13 - 07 - 2022

Keywords:
Constraints, clean water supply, institutional role, needs, Soppeng

Corresponding Author:
Emil Azmanajaya
Department of Civil Engineering, Balikpapan State Polytechnic;
Tel. +62-8115066561
Email: emil.azmanajaya@poltekba.ac.id

Abstract*. The dearth of clean water for the people in Soppeng Regency is a management problem that never gets a solution. Management of clean water supply is a key aspect of the solution to the problem of the dearth of clean water in the Soppeng Regency. This paper discusses the critical factors that are responsible for creating an impact on the work of the water supply program. The analysis involves selecting critical attributes and applying the Interpretive Structural Modeling (ISM) methodology to obtain level partitioning and the final ISM model. The results show that in implementing the clean water supply program, four key attributes need to be considered, namely the lack of institutional capacity, weak institutional governance, availability of raw water, and the role of the Central Government (relevant ministries).*

How to cite (CSE Style 8th Edition):
Azmanajaya E, Paulus CA, Hermansyah H, Pongtuluran EH, Jumarang I, Mahfud T. 2022. Key attributes in the clean water supply program in Soppeng Regency, South Sulawesi. JPSL **12**(3): 555-569. http://dx.doi.org/10.29244/jpsl.12.3.555-569.

INTRODUCTION

Indonesia is one of 193 countries that agreed on the SDGs commitment to implement the national program of clean and safe drinking water and sanitation access in 2030. Water utilization is used not only to supply domestic water demand but also to serve the multi sector community for power generation, agriculture, fisheries, and other activities. The clean water distribution for urban and rural communities is one of the most important sectors implemented in Indonesia, including the local government of Soppeng Regency, South Sulawesi. Soppeng Regency has five rivers, namely Langkemme, Soppeng, Lawo, Padangeng, and Lajaroko rivers (BPS Soppeng Regency 2010).

The five rivers flow through several hamlets in Soppeng Regency and empty into the Walanae River and Tempe Lake. Meanwhile, the headwaters that flow through the River in Soppeng originate from several Mountains in Soppeng Regency, including Mount Lapancu, Matanre, Malemping, and Addepungeng. Surface water from the river can be used and distributed as the main source of clean water after treatment by operating water treatment processes. However, the potential for surface water as raw water is increasingly limited.

Regulations and management institutions are not yet comprehensive, resulting in conflicts of interest of the user sector on the surface water (agriculture, plantations, and fisheries). The main problems in the water supply system are the dearth of raw water and the increase in groundwater consumption as a source of raw water for domestic use and industry. Afiatun *et al.* (2018) stated that, "Groundwater is a non-renewable source of water that needs to be protected. The high groundwater consumption has resulted in a decrease in water level and gradually caused land subsidence due to its continuing impact". Inevitably, it is necessary to study the development of clean water supply using a systematic approach to sustain the clean water supply in Soppeng Regency.

At present, water consumption is growing all over the world, while the available water resources are decreasing. Adams *et al.* (2013) stated that the perceived importance of water resources, water use, and water conservation in settlements; preferred source of information; preferred learning methods and topics; a view of how well the different levels of government protect water quality; environmental attitude; and demographics should be owned by the local government as clean water managers. In conditions of increasing shortages, many countries include water resource management strategies in their sustainable development plans (Primin 2018). Munasinghe (2019) stated that water supply policy and planning should be developed within a holistic, realistic, and participative framework.

By using an integrated approach of Multiple Criteria Decision Making (MCDM) to define a model that can be referenced when building a water supply system. The MCDM technique used here is the Interpretive Structural Modeling (ISM) methodology. Verma *et al.* (2022) stated that, "ISM focuses on the complex interrelationships between the selected factors and provides the best and analytically correct implementation model". Interpretive structural modeling, known by the acronym ISM, is a learning process that is interrelated or interactive (Attri *et al.* 2013). This method can be used to assist a group in identifying the contextual relationships between sub-elements of each element that make up a system based on ideas or determinants in a complex problem (Saxena 1992).

ISM is a technique used in modeling that is able to synchronize the opinions of experts in providing a concrete picture of the hierarchical structure of sub-elements of each system element and in finding key sub-elements and characters of each sub-element (Saxena *et al.* 2006; Sushil 2012). Sage (1977) and Warfield (1974) state that this technique consists of a different set of directly and indirectly related elements arranged into a comprehensive systematic model. Models are formed from the structure of a problem or complex problem in a carefully designed pattern that implies graphics and words (Raj *et al.* 2007; Ravi and Shankar, 2005; Singh *et al.* 2003; Raj and Attri 2011). Interpretive structural modeling (ISM) is a well-established methodology for identifying relationships between specific variables which define a problem or issue (Jharkharia and Shankar 2005).

For any complex problem to be considered, a number of factors may be associated with the problem. However, the direct and indirect relationships between these factors describe the situation so much more accurately than the ISM incorporates insights into a collective understanding of this relationship. Furthermore Attri *et al.* (2013) stated that ISM could be understood by cross-disciplinary user groups for a variety of uses, such as: (1) integrating the various opinions of participants, (2) addressing the broad and typical elements and relationships of a complex system, (3) problem solving with sufficient value the formulation of the model, (4) contains insight into the behavior of the system, and (5) is easy to understand and communicate to large groups. With its existing strengths, ISM is the right approach to identify constraints, needs, and institutional roles in the clean water supply program in Soppeng.

METHOD

This research was conducted from October 2019 to January 2020 in Soppeng Regency, South Sulawesi Province, Indonesia. The study was conducted using primary data obtained from discussions, questionnaires, interviews, and field surveys by respondents, experts, and the community in the study area; and secondary data obtained from several related reference sources. Elements and sub-elements in the clean water supply program in Soppeng Regency based on the expert discussion are presented in Table 1.

Table 1 Elements and sub-elements in the clean water supply program in Soppeng Regency

Elements		
Constraints	**Needs**	**Institution**
Sub-elements of constraints (notations)	Sub-elements of needs (notations)	Sub-elements of institution (notations)
Water source management policies are not integrated (K1)	Availability of raw water (B1)	Central government (L1)
Limited facilities and infrastructure for the clean water sector (K2)	Clean water supply technology (B2)	Regional government (L2)
Poor raw water quality due to pollution (K3)	Technology investment in supplying raw water and clean water (B3)	Local water company (L3)
Low awareness of clean living (K4)	Community participation in the supply of clean water (B4)	Local community (L4)
High investment in clean water supply facilities (K5)	Support of water resource management policies (B5)	Non-governmental organization (NGOs) (L5)
Poor spatial planning (K6)	Human resources in management (B6)	Private companies (L6)
Vulnerable to social conflicts (K7)	Clean water management agency (B7)	College/university (L7)
Lack of reliable human resources (K8)		
Limited water resources (K9)		
Lack of institutional capacity (K10)		
Weak institutional governance (K11)		
Inadequate water supply technology (K12)		

Source: Primary data analysis, 2020

After selection of the elements and sub-elements, the maximum efforts are required to determine the complex relationships among these sub-elements, and this procedure is carried out by professionals who have expertise in the intended program. In this research, 3 elements (constraints, needs, institution) and 26 sub-elements were identified after through literature reviews. The next step is to use the ISM method for the selected elements and sub-elements and further discuss the results obtained. Verma *et al.* (2022) stated that, The steps involved in ISM methodology are: a) creation of structural self-interaction matrix (SSIM), b) development of the reachability matrix, c) execution stage on level partition, d) classification of the selected factors, and e) development of the ISM model.

Creation of Structural Self-Interaction Matrix (SSIM)

Several structural categories and idea categories that reflect contextual relationships between elements can be developed using ISM, such as the SSIM. Pfohl *et al.* (2011) established that A variety of specialists from various sectors and academies were consulted during this step to construct the intricate contextual relationship between the specified elements. Here are four symbols that will be used to determine the direction of the relationship between two elements, namely (i) and (j): A: factor j will help to achieve factor i; X: factor i and j will help each other; O: both factors i and j are unrelated; and V: factor i will help to achieve factor j. The structural self-interaction matrix (SSIM) is generated in Table 2 through Table 4 based on the determined associations.

Table 2 SSIM of constraints

Sub-elements of constraints	***K1***	***K2***	***K3***	***K4***	***K5***	***K6***	***K7***	***K8***	***K9***	***K10***	***K11***	***K12***
K1	X	V	V	O	V	A	V	A	V	A	A	O
K2		X	O	X	X	A	X	A	X	A	A	X
K3			X	X	V	A	O	O	V	A	A	O
K4				X	O	O	O	O	O	A	A	O
K5					X	A	O	A	A	A	A	A
K6						X	V	O	V	A	A	O
K7							X	X	O	O	O	O
K8								X	A	X	X	V
K9									X	A	A	O
K10										X	X	O
K11											X	O
K12												X

Table 3 Structural self-interaction matrix (SSIM) of needs

Sub-elements of needs	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**
B1	X	V	V	V	V	V	V
B2		X	X	V	A	A	V
B3			X	V	A	V	V
B4				X	X	X	V
B5					X	X	V
B6						X	V
B7							X

Table 4 Structural self-interaction matrix (SSIM) of institution

Sub-elements of institution	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**
L1	X	V	V	V	V	V	V
L2		X	V	V	V	V	X
L3			X	V	O	O	O
L4				X	A	X	O
L5					X	V	O
L6						X	O
L7							X

Development of the reachability matrix

This matrix is a binary matrix resulting from the conversion of SSIM. The rules of conversion from SSIM to RM are as follows: (1) The symbol V in the SSIM entry I j), means that the RM I j) entry becomes 1, and the (j, I entry becomes 0; (2) The symbol A in the SSIM entry I j), means that the RM I j) entry becomes 0, and the (j, I entry becomes 1; (3) The symbol X in the SSIM entry I j), means that the RM I j) and (j, I entries are both 1; and (4) The symbol O in the SSIM entry I j), means that the RM I j) and (j, I entries become 0 as well. By setting the above-mentioned rules, the reachability matrix has been developed and is shown in Table 5 through Table 7.

Table 5 Reachability matrix (matrix M) of constraints

Sub-elements of constraints	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	Driver Power
K1	1	1	1	0	1	0	1	0	1	0	0	0	6
K2	0	1	0	1	1	0	1	0	1	0	0	1	6
K3	0	0	1	1	1	0	0	0	1	0	0	0	4
K4	0	1	1	1	0	0	0	0	0	0	0	0	3
K5	0	1	1	0	1	0	0	0	0	0	0	0	3
K6	1	1	1	0	1	1	1	0	1	0	0	0	7
K7	0	1	0	0	0	0	1	1	0	0	0	0	3
K8	1	1	0	0	1	0	1	1	0	1	1	1	8
K9	0	1	1	0	1	1	0	1	1	0	0	0	6
K10	1	1	1	1	1	1	0	1	1	1	1	0	10
K11	1	1	1	1	1	1	0	1	1	1	1	0	10
K12	0	1	0	0	1	0	0	0	0	0	0	1	3
Dependence	5	11	8	5	10	4	5	5	7	3	3	3	

Table 6 Reachability matrix (matrix M) of needs

Sub-elements of needs	B1	B2	B3	B4	B5	B6	B7	Driver Power
B1	1	1	1	1	1	1	1	7
B2	0	1	1	1	1	1	1	6
B3	0	0	1	0	1	1	1	4
B4	0	0	1	1	1	1	1	5
B5	0	0	0	0	1	0	1	2
B6	0	1	0	1	1	1	1	5
B7	0	0	0	0	0	0	1	1
Dependence	1	3	4	4	6	5	7	

Table 7 Reachability matrix (matrix M) of institution

Sub-elements of institution	L1	L2	L3	L4	L5	L6	L7	Driver Power
L1	1	1	1	1	1	1	1	7
L2	0	1	1	1	1	1	1	6
L3	0	0	1	1	0	0	0	2
L4	0	0	0	1	0	1	0	2
L5	0	0	0	1	1	1	0	3
L6	0	0	0	1	0	1	0	2
L7	0	1	0	0	0	0	1	2
Dependence	1	3	3	6	3	5	3	

Table 4 through Table 7 also display the driver power and the dependence of each element. The driver power of the selected sub-elements refers to the number of variables that contribute to the success of meeting the goals, whereas the dependence of the selected factors refers to the number of elements that can be trusted to achieve the goals.

Execution stage on level partition

Singhal *et al.* (2018) established that, "The level division is carried out after the production of the final reachability matrix (M); to begin, each factor's reachability set, antecedent set, and intersection set are determined". In addition, components that have the same reachability set and intersection set will get the topmost level on the level partition. Once the top-level factor is set, the factor will be removed from the list of other factors, and the next level factor will be determined using the same procedure.

Classification of the selected elements

Elements with the same level in this matrix will be grouped. This matrix is then used to prepare the diagraph. At this level, the 26 selected sub-elements are classified into four groups, namely driving variables, dependent variables, autonomous variables, and linkage variables. The classification of 26 sub-elements is shown in Figure 1, Figure 3, and Figure 5. Aich and Tripathy (2014) explains the four quadrants as follows: (1) in the first quadrant which is also known as "autonomous variables" where the element group has the least driving force and dependence compared to other quadrants.

This autonomous variable does not have a significant impact on the work domain. (2) In the second quadrant known as the "dependent variable" refers to the group of elements that have a high dependence on other factors. (3) In the third quadrant, it is referred to as "'connecting variable", where the element has strong driving force and dependence. In this quadrant, it is a condition with the characteristics of the most unsafe and a problem in any work environment. (4) In the fourth quadrant, namely "driving variables" are elements that have a very high driving effect on other factors.

Development of the ISM model

At this stage, the ISM model will be generated by moving the entire number of elements with a description of the elements according to actual conditions. The results of the ISM will provide a very clear condition of the system elements and their relationship flows. Singhal *et al.* (2018) established that, "If there is a link between factors I and j, arrows and points will be used to depict that relationship". The final reachability matrix (Table 4 to Table 6) and all level partitions of the model can be used to create this ISM model. The initial digraph is known as the first directed graph. The final ISM model was created after removing all transitivity between variables, as shown in Figure 2, Figure 4, and Figure 6.

RESULTS AND DISCUSSION

The Constraints in the Clean Water Supply Program in Soppeng Regency

Based on the results of expert opinions on 12 sub-elements of the constraints in the clean water supply program (Table 5), two sub-elements with the largest power driver with a value of 10 were found are the lack of institutional capacity (K10) and weak institutional governance (K11). The other sub-elements have driver power values ranging from 3 to 8. The greater the value of the driver power determines the position of the driving force for the clean water supply program in the Soppeng Regency. The contextual relations between sub-elements of constraints are sub-elements of constraints in which one contributes or causes other sub-elements of constraints.

In Figure 1 it can be seen that the sub-elements of constraints of water source management policies are not integrated (K1, DP value 6, D value 5), poor spatial planning (K6, DP value 7, D value 6), lack of reliable human resources (K8, DP value 8, D value 5), lack of institutional capacity (K10, DP value 10, D value 3), weak institutional governance (K11, DP value 10, D value 3), located in the independent sector. This shows that the five sub-element constraints make a high contribution to the other sub-element constraints. Every change in each of these sub-elements will affect the other sub-element constraints.

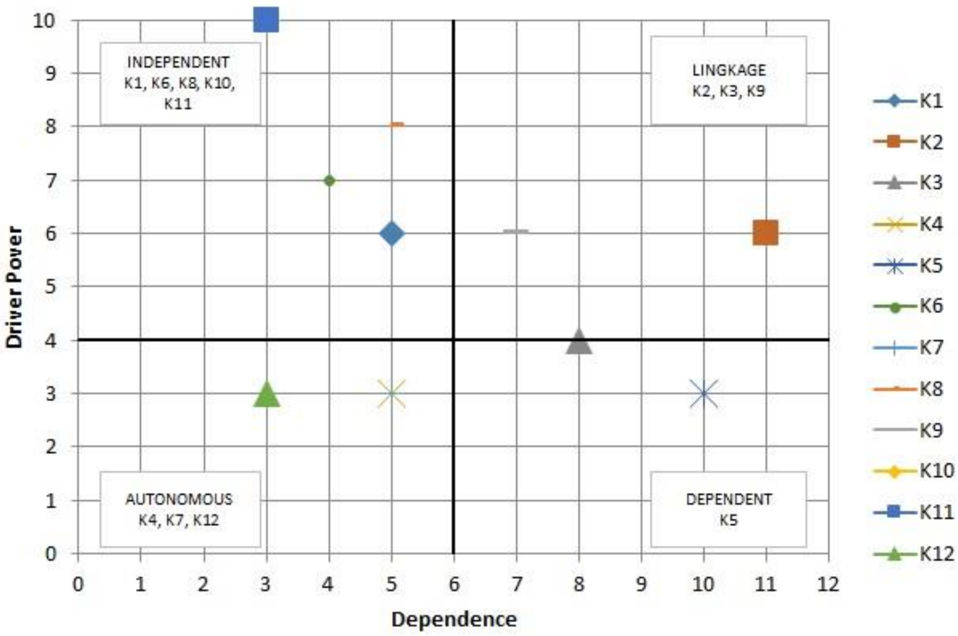

Figure 1 The driver power–dependence matrix for the constraint elements in the water supply program in Soppeng Regency

Sub elements of limited facilities and infrastructure of the clean water sector (K2), poor raw water quality due to pollution (K3, DP value 4, D value 8), limited water resources (K9, DP value 6, D value 7), lies in the linkage sector. This means that the occurrence of the three sub-elements of these constraints is strongly influenced and, at the same time, affects the occurrence of other sub-element constraints. Sub elements of high investment in water supply (K5, DP value 3, D value 10) facilities are in the dependent sector. This means that the occurrence of these constraints is strongly influenced by other sub-elements of constraints. While sub-elements of low awareness of clean living (K4, DP value 3, D value 5), easy to occur social conflicts (K7, DP value 3, D value 5), inadequate water supply technology (K12, DP value 3, D value 3), occupy autonomous sectors, this means that these sub-element constraints are generally not related or have little relationship with sub other obstacle elements.

The results of a hierarchical analysis of the constraint sub-elements in the provision of clean water are shown in Figure 2. The key obstacle sub-elements that are the power drivers for clean water supply in Soppeng Regency are the lack of institutional capacity (K10) and weak institutional governance (K11). These two sub-elements of constraints form the basis for other sub-elements. The next obstacle sub-element is the lack of adequate human resources (K8). Due to the lack of adequate human resources, spatial planning becomes incompatible with the function of the area (K6).

The next stage that must be solved in the provision of clean water is the constraints of water source management policies that are not integrated (K1), limited facilities and infrastructure of the clean water sector (K2), and limited water resources (K9). Furthermore, pollution is the cause of the poor quality of raw water that must be addressed (K3). If the constraints of the quality of raw water can be resolved, the clean water that is distributed to customers (local community) is more guaranteed. The quality of clean water that is distributed to the Soppeng community will certainly be guaranteed by the quality of the final level constraints, namely the investment in water supply facilities (K5), inadequate clean water supply technology (K12), low awareness of clean living (K4), and susceptibility to social conflict (K7).

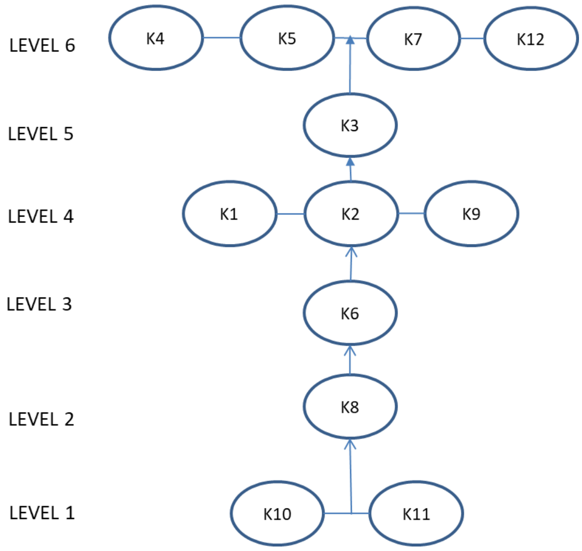

Figure 2 The hierarchy structure of the sub-element constraints in the water supply program in Soppeng Regency

Figure 2 shows that the power drivers for clean water supply in Soppeng Regency are the lack of institutional capacity (K10) and weak institutional governance (K11). These two sub-elements of constraints form the basis for other sub-elements. For this reason, weak institutional capacity and institutional governance are elements of the obstacle that need to be resolved first. In improving weak institutional capacity and institutional governance, principles or standards are needed in managing institutional designs. The next obstacle sub-element is the lack of adequate human resources (K8). In line with Loera and Salazar (2017) the role of human resources in management is undoubtedly more relevant, if translated into fundamental elements to provide quality services to residents; regardless of the sociodemographic conditions in which they live, reliable human resources are needed in providing quality, sustainable and efficient water services.

Chatterji *et al.* 2017 stated that the most effective process for managing water resources were people or users themselves to become proper planners and micro-planning. Community participation in planning is very important in successful collaborative and spatial planning of clean water supply. Lack of community participation will lead to problematic spatial planning (K6). This is in line with the findings of Natarajan (2017). The distinctive role of local wisdom as lay knowledge is very clear in terms of making regional strategies. The process of generating knowledge in planning supports the determination of the involvement of non-tokenistic from the public and provides information on the interaction of local communities with policymakers. The next stage that must be solved in the provision of clean water is the constraints of water source management policies that are not integrated (K1), limited facilities and infrastructure of the clean water sector (K2), and limited water resources (K9).

These three obstacles can be solved simultaneously or separately, where solving one obstacle is not a requirement for solving other obstacles. As a result of policies that are not integrated management of water sources causes uneven distribution of water sources, so the availability of raw water is limited. This non-integrated water source management policy is compounded by the lack of clean water sector facilities and infrastructure. According to Koppen *et al.* (2020), several policies in water resource management that can be implemented are: (1) Leverage the cost-effectiveness and water efficiency of multi-use infrastructure; for those who use more water must contribute more to the infrastructure costs, (2) Using community investment in self-sufficiency and co-management, and (3) Enabling community-driven water services. The clean water supply in Soppeng is dealing with the problem of contaminated raw water quality (K3). Raw water contamination is caused by the waste of pesticides and fertilizers from agriculture as well as sedimentation in weir buildings due to soil surface erosion during heavy rains.

The solution to the erosion problem is the creation of sediment traps along eroded forest slopes and a reforestation program. Meanwhile, to reduce pesticide and fertilizer pollution, it is necessary to build sedimentation and use water plants as organic processing to bind fertilizers and pesticides from water. Haerunnisa (2014) stated that the use of water hyacinth (*Eichornia crassipes*) in Tempe Lake water could reduce copper (Cu) levels in water to 81% from the initial level and the average weekly reduction was 0.012 Mg/L. Ratnani *et al.* (2013) also stated that the use of water hyacinth in tofu wastewater can reduce COD from 672 ppm to 160 ppm and can increase the pH value from 4.6 to 7.3. Furthermore, Zumani *et al.* (2015) stated that in 14 days water hyacinth could reduce the cadmium concentration of mineral water from 2 ppm to 0.01 ppm.

The final level of constraints for the clean water supply program in Soppeng are: (1) the low awareness of clean living (K4), that characterized by a large number of residents bathing and washing in the River; (2) conflicts of interest in water use (K7) that occur due to the high usage of the water sector to community needs and the high usage in the agricultural sector; (3) poor water quality conditions coupled with the distance between houses that far apart require high investment in the management and provision of clean water facilities (K5); and (4) improper use of raw water treatment technology (K12), causing incomplete clean water treatment and making clean water at a high cost. These four constraints can be overcome with the existence of a pro-environment policy and a program to regulate water use for Soppeng Regency.

The Needs in the Clean Water Supply Program in Soppeng Regency

Based on the results of expert opinion, there is one key requirement sub-element that is also a power driver in the clean water supply program (Table 6), namely the raw water availability sub-element (B1). The contextual relationship between sub-elements of needs is a sub-element of needs that is more important than other sub-elements of needs. Based on the results of the analysis, as shown in Figure 3, it can be seen that the sub-element needs the availability of raw water (B1, DP value 7, D value 1) and clean water treatment technology (B2, DP value 6, D value 1), lies in the independent sector. These two sub-elements (B1 and B2) have a high driving value with a low level of dependence so that they make a high contribution to other sub-elements of needs, every change in these two sub-elements will affect other sub-elements of needs.

The sub-elements of community participation (B4, DP value 5, D value 4), human resources (B6, DP value 5, D value 5) and investment (B3, DP value 4, D value 4), lie in the sectoral environment, this means that the occurrence of the two sub-elements of needs is strongly influenced and at the same time influences the occurrence of other sub-elements of needs. The policy support sub-element (B5, DP value 2, D value 6), and the clean water management agency (B7, DP value 1, D value 7), are in the dependent sector, this means that the occurrence of these two needs is strongly influenced by other sub-elements of needs.

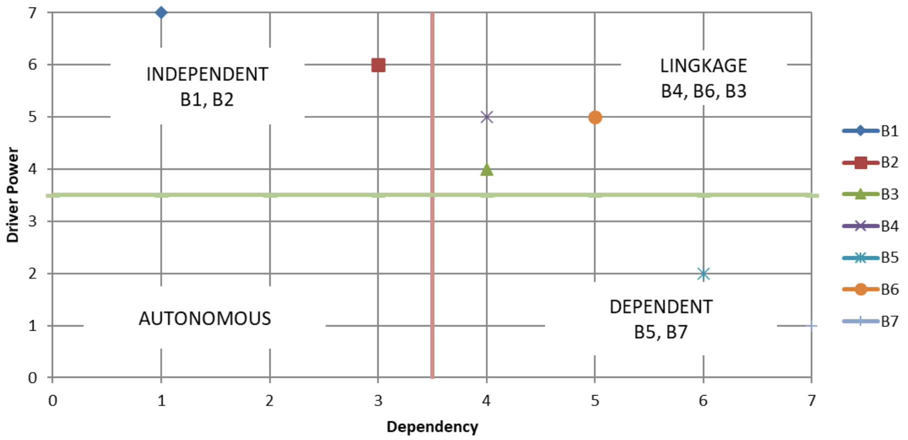

Figure 3 The driver power–dependence matrix for the need elements in the water supply program in Soppeng Regency

From this analysis it is obtained a hierarchy of sub-elements of needs as shown in Figure 4. The key sub-element of needs that is the power driver for sustainable water supply in Soppeng Regency is the availability of raw water (B1). This sub-element needs to be the basis of the first to be fulfilled before the other sub elements. Sub element of the next requirement is clean water treatment technology (B2). This sub-element needs to be provided as a tool to treat the available raw water. Besides technology, the role of local communities (B4) and the availability of reliable human resources (B6) are also needed. All elements of the above needs require investment in technology to supply raw water and clean water that is feasible and proportionate (B3). For this reason, local and central government support is urgently needed in the form of policy support (B5), and the final level in the need for clean water is a water management agency (B7).

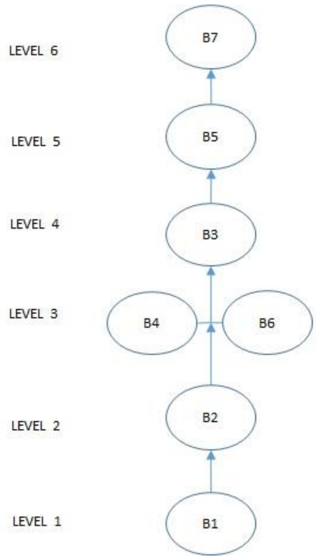

Figure 4 The hierarchy structure of the sub-element needs in the water supply program in Soppeng Regency

Figure 4 depicts that power driver for sustainable water supply in Soppeng Regency is the availability of raw water (B1). For this reason, the availability of raw water that can be utilized or processed into clean water has become an important and important element of necessity. One solution to the problem of availability of raw water that can be applied is the concept of integrated water supply systems, a concept that utilizes treated wastewater as an alternative water source (Afiatun *et al.* 2018). Nielsen *et al.* (2006) also stated that to assess the viability of the water source, several aspects relating to water quantity and quality must be considered, which can be aided by using numerical modeling tools. This includes: (1) raw water availability, particularly during low flow conditions (droughts), (2) The effects of catchment land use upon pollution generation, (3) The ambient water quality in the river or stream, and (4) The assessment methodology is described, highlighting the application of numerical modeling tools. Sub-element of the next requirement is clean water treatment technology (B2).

Water treatment technologies such as bioremediation, membrane bioreactors, and advanced oxidation processes can be of the technologies that can be developed for water supply (Oputu *et al.* 2015). Besides technology, the role of local communities (B4) and the availability of reliable human resources (B6) are also needed. Although various factors affecting the performance of water utilities have been identified, human resource management factors are indispensable in the management of water resources, such as some previous studies (see, for example, Lutz and Salazar 2012; Pineda and Briseño 2012). The need for adequate and proportional investment in raw water and clean water supply technology (B3) needs to be supported by policies (B5). Gwenzi *et al.* (2017) stated that Biochar water treatment, with excellent capacity to remove several contaminants from aqueous solutions, has several potential merits compared to existing low-cost methods (i.e., sand filtration, boiling, solar disinfection, chlorination).

The need for policies in providing clean water must pay attention to the indicators in the 2 constraint sub-elements discussed earlier, the 6 sub-elements of needs, and the formation of institutions such as water management agency (B7) as dynamic and sustainable cogs. In line with Lienert *et al.* (2015), for structured decision-making for sustainable water infrastructure planning and future scenarios, takes three pillars of sustainability and their respective attributes (indicators, benchmarks) to measure how well these goals are achieved then make strategic decision alternatives, including "business as usual" scaling up of central water supply and wastewater systems and semi- to fully decentralized alternatives. In order to deal with uncertainty in the future, socio-demographic scenarios were developed. Jacobs *et al.* (2016) established that, "There is an expectation that increased stakeholder engagement, integration of stakeholders in planning and implementation of activities, greater attention to resolving uncertainty, and focus on adaptive management will lead to more sustainable use". Furthermore, Azmanajaya *et al.* (2020) stated that there are 18 (eighteen) attributes that could affect the sustainability status of the availability of the clean water management installation (IPAB) in Soppeng need to be intervened and improved so that the IPAB sustainability index value can increase.

The Institution involved in the Clean Water Supply Program in Soppeng Regency

Another challenge in successfully developing the water infrastructure is related to the position and relations with other water resources management stakeholders. Based on the results of expert opinion, it was found one sub-element of the institution, which was a key actor as well as a power driver for the clean water supply program in Soppeng Regency is the central government. Contextual relations between sub-elements of the institution are sub-elements of the institution, which is more influential than other sub-elements of the institution.

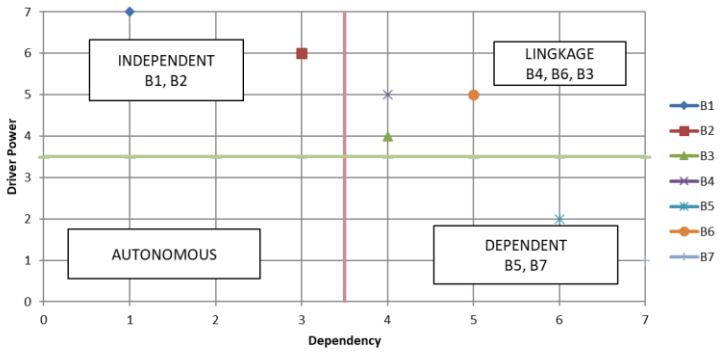

Figure 5 The driver power–dependence matrix for the institutional elements in the water supply program in Soppeng Regency

Based on the analysis as shown in Figure 5 shows that the sub-elements of the central government institutions (L1, DP value 7, D value 1) and local government (L2, DP value 6, D value 3), are located in the independent sector and provides a high contribution as the main driver of other sub-elements of the institution, any changes in these sub-elements will affect other sub-elements of the institution. The sub-elements of local society (L4, DP value 2, D value 6) and private companies (L6, DP value 2, D value 5) are in the dependent sector, this means that the existence of these two institutions is strongly influenced by other institutional sub elements. While the sub-elements of the Regional Water Supply Company (L3, DP value 2, D value 3), NGOs (L5, DP value 3, D value 3), and college/university (L7, DP value 2, D value 3), occupy the autonomous sector, this means that the three sub-elements of the institution are generally not related or have little relationship with other sub-elements of the institution.

From this analysis, the hierarchy of institutional sub-elements is obtained, as shown in Figure 6. The key institutional sub-element is the Central Government (L1) which acts as a driving force for the availability of clean water in Soppeng Regency. The next sub-element of the institution is the local government (L2). The role of the local government is no less important in managing raw water sources to become clean water which will be the responsibility of the next institution, namely the regional water supply company (L3). The level of last institutional element that influences the provision of clean water is college/university (L7), communities (L4), non-governmental organizations (L5), and private companies (L6).

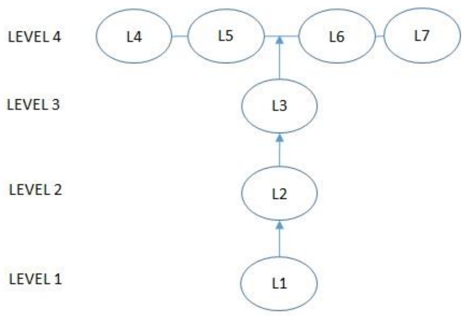

Figure 6 The hierarchy structure of the sub element institutional in the water supply program in Soppeng Regency

Figure 6 shows that the Central Government (L1) has a strong role in the availability of clean water in Soppeng Regency. This sub-element of the institution forms the basis for other sub-elements. For this reason, the role of the central government is the most influential in the supply of clean water. This is in line with OECD (2016), central governments tend to play an important role in water security policy-making and implementation. They are also heavily involved in the regulation of water services. This implies that clean water provision must develop and further strengthens a network of functional cooperation relations not only with local government offices but also with other institutions implicated in water management and regional development: the water management authority and regional environmental protection agency, regional and local development agencies, customer associations, academia (Barjoveanu *et al.* 2011). According to INDII (2017), in favor of the development of people's welfare, regions may enter into public-public and/or public-private cooperation based on the achievement of mutual benefits and efficiencies and effectiveness of public service deliveries. This cooperation can be fostered by several agencies at the level of the next sub-element (L4, L5, L6, L7). These four institutions are at the same level so it can be interpreted that the provision of clean water by the public and the private sector has the same role and potential in Soppeng Regency. While universities play a role in the development of clean water treatment technology. The presence of NGOs can play a role as social supervisors in the water supply sector. Finally, as Jacobi *et al.* (2014) stated, the institutional reforms in water governance must involve changes in the 'rules of the game', expressed by the coexistence of formal law, informal norms and practices, organizational structure, and strengthening institutional capacity.

CONCLUSION

Soppeng Regency, almost throughout the year, always faces the problem of clean water deficit for the community. One solution to dealing with clean water deficit is to know the root of the problem, such as constraints, needs, and institutional roles for the clean water supply program in Soppeng Regency. From the results of the study, there were 26 important attributes divided into 3 elements in determining the success of the clean water supply program in Soppeng Regency. Two important attributes that are the main obstacles in the provision of clean water are the lack of institutional capacity and weak institutional governance. The attribute of main need for the provision of clean water is the availability of raw water, and the attribute of the institution that plays an important role in determining the success of this clean water supply program is the central government (relevant ministry). The clean water supply program in Soppeng Regency requires the role of the district government to formulate a policy plan for the provision of raw water, while the central government's role is urgently needed in terms of providing investment for clean water facilities and infrastructure in Soppeng Regency.

ACKNOWLEDGMENTS

Acknowledgments to the Soppeng Regency Government, the Soppeng Regency Public Works Office, the Soppeng Water Supply Company, and the Soppeng Regency Bappeda, for assistance in the field and the availability of secondary data.

REFERENCES

[INDII] Indonesia Infrastructure Initiative. 2017. *Scoping Study on Development of Regional Water Supply Systems*. Jakarta: PRAKARSA. [accessed 2022 Jun 28]. https://www.neliti.com/publications/45309/asset-management-in-infrastructure-in-indonesia.

[BPS Soppeng Regency] Badan Pusat Statistik Kabupaten Soppeng. 2010. *Status Lingkungan Hidup Daerah Kabupaten Soppeng*. Soppeng: BPS Kabupaten Soppeng.

[OECD] Organisation for Economic Co-operation and Development. 2016. *Water Governance in Cities, OECD Studies on Water*. France: OECD Publishing.

Adams DC, Allen D, Borisova T, Boellstorff DE, Smolen MD, Mahler RL. 2013. The influence of water attitudes, perceptions, and learning preferences on water- conserving actions. *Natural Sciences Education*. 42(1):114–122. doi:https://doi.org/10.4195/nse.2012.0027.

Afiatun E, Notodarmojo S, Effendi AJ, Sidarto KA. 2018. Cost minimization of raw water source by integrated water supply systems (a case study for Bandung, Indonesia). *International Journal of GEOMATE*. [accessed 2022 Jul 10]; 14:32–39. https://doi.org/10.21660/2018.46.98137.

Aich S, Tripathy S. 2014. An interpretive structural model of green supply chain management in Indian computer and its peripheral industries. *International Journal of Procurement Management*. 7(3):239–256.

Attri R, Dev N, Sharma V. 2013. Interpretive structural modelling (ISM) approach: An overview. *Research Journal of Management Sciences*. 2(2):3–8.

Azmanajaya E, Paulus CA, Paranoan N. 2020. The Sustainability index of the provision of clean water treatment plants (IPAB) in supporting SDG 2030 programs for the availability and management of sustainable clean water in Soppeng Regency, South Sulawesi Province, Indonesia. *IOP Conf. Series: Journal of Physics: Conf. Series*. [accessed 2022 Jul 11]; 1464(012052):1–8. https://doi.org/10.1088/1742-6596/1464/1/012052.

Barjoveanu G, Dascalescu I, Dorus M, Teodosiu C. 2011. Institutional capacity assessment for water and wastewater management: a case-study for Iasi County, Romania. [accessed 2022 May 11]. https://www.researchgate.net/publication/275713032_Institutional_capacity_assessment_for_water_and_wastewater_management_a_case-study_for_Iasi_County_Romania.

Chatterji M, Arlosoroff S, Guha G. 2017. *Conflict Management of Water Resources*. Routledge. New York (NY): Ashgate Publishing.

Gwenzi W, Chaukura N, Noubactep C, Mukome FN. 2017. Biochar-based water treatment systems as a potential low-cost and sustainable technology for clean water provision. *Journal of Environmental Management*. 197:732–749. doi:https://doi.org/10.1016/j.jenvman.2017.03.087.

Haerunnisa H. 2014. Penggunaan eceng gondok (*Eichornia crassipes*) dalam penurunan kadar logam tembaga (Cu) pada perairan danau tempe Kabupaten Wajo. *Jurnal Galung Tropika*. 3(2):18–30.

Jacobi PR, Stefano LD, López-Gunn E, Solanes M, Delacámara G, Marín G, Embid A, Empinotti V, Blanco E, Donoso G, *et al.* 2014. Reforming water governance structures. In: Willaarts BA, Garrido A, Llamas MR, editors. *Water for Food and Wellbeing in Latin America and the Caribbean. Social and Environmental Implications for a Globalized Economy*. Oxon (NY): Routledge. p 286–315.

Jacobs K, Lebel L, Buizer J, Addams L, Matson P, McCullough E, Garden PO, Saliba G, Finan, T. 2016. Linking knowledge with action in the pursuit of sustainable water-resources management. *Proceedings of the National Academy of Sciences*. 113(17):4591–4596. doi:https://doi.org/10.1073/pnas.0813125107

Jharkharia S, Shankar R. 2005. IT- Enablement of supply chains: Understanding the barriers. *Journal of Enterprise Information Management*. 18(1):11-27. doi:https://doi.org/10.1108/17410390510571466.

Koppen BV, Hofstetter M, Nesamvuni AE, Chiluwe Q. 2020. Integrated management of multiple water sources for multiple uses: Rural communities in Limpopo Province, South Africa. *Water SA*. [accessed 2022 Jun 11]; 46(1):1–11. https://doi.org/10.17159/wsa/2020.v46.i1.7870.

Lienert J, Scholten L, Egger C, Maurer M. 2015. Structured decision-making for sustainable water infrastructure planning and four future scenarios. *EURO Journal on Decision Processes*. 3(1):107–140. doi:https://doi.org/10.1007/s40070-014-0030-0.

Loera E, Salazar A. 2017. Gestión de recursos humanos en organismos de agua de Hermosillo y Mexicali [Human resources management in the water utilities of Hermosillo and Mexicali]. *Estudios Fronterizos*, [accessed 2022 Jul 23]; 18(36):25–53. https://doi.org/10.21670/ref.2017.36.a02.

Lutz AN, Salazar A. 2012. Evolución y perfiles de eficiencia de los organismos operadores de agua en México. *Estudios Demográficos y Urbanos*. [accessed 2022 Jul 20]; 26(3):563–599. https://doi.org/10.24201/edu.v26i3.1375.

Munasinghe M. 2019. *Water Supply and Environmental Management*. New York (NY): Westview Press.

Natarajan L. 2017. Socio-spatial learning: A case study of community knowledge in participatory spatial planning. *Progress in Planning*. 111:1–23. doi:https://doi.org/10.1016/j.progress.2015.06.002.

Nielsen C, Hou FKK, Ayog J. 2006. Assessment of raw water quantity and quality for water supply. *Ingenieur*. 32:39–42.

Oputu OU, Ayanda OS, Fatoki OO, Akintayo CO, Olumayede EG, Amodu OS. 2015. Water treatment technologies: principles, applications, successes and limitations of bioremediation, membrane bioreactor and the advanced oxidation processes. Foster City: OMICS Group eBooks. https://doi.org/10.4172/978-1-63278-058-4-059.

Pfohl HC, Gallus P, Thomas D. 2011. Interpretive structural modeling of supply chain risks. *International Journal of Physical Distribution and Logistics Management*. 41(9):839–859.

Pineda N, Briseño H. 2012. ¿Por qué son mejores los organismos de agua de Baja California que los de Sonora? Instituciones locales y desempeño de los organismos públicos**.** *Región y Sociedad,* 3:181–212.

Primin O. 2018. Clean water of Russia: Problems and solutions. *IOP Conference Series: Materials Science and Engineering*. 365(022064):1–8. doi:https://doi.org/10.1088/1757-899X/365/2/022064.

Raj T, Attri R. 2011. Identification and modelling of barriers in the implementation of TQM. *International Journal of Productivity and Quality Management*. 28(2):153–179. doi:https://doi.org/10.1504/IJPQM.2011.041844.

Raj T, Shankar R, Suhaib M. 2007. An ISM approach for modeling the enablers of flexible manufacturing system: The case for India. *International Journal of Production Research*. 46(24):1–30. doi:https://doi.org/10.1080/00207540701429926.

Ratnani RD, Hartati I, Kurniasari L. 2013. Pemanfaatan eceng gondok (*eichornia crassipes*) untuk menurunkan kandungan cod (chemical oxygen demond), ph, bau, dan warna pada limbah cair tahu. Laporan Penelitian dan Pengabdian Masyarakat. Semarang: Lembaga Penelitian dan Pengabdian Masyarakat.

Ravi V, Shankar R. 2005. Analysis of interactions among the barriers of reverse logistics. *Technological Forecasting and Social Change*. 72:1011–1029. doi:https://doi.org/10.1016/j.techfore.2004.07.002.

Sage AP. 1977. *Interpretive Structural Modeling: Methodology for Large Scale Systems*. New York (NY): McGraw-Hill.

Saxena JP. 1992. Hierarchy and classification of program plan element using interpretative structural modelling. *Systems Practice*. 12(6):651–670. doi:https://doi.org/10.1007/BF01083616.

Saxena JP, Sushil, Vrat P. 2006. *Policy and Strategy Formulation: An Application of Flexible Systems Methodology*. New Delhi: GIFT Publishing.

Singh MD, Shankar R, Narain R, Agarwal A. 2003. An interpretive structural modeling of knowledge management in engineering industries. *Journal of Advances in Management Research*. 1(1):28–40. doi:https://doi.org/10.1108/97279810380000356.

Singhal D, Tripathy S, Jena SK, Nayak KK, Dash A. 2018. Interpretive structural modelling (ISM) of obstacles hindering the remanufacturing practices in India. *Procedia Manufacturing*. 20:452–457.

Sushil. 2012. Interpreting the interpretive structural model. *Global Journal of Flexible Systems Management*. 13(2):87–106. doi:10.1007/s40171-012-0008-3.

Verma A, Tripathy S, Singhal D. 2022. The significance of warehouse management in supply chain: an ISM approach. *Decision Making: Applications in Management and Engineering* [accessed 2022 Aug 19]; 5(1):1–19. https://doi.org/10.31181/dmame0321052022v.

Warfield JW. 1974. Developing interconnected matrices in structural modelling. *IEEE Transactions on Systems Men and Cybernetics*. 4(1):51–81. doi:https://doi.org/10.1109/TSMC.1974.5408524.

Zumani D, Suryaman M, Dewi SM. 2015. Pemanfaatan eceng gondok (Eichhornia crassipes (Mart.) Solms) untuk fitoremediasi kadmium (Cd) pada air tercemar. *Jurnal Siliwangi Seri Sains dan Teknologi*. 1(1): 22–31.