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Understanding Local Perspectives on Micro Hydropower Management in Galkot Municipality, Nepal: A Structural Equation Modeling Approach

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Abstract

This study examines the factors influencing local participation in micro hydropower (MHP) management in Galkot Municipality, Nepal, focusing on perceived benefits, knowledge, and attitudes. A quantitative research design was employed, collecting data from 285 MHP users in Ward No. 8 of Galkot Municipality through structured questionnaires. Structural Equation Modeling (SEM) was used to analyze the relationships between participatory behavior and key determinants, including perceived benefits, knowledge, and attitudes. The findings reveal a positive correlation between knowledge and participatory behavior ($\beta = 0.42$, $p < 0.05$), with informed communities more engaged in MHP governance and maintenance. Perceived benefits, such as economic diversification and energy security, also significantly influence participation ($\beta = 0.41$, $p < 0.05$). However, over 50% of respondents reported a lack of technical expertise, highlighting a critical gap in local capacity. The study emphasizes the need for systematic training programs and the establishment of local maintenance hubs to ensure MHP sustainability. Despite positive outcomes, 98.95% of respondents faced management challenges, with technical skills and government support identified as key areas for improvement. The study suggests that decentralized governance, technical skill development, and better coordination between stakeholders can enhance MHP system reliability. Additionally, the findings underscore the importance of economic necessity and service reliability in driving community involvement, rather than abstract environmental attitudes. Policy recommendations include strengthening local technical training, improving government incentives for MHP-based businesses, and establishing local repair networks. This study provides a valuable framework for optimizing MHP as a sustainable energy solution aligned with SDG 7.

Keywords: *Micro Hydropower, Community Participation, Renewable Energy, Rural Electrification, Nepal, Sustainable Development*

1. Introduction

Nepal, a landlocked and mountainous country in South Asia (Devkota et al., 2018; 2021) with a population nearing 30 million, is endowed with vast hydropower potential - estimated at over 50,000 MW (Louis et al., 2016). However, despite this resource abundance, the country remains one of the lowest per capita energy consumers in the world (Saeed et al., 2021). More than 80% of Nepal's population resides in rural areas, where access to modern energy remains inadequate.

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In these areas, household energy consumption is still dominated by traditional biomass sources such as firewood, agricultural residues, and animal waste, which contribute to deforestation, indoor air pollution, and adverse health and environmental outcomes (Upadhayay, 2009; Balbi et al., 2021). Nepal's complex topography-ranging from the Terai plains to the high Himalayas-presents significant logistical barriers for centralized energy infrastructure expansion (Kyriazis et al., 2013). The country's dependence on imported petroleum products for its urban and transportation energy needs further exacerbates its trade deficit and economic vulnerabilities (Ogino et al., 2019). In this context, decentralized renewable energy systems, particularly micro-hydropower (MHP) plants-typically producing less than 100 kW-have emerged as a promising solution for rural electrification and energy access (Rodríguez-Ardura & Meseguer-Artola, 2020).

Nepal's journey with micro- and small-scale hydropower dates back to the 1960s, with development gaining momentum during the oil crises of the 1970s and institutional consolidation in the 1980s (Louis et al., 2016). Initially supported through international aid and government initiatives, MHP systems were implemented primarily in remote and underserved regions, especially in the Mid- and Far-Western hills. These efforts significantly contributed to rural development, demonstrating that MHP can be a cost-effective and context-appropriate solution for energy access in geographically isolated communities (World Energy Council, 2001; Murni, 2014). Yet, despite these successes, challenges persist. Many MHP systems suffer from technical shortcomings, including limited local capacity for maintenance, scarcity of spare parts, and operational inefficiencies (Poudel et al., 2020). Financial barriers-such as high upfront investment and limited access to credit-further threaten their long-term sustainability. Additionally, governance-related issues, such as fragmented institutional coordination and ambiguous policy guidelines, complicate effective management of these decentralized systems (Ghale et al., 2000).

So far numbers of studies has been conducted in the context of micro-hdropower related issues in Nepal. Micro-hydropower (MHP) in Nepal has emerged as a vital solution for rural electrification. In their study Gurung et al. (2011) and Joshi (2024) mentioned that micro-hydropower is playing a crucial role in enhancing the socio-economic status of remote communities (Gurung et al., 2011; Joshi, 2024). Despite its promise, long-term sustainability remains a significant challenge due to various technical, financial, institutional, and social factors. Butchers et al. (2021) emphasize the complexity of MHP sustainability, noting that weaknesses such as poor construction quality, inadequate operator retention, and insufficient quality control throughout the project cycle can hinder operational success. Similarly, Butchers et al. (2020) found that reliability, financial viability, and strong community engagement are critical to sustaining MHPs. Bhandari et al. (2018) contributed by developing a comprehensive sustainability assessment model, incorporating 54 indicators across economic, social, environmental, and technical dimensions, demonstrating that site-specific and stakeholder-informed models improve project feasibility evaluations. Poudel et al. (2021) further underline the importance of participatory design, sufficient system capacity, and post-installation support. Butchers et al. (2022) addressed the absence of transparent costing data by presenting cost estimation tools for locally manufactured MHP equipment, enabling more accurate financial planning. Baral et al. (2012) identified policy and institutional fragmentation as a barrier to effective grid integration, calling for reforms to promote private investment and decentralization. Case studies like Barpak (Ghale et al., 2020) highlight the untapped potential of MHP, while Joshi (2024) and Gurung et al. (2011) reinforce its broader development benefits, including poverty alleviation, improved livelihoods, and reduced reliance on traditional fuels.

Studies clearly identified that a critical factor influencing the success of MHP systems is community participation. Unlike large-scale hydropower projects governed by centralized authorities or private investors, MHP projects often rely on local user committees for operation and maintenance. However, effective participatory governance is often undermined by low technical literacy, limited awareness of benefits, and weak institutional support. Consequently, even well-intentioned MHP projects frequently underperform due to insufficient local engagement (Firouzbakht et al., 2021; Kursan Milaković, 2021). To address this gap, recent studies have turned to behavioral frameworks such as the Theory of Planned Behavior (TPB), Social Cognitive Theory (SCT), and the Theory of Reasoned Action (TRA), which highlight how individual attitudes, perceived benefits, knowledge, and social norms shape participatory behaviors in community energy initiatives (Conner et al., 2002; Gao et al., 2021). However, empirical evidence from rural settings such as Nepal remains limited. Most existing research has emphasized the technical and economic dimensions of MHP, often overlooking the behavioral and institutional factors critical to sustainability.

This study contributes to the literature by examining how individual perceptions-specifically perceived benefits, technical knowledge, and environmental attitudes-influence participation in MHP governance in Nepal's Galkot Municipality. Drawing on survey data from 285 users and employing Structural Equation Modeling (SEM), the study investigates the behavioral underpinnings of decentralized energy governance. It further identifies key institutional and policy barriers that hinder long-term sustainability. By situating the analysis within the broader goals of Sustainable Development Goal 7 - ensuring access to affordable, reliable, sustainable, and modern energy for all-this research offers practical insights for policymakers, energy practitioners, and development partners. The findings are not only relevant for Nepal but also offer broader lessons for other countries where rural electrification efforts rely on community-managed renewable energy systems.

The remaining sections are organized as follows: Section 2 presents a literature review highlighting key studies on micro-hydropower and community participation. Section 3 outlines the research methods, including data collection and the use of Structural Equation Modeling (SEM). Section 4 reports the results derived from SEM analysis. Section 5 provides a detailed discussion of the findings in relation to existing literature. Finally, Section 6 concludes the study, summarizing key insights and offering practical policy recommendations for improving MHP sustainability.

2. Literature Review

2.1. Micro Hydropower and Rural Development

Micro hydropower plants play a vital role in providing energy to rural communities worldwide. These systems directly benefit local populations, but their long-term performance remains a concern due to operational challenges that arise without proper sustainability assessments (Butchers et al., 2020). Available literature highlight the importance of financial viability, technical reliability, and community participation in ensuring project success. In Nepal, Butchers et al. (2020) used a combination of quantitative and qualitative methods to analyze micro hydropower sustainability. Their findings revealed that interactions between financial stability, technical security, and community engagement evolve over time, with some plants producing irreversible effects. The study emphasized the need for proper maintenance, though technical issues often originated from design and installation phases.

In Malaysia, Soon et al. (2019) examined hybrid energy systems combining micro hydropower with solar PV, diesel generators, and energy storage. Their results showed cost-effective electricity generation (RM0.519/kWh) with reduced diesel dependency. However, rural electrification faces challenges such as high grid expansion costs (RM2.7 million/km) and weak policy frameworks. Similarly, Erinofiardi et al. (2017) identified Indonesia's micro hydropower potential as a clean and affordable energy source but noted institutional and technical barriers to large-scale adoption. Sedhai (2013) highlighted Nepal's reliance on micro hydropower due to its mountainous terrain, where financing schemes help mitigate high initial investment costs.

Table 1: Micro Hydropower and Rural Development

Author (Year), Location	**Key Findings**	**Recommendation**
Butchers et al. (2020), Nepal	Financial, technical and community factors interact to affect sustainability	Address early technical issues; focus on reliability and community management
Soon et al. (2019), Malaysia	Hybrid systems reduce costs (COE: RM0.519/kWh)	Integrated rural solutions needed; policy improvements required
Erinofiardi et al. (2017), Indonesia	Micro-hydro preferable to large hydro; high potential	Address development barriers to increase renewable share
Sedhai (2013), Nepal	Viable despite high initial costs; financing helps	Strategic solution for remote electrification

2.2. Participatory Behavior in Micro Hydropower Development

The concept of global competition, technological changes and developments, communication, environmental issues etc. are becoming increasingly common in everyday life in our society today with the acceleration of globalization. Community participation is critical for the success of micro hydropower projects. Saha and Idsø (2016) applied the Theory of Planned Behavior (TPB) and Motivation-Opportunity-Ability (MOA) model to study Norwegian municipalities' involvement in hydropower development. Key barriers included limited participation opportunities, threats to cultural heritage, and environmental concerns. Mohammad and Farjana (2018) linked participatory approaches to democratic governance, emphasizing equity and local empowerment. In Switzerland, Tabi and Wüstenhagen (2017) found that social acceptance of hydropower projects depended on procedural fairness and equitable benefit distribution. Meanwhile, Maran et al. (2014) highlighted the impact of climate change on hydropower viability, stressing the need for adaptive management strategies.

Table 2: Participative Behavior in Micro Hydropower

Author (Year), Location	Key Findings	Recommendation
Saha & Idsø (2016), Norway	Municipal participation affected by benefits, attitudes, opportunities	Need participation frameworks addressing cultural/water impacts
Mohammad & Farjana (2018)	Participation rooted in democratic principles	Empowerment and equality crucial for development
Tabi & Wüstenhagen (2017), Switzerland	Justice dimensions critical for acceptance	Ensure procedural and distributional justice
Maran et al. (2014)	Climate change affects hydropower viability	Improve retention capacities; model climate impacts

2.3. Opportunities and Challenges in Micro Hydropower Management

The adoption and implementation of micro hydropower systems vary significantly across different regions, influenced by a range of economic, environmental, and policy factors. In Asia, particularly in the Himalayan countries, Hussain et al. (2019) identified multiple challenges-economic, social, and environmental-that hinder the widespread use of micro hydropower. Nonetheless, the study affirmed the sector's critical role in achieving renewable energy targets across the region. In Africa, the experience of Rwanda serves as a notable example. Geoffrey et al. (2018) reported a rapid expansion of small hydropower projects, largely driven by government incentives. However, this growth has been tempered by a shortage of technical expertise, limiting the effective operation and sustainability of these systems. In China, strong policy backing for renewable energy, including micro hydropower, has played a significant role in advancing sustainable development, as noted by Peidong et al. (2009). Similarly, in Laos, Jusi (2011) underscored the importance of managing hydropower resources sustainably, highlighting the delicate balance between promoting economic growth and ensuring environmental protection. In the context of Nepal, Gurung et al. (2013) found that, despite notable government efforts, the implementation of rural micro hydropower systems has been sluggish. Financial limitations and technical constraints continue to impede the effective rollout and maintenance of these initiatives. Collectively, these regional experiences illustrate both the potential and the complexities involved in the management of micro hydropower systems, emphasizing the need for context-specific strategies that address local challenges while leveraging existing opportunities.

Table 3: Opportunities and Challenges

Author (Year), Location	Key Findings	Recommendation
Hussain et al. (2019), Asia	Vital for renewables despite challenges	Develop SDG7-compliant projects
Geoffrey et al. (2018), Africa	Rapid growth (65% 2007-2017); Rwanda example	Invest in technical capacity building
Peidong et al. (2009), China	Strong policy support drives growth	Integrated strategy with legislation needed
Jusi (2011), Laos	Must balance development and sustainability	Improve coordination and capacity building
Gurung et al. (2013), Nepal	Slow progress despite policies	More effective RET implementation needed

2.4. Micro Hydropower Management Mechanisms

One of the best sources of renewables is electricity supply for hilly and rural areas, with hydroelectric micro hydropower stations. Effective management of micro hydropower systems necessitates overcoming a range of technical, financial, and policy-related barriers that differ across national contexts. In India, Luthra et al. (2015) identified several key obstacles to the broader adoption of renewable energy technologies, including limited access to financial resources, inadequate market awareness, and unstable policy environments. These challenges hinder the scaling and sustainability of micro hydropower initiatives. In Bangladesh, Razan et al. (2012) examined the potential of off-grid hydropower systems and emphasized their critical role in addressing persistent energy shortages, particularly in remote and underserved regions. The study highlighted how micro hydropower can provide a practical and decentralized solution to rural energy access. In the case of Nepal, Butchers et al. (2020) emphasized the urgent need for technical training and capacity-building programs to enhance the reliability and performance of micro hydropower plants. However, Upadhayay (2009) offered a more critical perspective, arguing that many micro hydropower projects in Nepal are often short-term interventions lacking long-term sustainability. These insights collectively underscore the importance of integrated strategies that address technical shortcomings, secure financial investments, and establish consistent policy frameworks to ensure the effectiveness and longevity of micro hydropower systems.

Table 4: Management Mechanisms

Author (Year), Location	Key Findings	Recommendation
Luthra et al. (2015), India	Multiple barriers to adoption	Sensitivity analysis; focus on renewables potential
Razan et al. (2012), Bangladesh	Significant river-based potential	Develop through proper site studies
Butchers et al. (2020), Nepal	Training exists but quality varies	Improve service standards and reliability
Upadhayay (2009), Nepal	Temporary but effective solutions	Consider more sustainable long-term approaches

From the literature review, it is clear that micro hydropower presents a viable solution for rural electrification but requires robust management, community engagement, and supportive policies to overcome regional challenges. Future research should focus on improving sustainability assessments, enhancing participatory approaches, and addressing technical and financial barriers to ensure long-term success.

3. **Methodology**

3.1. Conceptual Framework and Hypothesis

This study builds a conceptual framework grounded in behavioral theories to investigate the determinants of municipal participation in the management and development of micro-hydropower projects (MHPs) in Galkot Municipality, Nepal. Drawing upon the Theory of Planned Behavior (Conner et al., 2002), Theory of Reasoned Action (Gao et al., 2021), Social Cognitive Theory (Kursan Milaković, 2021), and Behavioral Theory (Firouzbakht et al., 2021), the framework integrates psychological, cognitive, and contextual elements that shape participatory intentions and actions. The framework (as shown in Figure 1) is further refined using the MOA (Motivation-Opportunity-Ability) model, in which motivation reflects perceived benefits, ability is operationalized through knowledge, and opportunity is conceptualized through enabling institutional attitudes. The outcome construct, Participatory Behavior (PARB), refers to the extent to which municipalities actively engage in planning, decision-making, and implementation of MHPs. The conceptual model adapted from Saha & Idsø (2016) and tailored for this study, proposes three key independent variables: Knowledge (KN), Attitude (ATT), and Perceived Benefit (PB), each hypothesized to positively influence municipal participation in MHP management.

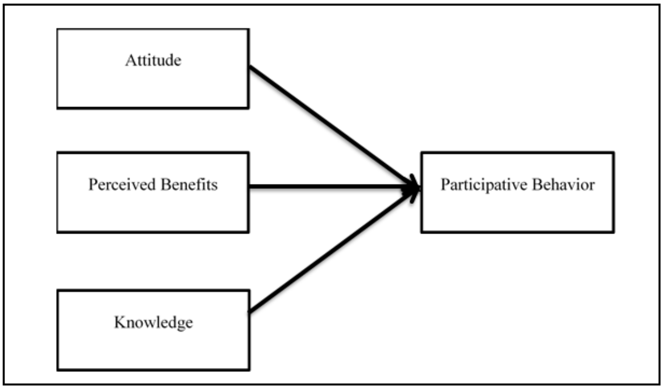

Figure 1: Conceptual Framework

Source: Modified from Saha & Idsø (2016)

Participatory behavior (PARB): The perceived benefits are relevant for local communities and are vital in motivating local municipalities to participate in determining their participatory behavior. Relevant benefits for the municipality of tourists have been identified as a key factor for the participating motivation and have been identified as an essential determinant in the choice of participation in the participation of MHPs management (Kim & Bang, 2021).

Knowledge (KN): Sensitivity, experience, knowledge, skills and the ability to access information all contribute to the ability of the actor to participate. Four items related to knowledge. In order to determine ability, two aspects were selected after previous research awareness and knowledge. In this study, the ability of municipalities to know and to become aware of new hydropower developments was measured (Kim & Bang, 2021).

H_1: The participative conduct of municipalities in the development of new hydropower is positively related to the capacity of municipalities to participate: the higher its capacity and participation.

Attitude (Att): The project seeks to determine the participation and attitudes of the municipalities in the development of new hydropower plants and potential challenges for further development in Norway.

H_2: Attitude directly affects the participation of municipalities in the management of hydropower.

Perceived Benefit (PB): In order to statistically test whether the independent variables The perceived benefit (PB) are in a positive direct relationship with the Dependent Variable Municipalities, regression analyzes were carried out (Att), the ability(Aw,Kn) and the opportunity(Opp) (Koivisto & Hamari, 2014).

H_3: Participation of municipalities in the development of new hydropower is positively affected by the perceived benefits of new development; the larger their perceived advantage, the greater their participation.

Variable construct

The variables for the study is adopted from Rasool et al. (2015)analyze and explore the status of different solutions presented for management of electricity throughout the world and determine requirements for the development of a new electricity management system. We apply standard systematic review method with the manual search of three digital libraries. Out of 74 primary studies, 27 studies are software contributions, 13 studies are hardware solutions, 18 studies represent the theoretical work and 16 studies contribute proposed ideas. The quality of the contributions is fair as 74 articles out of 209 were selected as candidate studies after manual peer review. Currently, the solutions presented by different researchers are limited in scope. Many researchers are working on tool contributions, but most of them are only providing solutions for specific regions and communities. There is a need to develop a generic Electricity Management System (EMS, the detail description of the determined variables defined in the table 5.

Table 5: Variable Construct

Construct	**Observed Variables**	**Variable Notations**	**Descriptive**
Perceived Benefit (PB)	Diversifies	PB1	Diversifies in the economy
	New Market	PB3	Creation of new market
	Advantages	PB5	Greater advantage of hydropower construction
Attitude (Att)	Combat	Att2	Combating climate change through hydropower
	Modernizing	Att3	Modernizing older small power plants generates plenty of energy
	Consequences	Att4	Threat to the cultural heritage by hydropower construction
	Fish Fauna	Att5	Effects on the Fish Fauna by hydropower project
	Impact	Att6	Recreational opportunities and tourism business will be impacted

Knowledge (KN)	Understanding	KN1	Knowledge about hydropower development
	Impact	KN3	Knowledge about the impact of hydropower development
	Knowledge	KN5	We have knowledge about electricity
Participative behavior (PARB)	Contribution	PARB1	Contribution to hydropower planting planning programs
	Assistance/ Resources	PARB3	It is help from people to develop new hydropower
	Meet with Developers	PARB5	It is a way of discussions with people about micro hydropower issues.

Study Area, Population and Sample Size

Explanatory research design is used to have the cause-and-effect relationship of the variables used for the study. Baglung is surrounded by the districts of Parbat, Myagdi, Rukum, Rolpa, Pyuthan, and Gulmi (Policy, 2021) which is divided into 59 Village Development Committees and one Municipality. Baglung is known as the "District of Suspension Bridges" because of its numerous suspension bridges. Galkot Municipality was formed from the villages of Dudhilabhati, Narethanti, Hatiya, Harichaur, Malm, Kandewas, Pandavakhani, and Righa in Savik with 11 Wards and 8 Village Development Committees. People of various castes, castes, languages, religions, and cultures live in the city, including Khas (Brahmin, Chhetri, Thakuri), Janajati (Magar, Newar) minorities, Dalits, and Muslims. Kandebash is the one of ward from 11 wards where four tole are included. These survey conducts in Galkot municipality ward no 8 which consist 2532 populations and 539 household (Mattingly, 2021). Using the probability sampling technique, a total of 285 respondents were chosen from the different village of Galkot municipality ward no.8.

Instruments, Procedure of Data Collection and Data Analysis

The main research instrument used in this study was structured questionnaire. The interview was conducted among the consumers of micro-hydro power of Galkot, Baglung, and Quantitative data was extracted through the interview the questionnaires are generated through the Kobo toolbox. From the questionnaire survey primary data have been collected. The researchers have developed the questionnaire according to the objective of the study. the collection if survey start in April 10 and end in June 25. Moreover, the techniques used in data analysis are descriptive analysis and inferential analysis. Descriptive statistics used for the study are mean, maximum and minimum values whereas software tools used for the inferential statistics are; SPSS, AMOS and Microsoft Excel were used for data entry. Factor analysis is done through SEM.

4. Result

4.1 Socio demographic Profile of the Respondents

Socio- demographic deals with the characteristics that presented visitors' sex, age, marital status, education level, occupation, and monthly income. Table 6 reveals the individual characteristics of Consumers of micro hydropower electricity users of Galkot municipality Ward No 8.

Table 6: Socio Demographic Characteristics

Variable	Category	Frequency	Percentage
Sex	Male	180	63
	Female	105	37
Age	Below 25	43	15
	26-40	104	36.49
	41-55	77	27
	56-70	46	16
	Above70	9	3
Marital Status	Single	40	14
	Married	228	80
	Divorced	3	1
	Widowed	14	5
Education level	Below SLC/SEE	60	21
	SLC/SEE	74	26
	10+2	54	19
	Bachelors and Above	57	20
Occupation	Farmer	134	49.12
	Student	35	12.28
	Business	49	17.19
	Teacher	14	4.91
	Private Employee	38	13.33
	Government Job	9	3.15
Monthly Incomes in Rs.	Below 10000	157	55
	10000-20000	57	20
	20000-30000	46	16
	30000-40000	17	6
	Above 40000	9	3

4.2 General Knowledge on Micro Hydropower Community Electrification

The observation on general knowledge about micro hydropower community electrification reveals that all the respondents are micro hydropower users which shows that the monthly consumption of micro hydropower in unit. Our study found 146 respondents consume less than 15 units in a month, 113 respondents consume 15 to 30 units, 10 respondents consume 30 to 45 units, 7 respondents consume 45 to 60 units, and only 9 respondents consume more than 60 units. Because the minimum unit of consumption is between 10 and 15, the majority of respondents consume only the minimum unit. (Adhikari et al., 2014) found that the average household consumption of electricity is 25.5 units in the peak section, ranging from 15 to 40 units. However, in the off-section, households/business firms consumed between 10 and 25 units on average, with an average of 16.5 units. In general, total average electricity consumption ranges from 12.5 units to 32.5 units, with households/business firms consuming an average of 42 units. The majority of survey respondents agreed that using micro hydropower increases family income. By inspecting the responses, respondents revealed that 90.88% used the electricity 8 to 10 hour per day, 5.26% consumed electricity more than 10 hour per day, and near 4% used electricity 4 to 8 hours per day. From the observation researcher analyzed that maximum user of micro hydropower paid only minimum unit of fee per months. The minimum fee of per month is Rs. 80 and Rs.

4.3 Micro Hydropower Management - Challenges and Managerial Solution

Responses were asked whether they have or faced challenges in the development and management of micro hydropower in Galkot Municipality, Baglung District. A substantial 98.95% of respondents acknowledged issues in micro hydropower management, with key challenges being: lack of regular training for local users (59.69%), insufficient technical expertise within rural communities (53.68%), and inadequate government support (33.68%). Political instability (2.81%) and other minor issues (5.86%) were also mentioned but were perceived as less impactful. These findings reveal that while micro hydropower presents a promising renewable energy solution for rural Nepal, its sustainability is threatened by critical institutional and capacity-related gaps. The absence of continuous training and skilled personnel reflects a systemic weakness in enabling local ownership and technical independence for long-term system operation and maintenance. Additionally, Nepal's rugged terrain and limited financial resources further constrain the sector, increasing installation costs and hindering infrastructure expansion. Although most respondents (88%) noted that these challenges occur infrequently, their impact is often severe-likely stemming from sporadic maintenance and unexpected technical failures. This pattern underscores that while systems may remain functional under normal conditions, their long-term reliability is compromised due to weak support mechanisms and inadequate resilience planning.

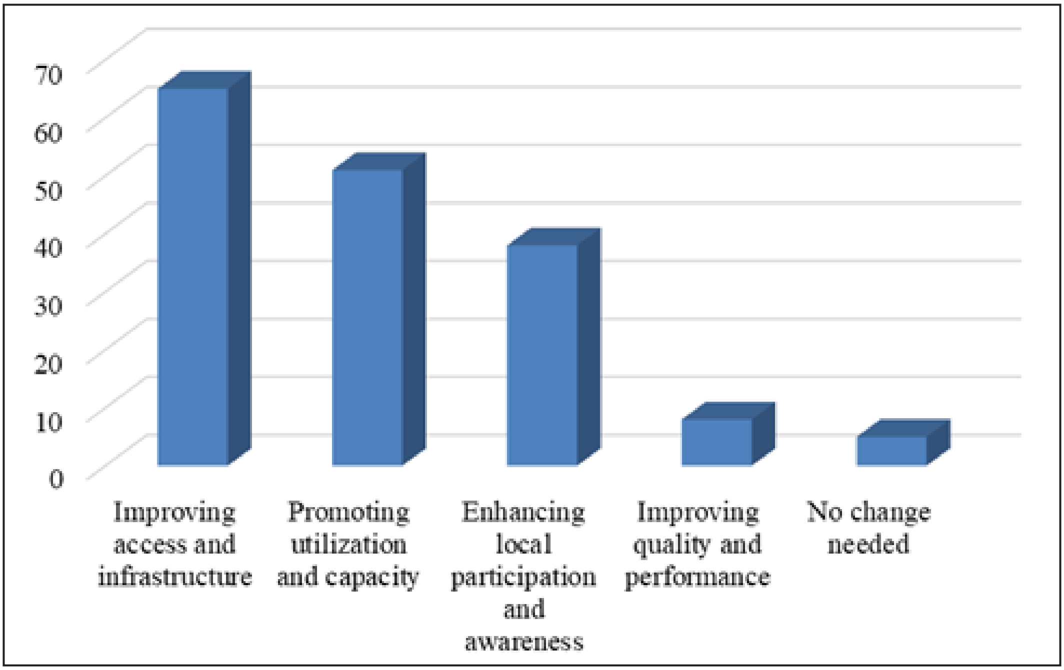

Figure 2: Suggestion for Effective Micro Hydropower Management

To understand managerial solutions for micro hydropower development and management, respondents were asked a series of questions. They were first asked whether micro hydropower development in their locality was manageable. They were then invited to suggest ways local people could address challenges, with options such as grabbing opportunities, proper fund utilization, learning managerial skills, and others. To assess stakeholder responsibility, respondents identified who should be more accountable-individuals, local communities, the government, or others. Additionally, they were asked whether the COVID-19 pandemic had affected micro hydropower development, and if so, to specify the types of effects encountered. The study identifies key strategies such as learning managerial skills (95.09%), proper fund utilization (78.95%), and seizing local opportunities (66.67%) as critical to enhancing system performance (Figure 2). Among these, capacity building through skill development emerges as the most prioritized solution by the respondents. Stakeholder responsibility plays a pivotal role in effective management. The findings highlight that local communities or user groups (99.3%), government agencies (82.81%), and individuals (57.91%) all share accountability in ensuring sustainability. The overwhelming emphasis on community and government roles suggests a strong preference for collective, institutional approaches rather than relying solely on individual efforts. Open-ended responses further emphasize the importance of improved coordination among stakeholders, access to repair and maintenance parts, and increased local engagement in decision-making processes. These insights support the need for decentralized governance models and stronger local ownership. While the COVID-19 pandemic was not directly cited, its indirect effects-such as funding shortfalls and logistical barriers-likely exacerbated existing managerial and operational challenges.

3.5 Inferential Analysis

This section presents inferential analysis using data from 285 respondents. It includes summary statistics, factor analyses (EFA and CFA), and structural modeling. The findings confirm reliability, validity, and model fit, revealing that perceived benefit, attitude, and knowledge significantly influence participatory behavior in micro hydropower management in Galkot Municipality.

Summary Statistics

Summary statistics covers the statistics result of mean, standard deviation, skewness and kurtosis which were collected from 285 respondent without missing of data. Mean and standard deviation are analyzed to see the scatter plot of the data. Skewness and kurtosis are determined to see the normality distribution. Our result showed mean=2.40 to 4.28, standard deviation=0.74 to 0.99, skewness= -2 to +2, kurtosis= -5 to +5 which fit the conditions by Wungo et al., (2021) which is acceptable and have perfect distribution of normality and outliers.

Exploratory Factor Analysis (EFA)

Exploratory factor analysis (EFA) determines the significance of a set of response-influencing constructs. KMO and Bartlett's test is performed to examined the correlation between the factors. KMO= 0.7.39, Bartlett's Test=0.000, which is shown by our result lie under the conditions mentioned by Shrestha (2021). Thus, the dataset is correlated. Common method bias is a phenomenon caused by the measurement method used in the study rather than the network of causes and effects connecting the latent variables in the study (Bell, 2019). Harman's single factor techniques was used to verify the biasness in the study. Cumulative percentage of single factor must be less than 50% (Harman, 1960) and our result showed 22.336% which means the data is biasfree. The extraction values, of the dataset are very high, indicating that the extraction values are good. The communalities between the measured items loaded on the EFA model in this study ranged from 0.583 for Att2 to 0.744 for PB1. As a result, we can use all of these variables in our factor analysis.

Measurement Model

Measurement model is analyzed to get the result of validity and reliability of dataset by observing CR, AVE, MSV of the constructs. Table 7 showed the minimum value for CR, AVE, MSV are 0.771, 0.523, 0.005 respectively. In order to evaluate the measurement instruments, we consider only two validity methods in this study: convergent validity and discriminant validity. The requirements to meet the convergent validity are; AVE>MSV, CR>AVE, AVE>R. similarly requirements for discriminate validity are; AVE > MSV and). Our result from table 7 suited under the needed requirements, so we assured the dataset are reliable and valid. Cronbach's Alpha is used to measure internal consistency. The higher value of cronbach's alpha indicates greater internal consistency. Here, our finding revealed that the value of cronbach's alpha is greater than 0.70 which represent good internal consistency among variables.

Table 7: Reliability and Validity

Construct	Indicator	Factor Loading	CROANBACH ALPHA	CR	AVE	MSV
Attitude	Att2	.762	0.847	0.848	0.527	0.005
	Att3	.778				
	Att4	.785				
	Att5	.826				
	Att6	.784				
Knowledge	KN1	.834	0.771	0.775	0.536	0.014
	KN3	.844				
	KN5	.804				
Perceived Behavior	PARB1	.815	0.769	0.771	0.529	0.014
	PARB3	.837				
	PARB5	.825				
Perceived Benefit	PB1	.855	0.757	0.763	0.523	0.011
	PB3	.827				
	PB5	.773				

Table 8: Latent Construct Correlation

SEM correlations				
	PARB	Att	PB	KN
PARB	0.727			
Att	-0.010	0.726		
PB	-0.107	-0.068	0.723	
KN	0.118	0.012	-0.021	0.732

Confirmatory Factor Analysis (CFA)

Confirmatory factor analysis (CFA) is measured to know whether a set of components has the expected effect on responses (Saeed et al., 2021). Like (Wong, 2002) our result for 7 indicators meets its basis point which are; CMIN/df= 0<5, RMR=0.28<0.08, GFI=0.96>0.80, CFI =0.988>0.80, TLI=0.984>0.90, IFI=0.988>0.90, RMSEA=0.027<0.08. We are definite that the model fits perfectly and is good match for the dataset.

Structural Model

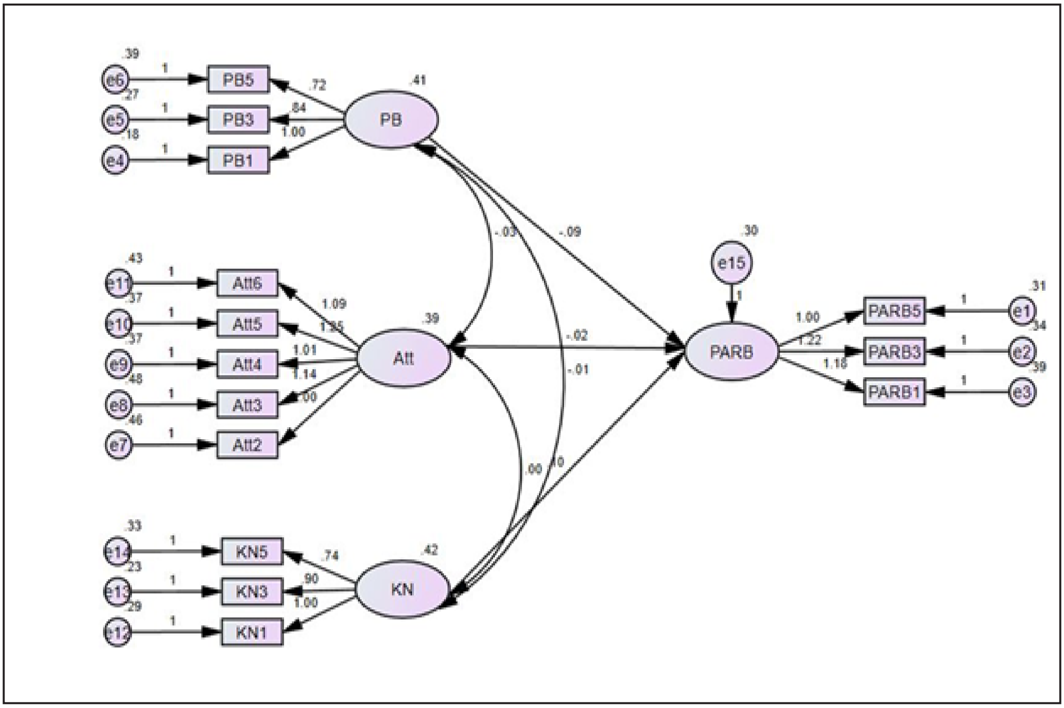

Figure 3: Structural Model

We consider four constructs with 14 variables after a trial-and-error process. The path analysis for this study is performed using the AMOS software, and the results are based on that output. This model has three variables: latent variables, observed variables, and error variables. The analysis illustrates that respondent's Participative Behavior on MHPM is significantly influenced by their

Perceived Benefit (β=0.41, p<0.05) the value of R^2 is 0.41 and it reflect that in independent variable, 41% of variance is explained by all the three construct taken together, Attitude (β=0.39, p<0.05) the value of R^2 is 0.39 and it reflect that in independent variable, 39% of variance is explained by all the three construct taken together, Knowledge (β=0.42, p<0.05) the value of R^2 is 0.42 and it reflect that in independent variable, 42% of variance is explained by all the three construct taken together. It seems to have a significant impact on local peoples participative behavior on MHP at Galkot municipality. Evidence suggest that, for the domain selected for this study, the trust factor associated with Knowledge is the most influential factor affecting Participative Behavior on MHP in their study found that trust factor is the most significant factor to consider.

Test of Hypothesis

A hypothesis is an assumption, proposed for the argument and tested to see if it is true. To have the significant relationship the significance level must be less than 0.05 (Lieber and L. 1990). The result from Table 9 shows H_1 and H_3 have the significant relationship whereas H_2 have insignificant relationship. Hence, we accept H_2 and reject H_1 and H_3.

Table 9: Path Estimates for Structural Model

Hypothesis	Relationship	Estimate	S.E.	C.R.	P	Significant/ Insignificant
H1	Perceived Benefit →Participatory behavior	-0.144	0.067	-2.143	0.032	Significant
H2	Attitude → Participatory behavior	-0.027	0.050	-0.548	0.584	Insignificant
H3	Knowledge→Participatory behavior	0.145	0.066	2.192	0.028	Significant

5. Discussion

Micro hydropower (MHP) has proven to be a transformative renewable energy solution for rural electrification in Nepal, particularly in geographically isolated areas such as Galkot Municipality. As Nepal pursues energy access and sustainability goals in line with SDG 7 (Affordable and Clean Energy), understanding the socio-institutional dynamics underlying MHP implementation becomes critical. This study analyzed community-level perceptions regarding MHP management with a focus on participatory behavior, perceived benefits, knowledge, and attitudes. The findings generate vital implications for the sustainable development of MHPs in Nepal and similar socio-geographic contexts.

One of the most significant findings of the study is the positive relationship between knowledge and participatory behavior (β = 0.42, p < 0.05). Communities equipped with greater technical and managerial knowledge are more likely to engage actively in the governance and maintenance of MHP systems. This aligns with prior studies (e.g., Butchers et al., 2020) which emphasize that informed local stakeholders are better positioned to support and sustain decentralized energy systems. However, over 53% of respondents still reported a lack of technical expertise, underscoring a widespread capacity gap that undermines system longevity. Addressing this requires a systematic and institutionalized approach to local capacity building. Community training programs focusing on system operation, basic electrical engineering, financial recordkeeping, and governance practices should be regularly conducted in partnership with rural municipalities, NGOs, and private energy consultants. In addition, the establishment of local repair and maintenance centers-with adequate supply chains for spare parts-would enable faster troubleshooting and reduce system downtime, a concern raised by over 40% of respondents.

Perceived benefits emerged as another strong predictor of participation ($\beta = 0.41$, $p < 0.05$), indicating that communities are more willing to participate in MHP governance when they observe tangible socio-economic improvements. Respondents linked MHP projects to several critical outcomes: economic diversification (PB1), enhanced market access (PB3), and energy security (PB5). These perceived benefits not only enhance user satisfaction but also generate a sense of local ownership and accountability-factors widely acknowledged in community energy literature. Nevertheless, 33.68% of respondents noted insufficient government support, which negatively affects perceived benefits and weakens community motivation. This gap highlights the need for targeted policy interventions, including subsidies for small-scale enterprises powered by MHP (e.g., agro-processing, cold storage, and carpentry), tax incentives, and access to concessional finance. If designed effectively, such measures can transform MHPs from standalone infrastructure into local development catalysts that create jobs, increase productivity, and attract youth engagement.

Interestingly, the study found that attitude, although showing a moderate coefficient ($\beta = 0.39$), did not have a statistically significant impact on participatory behavior ($p > 0.05$). This finding deviates from literature in more developed contexts (e.g., Saha & Idsø, 2016) where environmental consciousness and cultural attachment to local ecosystems significantly influenced energy-related attitudes and behaviors. In the case of Galkot, it appears that economic necessity and service reliability are the overriding concerns, outweighing abstract or long-term environmental values. This suggests that contextual factors-such as poverty, limited alternatives, and underdeveloped infrastructure-may temper the role of attitudes in shaping collective action. To refine these insights, future research should incorporate qualitative investigations of cultural norms, environmental perceptions, and intergenerational perspectives on renewable energy systems. Such approaches could help uncover the latent drivers and barriers behind seemingly contradictory behaviors observed in rural energy communities.

A striking 98.95% of respondents reported experiencing management-related challenges, particularly in the areas of training, technical expertise, and institutional support. Specifically, 59.69% pointed to a lack of managerial training, while 53.68% cited a shortage of skilled technicians. These findings reinforce earlier assessments (e.g., Gurung et al., 2013) which observed that many MHP projects in Nepal suffer from weak post-installation support structures and poor knowledge transfer mechanisms. The respondents' proposed solutions-managerial skill development (95.09%), efficient fund utilization (78.95%), and local opportunity exploitation (66.67%)-suggest a collective recognition of the importance of good governance. In this regard, decentralization offers a promising pathway. Empowering user committees to take ownership of MHP operations, while providing institutionalized support from municipal governments, provincial authorities, and development partners, could help establish a resilient governance framework. Mechanisms such as local audits, transparent budgeting, and inter-ward coordination platforms could further enhance accountability and performance.

Informed by the findings, this study proposes multi-tiered recommendations to enhance the sustainability of Micro-Hydropower (MHP) systems. First, local capacity must be strengthened through routine technical training in collaboration with TVET institutions and energy NGOs, alongside establishing community-level maintenance hubs with trained youth technicians and accessible spare parts. Second, government and stakeholder coordination should be enhanced by designing subsidy schemes for MHP-dependent enterprises and integrating rural electrification policies with broader development programs in agriculture, education, and public health. Third, community engagement must be improved by institutionalizing participatory planning and launching awareness campaigns on MHP benefits. Fourth, inclusive governance should be promoted by ensuring representation of women and marginalized groups in MHP committees and encouraging youth participation through entrepreneurial training.

While the study offers valuable insights, its findings are geographically limited to Ward 8 of Galkot Municipality, potentially affecting generalizability. Future research should expand to diverse regions in Nepal, incorporate variables like environmental impact and gender dynamics, and adopt longitudinal approaches to track MHP sustainability over time.

6. Conclusion

Micro hydropower (MHP) plays a crucial role in rural electrification and poverty alleviation in Nepal. However, the long-term sustainability of MHP systems is heavily reliant on community engagement and effective management. This study, grounded in the MOA (Motivation, Opportunity, Ability) model and the Theory of Planned Behavior, investigates local perceptions of MHP management in Galkot Municipality. The findings reveal that knowledge ($\beta=0.42$, $p<0.05$) and perceived benefits ($\beta=0.41$, $p<0.05$) significantly enhance participatory behavior. In contrast, attitude ($p>0.05$) had no statistically meaningful impact, marking a deviation from behavioral theories typically developed in Western contexts. This suggests that, in rural Nepal, practical benefits and technical understanding play a more influential role in driving community involvement than abstract attitudes. Despite the benefits of MHP, 98.95% of respondents reported facing management challenges, primarily due to insufficient technical skills (53.68%) and a lack of government support (33.68%). These findings highlight the need for structured capacity-building programs, decentralized governance, and the availability of spare parts to ensure the system's reliability. Furthermore, the study was limited to Ward 8 of Galkot, so future research should broaden its scope to include diverse geographic and socio-economic settings. Additional variables such as gender dynamics, climate resilience, and financing models should also be incorporated for a more comprehensive understanding of MHP management. Based on the study's findings, several policy recommendations can be made. First, there is a need to strengthen local technical training through partnerships with vocational institutes. Second, government incentives for MHP-based small businesses should be enhanced to boost economic returns. Third, stakeholder coordination between municipalities, user committees, and private suppliers needs improvement. Lastly, establishing local repair networks is crucial to minimize downtime and ensure the long-term operation of MHP systems. By addressing these gaps, Nepal can optimize the potential of MHP as a sustainable energy solution, which aligns with the objectives of SDG 7 (Affordable and Clean Energy) and contributes to rural development goals. This study not only adds to the limited literature on community perceptions of MHP but also provides a practical framework for policymakers and development practitioners involved in off-grid electrification.

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