Diagnosing Functionality and Sustainability of Community Managed Water Supply Scheme

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Abstract

The functionality and sustainability of the water supply project is a major challenge in development in rural areas of Nepal. This study primarily focuses on water supply projects built around Dordi Rural Municipality and Sundarbazar Municipality of Lamjung district. A total of 250 water projects were studied. Data was extracted from NWASH-MIS. This research commences by analyzing various components to calculate the functionality score and assess the maintenance needs of key structures of each project. With these two derivations, the relation between these two metrics is studied. It is elaborated through different charts to effectively derive a conclusive dependency between these two components. It was found that the repair condition of an intake is not related to the functionality of a water supply scheme and there is a negative linear relation between functionality with the condition of Reservoir Tank and Collection Chamber in the scheme. Using the Inferential Statistical Analysis approach such as Spearman's rank correlation coefficient test, we were able to determine if there were a significant correlation between Institutional Capacity with the Functionality Score of schemes under study. There is a strong positive relationship between management practices and functionality ($\rho = 0.76$, $p<0.00$). The mathematical relationship between them in low-risk zone of functionality is shown through the simple linear regression model. Result shows that the scheme with lower population (less than 100) are in the higher risk of functionality. Lastly, we found that there is a moderate positive relationship between functionality and the provision of remuneration for Village Maintenance Worker in the committee ($\rho = 0.57$, p-value = $9.5e^{-24}<0.05$).

Keywords

Sustainable Development Goals, water supply services, functionality, national WASH MIS

1. INTRODUCTION

1.1 Background

Community managed water supply projects have become a must agenda in all forms of global development strategies, in the recent decades. As Nepal approaches the completion of first 40% of the SDG era, there is a dire need for a strategic re-orientation of management and maintenance of such community managed water supply projects. For this, water professional can contribute learnings and pivot from past successes and failures.

An annual Report, [1] revealed that by 2020, up to 25% of the global population lacked access to safely managed drinking water in their homes. Further, the report showed, during the covid pandemic about 30% of people couldn't wash their hands with soap and water within their homes. Thus, if current trend persists, billions of children and family will be left without WASH

services, stating that by 2030, only 81% of world's population will have access to safe drinking water at home, leaving 1.6 billion without.

The larger part of the lives deprived of functional services is in the rural area of developing countries, where most fetch water at some walking distances from their homes. Even among those water projects which are entitled as improved, a substantial number does not deliver water that is safe for drinking [2]. Accordingly, SDGs, under target 6.1 focuses universal and equitable access to safe and affordable drinking water for all [3]. Sustained functionality of water supply infrastructure is an indispensable part for achieving Universal access to safe drinking water [4].

In developing countries, Government, NGOs, INGOs, DPs and other organizations invest huge amount every year for the implementation of the water supply projects in spite of that certain number of projects fail after a short period of time. The functionality and the sustainability have been a matter of concern in a water supply projects with an increment of such an investment.

The non-functionality of water supply scheme has been a major problem in many developing countries, and this trend is particularly observed in Nepal. Functional water supply projects have been a serious challenge since decades. Coverage of water supply has more than doubled in last 30 years leading to achieving basic water supply coverage as 93% now. But the actual benefitted population grew by a mere 50%. As per the NMIP 2014, only 25% of existing water supply schemes are functioning well, 36% need major repair and more than 39% of the schemes have been pointed out seeking major repair, rehab and complete reconstruction.

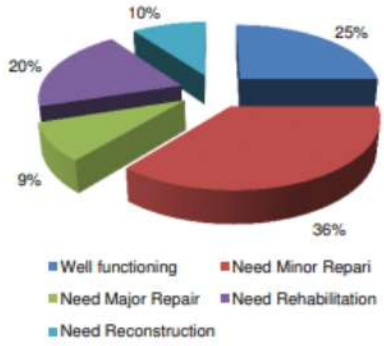

Figure 1: Functionality Status of Water Supply System

Figure 1 shows most of the infrastructures in Nepal are at a questionable state in terms of their functionality and sustainability. There is hindrance to achieve functional and sustainable use to safe water services. Poor planning and maintenance program, lack of reserve fund, absence of ownership among community members, environmental challenges have caused many water supply services to be at the high risk-zone of functionality.

When a water system is built, continued efforts are required to keep the system working. Surprisingly, however, the requirement of maintenance need in civil asset for the functionality status of WASH services have rarely been analyzed in a systematic way- a gap this study intends to fill. Government mostly focuses in coverage of water services, in order to meet national and international targets [5]. Besides, increasing the access of population to water supplies, it is also equally important to provide the needed and required maintenance to

the existing infrastructure leading to the functional services.

1.2 Rationale

The Government has always sought to increase the water supply coverage in order to meet the national and the international targets and overall, there is far too little focus on maintenance of the services. In addition to increase the population to water supplies, it is equally important to provide the needed maintenance to the existing infrastructure leading to the functional services. Every year significant amount of money is invested to build and develop these water supply projects. But, construction of new projects alone will not solve the water supply problem if the ones that are already built and deployed don't function properly. Hence, the functionality and sustainability of the water supply systems has been a matter of concern with an increment of such an investment. However, no study has ever been attempted to see if fulfillment of requirement of maintenance need in civil asset directly impacts on the functionality of service delivered. So, this study aims not only to identify the relations of repair conditions of structures with that of functionality but also recognize the importance of management practices and yard connection for functional water supply services. Moreover, it aims to relate the impact of each factor that makes the water supply infrastructure sustained over time.

1.3 Objectives

The main objective of the study is to assess the functionality of community managed water supply scheme.

The specific objectives are as follows:

- To exhibit relationship between the functionality of water supply services and the conditions of Key structures.
- To analyze the conditions of each of the key structures and assess their relative impact in determining the risk for functionality.
- To investigate the indicator of sustainability and evaluate its relationship with functionality.

2. METHODOLOGY

2.1 Study Area

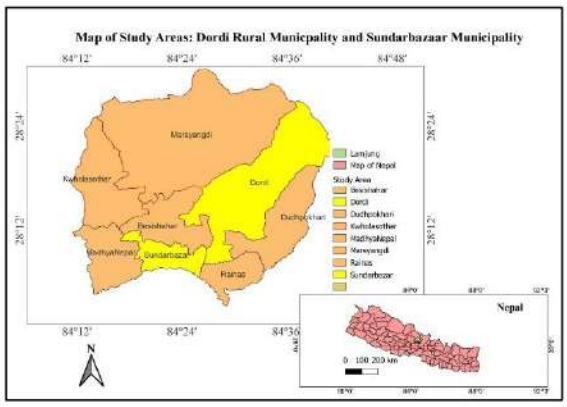

Figure 2: Location of study areas

The study was carried out in Sundarbazar Municipality and Dordi Rural Municipality of Lamjung District. Since the focus of study was to assess the functionality and sustainability of community managed water supply scheme, 250 projects were selected in order to achieve the desired objective. [6] noted that formula of having a sample of at least 100 subject is still a widespread assumption for regression analysis. Purposive sampling was used to select only gravity flow water supply projects. The Figure 2 shows the map of study area. These two paalikas,

Sundarbazar Municipality and Dordi Rural Municipality were purposively selected as it was recommended by experts.

2.2 Data Collection Method

Data Sources

This study is secondary data analysis extracted from National WASH MIS. Since the development of National WASH MIS in 2017, all data collection on water and sanitation are in line with this MIS. The survey is commissioned by Department of Water Supply and Sewerage Management and this study makes the use of data from 2018 which were collected across the country, sourcing the records from down to the ward level. It consists of lots of information regarding water supply project status, household served, physical structure, WSUC management information, maintenance cost etc. The household survey was of more than 1,000,000 households with 13,663 schemes had already been mapped.

Key informant interview

Purposive Sampling was used to select key informants. It was drawn from experts working as a consultant in DWSSM. Interview was conducted with two experts, team leader in Institutional Support and Service advisory consultant and Monitoring and Evaluation Expert to assess and ensure the reliability of data on NWASH MIS. It consisted a list of open-ended questions with semi-structured interviews which was used as it allowed the respondent to openly share their views based on their knowledge, understanding and experience. The questionnaire was based on the kind of information and the quality of data that can be extracted from NWASH-MIS to assess functionality and sustainability of water supply scheme.

2.3 Data Analysis

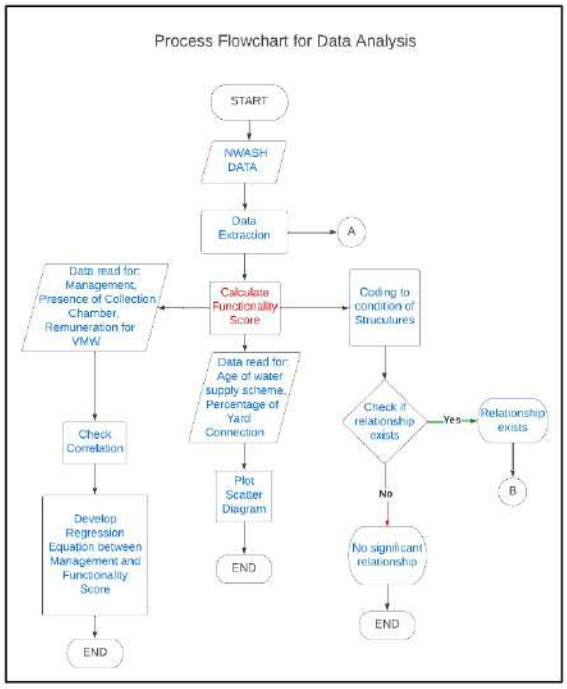

Figure 3: Data analysis flowchart

Python programming language was used for computational Data Analysis. For the purposes of this thesis, I have selected PyCharm, a popular Integrated Development Environment for Python, to model and process my research data. All the necessary data were loaded into Python (Version 3.10.5). Figure 3 shows the adopted methodology to assess the functionality of the scheme. According to the flowchart, selected features are analyzed against the functionality to obtain the desired objective.

Quantitative analysis

The total functionality score is calculated based on the functionality indicator as per Appendix C. Functionality score below 60% was considered to be in the high-risk zone of functionality and score

above 60% was considered to be in the low-risk zone of functionality.

Descriptive Statistics such as Median is used in this study. The median value of population is used as a demarcation to distinctly separate the low population water supply scheme.

To get the conclusive evidence that the distribution of data is 'normal' or 'not normal', primarily D'Agostino and Pearson's test was performed. Null hypothesis for this test is:

H_0: Sample comes from a normal distribution

Inferential Statistical Analysis such as Spearman's rank correlation coefficient test was used to measure the strength of relationship between institutional capacity and functionality of water supply scheme. The Statistical significance was then determined by calculating the p-value. A p-value of $< =0.05$ implies that the null hypothesis can be rejected. The general form of null hypothesis for Spearman correlation is as:

H_0: There is no association between two variables.

To quantify the relationship between them, regression analysis is done. The performance of simple linear regression model is analyzed in terms of R^2. The same correlation test was performed to determine the importance of collection chamber in the scheme.

The relationship between yard connection in low population water supply scheme and functionality score is analyzed through the scatter diagram. Further, one of the indicators of sustainability (provision of remuneration for VMW) was analyzed against the functionality to determine the significance of their relationship through the use of Spearman's rank correlation coefficient test.

Qualitative analysis

The indicators of functionality were derived from Monitoring and Evaluation Framework [7] and indicator-based scoring system is done, allowing for quantification of qualitative data.

Each response or observation on report was given a weight as follows:

If the response obtained were contributed positively towards that category, it was given a score of value 1. If the answer didn't contribute positively, the score is given as 0.

Two types of questions were seen in the data:

- Type I: Yes/No Questions, for example: Has Remuneration been provided for the VMW?
- Type II: Open ended questions, for example: Information on adequacy of tools for VMW

  Some of the questions involved numerical answers. For example, what is the number of VMW in the committee?

The responses were aggregated and were scored accordingly.

Conditions of Structures such as good, minor repair, major repair, reconstruction is assigned as per the data extracted from MIS in each project. Coding was then done based on the requirement of costing for structure as shown in Table 1. Tentative costing based on the maintenance need of structure was designed by the expert. For

example, Minor repair requires 15% of actual cost and hence it is coded as 0.15.

Table 1: Coding to score the condition of structure

Condition	Costing for Structure	Score
Good	0	0
Minor Repair	15% of actual cost	0.15
Major Repair	40% of actual cost	0.4
Reconstruction	100% of actual cost	1

Table 1 presents the score assigned to each condition of Key structures. The water supply project having multiple intakes with varying condition is coded by weighted average based on the discharge, RVT was coded based on its size, Collection Chamber, Distribution Chamber, Break Pressure Tank given with equal weightage.

Scatter plot was made to show the relationship of these structures against functionality. The information obtained under the Institutional capacity (Management level) were converted to scores by coding each case according to the metric shown in Table 2. Total Score of 2 is assigned to the institutional factor.

Table 2: Coding institutional factor to score the outcome condition

Institutional Efficiency	Score	Remarks
1. Provision of Operation and Maintenance Service	1	
1.1 Presence of Outsourced Maintenance Services	They are mutually exclusive.	If yes then, score =1 else if no then, go to sub-category 1.2
1.2 Number of VMWs		See Appendix B
2. Percentage of VMW who perceive adequate tools	1	See Appendix B

3. RESULTS AND DISCUSSIONS

The median of the population dataset of sample size, n = 250 projects was obtained as 97. Hence, further study is carried out by considering population less than 100 as a low population water supply scheme (small-scale projects).

The functionality scores below 60% was considered to be in the high-risk zone of functionality and score above 60% was considered to be in the low-risk zone of functionality, which was derived from M & E framework of water supply system functionality and sustainability.

3.1 Functionality with conditions of key structures

The graphical plot, Figure 4 shows that there is very less to minimum relation between the conditions of intake of these water supply scheme with the functionality. The reason for this is that there seems a significant number of projects being undertaken with high functionality score despite the condition of intake being in dire need for reconstruction.

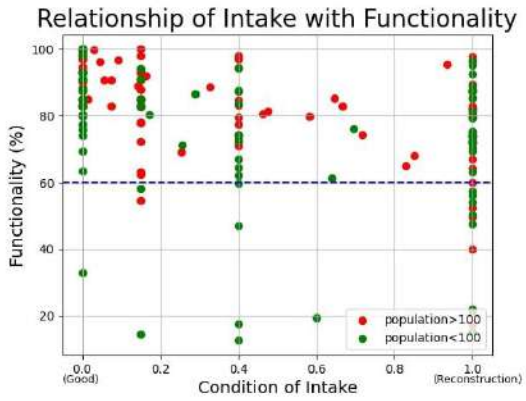

Figure 4: Relationship between repair condition of intake and functionality

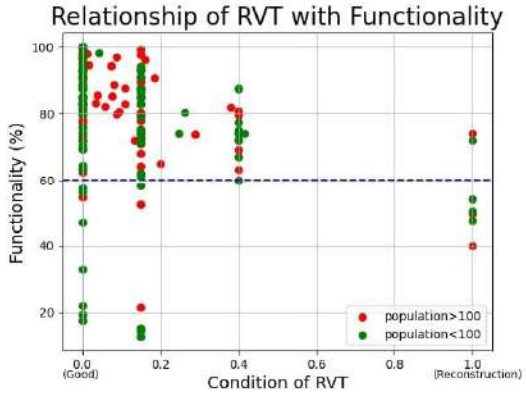

Figure 5: Relationship between condition of RVT and functionality

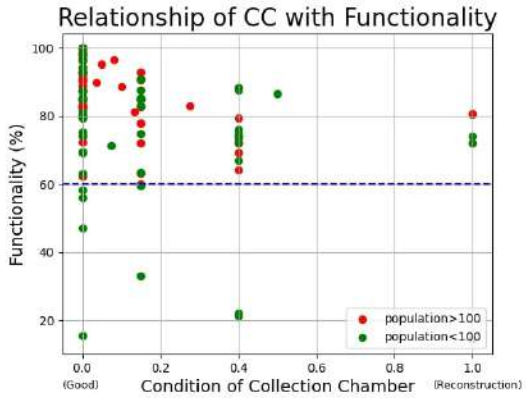

Figure 6: Relationship between condition of CC and functionality

The Figure 5 shows the relationship between conditions of RVT with functionality. In the above graph, the green dot represents water supply projects serving population of less than 100 whereas the red dots represent project serving population more than 100. Irrespective of the scale, it was found that, there is a negative linear relation between functionality and the condition of RVT. As the quantitative measure of RVT values increased, the functionality score of schemes would go down requiring some significant repair and maintenance. Further, the graph also indicates that small scale projects (scheme with population <100) are at a greater risk and also required significant repair and maintenance. The zone below functionality score of 60 percentage, separated by blue stitch line are at the higher risk of functionality.

The Figure 6 above shows the relationship between conditions of Collection Chamber and functionality of the water supply scheme. Likewise, there is also a negative linear relation between functionality and the condition of CC. As the condition of CC worsen from good to reconstruction, the functionality score of schemes would go down requiring some significant repair and maintenance. It also indicates the scheme with low population are in the higher risk of functionality.

To understand the importance of CC in the scheme, correlation between the presence of collection chamber and the functionality of water supply scheme is inspected through Spearman's rank correlation coefficient test. As per the Spearman's rank correlation coefficient result, the value of coefficient is obtained as $\rho = 0.063$. The significance test, p-value = $0.32 > 0.05$ implies that the null hypothesis can be accepted. This indicates that there is no any significant relationship between the presence of Collection

Chamber and the functionality of water supply scheme.

3.2 Functionality with age of water supply scheme

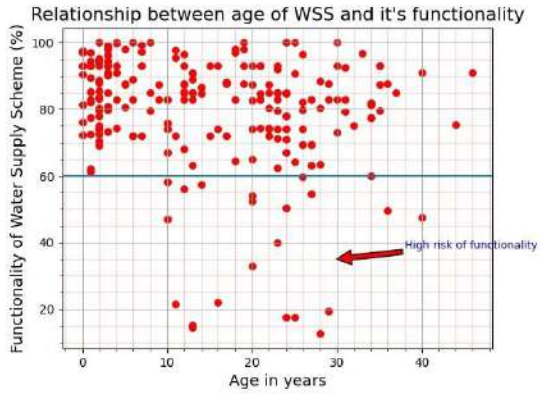

Figure 7: Relationship between age and functionality of water supply scheme

The Figure 7 represents the relationship between the age of the project (the no. of years since it was setup to the time of data collection) and its functionality score. The water supply projects whose age lied between 0 to 10 years have a functionality score of greater than 60%. This showed that majority chunk of all new projects is healthy and well functional. Further, approximately 80% of older projects, with life between 10-40 years did have a similar functionality score. The data indicates that there is a consistent regular maintenance in these projects which enabled them to retain their functionality despite their age. The graph further depicts that there are altogether 20 projects lying in the risk zone of functionality. All the projects in the risk zone comprised of population less than 200. Among them, 83% of projects don't have VMW and provision of water tariff collection. Two projects are completely non-functional and households are benefitting from the neighboring water supply scheme. 84% of them hold structure which are in dire need for significant repair and maintenance.

3.3 Functionality with institutional capacity

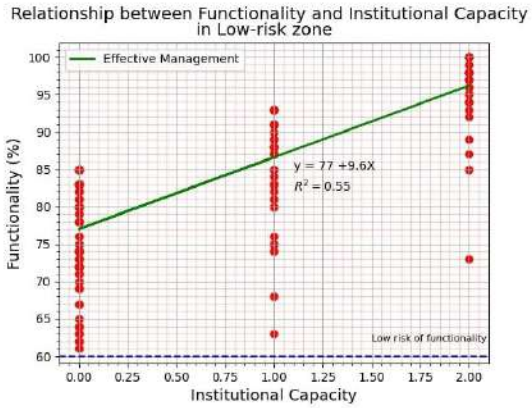

Figure 8: Relationship between functionality and institutional capacity

Based on D'Agostino and Pearson's test on institutional capacity, the result thus obtained have the p-value = $1.64e^{-26} < \alpha$ (0.05). It suggests that the variable is not normally distributed. Hence, non- parametric statistics test is used. For detecting correlation, Spearman's rank correlation coefficient is applied.

According to the Spearman's rank correlation coefficient result, the value of coefficient is obtained as $\rho = 0.76$. The significance test, p-value = $3.89e^{-23} < 0.05$ implies that the null hypothesis can be rejected. This means that there is a strong, positive, monotonic correlation between the Functionality and the Institutional capacity (management level).

To understand the functionality in terms of institutional capacity, the management practices and the functionality of scheme in low-risk zone were analyzed through the regression line.

The Figure 8 shows the regression line plotted between functionality and institutional management capacity of projects in the low-risk zone. The regression analysis shows the mathematical relationship between two variables. The result shows that 55% of variability in functionality score is explained by the model. It implies that with good management practices, there is a chance of decrease in risk of functionality.

3.4 Functionality with yard connection

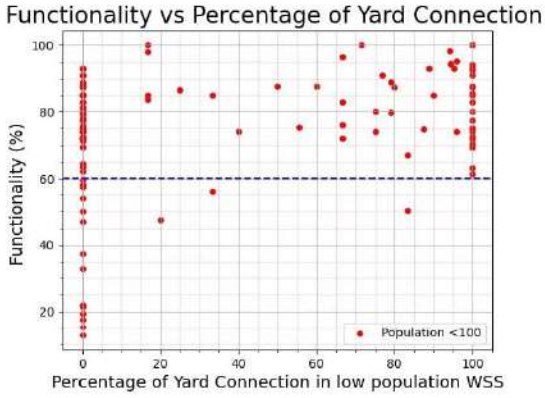

Figure 9: Relationship between functionality and yard collection

Figure 9 shows the scatter diagram of functionality with the percentage of yard connection in low population water supply scheme. Though the scatter diagram doesn't fully agree on the premise that the presence of yard connection increases the functionality, majority of water facilities on the plot do provide some confidence that increase in functionality score is likely associated with increase in yard connection. The graphical plot also shows that schemes owning fully connected yard (100%) have functionality score greater than 60 percentage. Further, the plot also exhibits that even in non-yard connection, 53 projects have functionality score greater than 60 percentage. The main reason behind such a good score in functionality with non-yard connection is that they have maximum of six numbers of connection of community taps (in one entire scheme) and as per collected data, most of them are supplying adequate quantity of water resulting 100% functional taps which is serving total population and the water is available throughout the year at the source which eventually leads to increase in functionality score.

3.5 Functionality and the presence of remuneration for VMW

The provision of remuneration for VMW falls under the financial factors of Sustainability. To check whether providing remuneration for VMW affects the functionality of water supply scheme, Spearman's rank correlation coefficient is applied. the value of coefficient obtained from this test is $\rho = 0.57$. The significance test, p-value $= 9.5e^{-24} < 0.05$ implies that null hypothesis can be rejected. It suggests that there is moderate, positive correlation between functionality and remuneration for VMW.

4. DISCUSSION

The study investigated the repair condition of key structures and compared its relationship with the functionality of scheme. The study focused on gravity flow water supply projects around Dordi Rural Municipality and Sudarbazar Municipality of Lamjung District. The data required for this research was extracted from NWASH MIS and further analyzed using statistical test. Mathematical modelling and computation were carried out using Python programming language on PyCharm.

It was found that the repair condition of an intake is not related to the functionality of a water supply scheme. The quantitative measure of conditions of RVT and CC were negatively related to the functionality implying that the functionality of any water supply scheme would decrease as the condition worsens from good to reconstruction. For instance, any damage or a leakage around RVT and CC impacts the functionality of the water supply scheme. It is in line with the previous study that there is an urgent need for improvements to water supplies services by users committee themselves through preventive maintenance.

Further, this study found that there is no any significant correlation between the presence of Collection Chamber with the functionality of the scheme. But, if a water supply scheme were to contain a Collection Chamber as a component in the built, lack of its timely maintenance would negatively impact the functionality of the scheme. This was more evident when we analyzed data from schemes with CC on them.

Improving on the managerial capacity of any water supply scheme plays an important role in the functionality of project. The results of this study strongly support this premise. At some instances, it was found that the management of a scheme had a greater role in determining the functionality of the scheme rather than its technical design. Figure 7 in this report shows a significant number of project older than 10 years with functionality score above 60. This finding does not warrant the idea that each water supply scheme with high functionality score has to have a good management. Many new schemes, due to their age, have a high functionality score. However, this study found a strong, positive and monotonic correlation between Institutional Management Practices and the functionality of the scheme. [8] mentioned that where VMW is absent in the committee, there is a long breakdown period. Analysis by [4] on their study revealed that the pathways leading to sustained functionality and use of water supply system are effective participation of community and good financial management system. This gives the idea that capacity of institution has a direct impact on the functionality of the scheme.

Further, the study found that a majority of small scale (population less than 100) water supply schemes in these two municipalities had a lower score of functionalities (less than 60 percentile). This could be due to lack of strong financial backbone for the scheme. Most of these projects run on monthly usage subscription (Tariff). On larger scale project, the consumption, and the payment for the same, provide sufficient financial flow for the schemes to carry out regular maintenances. The case is not be the same for these small-scale projects. The scale of operation, and the number of consumers that the scheme is currently providing for, coupled with regular issues of non-payment and/or payment defaults by its users provides enough challenges for a sound financial means of the scheme. Poor financial means result in untimely and/or delayed maintenance (VMW or outsourced). Some previous studies also agree that financing strategy is important to run the operations smoothly.

In addition to this, this study also shows that the majority of scheme lying in low-risk zone of functionality has yard connection. Provision of each tap connected to each house would make the convenience in water accessibility. There would be no conflict in regard to the availability of water. This could be explained by individual ownership and responsibility for one's own water point and willingness to pay for maintaining the infrastructure. Some previous findings also suggested that private tap may motivate more individual to take active role in management.

Eventually, provision of remuneration for VMW was analyzed against functionality. This analysis shows that there is a positive, moderate association between them. Payment for operation and maintenance is significantly related to improving the functionality of the scheme. This indicates that the presence of O & M fund allocated from the committee is critical for functionality of water supply systems. Some previous srudies show that voluntary labor is not sustainable in long term and hence, trained maintenance worker should be appointed for repair works accompanying them with payment for their service.

5. CONCLUSION AND RECOMMENDATIONS

Meeting the universal access to safe drinking water by 2030 requires the understanding of realization of the importance of functionality and sustainability of water supply scheme. As RVT and CC are negatively correlated with the functionality, it emphasizes the need of frequent preventive maintenance. There should be clarity in roles and responsibilities of the community with regard to the operation and maintenance of water supply scheme. Managerial capacity played the determining role in changing the functionality score rather than the technical factors like age of water facilities. It indicates the need of effective participation from the community for better management. To run the operation smoothly in community-based management model, small scale projects should be merged to survive against financial challenges. Low population water supply scheme is in the greater risk of functionality. As majority of small-scale projects are struggling with their financial sustainability, in this context, a more plausible solution for reducing the risk of functionality seems to be merging such small projects with the large one for effective management. Enhancing the merger model will decrease the load of finance among the community members making them at ease to pay their monthly subscription fee for the service received. The voluntary labor is not sustainable in long term and hence, trained maintenance worker should be appointed for repair works accompanying them with payment for their service. Further, one-house-one-tap campaign is also playing a major role for functional services, which needs to be implemented effectively. This form of analysis with a quantitative measure a hand would play an instrumental role in planning, executing and maintaining water supply projects from the governance level.

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