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We are expecting your continuous support in the future too.

Shanti Kala Subedi, PhD
Head, Research and Innovation Unit, Himalaya College of Engineering
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Contents

A Practical Significance Distributed File System: An Analysis *Gajendra Sharma and Gaurav Koirala*	1-12
Acceptance of E-Government Services and Public Participation in Developing Countries *Gajendra Sharma*	13-20
Agriculture and Engineering Interface to Cope Climate Change Effects in Nepal: A Review *Chandra Bahadur Budha and Govinda Prasad Sharma*	21-39
Alternative Fertilizer Options for Nepal - A Critical Review *Ray Beazleigh, Michael Lin and Surya P. Bhattarai*	40-51
An Approach to Solve Sudoku Using Image Processing and with Genetic Algorithm *Amit Pokhrel, Irajan Dhakal, Sagar Bhandari, Sahasramshu Pokhrel, Ashok GM and Himal Chand Thapa*	52-62
Biogas for Clean Energy Consumption and GHG Emission Reduction *Shanti Kala Subedi*	63-79
Building Permit Approval System: A Case Study of Kirtipur Municipality *Purna Bhadra Sapkota and Ashok Dhakal*	80-87
Diagnosing Functionality and Sustainability of Community Managed Water Supply Scheme *Sushma Kafle, Rajit Ojha*	88-99
Enabling Solar Mini-grid Development for Off-grid Electrification in Nepal *Narayan Prasad Adhikari and Khem Raj Bhandari*	100-111
Energy Consumption and Demand Projection of Manufacturing Industries in Kathmandu Valley *Ravikant Chaudhary, Ajay Kumar Jha, Hari Bahadur Darlami and Subir Karn*	112-118
Impact of Using Audio-Visual Aids in Online Teaching-Learning System *Shanti Kala Subedi and Bipul Mainali*	119-127
Parametric Study on Post-tensioned Concrete Box Girder Bridge in Earthquake *Laxman Khati and Rajan Suwal*	128-136
Stabilization of Silty Soil using Cement as Primary Binder and Epoxy Resin as Admixture *Shishir Dhakal, Sandesh K.C., Utsav Chimaria, Suvarna Singh Raut and Saurav Shrestha*	137-145

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A Practical Significance Distributed File System: An Analysis

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Abstract

The world's data collecting is growing and expanding. The infrastructure must be able to hold a large amount of data, which is becoming more crucial every day. Distributed File Systems could be used to accomplish this. For processing, storing, and analyzing massive amounts of unstructured data, the Distributed File System (DFS) is utilized. Google File System (GFS) and Hadoop Distributed File System are the most popular file systems (HDFS). We give a review of distributed file system design in this work. Scalability, availability, compatibility, extensibility, autonomy, and other factors are considered while comparing file systems.

Keywords

Distributed File System, Big Data, Design of DFS, Hadoop Distributed File System (HDFS), Google File System (GFS), Review of DFS

1. INTRODUCTION

Data is generated from a variety of sources, including business operations, transactions, social networking sites, web servers, and so on, and it can be structured or unstructured [1].Data sharing in distributed systems is already ubiquitous and becoming more so. In a distributed system, each user can be both a creator and a consumer of data. The Distributed File System (DFS) is a set of client and server services that enable an organization to organize numerous SMB file shares into a distributed file system using Microsoft Windows servers. By allowing shares in numerous different locations to be logically aggregated under one folder, it provides location transparency and redundancy to increase data availability in the face of failure or severe traffic. This type of system allows programs to store and access remote data in the same way that local files are stored and accessed, allowing users to access these files from any computer on the network. It is designed for batch processing, which means that data locations are accessible, allowing computation to move to where the data is stored while maintaining high bandwidth. DFS also provides capabilities like data sharing for numerous users, user mobility, and Location Transparency, which allows you to hide or not reveal any hint or tip about the file's location. The necessity for a Distributed File System arose from the disadvantage of the previous system, which needed users to know the physical addresses of all computers involved in the file sharing process.

When compared to a local file system, the requirements for a distributed file system are different. The requirements that must be considered when designing the Distributed File System are as follows [2]:

- The feature of fault tolerance must be well-implemented. One of the most

critical needs here is how quickly data can be restored following a failure.

- The size of the files kept in DFS will be enormous. The majority of the files are more than 1 GB. In DFS, handling these kinds of large files is critical. Some file systems will split files into chunks. The benefit of doing so is that the amount of data handled by a single operation is reduced from several GBs to a few MBs. However, it necessitates additional mapping procedures for each operation, which may result in a performance reduction.

- The majority of DFS files follow the write-once-read-many paradigms. As a result, many DFSs provide features that are optimized for file writers and readers [3]. Few of them also include effective functions for editing an existing file at any point in time. Some DFSs don't even have a feature that allows you to update an existing file.

- DFS relies heavily on metadata. Because most DFS systems accommodate millions of files, accessing every node directly is not an effective way to retrieve information on any given file. As a result, most DFS designate a single node as the central, which is responsible for maintaining the metadata of all files stored in the system. The metadata list will greatly speed up the retrieval of file information.

Nowadays, DFS enables the operation of massive data, large-scale computations, and transactions. The categories are based on the working logics and designs of the systems. Fault tolerance, replications, naming, synchronization, and design intent were used to make these classifications. The architecture of the Distributed File System can be understood from Figure 1.

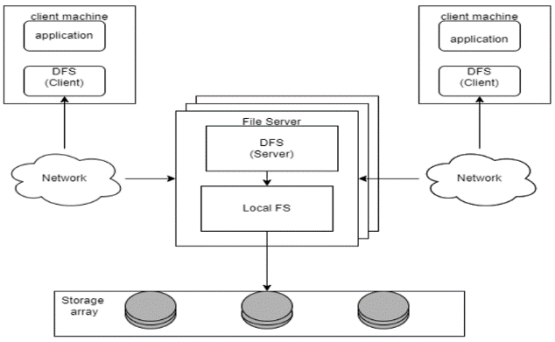

Figure 1: Distributed File System General Architecture

This paper is structured as follows. In Section 2, the background information required for the better understanding of DFSs presented in this paper is discussed. In this section, first the precise definition of the Distributed File System (DFS) is expressed. The most common Distributed File System architecture is explained, and in Section 3, the studies in design of DFS are presented. Finally, in Section 4, the general conclusion is discussed.

2. BACKGROUND

2.1 Design Goals of DFS

Early distributed file systems relied on a distant server to execute file system calls, which limited scalability and fault tolerance [4]. Modern approaches such as distributed hash tables, content-addressable storage, distributed

consensus algorithms, and erasure codes have considerably reduced such constraints. Two themes are emerging in view of projected exabyte-scale scientific data volumes [2]. First, distributed file systems' previously monolithic design is fragmented into services that provide a hierarchical namespace, data access, and distributed coordination individually. Second, the separation of storage and processing resources results in a storage architecture in which each compute node provides permanent storage. Google File System (GFS) and Hadoop Distributed File (HDFS) System are the most popular file systems.

In a number of ways, distributed file systems may strive for transparency. That is, they strive to be imperceptible to client programs, which see a system that resembles a local file system [2]. The distributed file system is in charge of locating files, transmitting data, and perhaps delivering the other features described below [5].

- Access transparency; Clients are ignorant that files are dispersed and can access them in the same way that local files are accessed.
- Location transparency;There is a consistent namespace that encompasses both local and distant files. The location of a file is not indicated by its name.
- Failure transparency; the client and client programs should operate correctly after a server failure.
- Replication transparency; to support scalability, we may wish to replicate files across multiple servers. Clients should be unaware of this.
- Heterogeneity; file service should be provided across different hardware and operating system platforms.

2.2 Issues in Distributed File System

When developing a distributed file system, there are a number of considerations to keep in mind. Transparency, flexibility, reliability, performance, scalability, and security are the several topics discussed in this section [6].

A. Transparency

The most important design issue is to hide from the users the fact that processes and resources are physically distributed across the network.

B. Flexibility

The easiest strategy to achieve flexibility is to decide whether each machine should use a monolithic kernel or a microkernel. Memory management, process management, and resource management are the three main functions of the kernel.

C. Reliability

Users prefer a distributed system with numerous processes because it protects them from single-processor system failures. As a result, in the event of a failure, a backup is available. The term "reliability" refers to the availability of data that is free of errors. All copies of a replication should be consistent.

D. Performance

It simply means that a program should run as though it were on a single CPU. Response time, throughput, system utilization, and the amount of network capacity consumed are the measures used to assess performance.

E. Scalability

Distributed systems are made to work with a small number of CPUs. It's possible that the distributed system will need to be expanded by adding more CPUs. There are limitations with centralized services, tables, and algorithms when supporting additional people or resources.

F. Security

Security consists of three main aspects namely,

1. Confidentiality which means protection against unauthorized access

2. Integrity, which implies protection of data against corruption

3. Availability, which means protection against failure and always being accessible

G. Fault Tolerance

In case a system has multiple servers' and if any Server breaks down, the other server takes up the load. This process is transparent to the user.

2.3 The Most Common DFS

Google engineers provided a solution to the problem in 2003, when the Internet giant faced scaling concerns and issues with storage media and the establishment of a distributed file system. The Google File System (GFS) refers to a collection of documents that have resulted in a much larger distributed file system application that is very similar to the GFS. The Apache Hadoop Distributed File System (HDFS) has been presented as a system file.

Google File Systems (GFS)

The Google File System (GFS) was first introduced in 2003 to suit Google's fast rising data processing demands. It's a scalable distributed file system designed for large-scale, data-intensive distributed applications. It has fault tolerance and gives great aggregate performance to a large number of clients while running on low-cost commodity hardware. GFS clusters are made up of hundreds, if not thousands, of storage units made from low-cost commodity hardware [7].

A. Goals

GFS shares many of the same goals as previous distributed file systems such as performance, reliability, and availability. Some of the design goals specific to GFS are as given below.

- Redundant storage of massive amounts of data on cheap and unreliable computers.
- It has to process huge numbers of requests
- GFS stores a huge number of files, totaling many terabytes of data.

B. Processes

GFS servers are Stateful. They have to maintain all the state information about the requests made by the clients.

C. Fault Tolerance

In GFS, all data is triple replicated. When a chunk server goes down, the master can always send data requests to the replicas until the node is up

and running again. In the event that the master fails, the system can easily select another node to build a metadata list by scanning all chunk servers and acting as master.

Hadoop Distributed File System (HDFS)

HDFS (Hadoop Distributed File System) is a fault-tolerant distributed file system designed to run on commodity hardware. HDFS is a file system that allows high-throughput access to application data and is well-suited to applications with huge data collections.

Hadoop includes a distributed file system (HDFS) that can store data across thousands of computers, as well as a way to spread work (Map/Reduce jobs) across those machines, allowing the work to be done close to the data [8]. The architecture of HDFS is master/slave. Large data sets are automatically divided into chunks that are maintained by multiple Hadoop nodes.

A. Goals

- As HDFS is designed for batch processing rather than interactive use by users, the emphasis is on high throughput of data access rather than low latency of data access.
- Detection of faults, quick and automatic recovery from them is a core architectural goal of HDFS.
- It should support tens of millions of files in a single instance.

B. Processes

HDFS servers are Stateful. They have to maintain all the state information about the requests made by the clients.

C. Fault Tolerance

One copy is placed on one node in the local rack, another on a different node in the local rack, and the final replica is placed on a separate node in a different rack, according to HDFS's placement rules. If the local rack's initial node fails, a request is forwarded to a different node in the same rack, where the replica is located. If that node fails as well, the request is sent to another node in a different rack. Fault tolerance is achieved in HDFS as a result of the use of replica placement policies.

3. STUDIES IN DESIGN OF DFS

There has been a lot of research into various designs. Only a few examples are mentioned in this article. This section focuses on the activities performed for unstructured data, small picture storage, and the benefits of these distributed file system designs. So, first, P2P and Client/Server technologies will be introduced in DFS design, followed by DFS designs based on HDFS and GFS. Table 1 outlines the many types of distributed file system designs and benefits relevant to the current study.

3.1 Related studies on P2P technology

Depending on the structure of the overlay maintained by participating peers, peer-to-peer networks are divided into two groups. Unstructured architectures, such as the pioneering Gnutella system, allow peers to create their own message routing paths [9]. To

access a resource, each peer will send requests to his virtual neighbors, effectively overloading the physical infrastructure (at least, this was the initial technique, which was eventually superseded by more "clever" routing algorithms).

DFS Peers are structured in both topologies, according to the DFS Architecture. A peer layout that is similar to that described in is discussed in. Because resource dependencies and links between participating nodes might be arbitrary, the DFS collaboration network resembles an unstructured peer-to-peer design. However, the overlay of namespace and storage aggregation and distribution is followed by a subset of requests. The location of DFS users and resources is managed using a Kademlia-based DHT shared by all peers in the DFS universe. Work on peer-to-peer content distribution networks (CDNs) and the Freenet censorship-free data delivery overlay is also relevant.

Distributed file systems are the forerunners of most modern peer-to-peer and distributed file sharing services, and as such have supplied the tools and mentality required to imagine contemporary global-scale data collaboration infrastructures from the start [4]. Frangipani and XFS are two of the most well-known early distributed file system ideas. Frangipani uses a two-layer method, separating file metadata from actual storage (a shared virtual disk).

3.2 Related studies on Client/Server technology for DFS Design

The majority of client/server applications fit into one of two categories: file server, or stateless, designs, and database styled transactional, or stateful, systems. Despite the fact that many client/server systems do not manage files or any other type of database, most of them have a design that is fairly similar to one of them [1]. Furthermore, there is a significant middle ground consisting of non-transactional stateful distributed architectures (including stateful file servers). These applications are sometimes referred to as "improved stateless" architectures [10].

For example, Microsoft's NTFS file system appears to be stateful to the user, but it is implemented as a "mostly stateless" system that uses event notification mechanisms to notify the client when events on the server that may be important to it occur; the client quickly rereads the changed data, and, with any luck, applications running on it will not notice the temporary inconsistency [11]. If one understands the fundamental ideas behind stateless system designs, a file system like this can be thought of as starting with a stateless approach and then cleverly adding mechanisms that hide many of the common issues found in stateless designs—an approach that gives the Microsoft system significant robustness. For example, the Web Services architecture invites one to follow a similar development path.

A study [11] presents a file system that keeps file replications in separate network areas. In the suggested system, they also construct a load detecting module. The module will monitor each file server's load and optimize overall system performance. A distributed file

system called KIV-DFS is presented by [12]. The Google file system is incompatible with mobile devices. The system is built on the client-server model. Users can work with data using the client module.

A distributed file system is presented in the work by [6]. The Name Server is in charge of data classification and storage allocation in this system. The Name Server was previously utilized to assist the Name Server's operations. A Data Server is a form of image to save that is placed beneath the Name Server. Data Servers are unrelated, and they have no idea what type of video is saved on the others. A fundamental technique to managing photos is to define the data and then use the descriptive information to carry out the operation. The image data is described using raw data, basic features, low-level features, and semantic features. Image data is shown using a tree structure. Raw data is the base node, and it refers to image data files. Low-level properties and key attributes of states are found in the middle child of the root node. Image data aspects such as color, texture, and geometry of images are examples of low-level features. Attributes such as name, kind, author, and creation time are all basic aspects. The leaf node, which expresses semantic properties such as a good writer, topic explanation, and low-level features [8].

3.3 Related studies in DFS based on Google File System

The Google File System is a scalable distributed file system created and implemented by Google for large distributed data-intensive applications. It has fault tolerance and gives great aggregate performance to a large number of clients while running on low-cost commodity hardware [9]. While it has many of the same goals as prior distributed file systems, this design was influenced by present and future observations of application workloads and technology environments, which differ significantly from previous file system assumptions. As a result, established design decisions have been reexamined, and radical new design points have been explored.

There are two replicas in the GFS: primary and secondary. The data chunk that a chunk server transmits to a client is known as a primary replica. On other chunk servers, secondary replicas act as backups. Which portions are primary or secondary is decided by the master server [12]. If a client modifies the data in a chunk, the master server notifies chunk servers with secondary replicas that they must copy the updated chunk from the primary chunk server in order to keep the chunk in its present state.

3.4 Related studies in DFS based on HDFS

Hadoop is a free and open-source software project [8]. Apache Hadoop has become a prominent corporate cloud-based technology applied as a whole ecosystem of services, thanks to a considerable technology investment supplied by Yahoo! Many multinational organizations, like Facebook, LinkedIn, Twitter, eBay, Samsung, J.P. Morgan, AOL, and others, have successfully implemented it [3]. The ecosystem includes a number of tools (Hive, Pig, HBase, Oozie, Zookeeper, Sqoop, Flume, Spark, Kafka, Impala) that enable businesses to store,

process, and analyze large amounts of data, provide real-time customer service, perform various types of optimizations, machine learning, ETL (extract, transform, load), and other operations.

HDFS is a distributed file system that handles files across the storage of a cluster. It's in charge of data replication and fragmentation. Depending on the file replication factor, large files are split into numerous blocks, each of which is replicated on multiple servers. This ensures that data is accessible even if one or more servers fail. The master-slave architecture is used by the distributed file system, which follows the "Write Once, Read Many" principle. It's a distributed "keyvalue" data storage system that's fault-tolerant and designed to manage huge files.

Clover, a NameNode cluster file system based on HDFS, is presented in the paper [9]. This file system takes advantage of two key features: an upgraded 2PC protocol that enables consistent metadata updates across many metadata servers, and a shared storage pool that provides reliable permanent metadata storage and facilitates distributed transaction operations [9]. Experiments demonstrate that by using quantized measurements, their system may provide superior metadata expandability ranging from 10% to 90% when each more server is added, while maintaining equivalent I/O performance Designed to work with big data files [6].

HatS [5]is a multi-tiered storage system based on the HDFS file system [7]. The DataNode architecture is a significant difference between hatS and HDFS. Each participating node in HDFS [6] maintains a single DataNode instance, which represents various storage devices, regardless of their features such as supported I/O rates and capacity. In hatS, on the other hand, each participating node hosts many DataNode instances, each of which represents a single type of storage device. Liu Jiang and colleagues [7] presented an optimization of a file system based on small files that delivers higher performance. A similar design with HDFS was presented by Farag Azzedin [10], although NameNode is distributed.

Article Name	Author (s)	Publish	Year	Pages	Advantages	Name of DFS
A High Performance and Low Cost Distributed File System	Tzong-Jye Liu, Chun-Yan Chung, Chia-Lin Lee	IEEE	2015	36-42	low cost, reliability, scalability, improve the overall system performance	NFS
Distributed File System with Online MultiMaster Replicas	Luboš Matějka, Jiří Šafařík, Ladislav Pešička	Second Eastern European Regional Conference on the Engineering of Computer Based Systems	2019	13-18	Scalability proper for mobile devices, Increase throughput, Increase the security of the data, improves the service availability	KIVDFS
ASDF: An Autonomous and Scalable Distributed File System	Chien-Ming, Wang, Chi-Chang Huang, Huan-Ming Liang	14th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing	2014	485-493	Scalability, Reliability, Compatibility, extensibility, autonomy	ASDF
A Kind Of Distributed File System Based On Massive Small Files Storage	DI LIU, SHT-JIE KUANG1	IEEE	2012	394-397	improve metadata management, high concurrency, storage efficiency, simple design, efficient design, storage capacity, scalability	QFS
The Hadoop Distributed File System	Konstantin Shvachko, Hairong Kuang, Sanjay Radia, Robert Chansler	IEEE	2010	1-10	Scalability, improves the overall availability, all of Goals in DFS design	HDFS

Distributed file system and classification for small images	Shaojian Zhuo, Xing Wu, Wu Zhang and Wanchun Dou	IEEE International Conference on Green Computing and Communication	2013	2231-2234	Reduce meta data, High Speed access	
hatS: A HeterogeneityAware Tiered Storage for Hadoop	Krish K.R., Ali Anwar, Ali R. Butt	18th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing	2018	502-511	Improve throughput , improve job completion time, improve the utilization of the storage device	Hats
Clover: A distributed file system of expandable metadata service derived from HDFS	Youwei Wang, Jiang Zhou, Can Ma, Weiping Wang, Dan Meng, Jason Kei	IEEE International Conference on Cluster Computing	2019	126-134	Expandability, bottleneck-less, no single point of failure	Clover
Towards a scalable HDFS architecture	F. Azzedin	IEEE International Conference on Collaboration Technologies and Systems (CTS	2017	155-161	Highly available, Widely scalable, fault tolerant,	
The optimization of HDFS based on small file	Liu Jiang, Bing Li, Meina Song	the 3rd IEEE International Conference on Broadband network and Multimedia Technology	2015	912-915	Increase the speed of reading, reduce the read request, reduce the write request received by the name node	

4. RESULT

Big data is a term for a collection of data that can be gathered, refined, managed, and processed using standard software in a reasonable amount of time. The definition of "size" in the context of big data is always evolving and expanding. As a result, a distributed file system should be able to handle and process such a massive amount of data. In Cloud and Grid computing, integrating enormous dispersed storage systems to provide large storage capacity is a critical and difficult task.

Various distributed file system designs were discussed in this article. A quick summary of how we used Distributed File Systems to achieve our goals using big data was offered. As a result, all DFSs are used to process, store, and analyze massive amounts of unstructured data. The Google File System exemplifies the characteristics required to run large-scale data processing workloads on commodity hardware. While certain design decisions are unique to our situation, many others may be applied to data processing tasks of equal scope and cost.

Although the speed of INetwork connectivity is critical for HDFS performance, it is not the only constraint. The data transfer speeds of hard drives are also crucial, especially in high-speed situations. Networks that serve a specific geographic area, such as a city or a metropolis. If you are uploading or writing a file to the HDFS. A data node, one of the replicas, hosts the client.will almost certainly be saved on the same data node.

REFERENCES

[1] A. B. Patel, M. Birla, and U. Nair, “Addressing big data problem using Hadoop and Map Reduce,” 2012. doi: 10.1109/NUICONE.2012.6493198.

[2] T. J. Liu, C. Y. Chung, and C. L. Lee, “A high performance and low cost distributed file system,” 2011. doi: 10.1109/ICSESS.2011.5982251.

[3] S. Ghemawat, H. Gobioff, and S. T. Leung, “The google file system,” in *Operating Systems Review (ACM)*, 2003, vol. 37, no. 5. doi: 10.1145/1165389.945450.

[4] C. M. Wang, C. C. Huang, and H. M. Liang, “ASDF: An autonomous and scalable distributed file system,” 2011. doi: 10.1109/CCGrid.2011.21.

[5] K. R. Krish, A. Anwar, and A. R. Butt, “HatS: A heterogeneity-aware tiered storage for hadoop,” 2014. doi: 10.1109/CCGrid.2014.51.

[6] S. Zhuo, X. Wu, W. Zhang, and W. Dou, “Distributed file system and classification for small images,” 2013. doi: 10.1109/GreenCom-iThings-CPSCom.2013.422.

[7] J. Liu, L. Bing, and S. Meina, “The optimization of HDFS based on small files,” 2010. doi: 10.1109/ICBNMT.2010.5705223.

[8] K. Shvachko, H. Kuang, S. Radia, and R. Chansler, “The Hadoop distributed file system,” 2010. doi: 10.1109/MSST.2010.5496972.

[9] Y. Wang, J. Zhou, C. Ma, W. Wang, D. Meng, and J. Kei, “Clover: A distributed file system of expandable metadata service derived from HDFS,” 2012. doi: 10.1109/CLUSTER.2012.54.

[10] F. Azzedin, "Towards a scalable HDFS architecture," 2013. doi: 10.1109/CTS.2013.6567222.

[11] D. Liu and S. J. Kuang, "A kind of distributed file system based on massive small files storage," 2012. doi: 10.1109/ICWAMTIP.2012.6413521.

[12] L. Matějka, J. Šafařik, and L. Pešička, "Distributed file system with online multi-master replicas," 2011. doi: 10.1109/ECBS-EERC.2011.12.

Acceptance of E-Government Services and Public Participation in Developing Countries

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Abstract

E-government is a means for governments to use the most innovative information communication technologies (ICTs) through electronic network with more convenient access to government information and services. ICTs develop public participation by facilitating citizens to interact better with each other. The government services are made available to the citizens in a convenient, efficient and transparent manner through e-governance. The objective of this study is to present how public participation is significant to enhance quality government services in developing countries such as Nepal. A conceptual framework was developed based on extensive literature review. The theoretical foundations proposed in this study are policy network theory and theory of intrinsic motivation. The key benefits of e-governance include efficiency, improved services, better accessibility of public services, and transparency. The result of ethical implementation of e-governance is creation of good governance. The e-governance requires a considerable increase in regulation and policy making abilities, with all the expertise and opinion-shaping processes.

Keywords

E-governance; e-government; public participation; challenging issues; ethics

1. INTRODUCTION

E-Government is defined as digital interactions between a government and citizens(G2C), government and businesses (G2B), government and employees (G2E), and between government and governments or agencies (G2G). The e-Government delivery models can be shortly summarized up as government to citizens (G2C), government to businesses (G2B), government to employees(G2E), government to governments (G2G) and citizens to governments (C2G) (Gartner, 2002). The digital interaction consists of governance, information and communication technology (ICT), business process re-engineering, and e-citizen at all levels of government organizations.

The emergence ICT directly affects the functions and roles of government. E-governance has been one of the main impacts of ICT. Many nations have realized the benefits of e-governance and have started offering their services through the online services [13]. Through the e-governance, the government services will be made available to the public in a convenient, efficient and apparent manner. The three prominent target groups that can be distinguished in governance concepts include government, citizens or public and

businesses organization. In this connection, e-governance has no distinct boundaries [8].

Implementing internet contents and public assessments, the e-government revolution has fallen short of its capacity to transform service delivery and public trust in government. It has the possibility of enhancing democratic responsiveness and increasing beliefs that government is efficient [7]. The impact of new technology on public-sector service delivery and public attitudes about government has long been controversial among political observers. The study investigates the content of e-government to locate whether it is taking advantage of the interactive features of the internet to enhance service delivery, democratic responsiveness and public outreach. Besides this, a national public opinion survey observes the capability of e-government to influence public views about government and their self-belief in the efficiency of service delivery [17].

E-government initiatives face serious challenges which are described in a number of studies [9,11]. These challenges seem to fall into three categories: management, infrastructure, and human factors. While the first category is solely linked to the supply side, the infrastructure and human factors belong to both the supply and demand side, i.e., public issues. In most cases, the greatest limitations toe-government are non-technical, in the management category, such as political opposition, deeply ingrained policies and practices, and internal employee resistance [14].

The objective of this study is to present how public participation is significant to enhance quality government services in developing countries such as Nepal. A conceptual framework was developed based on extensive literature review. The result of ethical implementation of e-governance is creation of good governance. Good governance is one of the most important public concerns that the government can offer to its people. It is one of the fundamental reasons why we have governments and we agree to abide by roles and responsibilities which fall under different forms of governance. Good governance facilitates that we can enjoy our fundamental rights to live with dignity, freedom and security, and can take advantage of various opportunities and services available to lead good quality lives.

2. E-GOVERNANCE IMPLICATIONS AND CHALLENGES

The successful implementation of e-government services is crucial for governments of developing countries [10]. Akman et al. (2005) [1] pointed out that the success of e-government adoption depends on people. Similar to any other innovations, the establishment of e-government brings a number of challenges for citizens as well as for governments. These challenges involve lack of awareness of e-government services, access, trust, security concerns, and the digital divide [4] and are obstacles that public must surmount in the implication and adoption process.

Developed countries take advantage from e-government services, but there is still much space for improvement [16]. A number of challenges involved in the adoption of e-government services still exist, which leads to the low levels of the adoption of e-government services. Some

researchers [16,4] have proposed the necessity for more study in the area of e-government adoption.

The Information Technology (IT) adoption is highly significant as e-government services are mostly provided using ICT. Adoption of e-government systems can be extended as per this understanding [19]. The e-government challenges can have a substantial effect on the development of government organizations' strength to provide digital services and transactions. Majority of challenges include poor ICT infrastructure, security and privacy issues. Security and privacy of information is crucial technical challenge recognized in this study and important issue for e-government implementation in the world [21].

There is a leading role of government in developing the ICT infrastructure as this is a fundamental need for successful e-government adoption. This can be ensured that the nation's internet backbone and the International Gateway are managed reliably. In addition, to reduce the rates for internet access through ISPs government should encourage developing of fiber optic network for efficient broadband communication [20]. The government should establish a favorable atmosphere for the adoption of ICT in everyday lives of people as this is the prerequisite of e-government.

3. E-GOVERNANCE IN DEVELOPING COUNTRIES: NEPAL CONTEXT

Nepal is located in the southern region of the Asian continent. South Asian countries are similar in a variety of ways, such as geography, IT infrastructure, literacy rate, and e-government services development and adoption. According to Almakki (2009) [2], Asian countries have challenges, such as the lack of good IT infrastructure as well as cultural issues. E-government is in its infancy in the developing nations, where countries share common challenges in the implementation of e-government services. The goals of the e-government of Nepal are to increase efficiency, effectiveness, transparency, and accountability in enhancing delivery of public services to its people. ICT infrastructure and networks are the backbone to implement e-governance. Nepal Telecom Company (NTC), the state-owned telecom operator, has been the major builder and operator of the national telecom network. NTC along with other private companies provide telecommunication services in the country. They provide the services of land line phone, GSM mobile, C-phone, sky phone, sky data, internet, V-SATand ADSL. As compared to other sectors, the telecommunication facilities have been enhanced considerably in recent years. The growth of telecom facilities in Nepal is satisfactory but still the rate of use of internet is low. In the meantime, more than 35 internet service providers are providing services and total international internet bandwidth used is in the ratio of 1: 2.25 with 58 Mbps and 122Mbps for uplink and downlink. More than 8%rural village development committees have lack of telephone facility. Majority of telecom facilities are centered in urban areas of the country.

The UN E-government survey 2012 found that many countries have put in place e-government initiatives and ICT applications for the people to further enhance public sector efficiencies and

streamline governance systems to support sustainable development. Among the e-government leaders, innovative technology solutions have gained special recognition as the means to revitalize lagging economic and social sectors. In five years, all the government agencies in Nepal would be interconnected via network and Nepal will provide public-centric and transparent services for its people. It will establish the knowledge-based society through this. At the end, Nepal will maximize the use of ICT to create values for individuals, organizations and all other parts of society, and create synergy effect through networking. According to the latest E-Government survey by the United Nations (UN), progress in online service delivery continues in most countries around the world.

Public Participation, Public Service Delivery and Bureaucratic Reform

E-governance allows people to communicate with government, participate in the governments' policy-making and public to communicate each other and to participate in the political process [15]. A successful implication of public service delivery (PSD)requires that governments develop better capacity to handle potential hazards. Such distinct systems, with different socioeconomic and political institutional environments influence the effectiveness of collaborative service delivery management between the countries. Claimed advantages are dependent on a government's ability to monitor new relations, issues and uncertainties. Thus, it needs to recognize the government capacities needed for efficient PSD and identify how they are used in different countries.

In order to overcome political and legal barriers, a transparent dealing of employees is becoming the regulation rather than the exception [5, p. 206]. Federal contractors are needed to fulfill with the minimum wage requirement. PSD may challenge the political legality of the government by delegating to private contractors the power of implementation that influences the public interest. Public concerns such as honesty, decency, integrity, accountability and impartiality may be weakened. PSD quality isa multifaceted notion. Therefore, it is difficult to estimate quality. The quality of PSD in some extend suffers from efficiency and cost.

4. THEORETICAL FOUNDATION OF THE STUDY

The present study is based upon some well-known theories. Some of them are given below:

4.1 Policy Network Theory

Policy network theory offers theoretical framework to observe policy making. Policy network theory provides a lens through which the interactions between groups or networks involved in policy making and their influence can be examined on the policy process. Dowding (1995) [6] and Marsh and Smith(2001) [12] agree that there are four main approaches to the study of policy networks: (1)the rational choice approach; (2) the personal interaction approach; (3) formal network analysis; and (4) the structural approach. Borzel (1998) [3] and Marsh and Smith (2001) [12] suggest that only a small minority of policy researchers attempt to confer any theoretical/explanatory power on the concept.

Policy network theory is useful to describe and explain e-governance policy-making processes in the developing countries and Nepalese context. However, limitations in the generic model appear in capturing the fundamentally different political and administrative systems, remarkably different cultural values in the applicability of some research methods common in developed countries [18]. It should be addressed which political and cultural aspects turn out to be different in Nepal and how they affect methodological and practical problems.

4.2 Theory of Intrinsic Motivation

This is the theory which can be described as a motivation to engage in activities that enhance or maintain a person's self-concept. It further states that the reward of performing an activity is the process of the activity itself and not an end result. Intrinsic motivation is when people are motivated by internal factors, as opposed to the external drivers of extrinsic motivation. Intrinsic motivation drives individual to perform things for the fun. The motivation is required to eliminate users' conservatism, fear of changing the environment and lack of involvement. Modern ICT and e-governance development allows people for engagement in government activities. This theory is widely used to understand information system related human behavior.

5. CONCEPTUAL FRAMEWORK DEVELOPMENT

The logical framework on e-governance is provided in figure 1. As a service provider, the state or government increasingly transforms into a regulator of outsourced or privatized services. The government policy-making will remain unaffected by changes of outsourced services.

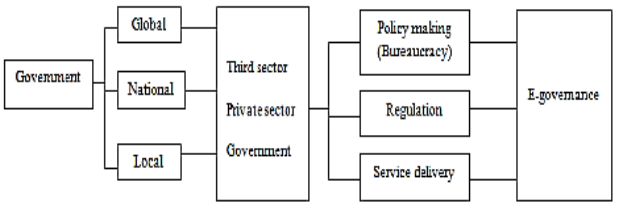

Figure 1: Logical model of e-government

The government has three prominent functions: operations, policymaking, and regulation. The globalization and liberalization policy force government to distinguish more clearly on each of these three functions. The policy-making function is increasingly divided between the global, the regional, the national, and to the local levels, involving each time actors from civil society and the private sector [10]. More or less the same can be stated as the operational function, from which the government is increasingly moving forward. The regulatory function, remains primarily at the nation-state level and involves non-state actors such as consumer organizations to a limited extent.

There are different stages of e-government, which reveal the extent of technical complexity and interaction with users: information dissemination (one-way communication); two-way communication; service and financial transactions; integration and political participation. The basic form of e-government uses IT for disseminating information, simply by posting information on the web sites. Two-way communications are characterized as an interactive mode between government and public. In this stage, the government incorporates email systems as well as information and data-transfer technologies into its web sites. An appropriate

example is the Social Security Administration's web site, where the agency receives new Medicare card applications and benefit statement requests, then processes and responds to service requests.

A proposed framework for e-government is presented in Figure 2. The framework presents four key variables of the service operation from an e-governance perception. These include linkages in terms of G2G, G2C andG2B; focus on customer service and cost cutting through trouble-free service delivery in a timely manner. It focuses the need to minimize bureaucratic problems. It is characterized by uncomplicated communication technology applications including telephone and VoIP to maintain a bilateral communication network. It delivers key form of e-services using an efficient workforce. Furthermore, it aims to empower public, reduce administrative corruption, increase efficiency in service delivery and improve in areas such as government finance, transparency, responsiveness, and civil service performance. Figure 2 presents the research model of e-government adoption.

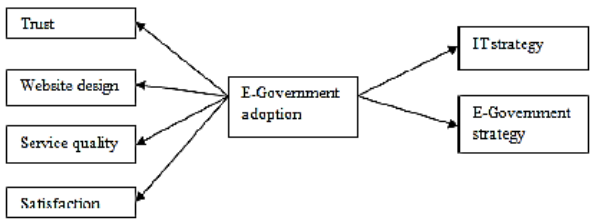

Figure 2: Conceptual Framework

The dependent variables on e-government adoption are trust, website design, service quality and satisfaction. Moreover, IT strategy and e-government strategy are also the constructs influencing e-government adoption. The framework also provides the primary e-governance implementation. In addition, it focuses that the e-government services are not trouble free. A systematic interchange of challenging issues, together with the political, socio-economic, and cultural environment may influence the policy making and implementation of e-governance architecture in developing countries. As a cost-saving and time saving mechanism e-governance has the potential to contribute to sustainable development as well. The above framework provides some guidance to policymakers and government sector managers with respect to the nature and prospect of such operations. As the significant issues are identified and discussed, it will provide them with a better understanding of the challenges and opportunities of e-governance services. It also provides academics and researchers with prospect of conducting empirical research to further enhance the framework.

The Web technology provides governments to share on demand with the public an information in unlimited quantities. Technology is further responsible to facilitate citizens to bring attention of local, regional and national governments. Though exploiting these capabilities within government systems are barrier that provides environmental, policy, legal, and cultural factors. In order to introduce effective e-Government it requires openness, transparency, collaboration as well as skill intaking advantage of the internet [22]. The high opportunity for two-way interaction between citizens and government creates need for global leadership. The government of particular nation has an

opportunity to provide guidance to e-Government objectives by promoting existing open online standards and considering the challenges to the Web and technology.

6. CONCLUSION

The implementation of e-governance is a challenging issue in least developed countries. Implementation requires basic components like ICT infrastructures, high speed and cost-effective connectivity, literacy rate, awareness, commitment and financial system. The factors influencing effective growth of e-governance are government process, leadership, roadmap and qualified human resource. The government has taken ICT as a strategic factor as it is an effective means to alleviate poverty. The main challenge to implement e-governance is to coordinate political will, financial resources and technical competency to transform policy into action. Ethics and policies should apply to all the initiatives of the government authorities. The government organizations should refer to these standards and policies when planning or making changes to their e-governance landscape. Ethical standards and policies will have to be regularly reviewed to keep them up to date with the latest technology developments.

REFERENCES

[1] Akman, A. Yazici, A. Mishra and A., Arifoglu, “E-Government: A global view and an empirical evaluation of some attributes of citizen”, Gov. Inform. Quart., vol. 22, pp 239-257., 2005.

[2] R. Almakki, Communities of Practice and Knowledge Sharing in E-Government Initiatives. The University of Manchester, 2009.

[3] T. Borzel, “Organising Babylon - On the different conceptions of policy networks., Pub. Admin., vol. 76, pp. 253-273, 1998.

[4] L. Carter and V. Weetakkody, “E-government adoption: A culture comparison, Inform. Sys. Front., vol. 10, pp. 473-482, 2008.

[5] C. Clark, R. Johnson and J. Mercer, Impact of Privatization and Managed Competition on Public Employees. In: Local Government Innovation: Issues and Trends in Privatization and Managed Competition, 2000.

[6] K. Dowding, Model or Metaphor? A Critical Review of the Policy Network Approach. Political Studies XLIII: 136-158, 1995.

[7] S. Gajendra, X. Bao, X and W. Qiang, “Public attitude, service delivery and bureaucratic reform in e-government: A conceptual framework, Inform. Tech. J., vol. 11, pp. 1544-1552, 2012.

[8] D.G. Garson, Public Information Technology and E-Governance, in: Sudbury, MA: Jones and Bartlett Publishers, 2006.

[9] A. Gartner, Majority of e-government initiatives fails or falls short of expectations, Gartner, Inc.'s Executive Programs, San Diego,2002.

[10] B. Gupta, S. Dasgupta and A. Gupta, “Adoption of ICT in a government organization in a developing country: An empirical study”. J. of Strat. Inform. Syst., vol. 17, pp. 140-154,2008.

[11] R. Heeks, Most e-government for development projects fail: How can risks be reduced?, I-Government Working Paper Series, Institute for Development Policy and Management, University of Manchester, UK, 2003.

[12] D. Marsh and M.J. Smith, “There is More than One Way to Do Political Science: on Different Ways to Study Policy Networks”, Pol. Studies, vol. 49, pp. 528-541, 2001.

[13] R. Palanisamy, “Issues and challenges in e-governance planning”, Electr. Gov., an Int. J. vol. 1, pp. 253-272, 2004.

[14] T.A. Parks, Few misconceptions about e-government, The Asia Foundation, 2005, http://www.asiafoundation.org/pdf/ICTeGov.pdf.

[15] D. Pilling, and H. Boeltzig, Moving toward e-government: effective strategies for increasing access and use of the Internet among non-Internet users in the U.S. and U.K., The Proceedings of the 8th Annual International Digital Government Research Conference, pp.35-46, 2007.

[16] United Nation E-Government Survey. Retrieved by <http://unpan1.un.org/ intradoc/groups/public/documents/UN-DPADM/UNPAN038853.pdf >, [Accessed 15.01.2014].

[17] D.M. West, "E-government and the transformation of service delivery and citizen attitudes", Pub. Admin. Rev., vol. 64, pp. 15-27, 2004.

[18] Zheng, M. Jong and J. Koppenjan, "Applying policy network theory to policy-making in China: The case of urban health insurance reform", Pub. Admin., vol. 88, pp. 398-417,2010.

[19] K.J. Bwalya, "Factors affecting adoption of e-government in Zambia", Electr. J. of Information. Syst. in Dev. Countries. Vol. 38. No.4, pp, 1-13, 2009.

[20] Alshehri and Drew, "Challenges of e-government services adoption in Saudi Arabia from an e-ready citizen perspective" World Acad. of Sc., Eng. and Tech., Vol.66, 2010.

[21] Layton, T, Information Security: Design, Implementation, Measurement, and Compliance. Boca Raton, FL: Auerbach publications, 2007.

[22] J.M. Alonso, O.A. and M. A. Amutio, Improving Access to Government through Better Use of the Web, W3C Interest Group Note 12 May 2009, Retrieved byhttp://www.w3.org/TR/egov-improving/,[Accessed 16.11.2015].

Agriculture and Engineering Interface to Cope Climate Change Effects in Nepal: A Review

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Abstract

This paper analyzes present energy consumption by industrial sector within Kathmandu Valley. Initially, author has gone through intensive literature review and prepare questionnaire. Kathmandu Valley is considered as hub of economic sectors. There are large numbers of industries therefore Sample Distribution method is applied to select location. Out of 1,372 industries, 239 industries have been visited to collect data regarding various energy sources available, technologies used, manufactured final products etc. Collected data is compiled using MS-Excel. It was found that total energy consumption by manufacturing industries in Kathmandu Valley is 16.4 PJ. Diesel is the main energy sources which contribute about 37.21% of total energy consumption. The energy demand is projected from base year 2019 to 2050 using MAED energy model tool. The energy demand for manufacturing industries in Kathmandu Valley is estimated to grow from 16.4 PJ in 2021 to 50 PJ at low growth rate (3.95%), 116 PJ at medium growth rate (7%) and 524 PJ at high growth rate (12.7%). However, the demand of diesel and electricity will increase from 38% and 6% in base year to 60% and 14% respectively by 2050.GHG emission in 2021 was 1,249.6 thousand metric tons and it is expected to increase by 2050 at low growth, medium growth, and high growth is 3842.8 thousand metric tons, 8890 thousand metric tons, and 40,043 thousand metric tons respectively.

Keywords
Agriculture, climate change, engineering, smart farming, sustainable agriculture.

1. INTRODUCTION

Agriculture is the front liner to national economy for most of the developing countries as reflected by its share in gross domestic product (GDP) and employment [1]. In the context of Nepal, agriculture and forestry sector jointly contributes 23.79% share to national GDP covering NRs. 822,686 million gross values in 2018/19[2]. This sector engages 65.6%[3] population with 83% of farmers doing agriculture as deriving primary source of income from agriculture[4]. Farming communities are dominated by subsistence and smallholders with limited commercialization. Majority farms face low productivity, less access to improved technologies, limited skill and labor shifting to non-farm sector for livelihood[5]. In addition, farming is dependent on elements of weather like rainfall, temperature, sunshine, pressure, wind and humidity which are parts of ecological factors having permanent interactions and independency, where change in any of them imparts others[6]. The events of climate related changes such as rapid rise in temperature, erratic rainfalls, storms and increase in frequency of extreme events such as landslides, floods or droughts lead toward risker farming. The agriculture planning under these changes and advocating better integration of adaptation and

mitigation actions to support sustainable agricultural development for food security, the climate-smart agriculture (CSA) is an obvious option[7]. Contextualizing CSA in Nepal is highly complex due to multiple dimensions of the agriculture production systems in the country with diverse climatic zones and socio-economic conditions. Government of Nepal (GoN) has developed National Adaptation Program of Action (NAPA), enacted a national Climate Change Policy in 2011 (CCP), and implemented Local Adaptation Plans of Action (LAPAs) promoting climate-friendly practices in agriculture which is one of the strategies set out in Nepal's Nationally Determined Contribution (NDC). The Agricultural Development Strategy-2015 (ADS) of Nepal aims to promote green technologies and reduce carbon emissions. The ADS targets capacity strengthening of agricultural extension staff and farmers on CSA practices and technologies for improved resilience to climate change and variability. The CSA technologies are broadly grouped under four categories; (i) change in agronomic practices, (ii) use of modern technologies and equipment to increase water, nutrient or other input use efficiency, (iii) information-related interventions such as use of information and communication technology (ICT) to disseminate climate information from agro-advisories and weather forecast services, and (iv) practices that reduce or transfer risks associated with farming, such as weather-index-based agriculture insurance[8].

Advancement in engineering technologies has evolved in farming over time. The advancement is witnessed from subsistence farming mode towards use of sophisticated technologies such as farm machinery, adapting protected hi-tech structures and developing suitable irrigation system to digital use of information, remote sensing, robotic, drones, cloud computing, big data analytics and artificial intelligence (AI). The new advancement has enabled farming towards precision or smart farming[9]. The integration of engineering has contributed farming to new advancement. Agriculture and engineering interface has enriched farmer-machine interaction in agriculture based on real time information. Some practices are witnessed on estimating agronomical parameters or crop's progression, digitalization of soil system, surge or risk of pest and disease, unseen state or risk associated with agriculture production and environmental impacts and enabling farmers to cope with them. Moreover, engineering component contribute agriculture to be efficient in terms of investment, return and technical aspects.

In line with these contexts, the global technology intervention needs to prioritize agriculture which is the major contributors of national economy. This review aims to come up with existing engineering interventions like protected structures, irrigations schemes, AI and ICTs in climate change scenarios and inspire stakeholders to develop and replicate joining hands by cross-sectoral and multifaceted support for ensuring integration in correct path to cope with effects of climate change dragging laggard agriculture sector.

2. METHODOLOGY

This paper is based on review of practice to cope climate change effects in Nepalese and global scenarios. The information was accessed mainly through review of existing policies, plans and programs, ongoing practices and the appropriate measures towards coping strategy for climate change effects in agriculture related to interventions.

3. RESULTS AND DISCUSSIONS

3.1 Agriculture mechanization situation and policies in Nepal

Mechanization broadly covers all levels of farming and processing technologies that ease and reduces hard labour, relieves labour shortages, improves productivity and timeliness of agriculture operations, increase resource-use efficiency, enhances market access and contributes to mitigating climate related hazards in sustainable way considering technological, socio-economical, environmental and cultural aspects from simple and basic hand tools to more sophisticated and motorized equipment. In this regard, mechanization is broadly including the application of tools, implements, powered machinery and equipment to achieve agricultural production, comprising both crop and livestock production as well as aquaculture and apiculture[10].

In Nepalese agriculture, mechanization is getting attention with labour shifting towards non-farm activities, increasing cost of production and market-oriented farming including demographic shift, socio-economic and policy changes in the country. The power-operated machineries like water pumps, tractors, harrows, rotavators, seed drills, threshers, combine harvesters, processing machine, sprayers, shallow tube-wells, treadle pumps and laser land levelers are in operation in Terai and use of tractors, power-tillers, mini-tillers, pump-sets and threshers is increasing in rural hills and mountains[11]. In addition, mechanization in Terai includes direct seeding of rice and wheat by zero tillage four-wheel operated tactor, minimum tillage by power tiller, use of rice transplanter, mechanized irrigation, intercultural operation by power weeder, harvesting by reaper and combine harvester, threshing by multi-crop thresher, mobile thresher and laser land leveler in larger farm while in hills, seed sowing by power tiller with seed drill, mini-tiller seeder, potato planter, maize planter, lifting irrigation, inter-culture operation by power weeder, harvesting by mini tiller reaper, brush cutter, serrated sickle and solar dryer for post-harvest processing are increasingly been used[12].

Agriculture mechanization in Nepal has been viewed as farm implements and machinery accesses and adoption which is largely import dependent. It was departure with provision of more efficient farm equipment and tools promotion in the first Five-Year Plan (1956-1960 AD) of the government emphasizing to reduce the farmer's burden of hard labor. Then after, private sector introduced tractors for ploughing and pump sets for water-lifting in irrigation from late 1960s and throughout 1970s, tractors and motorized pumps importation and adaptation throughout the terai and power tillers and milli-tillers in the hills largely extended only after

2006[13], [14]. Institutional development for farm mechanization started with establishment of Agricultural Implement Research Unit, Birgunj in 1960. Formerly, the Agricultural Engineering Directorate and now known as Center for Agricultural Infrastructure Development and Mechanization Promotion (CAIDMP) under Department of Agriculture (DoA), Nepal has mandate to develop infrastructure, farm building, farm roads, irrigation facilities and promote while, National Agricultural Engineering Research Center (NAERC) of Nepal Agricultural Research Council (NARC) is engaged in designing, testing, modification and promotion of tools and equipment[13].

Earlier, Nepal's major agricultural development policies and program such as "Agriculture Perspective Plan 1995-2015" and "National Agricultural Policy-2004" ignore mechanization due to fear of labour displacement in addition with small farm size, fragmented land holding, geographical constraints and narrow terraces in hills and mountains. However, with economic liberalization and mechanization realization in agricultural development sector "Agricultural Mechanization Promotion Policy-2014" has been formulated by GoN aiming to promote agriculture mechanization and commercialization and reduce food production costs through improving mechanization efficiency[11]. It focuses on promotion provision of subsidy on purchase of farm machineries. Further, "Agriculture Development Strategy 2015-2030" has designed mechanization options accessible through information dissemination, improve customer access to finance, capacity building for service and maintenance providers, enable the business environment for leasing agricultural equipment, revise regulation and taxes to support mechanization[15]. The promotional policy related to the availability, access and adoption of mechanization like liberal importing policy, tax exemption and low tariff in importation are found crucial as trigger in agricultural mechanization development. Other related policies focusing in related arena are "Rural Energy Policy-2006" with provision of subsidy in the use of rural renewable technologies such as solar dryer, solar pump, micro-hydro, cold storage facilities and machinery and equipment that run by renewable energy, low tariff rate for irrigation and "Industrial Policy-2010" emphasizing establishment of agro-based industries. Moreover, yearly credit policy, transport policy and subsidy policy of government have integral effect in favoring agricultural mechanization[11].

Next to present situation, optimized design of agricultural machinery in combine with digital data management will enable small-scale farmers to access atomized and semi-autonomous equipment and digital innovations in mechanization technologies which can make agriculture more attractive to rural youth towards the high-tech digitally supported machinery led farming ultimately viewed as smart farming where one can image the higher production and profitability in this competitive commerce led world. The possible application of agriculture technologies related to engineering like precision farming, AI, remote sensing, blockchain technology, internet of things (IoT), ICT and

LIDAR present the challenges to successful sustainable adoption[16].

3.2 Climate changes and its effects in Nepalese agriculture

Global climate has varied range of time and space scales due to various factors that are internal and external to the complex climate system. Human activities of industrial revolution have increased the concentration of greenhouse gases on atmosphere which essentially traps more heat in the global climate system and cause global warming[17]. The measurable elements of weather, rainfall (and other form of precipitation), temperature (heat level), sunshine (duration and intensity), pressure, wind (direction and velocity/speed) and humidity (absolute and relative) are part of ecological factors which have permanent interactions and independency, where change in any of them imparts others[6].

The 2021 United Nations (UN) Climate Change Conference (COP26) commitment for sustained progress toward the Paris Agreement and UN framework convention on climate change, by limiting increased global temperature to 1.5°C above pre-industrial levels encompasses the net zero global emissions by at least 2050 which can only be meet by technology innovations realized by societal and industrial level and governments, as well as corporations. Step with various options, digital technologies offer the potential solutions to climate changes where just by AI based systems could contribute to reduction of 4% in global emissions by 2030[18].

The climate change results variations in solar energy, temperature, precipitation, soil moisture and sea level [19], [20]. The rapidly retreating glaciers (average retreat of more than 30 m/year), rapid rise in temperature, erratic rainfalls and increase in frequency of extreme events such as floods and droughts like situation are some of the effects in Nepa [21]. Hydrological and meteorological data from Department of Hydrology and Meteorology indicate the increasing temperature in Nepal in consistent and continuous manner after the mid-1970s with maximum temperatures at an annual rate of 0.04-0.06^{0}C. The duration of summer monsoon originating from the Bay of Bengal and winter precipitation from western Mediterranean Sea are found to be longer than normal increasing trends and late onsets ultimately late withdrawals. High intensity rainfall continuous for several days lead to massive landslide and soil erosion in the hills and finally flashes riverine floods in Terai. The changes in the dates of onset and retreat of the monsoon, number and frequencies of extreme precipitation events, intermittent droughts like situation during the monsoon season increase significant cost in agriculture. The extreme topography of Nepal challenges to prepare and mitigate effects if possible and if not adapt to reduce impacts on lives and livelihoods [21], [22]. In contrast, droughts occurring from the end of March through until arrival of the monsoon season in hills and mountain of Sudurpaschim and Karnali Provinces and Terai of Province no. 1 and Madhesh Province[22]. The pre-monsoon drought coupled with high temperature could reduce soil moisture in many areas reducing the available water for irrigation thereby further reducing farming possibility in non-irrigated area[19].

Short-term extremes in temperature and precipitation are critical for crop growth coinciding with key stages of development. The yields of different crops and geographic limits has been altered by changes in soil moisture, temperature and precipitation. Increased temperature often results in steep drop in net growth and yield. Heat stress affects crop yield through impact on physiological development and crop maturation. Higher temperatures provide a conducive-environment for the majority of insect pests. Longer growing seasons, higher night temperatures and warmer winter help insect pests undergo multiple life-cycles and increase the chances of affecting plant production. Further, the pattern and extent of rainfall and evapo-transpiration processes affect soil moisture storage, run-off and water absorption by the plant which creates condition of excess or no water during different stages of plant production. Moisture stress during flowering, pollination and grain-filling stage is harmful to most crops. Increased evaporation from soil and accelerated transpiration in the plants themselves will cause moisture stress[23].

Therefore, the disaster like floods, landslides and droughts and their consequences are climate induced indirect effects related to extreme rainfall events or non-uniform distribution throughout the topography. Flood affect agriculture in the Terai region every year imparting standing crops in the field and landslide prone in hills and mountainous region. Excessive rain in some part and drought in other part triggering with increasing temperature challenges crop production and productivity.

The efficient mechanization to cope with ever-increasing demand in climate change scenarios will be sustainably managed with utilization, maintenance, co-ordination and control of resources use with precision farming aided by technologies. The primary intervention of new technologies to disseminate information and make aware of the successive effects through ICTs and engineering development in the aspect of protected high-tech structures and efficient irrigation schemes leads to the coping strategy towards climate changes vulnerability. The development of low-cost water efficient technologies and development of early warning systems related to drought, rainfall and flood forecasting are crucial to cope with inevitable climate change effects.

National Strategy for Disaster Risk Management (NSDRM)-2009, a basic reactive and relief guide to disaster risk reduction, preparedness and effective response and currently, Sendai Framework for Disaster Risk Reduction 2015-2030 targets and priorities for action to prevent new and reduce existing disaster risk aiming to achieve the substantial reduction of disaster risk and losses in lives, livelihoods and health [22], [24]. ADS-2015 has visioned about improved resilience of farmers through early warning system, climate information and weather indexation systems, pilot a farmers welfare fund, promote agricultural insurance, improve capacity of extension staff and farmers in CSA and establish a fund for preparedness and response. Functional agriculture risk information system for delivering information and services in coordination with multi-stakeholder such as local

level bodies, provinces, development partners, line agencies, response team and necessary investments in agriculture infrastructure and technologies generation are pre-requisites for supporting climate risk reduction functions in agriculture.

3.3 Intervention areas and technology option

Agriculture is benefitting from technological advancements globally. Technologies improvement in agricultural aims to optimize production efficiency, enhance quality, minimize environmental impacts and production-associated risks[16]. Appropriate invention can contribute to the precise use of resources, inputs such as fertilizer, seeds and pesticides and avoiding overuse and waste in the adverse climate changes impacts scenarios through eco-system-based approaches. In order for advancing technologies to make a difference, these need to be adopted and used in farms around the world which could be possibly with the private sector involvement in development and government formulating policies and regulations to create an enabling environment to flourish and reach the ultimate need ones [25]. Human intervention or technological options especially in the area of engineering are of major importance in coping with climate variations[26]. These interventions in farming include protected structures, precision farming, modern farm implements and machineries or automated equipment for farm operations, drip irrigation systems for optimizing production efficiency and quality, AI for pest and disease diagnostics and management options, remote sensing (satellite and drone imagery), and deploying of ground sensors (soil, crop or meteorological stations) leading to early warning system for minimizing production-associated risks and environmental impacts.

3.3.1 Protected structures

Increasing pressure on natural resources and small land holdings demand agricultural production system to be shifted to suitable interventions that can cope with climate changes and addressing population growth. Protected cultivation involving the use of structures (like greenhouses, net houses, screen houses, tunnels) is one of the options. On this regard, low volume high value horticultural crops management tool under protected condition increases competitive quality produce and productivity by 3-5 folds over open field condition. Protected cultivation enhances crops growth environments, prolong the harvest period, manage pests with minimal pesticide, use water and fertilizer efficiently, increase yields, improve quality, enhance stable production and off-seasoning[27]. The farms using protected cultivation facilities has been benefitted with increased farm profit by 68-73% in Taiwan who have been suffered by natural disaster shocks [28] that gives subsidizing idea for adoption of protected technology to mitigate the risks resulting from natural disaster shocks. Relating this, Ministry of Agriculture and Livestock Development (MoALD) has developed guidelines and standard for hi-tech greenhouse program in 2014/15 AD. Bamboo plastic tunnel, GI poly-tunnel, naturally ventilated greenhouse, fan and pad cooling greenhouse, agri-net house, shade house, high-tech and semi high-tech greenhouses are being adopted as controlled environment agriculture [12] for production of

vegetables, flowers and fruit sapling. These structures are generally recommended for selected crop in the selected area for targeted market place to get better return from the interventions and investment. Many donors funded projects and government funded projects such as Prime Minister Agriculture Modernization Project (PMAMP) has implemented programs on construction of protected structures and cultivation support [29].

The frequency of extreme weather events like drought periods and heat waves are of major challenges of changes in climate. The protected construction and covers protect crops from wind or hail storms facilitating in controlling internal temperature, humidity and radiation. This advances to the independence from the open field production and powered towards coping with climate change impacts. Technical and conceptual innovations in greenhouse designs like cover materials, shading screens, semi-/closed ventilation and improved natural and additional light are valuable in innovation of the protected structures to cope with abnormal climatic alternation and extreme weather conditions associated with climate changes [30].

The greenhouse cultivation has been benefited in both the winter and the warm seasons. During the winter season, inside greenhouses more favorable temperatures may be reached to grow heat-demanding species while during the warm season, the high solar radiation and exceeding temperature effects are compensated by the shading effect and can be regulated to certain extend by proper ventilation and/or cooling of the greenhouse. For the year-round use, instead of plastic films, greenhouses with screens (nets) have become common practice in recent years in some areas. The screens are permeable for air exchanges with the outside environment and transparent to very limited and reduced sunlight. Screenhouses can reduce the damage caused by the heavy rainfall and hailstones but cannot protect crop from rainfall. This can be said growing crop under high-tech greenhouses avoid strong dependency on the outdoor climatic effect [31]. In Nepal, recent increasing trends of cultivating ornamental plants and commercial vegetables under protected structures in terai and mid-hills to avoid frost and maintain required temperature during winter and escape rain in rainy seasons has made ensure of the high investment in farming. Besides this, fruit nursery and rice seedbeds under well-equipped protected tunnels ensure healthy sapling or planting material compared to outdoor otherwise affected.

3.3.2 Irrigation schemes

Drastic decline of rainfall pattern and increased temperature creates drought condition with decreased irrigation water and increased water conflict. Efficient water use technology is a major in coping with climate change where loss of water and cost involved are less. High efficiency irrigation (including drip and trickle irrigation) is the better option which save significant amount of water and increase area under irrigation that contribute to sustainable land management and relief to climate change effects. This leads to requirement of the innovative design of integrated water delivery and application schemes [32]. Micro irrigation (including drip irrigation, mini

sprinkler irrigation and bubbler irrigation) is being promoted throughout the world as a climate-adaptive technology that will reduce demand for groundwater and notably enhance the resilience of agriculture in light of ongoing groundwater overdraft and climate change–induced shocks [33], [34].

Next, the water harvesting technologies capturing small water resources and decentralized water management infrastructures are alternatives to improve rainwater use and climate resilience [35]. The invention of lift irrigation to augment water supply and water harvest technology as reservoir to store additional water in hills and deep tube-well and bore-well along with recharge technology in the flatland are crucial to capture the water stress or drought impacts [36], [37]. In addition, the sensor based digital equipment or technologies are helpful in combating the water or moisture stress or drought and act accordingly.

3.3.3 Artificial intelligence

AI technology makes agricultural practices more efficient, equitable and less damaging to the environment by helping farmers to improve crop yield, address the challenges of soil health and use resources more sustainably reducing the agricultural sector's greenhouse gas emissions [38]. Automated equipment AI having remote sensing in compliance with information and communication technology leads to digitalization. Camera or scanner censors applied in the computer vision systems are used in different agricultural production systems has made a simple and objective analysis of the images, videos and machine learning and produce adequate descriptive data for future analysis and automate laborious task in non-destructive way. Sensors monitor the soil or crop or meteorological parameter to generate data captured, processes by specific software and AI to provide intervention options go for proper decision to act on the crop [16]. It is estimated that AI-based advisories would be useful to increase production by 30% [39]. The development of intelligence devices that use computer vision, automation in the field and integration with agricultural machines can solve agricultural problems currently open [40]. Drones and robots are among these machines.

3.3.3.1 Drones

DRONE (Dynamic Remotely Operated Navigation Equipment), also known as UAVs (Unmanned Aerial Vehicles), is a flying device either with the help of autopilot or manually using the remote control or smartphone app that can significantly enhance risk and damage assessment and revolutionize the way to prepare for and response to disaster [41]. Drones in agriculture are used for soil and field analysis, planting, spraying crops, crop monitoring, irrigation, crop health monitoring and remote sensing which ensure permanent crop monitoring from planting to harvesting [42]. Added with the images and videos captured by special sensors of drones, farmers can view crop changes that are otherwise invisible to human eyes [43] irrespective to the physical geographical structure. Drones' application in disaster management and weather forecasting are valuable with respect to climate changes. Drones provide quick means after a disaster to gather

information and navigate the destruction by saving resources on manned or manual tasks. In addition, drones monitor dangerous and unpredictable weather using specialized sensors for weather parameters, collect data and prevent mishaps [44] delivering agricultural intelligence [45]. Drones do solve the difficulty of surveying and surveillance of disaster damage mapping by improving the speed of exploration work too [46] including insects and disease damage [47]. Crop insurers and insurance policy are benefited with the use of drone in assessment of crop losses after natural disasters for accurate and quick calculation of pay-out or detect the fraud [43], [48]. In Nepal, due to air safety and privacy rights reasons drone flights are restricted [43], [49]. However, drones are useful in monitoring the crops and plan the farms in climate changes inevitable effects scenarios with designing the proper legal regulatory policy.

3.3.3.2 Agricultural robots

Robotics can address the potential consequences of climate changes and increase efficient use of resources fighting their negative effects. Robotics has potential to make difference in scientific research, help in reducing emission of greenhouse gases and mitigating climate disasters. In terms of mitigating climate disasters, faster responses are possible assisting in rescuing victim and post disaster recovery. Robotics introduction in agriculture having combination of different intervention technology platform like sensor for monitoring, specific software as data processing, decision options for implementation and automated action on actualization give the real sense of complete AI [16]. Works on agricultural robots are in the early stages with different concept on evolution for potential innovation, implication and advancing technology to newer area. With given versatility, agrobots could be vital in labour intensive farm works in increasing sustainable crop production and management contributing in livelihood of smallholder farmers in developing countries. Currently, agricultural robotics autonomously used in weeding, irrigation, guarding the farms, reporting, ensure the adverse environment condition for production, increase precision and manage individual plants in multiple angles. To address more frequent drought, robots collect data and process them to be used in drought tolerant crop development by understanding combat phenomena to grow during drought [50]. Smart irrigation system technology compliance with automatic plant irrigator ensures the soil fertility, moisture content and temperature with respect to better crop growth and apply water effectively in stress condition. Agrobots could be useful in predicting the weather and other conditions related to agriculture and helps in accurate projection or prediction of concerns of farmers [39].

3.3.4 Information and communication technology

Information related to climate, weather, precipitation, and disaster are critically important. Monitoring and data dissemination by typical ICT to access daily weather forecasts and long-range predictions for environmental protection and economic development imparts on preparedness of safety of life and property. ICTs play role in disaster prevention, mitigation, response and

recovery by timely, predicable and effective information as early warning and alerts community at risks [51]. Community risk knowledge is acquired through systematically collected data, conduct risk assessment and disseminate the information as early warning to the at-risk communities prior to the disasters strike [52]. Untimely rain, drought, hail storm and strong wind have been responded as primary climate related hazard and improving forecasting and dissemination of climate information and promotion of farm-level adaptation measure access through early warning are first step to improve community resilience to climate change [53]. Early warning (EW) is the provision of empowering communities or individuals in threat by hazards to act appropriately in time and finally reduce the possibility of injury, loss of life, damage to property and the environment, loss of livelihoods and enhance the resilience of a society. EWS is progressive in deploying international commitment, better forecasting techniques, improved technology for communication and sharing of information and provide climate change adaptation in disaster risk reduction [54]. A complete and effective EWS consists of four inter-related components (i) risk knowledge, (ii) monitoring and warning service, (iii) dissemination and communication, and (iv) response capability. In climate change scenarios with scarce financing resources, the EWS should address all components with well designed and implemented in accordance with local institutional capacity and participation to enhance the potential action upon an early warning [54], [55]. Major challenge remains in the operational ground to achieve the potential benefits from communicating risk information by the concerned authorities and communities at-risk. The comprehensive, clear and concise messages must be accessible to all users to reduce economic losses to better protect their assets and livelihoods. The advances in science and technology have contributed to know vulnerability warning messages and building and mobilizing their response capability to reduce risk [29]. The long-term seasonal forecasting, such as weather, climate, drought, and land degradation trend is most successful EWSs while short-term imparts of floods, geologic hazard and water pollution are harder to predict [56]. The communication of early warning information tools like short message service (SMS) (cellular phone text messaging), email, radio, TV and web service are ICTs' key elements [57]. Remote sensing technologies, IoTs, ICTs based agro-advisory services, internet and network computer and e-adaptation and e-resilience are among developed ICTs' EWS technologies.

3.3.4.1 Remote sensing

Remote sensing a tool for monitoring the real-time reliable continuous stream of data on environmental and meteorological phenomena. The advancement and availability of automated sensors that capture, analyze and predict adverse impacts through remote data, enhance the setting up of effective EWS, especially on global scale phenomena where traditional in-situ monitoring may be very difficult and time consuming [6], [57].

3.3.4.2 Internet of Things

IoT refers to scenarios where network connectivity and computing capability extends to objects or sensors to generate, exchange and consume data remotely providing feedback and make decision [58], [59]. The IoT devices are designed for self-report in real-time, improve efficiency and bring important information to the surface more quickly than a system to allow worldwide web communicating with one another [60]. The successful combination of wireless sensor network and the mobile communication technology in digital agriculture make control in monitoring and faster reaction remotely [61].

IoT technology of real-time wireless sensor network as EWS, monitor temperature and humidity and GSM SMS will notify the user to take environmental regulation measures. Wireless sensor node collects soil moisture, nitrogen concentration, pH value, precipitation, temperature, air humidity and CO_2 concentration and wireless sensor network forward them to central control device. As soon as abnormalities are detected by analyzing the environmental factors, early warning function be enabled and GSM warning messages be sent to the system user to take decision at right time and reference [62]. In the greenhouses, the sensors are able to measure four parameters in climatic adjustment: temperature, relative humidity, light irradiance and air carbon dioxide content and leads to the greenhouse environmental control system which adjusted the ventilation, heating and misting [63].

3.3.4.3 ICT based agriculture extension and agro-advisory services

An integration of Android Apps and a web-based system is an alternative to enhance and improve the manual system of current advisory service in the agriculture development. The system is able to detect and record information and these data are used by the advisory team to measure risk factor and helps in alerting the farmers with advice to do necessary actions [64]. Smartphones, internet services, mobile networks, televisions and radio widespread has created opportunities to disseminate relevant information faster and rapidly covering larger mass than ever challenges the extension worker efficiency. The internet-based initiatives for knowledge sharing and weather forecast using geographic information systems (GIS), global positioning system (GPS) services in agro-meteorological initiatives through Android agricultural apps [65] that helps in reducing risk and uncertainties [66]. These apps reduce time delays between monitoring, problem detection and provision of recommendation [67].

3.3.4.4 Internet and networked computers

Cloud computing (Google, Yahoo and Microsoft) have started incorporating maps and satellite imagery for a near-real-time mode [57]. Big data analytics through historical agrometeorological datasets, regression methods and neural network methods are mainly used for forecasting data in different problems with the aid of ICT have remote sensing to generate collect, process and visualize large data for future predictions and make decisions for the management [68].

3.3.4.5 e-adaptation and e-resilience

ICTs-mobile phones have been diffusing information rapidly to strengthen the physical preparedness of livelihood systems, institutions and organizations and social networks for climate change related events through GIS, GPS and modeling application. The establishment of multi-sectorial alliances to implement ICT related solutions in the field and ICT entrepreneurs need the provision of technical and financial support as incentives to access and connectivity in climate change affected regions. ICT based national programs and strengthening the internal capacity to adjust, change and transform of nationwide organizations to provide service of local adaptive actions for recovering from adverse climatic events [69].

4. GAP ASSESSMENT

Based on above discussion, we identify some gaps. Firstly, we identify the need for hazard mapping that provides bases for identification for planning to reduce the impact of climate change. Secondly, a lack of country specific research on appropriate technology that support for adaptation and mitigation measures for climate change hazards for smallholder farmers. Thirdly, assessment of appropriate technology is needed including the sustainable utilization of these technology. Fourthly, an institution that looks after climate resilient technology including technological and economic aspects is lacking. Finally, a commitment for assurance of budget including the implementation for climate smart investment plan need to be assured.

5. CONCLUSION

This paper draws conclusions that has implications on integration of new innovation the research and also on policy measures in Nepalese agriculture. The short-term and long-term strategies need to be developed to mitigate the effects of climate change hazards and promote adaptations of suitable technology in agriculture sector. While a short-term mitigations and adaptations measures could be borrowed from outside, the medium- and long-term solution should be based on context specific assessment and research evidences. The government approach of handling climate change impacts through preparedness, rescue, relief and recovery could be better developed through innovative technology such as digitalization of data base and early warning system developed based on integrated data base. The new innovations that link agriculture and engineering should focus on cost effective measure and sustainability of the technology. Research on technology, its development and dissemination among farmers should be based on the assessment of data and evidences for greater reliability and also on assessment of gap that show difference between actual and desired condition. A digital based problem solution measure based on real time data would augment for the sustainable solution of the problem leading to development of climate resilient agriculture.

REFERENCES

[1] T. Mogues, B. Yu, S. Fan, and L. Mcbride, “The Impacts of Public Investment in and for Agriculture: Synthesis of the Existing Evidence,” Rome, Italy, Oct. 2012.

[2] MoALD, "Statistical information on Nepalese agriculture 2076/77 (2018/19)," Kathmandu, 2021.

[3] CBS. (2013a), *National Sample Census of Agriculture Nepal 2011/12*. Kathmandu, Nepal: Central Bureau of Statistics (CBS), National Planning Commission, Government of Nepal, 2013.

[4] CBS (2013b), *National Agriculture Statistics 2011 - Summary Result*. Kathmandu: Central Bureau of Statistics (CBS), National Planning Commission, Government of Nepal, Kathmandu, Nepal, 2013.

[5] P. P. Regmi, "Innovative agriculture technologies in South Asia," in *Innovative Agricultural Technologies in South Asia*, N. Sultana, F. N. Jahan, and S. M. Bokhtiar, Eds. Dhaka, Bangladesh: SAARC Agriculture Centre, 2018, pp. 1–15.

[6] P. O. Simeon, H. E. Jijingi, and N. J. Apaji, "Climate change: a challenge to sustainable land resource management in agriculture and the extension of arable crops mechanization in Nigeria.," *Scientific Papers Series - Management, Economic Engineering in Agriculture and Rural Development*, vol. 18, no. 3, 2018.

[7] S. Asfaw, L. Lipper, N. McCarthy, D. Zilberman, and G. Branca, *Climate-Smart Agriculture - Building Resilience to Climate Change*. 2017. doi: 10.1007/978-3-319-61194-5.

[8] B. Poudel, R. C. Khanal, A. KC, K. Bhatta, and P. Chaudhari, "Climate-smart agriculture in Nepal: Champion technologies and their pathways for scaling up," 2017.

[9] I. Charania and X. Li, "Smart farming: Agriculture's shift from a labor intensive to technology native industry," *Internet of Things (Netherlands)*, vol. 9. 2020. doi: 10.1016/j.iot.2019.100142.

[10] FAO & AUC, *Sustainable agricultural Mechanization - A framework for Africa*, vol. 55. 2018.

[11] D. Gauchan and S. Shrestha, "Agricultural and rural mechanisation in Nepal: Status, issues and options for future," *Rural Mechanisation. A Driver in Agricultural Change and Rural Development*, no. July, 2017.

[12] G. P. Sharma, "Innovative Agricultural Technologies in Nepal," in *Innovative Agricultural Technologies in South Asia*, N. Sultana, F. N. Jahan, and S. M. Bokhtiar, Eds. Dhaka: SAARC Agriculture Center, Bangladesh, 2018, pp. 110–134.

[13] H. Takeshima, "Overview of the Evolution of Agricultural Mechanization in Nepal: A Focus on Tractors and Combine Harvesters," *IFPRI Discussion Paper*, vol. 01662, no. July, 2017.

[14] H. Takeshima and M. Bhattarai, "Agricultural Mechanization in Nepal—Patterns, Impacts, and Enabling Strategies

for Promotion," in *Agricultural Transformation in Nepal*, Singapore: Springer Singapore, 2019, pp. 261–289. doi: 10.1007/978-981-32-9648-0_10.

[15] MoALD, "Agriculture development strategy (ADS)-2014," Kathmandu, Jan. 2014.

[16] S. S. Valle and J. Kienzle, "AGRICULTURE 4.0 Start Agricultural robotics and automated equipment for sustainable crop production," *Integrated Crop Management*, vol. 24, 2020.

[17] J. M. Lough, "Chapter 2 Climate and Climate Change on the Great Barrier Reef," *Climate Change and Great Barrier Reef*, 2007.

[18] Y. K. Dwivedi *et al.*, "Climate change and COP26: Are digital technologies and information management part of the problem or the solution? An editorial reflection and call to action," *Int J Inf Manage*, vol. 63, 2022, doi: 10.1016/j.ijinfomgt.2021.102456.

[19] C. Aydinalp and M. S. Cresser, "The Effects of Global Climate Change on Agriculture 1," *Gli effetti del cambiamento climatico in agricoltura*, vol. 3, no. 5, 2008.

[20] G. Malla, "Climate Change and Its Impact on Nepalese Agriculture," *Journal of Agriculture and Environment*, vol. 9, pp. 62–71, 2008, doi: 10.3126/aej.v9i0.2119.

[21] M. Karki, P. Mool, and A. Shrestha, "Climate Change and its Increasing Impacts in Nepal," *The Initiation*, vol. 3, pp. 30–37, Jan. 2009, doi: 10.3126/init.v3i0.2425.

[22] M. Aryal, A. Giri, D. B. Basnet, and M. Kandel, "Policy framework for climate-induced disaster risk management in agriculture sector of {Nepal}.," *Journal of Agriculture and Environment*, vol. 19, 2018.

[23] R. C. Khanal, "Climate Change and Organic Agriculture," *Journal of Agriculture and Environment*, vol. 10, 2009, doi: 10.3126/aej.v10i0.2136.

[24] United Nations, "Sendai Framework for Disaster Risk Reduction 2015-2030," 2015. [Online]. Available: https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf

[25] G. Séverac, A. Savary, J. Peyrache, and R. Lenain, "Agricultural robotics: Part of the new deal? FIRA 2020 conclusions: With 27 agricultural robot information sheets," *Agricultural robotics*, 2021.

[26] UNFCC, *Technologies for adaptation to climate change / UNFCCC*. 2006. doi: 10.29171/azu_acku_pamphlet_qc903_t434_2006.

[27] FFTC, "Protected cultivation of high-value crops under changing climate conditions," *Food and Fertilizer Technology Center for the Asia and Pacific Region*, 2017. https://www.fftc.org.tw/en/activities/detail/111

[28] P. A. Liao, J. Y. Liu, L. C. Sun, and H. H. Chang, "Can the adoption of protected cultivation facilities affect farm sustainability?," *Sustainability (Switzerland)*, vol. 12, no. 23, 2020, doi: 10.3390/su12239970.

[29] A. Kafle and P. Atreya, "Protected horticulture technology development: some intervention and future needs for Nepal," Apr. 2019.

[30] N. Gruda, M. Bisbis, and J. Tanny, "Influence of climate change on protected cultivation: Impacts and sustainable adaptation strategies - A review," *Journal of Cleaner Production*, vol. 225. 2019. doi: 10.1016/j.jclepro.2019.03.210.

[31] N. Castilla and E. Baeza, "Greenhouse site selection," in *GAPs for greenhouse vegetable crops: Principles for Mediterranean climate areas*, 217th ed., Rome: FAO Plant Production and Protection Paper, 2013, pp. 21–23.

[32] K. Nkya, A. Mbowe, and J. H. J. R. Makoi, "Low -Cost Irrigation Technology, in the Context of Sustainable Land Management and Adaptation to Climate Change in the Kilimanjaro Region," *Journal of Environment and Earth Science*, vol. 5, no. 7, 2015.

[33] T. Birkenholtz, "Assessing India's drip-irrigation boom: efficiency, climate change and groundwater policy," *Water Int*, vol. 42, no. 6, 2017, doi: 10.1080/02508060.2017.1351910.

[34] X. Zou, Y. e. Li, Q. Gao, and Y. Wan, "How water saving irrigation contributes to climate change resilience-a case study of practices in China," *Mitig Adapt Strateg Glob Chang*, vol. 17, no. 2, 2012, doi: 10.1007/s11027-011-9316-8.

[35] L. Rosa *et al.*, "Potential for sustainable irrigation expansion in a 3 °c warmer climate," *Proc Natl Acad Sci U S A*, vol. 117, no. 47, 2020, doi: 10.1073/pnas.2017796117.

[36] G. Kar, P. Panda, S. Pradhan, and S. Ambast, *Climate change mitigation and adaptation strategies through efficient water management in agriculture*. 2016.

[37] B. Thapa and C. A. Scott, "Institutional strategies for adaptation to water stress in farmer-managed irrigation systems of Nepal," *Int J Commons*, vol. 13, no. 2, 2019, doi: 10.5334/ijc.901.

[38] A. Elbehri, H. Eskandar, and R. Chestnov, "Adopting artificial intelligence solutions for agriculture: potential, the process, the success factors, and key recommendations," in *Digital agriculture in action – Artificial Intelligence for agriculture*, A. Elbehri and R. Chestnov, Eds. Bangkok: FAO; ITU;, 2021, pp. 1–8. doi: 10.4060/cb7142en.

[39] T. Talaviya, D. Shah, N. Patel, H. Yagnik, and M. Shah, "Implementation of artificial intelligence in agriculture for optimisation of irrigation and application of pesticides and herbicides," *Artificial Intelligence in*

Agriculture, vol. 4. 2020. doi: 10.1016/j.aiia.2020.04.002.

[40] D. I. Patrício and R. Rieder, "Computer vision and artificial intelligence in precision agriculture for grain crops: A systematic review," *Computers and Electronics in Agriculture*, vol. 153. 2018. doi: 10.1016/j.compag.2018.08.001.

[41] A. Rani, A. Chaudhary, N. K. Sinha, M. Mohanty, and R. S. Chaudhary, "Drone : the Green Technology for Future Agriculture," *Soil Helath: Technological Interventions*, vol. 2, no. 1, 2019.

[42] S. L. Muraru, P. Cardei, V. Muraru, R. Sfîru, and P. Condruz, "Researches regarding the use of drones in agriculture," in *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM*, 2019, vol. 19, no. 6.2. doi: 10.5593/sgem2019/6.2/S28.086.

[43] F. Greenwood, "Drones on the horizon: new frontier in agricultural innovation," *ICT Update*, vol. 82, pp. 2–4, Dec. 2016.

[44] S. Prasanna and J. Jebapriya, "IoT BASED AGRICULTURE MONITORING AND SMART FARMING USING DRONES," *Mukt Shabd Journal*, vol. IX, no. Iv, 2020.

[45] F. Veroustraete, "The Rise of the Drones in Agriculture," *EC Agriculture*, vol. 2, no. 2, 2015.

[46] Q. Ren, R. Zhang, W. Cai, X. Sun, and L. Cao, "Application and Development of New Drones in Agriculture," in *IOP Conference Series: Earth and Environmental Science*, 2020, vol. 440, no. 5. doi: 10.1088/1755-1315/440/5/052041.

[47] D. van der Merwe, D. R. Burchfield, T. D. Witt, K. P. Price, and A. Sharda, "Drones in agriculture," in *Advances in Agronomy*, vol. 162, 2020. doi: 10.1016/bs.agron.2020.03.001.

[48] R. G. Garg, "Insuring Indian farmers more effectively," *ICT Update*, vol. 82, no. 12, Apr. 2016.

[49] Himalayan News Service, "Govt designates restricted zones for drone flight," *The Himalayan Times*, Kathmandu, Feb. 19, 2019.

[50] S. Pell, "robot farmers the perfect 'comrade' in the war against climate change?," *https://robotical.io/blog/are-robot-farmers-the-perfect-comrade-in-the-war-against-climate-change/*, Sep. 04, 2021. https://robotical.io/blog/are-robot-farmers-the-perfect-comrade-in-the-war-against-climate-change/

[51] ITU, "Turning digital technology innovation into climate action," Geneva, Switzerland, 2019.

[52] S. Kanta Kafle, "Disaster Early Warning Systems in Nepal: Institutional and Operational Frameworks," *Journal of Geography & Natural Disasters*, vol. 07,

no. 02, 2017, doi: 10.4172/2167-0587.1000196.

[53] D. K. Mengistu, "Farmers' perception and knowledge on climate change and their coping strategies to the related hazards: case study from Adiha, central Tigray, Ethiopia," *Agricultural Sciences*, vol. 02, no. 02, 2011, doi: 10.4236/as.2011.22020.

[54] J. Cools, D. Innocenti, and S. O'Brien, "Lessons from flood early warning systems," *Environmental Science and Policy*, vol. 58. 2016. doi: 10.1016/j.envsci.2016.01.006.

[55] United Nations, "Global survey of early warning systems: An assessment of capacities, gaps and opportunities towards building a comprehensive global early warning system for all natural hazards," 2006. [Online]. Available: https://www.unisdr.org/2006/ppew/info-resources/ewc3/Global-Survey-of-Early-Warning-Systems.pdf

[56] J. E. Quansah, B. Engel, and G. L. Rochon, "Early Warning Systems: A Review," *Journal of Terrestrial Observation*, vol. 2, no. 2, 2010.

[57] V. F. Grasso, "Early warning systems. State-of-Art Analysis and Future Directions," 2012.

[58] CNS Precision Assembly, "Internet of Things," 2021. https://www.cns.org.au/internet-of-things-iot/

[59] K. Rose, S. Eldridge, and L. Chapin, *The Internet of Things: An Overview*. The Internet Society, 2015.

[60] W. Kenton, "The Internet of Things (IoT)," May 28, 2021. https://www.investopedia.com/terms/i/internet-things.asp

[61] X. H. Li, X. Cheng, K. Yan, and P. Gong, "A monitoring system for vegetable greenhouses based on a wireless sensor network," *Sensors (Switzerland)*, vol. 10, no. 10, 2010, doi: 10.3390/s101008963.

[62] X. Ding, G. Xiong, B. Hu, L. Xie, and S. Zhou, "Environment monitoring and early warning system of facility agriculture based on heterogeneous wireless networks," 2013. doi: 10.1109/SOLI.2013.6611431.

[63] T. Ahonen, R. Virrankoski, and M. Elmusrati, "Greenhouse monitoring with wireless sensor network," 2008. doi: 10.1109/MESA.2008.4735744.

[64] H. Nasir, A. N. Aris, A. Lajis, K. Kadir, and S. I. Safie, "Development of Android Application for Pest Infestation Early Warning System," 2019. doi: 10.1109/ICSIMA.2018.8688774.

[65] R. Paudel, P. Baral, S. Lamichhane, and B. P. Marahatta, "ICT Based Agro-Advisory Services in Nepal," *J Inst Agric Anim Sci*, vol. 35, no. 1, 2018, doi: 10.3126/jiaas.v35i1.22510.

[66] R. Abraham, "Mobile Phones and Economic Development: Evidence From

the Fishing Industry in India," *Information Technologies and International Development*, vol. 4, no. 1, 2007, doi: 10.1162/itid.2007.4.1.5.

[67] D. Vora and R. Jain, "Digital agriculture in action," in *Digital agriculture in action - Artificial intelligence for agriculture*, A. Elbehri and R. Chestnov, Eds. Bangkok: FAO; ITU;, 2021, pp. 19–23. doi: 10.4060/cb7142en.

[68] M. R. Bendre, R. C. Thool, and V. R. Thool, "Big data in precision agriculture through ICT: Rainfall prediction using neural network approach," in *Advances in Intelligent Systems and Computing*, 2016, vol. 438. doi: 10.1007/978-981-10-0767-5_19.

[69] R. K. P. Singh and K. M. Singh, "Climate Change, Agriculture and ICT: An Exploratory Analysis," *SSRN Electronic Journal*, 2012, doi: 10.2139/ssrn.2027780.

Alternative Fertilizer Options for Nepal - A Critical Review

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Abstract

Food security in Nepal has been a challenge due to low productivity of agricultural crops. Access to fertilizer has been the bottleneck for increasing productivity in Nepalese agriculture. The ever-increasing price for fertilizer and unreliable supply will put further pressure on Nepalese agriculture in the future. Therefore, an alternative fertilizer plan based on recovering fertilizer products from various agricultural and municipal organic wastes has been explored. Developing fertilizer products from a wide range of organic wastes has been a topic of interest world-wide, and recently there has been major progress on new methods of organic recycling. For example, Biotech Ltd has patented an aerobic thermophilic digestor technology that is in use for the rapid composting of various organic wastes with high fertilizer value. Rapid digestion of varied organic wastes, including poultry wastes, and their co-digestion with other organic wastes (e.g., food, sludge, green waste) were evaluated to produce a wide range of composted products that can be further composted or to produce dry organic pallets, granules or to develop custom blends of fertilizer in an organo-mineral mix as a complete fertilizer suitable in different cropping industries. Palletization and dry organo-mineral fertilizer products have longer storage, are cost effective to transport and in land application. Innovation and practice change in the production of organo-mineral fertilizers complemented with best practice management in crop production, are expected to result in transformational gain of agriculture productivity and profitability in Nepal.

Keywords
Fertilizer, plant nutrients, sustainable agriculture, organic waste

1. BACKGROUND

We discuss the role of agriculture in the Nepalese economy, causes of poor agricultural productivity, issues related to poor fertilizer supply chain function, and suggest use of alternative fertilizer products that provide the sustainable soil management options required to gain productivity of agricultural crops in Nepal.

1.1 Role of Agriculture in the Nepalese economy

Nepal is currently on the verge of an economic transformation. Agriculture remains the principal economic pillar, employing ~65% of the population and contributing 32% of the national GDP of $33.66 billion in 2017. Out of the total 147,181 square kilometer land area of Nepal, agricultural, forestry and pasture covers ~28%; ~40% and ~12% of land use respectively [1]. Traditional agriculture in Nepal features integrated farming (mixed farming operations consisting of agroforestry, animals and crops), that offer closed loop, low input, subsistence and sustainable farming that do not solely rely on inorganic fertilizers for plant nutrition. However, a post green revolution since 1965 has brought

new high yielding crop varieties that require fertilizers for intensive farming, in a quest for a rapid increase in production and productivity to secure food self-sufficiency, to feed a growing population. This approach has not been successful for driving sustainable agricultural productivity and food supply in Nepal. The failure has been largely ascribed to inadequate and inefficient coordination of the supply of inputs viz, high yielding varieties with fertilizers, irrigation, and appropriate agronomic practices for diseases and pest management, harvest and postharvest operations, which are essential for securing the green revolution results achieved in other countries.

1.2 Food sufficiency in crisis- a challenge before the agriculture economy

Nepal exported more food than it imported until the early 1980s. It started to become a net importer of food, particularly cereals, in the early 1980s. But until 2002, the import was only marginal, accounting to about 1.3% of the available food [2]. By the 1990s, India was rebounding with higher productivity and volume in agricultural commodities, mainly riding on the success of the Green Revolution and favorable agricultural policies and support from the government, conferring competitive advantage to Indian produce compared to Nepalese ones. The Agricultural Perspective Plan of 1995, which guided Nepal's agriculture practice for two decades aimed to improving crop productivity but the commercialization of agriculture did not become a reality. In 2001 Nepal imported food and farm products valued at $11.84 million annually from India. By 2021, the food import soared 78 times reaching $1 billion, largely paid by remittance income of Nepalese.

In 2021, Nepal's largest food import was rice (1.29 MT) valued at $402.91 million. Two decades earlier rice imports amounted to 8,025 tonnes worth $1.74 million, showing Nepal is becoming dependent on processed agricultural goods at a fast rate. Imports of processed food in 2020-21 reached 101,391 tonnes, a ten-fold increase over the previous year. Importing agricultural commodities to meet domestic demand has become a common practice in a globalized economy; however, it can be a serious issue when exports from the country remain stagnant or in decline while the imports soar at an alarming rate. Economists argue that Nepal should produce high value foods to harness comparative advantage, e.g. chayote squash from Ilam district, pears from Palpa district, and rainy season vegetables from the hills and mountains of Nepal.

2. FERTILIZER CHALLENGES FOR NEPALESE AGRICULTURE

2.1 Mineral Fertilizers Use in Nepal

Mineral fertilizer was first introduced to Nepal in the 1950s, and organized supply began in 1965 by the agriculture input supply corporation (AISC) which imported 4200 tons of fertilizers. To promote fertilizer supply and use the government reintroduced a fertilizer subsidy scheme in 2009 with AISC as the sole importer and distributor for the country. Based on data for formal imports, fertilizer use in Nepal increased from less than 10,000 nutrient tons in 1970 to over 90,000 nutrient tons in 1994/1995 and remained at that level until 2012/2013. During 2000-2013,

households applied less than 30 kg/ha of fertilizer nutrients. The low use of fertilizer application was attributed with persistently low crop yields in Nepal. Since then fertilizer consumption has increased by 33% per year. The yearly consumption in 2018 reached to 86.9 kg/ha from the 65.5kg/ha used in 2017. The current estimate for fertilizer use suggests that Nepal needs approximately 500,000 to 800,000 metric tons of fertilizer per year. Household use of fertilizer nutrients is still consistently low compared to other south Asian countries.

Urea (46% N) and DAP (18% N and 46% P) are widely used (80%) fertilizers in Nepal. Their preference is associated with high nutrient concentration, offering transport economy for reaching remote and mountainous regions. An estimate suggests that 70% of fertilizer supplied in the Terai region is primarily used for rice, whereas the Hill and Mountain Regions, receive negligible fertilizer for use with rice, wheat and maize grown in these areas. With increasing use of N fertilizers in farming, issues of micronutrient deficiency (B, Zn, and Mo) surface progressively, particularly in areas where high yielding crop varieties are intensively grown in heavily N fertilized soil.

2.2 Mineral Fertilizer Supply Chain Issues

The twenty-year agriculture perspective plan (APP) started in 1997 identified chemical fertilizer as an engine of agriculture growth for Nepal. Fertilizer was expected to contribute 64 to 75% of the targeted total agriculture growth. APP envisaged an increase in fertilizer usage from 31 kg nutrient/hectare of the base year 1995 to 131 kg nutrient/hectare by 2017. However, fertilizer use in Nepal never reached to APP target for 2017. Nepal's annual fertilizer demand stands at 0.8 MT and fertilizer use in 2020 was only 86.9 kg/ha, about half the target.

Low use of fertilizer products in Nepal is largely related to poor access caused by inefficient import supply, poor distribution, lack of quality control, high cost for fertilizer and poor agronomic advice and information on use of fertilizers for different crops and soil conditions.

2.3 Challenges for Excessive Dependency on Mineral Fertilizer

Nepalese farmers have for a long time been impinged by a fertilizer crisis brought about by soaring fossil fuel prices and lack of industry consolidation. The price of synthetic fertilizer has more than doubled since 2020, causing great stress in farming communities. Fertilizer, as a source of plant nutrients, is a crucial input directly impacting agricultural production and also mediates efficiency of other production inputs (e.g., water) in farming. Access to fertilizers on time, with a standard quality and steady price, is a stabilizing input for farming, and has been a large cause for the divide between rich and poor farmers in many communities and countries.

Increasing dependency on inorganic fertilizer and its sole application for plant nutrition has caused long-term changes in soil physical, chemical and biological properties contributing to poor soil fertility. There is wide-spread realization of long-term soil fertility losses when all essential plant nutrients are not replenished in balanced ways, as applying N fertilizer alone cannot sustain higher yields due to limitations associated with the deficiency of other nutrient elements. An organic

based complete fertilizer application to soils can potentially overcome this issue.

We strongly argue that producing more synthetic fertilizers should not be the only answer to this serious challenge. Nations should also provide support for nature-based, alternative options, including low input farming practices that help farmers reduce or forgo synthetic fertilizers, and biological products that substitute for harsher chemical inputs.

Considering existing socio-economic, cultural, trade and policy constraints for fertilizer management, soaring fertilizer price, and the adverse effects of unbalanced use of the inorganic fertilizers, the country needs alternative fertilizer options to achieve the desired growth in agriculture and food production.

3. ALTERNATIVE FERTILIZER OPTIONS FOR NEPAL

Based on the source of the materials, the fertilizers can be classified based on source as synthetic, natural (in organic and organic fertilizers) and biological (see figure below). The fertilizers are also classified based on the formulation as straight, mix, complete, incomplete, soluble and insoluble, pure or blends.

3.1 Reformulated synthetic, chemical, or mineral fertilizers

Synthetic fertilizers are also known as chemical and mineral fertilizers. Synthetically derived fertilizers are manufactured from minerals, gasses in the air and inorganic waste materials. These are best known for being fast-acting and coming in a variety of forms such as liquid, pellet, granule, and spike. Common fertilizers currently in market, e.g. Urea, DAP are pre-dominantly synthetic fertilizers. New innovation in synthetic fertilizers such as slow or controlled release fertilizer (e.g. sulphur coated urea), nitrogen inhibitors in N fertilizer, Nano urea, new formulations of liquid fertilizer that can be applied through drip irrigation have been reported to have greater fertilizer use efficiency compared to the conventional fertilizers products [3].

3.2 Natural of Organic Fertilizers

A natural or organic fertilizer relies on plant, mineral, and animal sources for its nutrients. Ingredients such as compost, poultry and livestock manure, bone meal, blood meal, fish meal, greensand, rock phosphate, alfalfa meal and kelp are common in natural fertilizers (more on some of these in a bit). Organically derived fertilizers typically have a lower nitrogen, phosphorus, and potassium (NPK) analysis than synthetic fertilizers, and are slow release, hence support plant nutrition for long periods of time. Therefore, the effects of organic fertilizers on crops are usually subtle. Organic fertilizers also stimulate beneficial soil microorganisms and improve soil structure. Soil microbes play a key role in converting organic fertilizers into soluble nutrients that can be absorbed by plants. Organically derived fertilizers often provide the secondary and micronutrients plants need, that are usually absent in synthetic fertilizers. The simple comparison of organic vs synthetic fertilizers effects on plants and soil is given below.

3.3 Biofertilizers

Biofertilizers are substances containing a variety of microbes that have the capacity to enhance plant nutrient uptake by colonizing the rhizosphere and make nutrients easily accessible to plant root hairs. The main sources of biofertilizers contributors are bacteria, fungi, and cyanobacteria (blue-green algae). The most striking relationship that these have with plants is symbiosis, in which the partners derive benefits from each other, particularly in the legume family of crops.

Common biofertilizers are:

i. Nitrogen fixing biofertilizers (symbiotic nitrogen fixing bacteria, e.g. Rhizobium, and free-living nitrogen fixing-cyanobacteria)
ii. Phosphate solubilizing biofertilizer (e.g. *Bacillus, Pseudomonas, Aspergillus*)
iii. Phosphate mobilizing biofertilizer (e.g. *Mycorrhiza*)
iv. Plant growth promoting biofertilizers (e.g. *Pseudomonas spp)*
v. Potassium solubilizing biofertilizer (e.g. *Aspergillus niger, Bacillus spp*)
vi. Potassium mobilizing biofertilizer (e.g. *Bacillus spp*)
vii. Sulfur-oxidizing biofertilizers (e.g. *Thiobacillus*)

Biofertilizer production essentially depends on the availability and isolation of targeted microbes from a specific environment, including the rhizosphere and plant tissues. Candidate microbes are cultivated and multiplied using a fermenter under optimal growth conditions.

Protocols for mass multiplication of these biofertilizer species are available and commercial production of biofertilizers products has been well established in a number of countries for mass scale use of biofertilizer products by growers. Establishment and development of an appropriate biofertilizer industry is highly timely for Nepal as well. Biofertilizers are well known for their cost effectiveness, environment-friendly nature, and composition [4]. The Indian biofertilizers market is expected to grow from $110.07 million in 2022 to $243.61 million by 2029, exhibiting a CAGR of 12.02% in the forecast period.

Biofertilizer manufacturers, suppliers and Indian exporters is given in the link (https://www.maharashtradirectory.com/product/bio-fertilizers.html). Commonly produced biofertilizer in India can be found in this link (https://agritech.tnau.ac.in/farm_enterprises/Farm%20enterprises_%20biofertilizer.html)

3.4 Phyto-accumulators and phyto-extractors

Phyto-accumulators/phyto-extractors are plant species which have the capacity to absorb and accumulate specific nutrient elements from soil. Identification of plant species with high micronutrient uptake favors crop nutrient management in organic farming. Use of plant biomass in the form of green manure, mulch or as compost alleviate micronutrient deficiency in organic farming. Phyto miner crops such as *Glyricidia maculeata, Calatropis gigantea* etc are popular for their high nutrient contents and use for green manure [5]. Fertilizer trees enhance soil health by drawing nitrogen from the air and transferring it into the soil through their roots and

leaf litter, replenishing exhausted soils with rich sources of organic nutrients. They can also bring nutrients from deep in the soil to the surface for crops with shallow roots. This method ensures nutrient recycling by the virtue of trees that contribute the crop nutrient use efficiency.

4. FUTURE FERTILIZERS OPPORTUNITIES FOR NEPAL

Organic wastes are potential resources for the future fertilizers for farming worldwide. These vast resources with both diffused and point source in origin can be collected and processed for number of uses including biogas, compost, organo-mineral fertilizers and soil amendment products. Technologies for collection, separation, digestion, composting and fertilizer product development using organic wastes are rapidly advancing worldwide. Nepal should proactively take this emerging business opportunity for addressing both the issue of waste management, while also developing innovative fertilizer products to address the acute shortage of fertilizer the country experiences every year.

4.1 Organic Waste to Fertilizer

Agricultural waste (on farm and in food processing industries)

Agricultural waste is an unwanted or unsalable material produced wholly from agricultural operations directly related to the growing of crops or raising of animals for the primary purpose of making a profit or for livelihood. In Nepal, large quantities of agricultural waste arises from livestock, poultry and aquaculture operations. Significant waste originates in the cropping sector e.g., fruit and vegetable farming. The accounting of agricultural waste in Nepal is not up to date, hence data for all agricultural wastes is unavailable. We present only a case study of the poultry industry to showcase the volume of waste in the poultry sector.

The annual liquid and solid waste production from the poultry industry in Nepal is 618.86 million liters and 2.7 million tons respectively. 81.9% of liquid waste generated from sullage and 18.1% from sewage. 99% of poultry solid waste was generated from poultry manure i.e. 2.66 million tons/year. Poultry farms in Nepal emit 30.41 Gg CO_2-eq of methane gas (CH_4) annually from manure management. With the assumption of 50% moisture content in poultry manure, the dry weight of poultry manure waste is 1.33 million tons/year. The NPK load in the broiler is about 3.3, 1.3 and 1.3% respectively on the dry weight basis [6], therefore, potential recovery of NPK from poultry is about 43.9, 17.7 and 17.7 tons from poultry litter alone. A large quantity of waste from poultry processing and other livestock-based operation such as piggeries are not included in these calculations.

Municipal solid waste

Solid waste management in municipalities of Nepal is a major issues that requires a sustainable solution. Detailed data on municipal waste in Nepal is patchy. Taking baseline data from a solid waste management in Nepal report by the Asian Development Bank 2013, estimated waste projection for 2017 has been made. The projected data shows waste generation in municipalities of Nepal is about 3023 tons per day and the average per capita waste generation is 0.223 kg/person/day. On average the composition of waste is primarily decomposable about 60% and about 25% is recyclables such as plastics, papers

and metals. With the help of Multi Criteria Decision Matrix (MCDM), this paper suggests that the suitable methods of waste management for Nepalese municipalities are waste to bio-energy and fertilizer production [7].

After the waste is sorted, its physical components were determined to be; organic materials (73.7%), and Laboratory analysis of the organic components of the waste indicated that the mean nitrogen (N), phosphorus (P), and potassium (K) contents were 11.0, 3.2, and 10.7 g kg^{-1}, respectively. The mean contents of other elements were calcium (Ca) (87.7 g kg^{-1}), sodium (Na) (18.4 g kg^{-1}), and sulfur (S) (2.3 g kg^{-1}). The mean organic-matter content of the organic components of waste was 223.7 g kg^{-1}. The physical and nutrient contents of the waste varied widely within and between municipality. The high content of organic matter and some essential macronutrients in the waste suggest its high value for use in the production of organic and organo-mineral fertilizers for agriculture use [8]. With the daily estimate of 3023 ton solid waste containing 70% organic matter, with estimated moisture contents of 50%, could recover daily 11.64. 3.39 and 11.32 ton of NPK respectively. On a yearly basis the potential recovery can be up to 4249, 1236 and 4132 tonnes of NPK respectively. This equates to about 50% of the total N fertilizer currently imported for use in agriculture in Nepal.

Biosolids

Municipal waste in developed countries also include biosolids. Biosolids – primarily dead bacteria – from sewage plants, are rich in nutrients and can potentially be used as fertilizers. Currently Nepal does not have an organized sewage system for collection and processing of biosolids, but these could be a future potential source when new regulations for the development of sewage become mandatory in new urban development.

4.2 Processing of organic wastes for fertilizers product

Conventional composting

Recycling of organic waste to compost provide a range of benefits related to nutrient recovery, environmental benefits, soil health benefits, reducing greenhouse gas emission and improving soil properties for nutrient and water holding capacity. Composting is a great way to recycle organic wastes as it reduces the volume of the waste stream (as about 0.5 – 0.6 tons of compost at 50% moisture is recovered from 1 ton of organic wastes with 60% moisture), this also cuts methane emissions from landfills, improve soil health and lessens soil erosion, conserves water and reduces the burden of personal food waste.

Compost quality standards are very important for developing consistent products that produce predictable results. Using very heterogeneous materials for diverse organic waste can be challenging for producing a consistent quality of compost. Compost quality standards are country specific. The Australian Standard for Composting (AS4454-2012) requires the heap be turned a minimum of three times (outside to inside) with the internal temperature reaching at least 55°C for three consecutive days before each turning to ensure adequate pathogen destruction (https://www.soilwealth.com.au/imagesDB/news/AS4454-2012A1.pdf).

In spite of the numerous benefits reported for compost, large scale adoption of compost for replacement of fertilizers is still constrained by high costs of compost for purchase, transport costs, storage and field application, inconsistent quality of the product and need for large quantity for complete replacement of fertilizer [9].

Vermicomposting

Vermicompost involves earthworm for digestion and aerobic decomposition of organic wastes, and the activity of micro- and macroorganisms at room temperature. Some of the commonly used feedstocks for vermicompost are food scraps, yard waste, sawdust, animal manure and bedding material. Manure-based vermicomposts tend to have higher levels of nitrogen and other nutrients than the previously mentioned feedstocks, but vermicompost can be successfully produced from urban organic wastes and from plant sources. Mixture of leguminous and non-leguminous crop residues enriches the quality of vermicompost. Vermicomposting, or worm composting, produces a rich organic soil amendment containing a diversity of plant nutrients and beneficial microorganisms. Vermicomposting is the process by which worms are used to convert organic materials (usually wastes) into a humus-like material known as vermicompost. Vermicompost is better than compost due to its higher nitrogen (2-3%), phosphorus (1.55-2.25%) and potassium (1.85-2.25%) content, and its ability to improve soil structure and increase water-holding capacity. Vermicompost is an ideal organic manure for better growth and yield of many plants. Higher production cost, need of extra care for worms, space, time and the occurrence of worm pests and diseases are some of the reported disadvantages associated with vermicompost compared to the compost. Vermicomposting is rapidly expanding to on-farm vermicomposting and vermiculture in many countries in the world. Numerous handy resource materials are available as a manual for operation (https://urbanwormcompany.com/vermicomposting-ultimate-guide-beginner-expert/).

Earthworm feeding can reduce the volume of organic waste by 40–60%. Each earthworm weighs about 0.5 to 0.6 gram, eats waste equivalent to its body weight each day and produces cast equivalent to about 50 percent of the waste it consumes in a day. The moisture content of castings range from 32-66% and the pH is ~7.

Red earthworm species, like *Eisenia foetida,* non-burrowing earthworms, are efficient composters as they eat 10% soil and 90% organic waste; converting this into vermicompost faster than burrowing earthworms. They thrive in temperatures ranging from 25 to 30°C and 40–45 percent moisture levels in the pile. Small-scale vermicomposting (5-10 tons/year) are customised for personal requirements, whereas commercial scale vermicomposting recycle large quantities of organic waste in modern facilities with the production of more than hundreds of tons annually. Large scale adoption of the vermicompost products is also constrained by similar reason as for the compost.

Aerobic thermophilic digestion for rapid composting

Aerobic composting is decomposition of organic matter using microorganisms that require oxygen.

The microbes responsible for composting are naturally occurring and live in the moisture surrounding organic matter. Oxygen from the air diffuses into moisture and is taken up by the microbes. As aerobic digestion takes place the by-products are heat, water and CO2.

The heat produced in aerobic composting is sufficient to kill harmful bacteria and pathogens as these organisms are not adapted to these environmental conditions. It also helps support the growth of beneficial bacteria species including psychrophilic, mesophilic, and thermophilic bacteria which thrive at higher temperature levels.

The thermophilic aerobic digestor of PBT Ltd Taiwan takes 4-8 hours for complete digestion of the organic waste in a vessel aerobic composting process in the presence of thermophilic bacterial inoculants. The digested product is free of major compost pathogens such as E. coli, Salmonella, Listeria etc. The digested materials can go through a week-long fermentation phase for maturation, or for conventional composting or processed as pellets or granulated fertilizer in a dry form for ease of storage, transport and handling. This is a close loop in-vessel system generally housed under the protection from weather. No leachate is produced as any surplus moisture is extracted as water vapour which can be condensed and reused for the digestor or watering nearby vegetation.

These kind of in vessel aerobic thermophilic systems are gradually gathering interest due to their precision control of the composting process, closed loop operation, rapid compost process and pathogen elimination. These also take less space and allow further value-added compost product formation, their adoption by industry is likely in the near future. In vessels system also allows for bringing automation and strict process control that allow developing custom designed compost as per the need of the user. The HotRot Compost, as commercialized by a NZ company is an example (https://www.globalcomposting.solutions/how-hotrot-techonology-works)

Figure 1: Rapid composting pilot plant set up for the monitoring of temperature and mixability in a thermophilic digestor

Waste to Biogas Option

A large proportion of Nepal's municipal waste is biodegradable, that can provide feedstock for Bio-CNG digesters, producing energy and fertilizer from biodegradable wastes. Nepal currently hosts more than 0.3 million domestic scale biogas operations. Scaling up for large-scale biogas plants to accommodate large volumes of urban and agricultural waste is very timely. There are more than 344 large-scale biogas plants in the country, but only a few of them have digesters larger than 3,000 m3, which is considered a threshold for commercial viability [10].

A recent waste management baseline survey of Nepal indicates that urban municipalities in Nepal generate nearly 2,400 metric tons per year of solid waste on average, more than half of which is organic. This means that almost 10,000 metric tons of purified biogas (bio-CNG) with more than 90% methane concentration can theoretically be produced in the municipalities [10].

An additional 1.5 million metric tons of bio-CNG per year could be generated using livestock manure across the country. Even if we only use 10% of this waste, we could still generate nearly 145,000 metric tons of bio-CNG per year - equivalent to more than 10 million LPG cylinders - and help reduce Nepal's LPG imports by 30%, narrow the trade gap with India and save foreign currency. Furthermore, the spent effluent from the digesters, as a by-product of biogas plants, could substantially reduce Nepal's imports of chemical fertiliser, and promote organic farming [10].

Organo- mineral Fertilizers

The combination of animal manure and mineral fertilizer to produce *organo-mineral fertilizers (OMF)* is a new concept in animal waste management. Organo-mineral fertilizers are characterized as a mixture of organic and mineral fractions and can be produced in several N, P and K proportions suitable for crop requirements. Usually, as a derivate to regional organic sources, the final product can be granulated, pelleted or powdered.

Compared with animal manure, OMF have higher nutrient concentration so that lower application rates can be used. The production of OMF produces a more stable, balanced, and uniform product with predictable nutrient availability and nutrient release. The advantage of OMF over mineral fertilizers is the supply of a range of macro and micronutrients in addition to organic matter, can improve plant growth parameters such as yield and nutrient uptake to a greater degree, than when manure or fertilizers are used alone [11].

Organic Fertilizer Product Development

An organic waste to fertilizer production line uses highly variable organic wastes as the raw material (such as organic waste, straw, excrement from livestock and poultry, cake, meal, agricultural and sideline product), which impact the consistency of the final product. Latest technologies on rapid composting digestors, and the control and automation of the system allows for controlling the variability and result in better consistent products. This process allows for pathogen control and custom blend of compost with inorganic fertilizers, development of products that can be stored, more easily transported and used in the field using current fertilizer applicators.

Equipment Operation Flow for Organic Fertilizer Granulation Production Line

i. The raw material is accumulated and fermented. The production of any kind of qualified and high-quality organic fertilizer must go through compost and fermentation.
ii. Mixing and crushing.
iii. Crushing machine includes semi-wet material crusher, chain crusher, hammer crusher, etc.; mixing machine includes

double shafts horizontal mixer, horizontal mixer, single shaft mixer, etc.

iv. Granulation.

v. In the production of organic fertilizer, the choice of granulation method is very important. At present, there are many different ways, like disk, drum, or extrusion types.

vi. Drying.

vii. Most materials have formed granules after granulation, but at this time the granules still need to be dried because their water content and strength cannot reach standards.

viii. Cooling.

ix. The dried granules are sent to the cooler by a belt conveyor to cool to near room temperature, so that the strength of the granules is improved and its water content reduced.

x. Screening.

xi. Some powdery materials still exist in the cooled granules, so it is necessary to sieve out the fine powder and large particles, and then let them be processed by certain machines.

xii. The final products should be coated, then a protective film formed on the surface of particles to isolate then from outside air.

xiii. The resultant products are packed by automatic packaging machines.

5. INTEGRATED SOIL FERTILITY MANAGEMENT- BASIS FOR SUSTAINABLE CROP PRODUCTIVITY

Fertile and healthy soil is the foundation for sustainable crop productivity. Soil fertility is the ability of soil to sustain plant growth and optimize crop yield. Fertilizer management is one of the aspects of the soil fertility management, therefore, developing fertile soil needs a holistic approach, not just for fertilizer management.

Advancing food security and environmental sustainability in farming systems requires an integrated soil fertility management approach that maximizes crop production while minimizing the mining of soil nutrient reserves and the degradation of the physical and chemical properties of soil that can lead to land degradation, including soil erosion. Such soil fertility management practices include the use of fertilizers, organic inputs, crop rotation with legumes and the use of improved germplasm, combined with the knowledge on how to adapt these practices to local conditions. A new paradigm for nutrient management is required (feed the soil not the crop), underpinned by reducing crop fertilizer demand, utilizing legacy soil nutrients/fertilizers, using recycled and recovered nutrients/fertilizers, and increase fertilizer/nutrient recovery.

6. CONCLUSION

Fertilizer imports and supply to farmers has been continuously challenging in Nepal for a long time. The recent failure in supply chains has been further compromised due to increasing fertilizer prices and global transport disruption caused by COVID and Ukraine-Russian war. The declining food security in Nepal has been well linked to a poor fertilizer supply chain and inaccessible fertilizer products delivered on time to the

growers. In the face of rapidly declining soil fertility status of agricultural soils in Nepal, a complete remodeling of fertilizer supply chains of alternative fertilizers need to be considered. We have discussed developing alternative fertilizers utilizing wide-spread organic wastes, utilizing a number and aerobic and anaerobic digestions methods, and vermiculture for rapid composting. An integrated and holistic approach for soil fertility management harnessing the potentials of all other alternative fertilizers (biofertilizers, natural fertilizers, legumes, phytoaccumulators) has also been recommended.

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REFERENCES

[1] CBS, "Waste management survey of Nepal 2013," Thapathali, Kathmandu, Nepal, 2013.

[2] S. Prasain, "How Nepal, a country of farmers, became a food importer over the years," *The Kathmandu Post*, Kathmandu, Nepal, Feb. 02, 2022.

[3] IFFCO, "Nano Urea (Liquid) Fertilizer," 2022.

[4] D. Dasgupta, K. Kumar, R. Miglani, R. Mishra, A. K. Panda, and S. S. Bisht, "Microbial biofertilizers: Recent trends and future outlook," in *Recent Advancement in Microbial Biotechnology: Agricultural and Industrial Approach*, 2021. doi: 10.1016/B978-0-12-822098-6.00001-X.

[5] S. Adarsh, S. Mathew, A. S. Roshni, K. T. Gopika, V. Nirosha, and A. P. Arya, "Phyto-accumulators to mitigate micronutrient deficiency in organic farming," *International Journal of Agricultural Sciences*, vol. 13, no. 1, 2022.

[6] N. Griffiths, "Best practice guidelines for using poultry litter on pastures," 2011.

[7] M. K. Maharjan and S. P. Lohani, "Municipal Solid Waste Management in Nepal: Opportunities and Challenges," *Journal of the Institute of Engineering*, vol. 15, no. 3, 2020, doi: 10.3126/jie.v15i3.32185.

[8] N. M. John, S. O. Edem, N. U. Ndaeyo, and B. A. Ndon, "Physical composition of municipal solid waste and nutrient contents of its organic component in Uyo Municipality, Nigeria," *J Plant Nutr*, vol. 29, no. 2, 2006, doi: 10.1080/01904160500464836.

[9] P. Dhakal, S. Devkota, and R. H. Timilsina, "Factors affecting the adoption of biofertilizers in Chitwan District, Nepal," *J Pharmacogn Phytochem*, no. SP1: 3050-3054, 2018.

[10] S. Dulal, "Waste to value with biogas in Nepal. How to increase the demand for biogas and scale up commercial plants to reduce LPG imports," *Nepali Times*, Kathmandu, Nepal, Jun. 01, 2022.

[11] W. B. Smith, M. Wilson, and P. Pagliari, "Organomineral Fertilizers and Their Application to Field Crops," in *Animal Manure: Production, Characteristics, Environmental Concerns, and Management*, 2020. doi: 10.2134/asaspecpub67.c18.

An Approach to Solve Sudoku Using Image Processing and with Genetic Algorithm

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Abstract

Sudoku is logic-based puzzle and quite a popular game. The 9 by 9 square grid Sudoku puzzle is the one that we have taken into an account. For solving sudoku puzzle, we have used image processing along with genetic algorithm. In the first phase, the raw and unsolved image is first gray scaled and then Gaussian blur is applied to reduce noise. Then it goes through a main frame extraction stage where adaptive thresholding, maximum contour detection, perspective transformation and small grid segmentation are performed respectively. The individual 81 grids are passed to the CNN model for digit recognition. Then finally, genetic algorithm is used to find the optimal solution of Sudoku problem.

Keywords
Gaussian, Genetic, Adaptive thresholding

1. INTRODUCTION

A Sudoku puzzle consists of 81 cells which are divided into nine columns, rows and regions. The task is now to place the numbers from 1 to 9 into the empty cells in such a way that in every row, column and 3×3 region each number appears only once. A Sudoku has at least 17 given numbers but normally there are 22 to 30.

The three basic rules for playing Sudoku are:-

•Each row must contain all numbers from 1 to 9.

•Each column must contain all numbers from 1 to 9.

•Each box must contain all numbers from 1 to 9.

For manipulation of images, Image processing is used which is a method to perform some operations on an image, in order to get an enhanced image or to extract some useful information from it. It is a type of signal processing in which input is an image and output may be image or characteristics/features associated with that image. Some of the important applications of image processing in the field of science and technology include computer vision, remote sensing, feature extraction, face detection, forecasting, optical character recognition, finger-print detection, optical sorting, argument reality, microscope imaging, etc. Image processing basically includes the following three steps: Importing the image via image acquisition tools, Analyzing and manipulating the image, Output in which result can be altered image or report that is based on image analysis. In our project, image processing is mainly used for features such as Gaussian blur, adaptive thresholding, main frame detection, perspective transformation, grid segmentation, digit extraction and many more.

During digit recognition stage, Convolutional Neural Network (CNN) model is used. CNN is a type of artificial neural network used in image recognition and processing that is specifically designed to process large pixel data. Neural Networks mimic the way our nerve cells communicate with interconnected neurons and CNNs have a similar architecture. What makes them unique from other neural networks is the convolutional operation that applies filters to every part-of the previous input in order to extract patterns and features maps. In our project, a pre-trained model CNN model is used for MNIST handwriting digit recognition considering 28*28 pixels.

2. LITERATURE REVIEW

Muhammad Usman Tariq and Sara Aqab in their study "Handwriting Recognition using Artificial Intelligence Neural Network and Image Processing" [1]writes about Handwriting character recognition which refers to the computer's ability to detect and interpret intelligible. Handwriting input from Handwriting sources such as touch screens, photographs, paper documents, and other sources. Handwriting characters remain complex since different individuals have different handwriting styles. This paper aims to report the development of a Handwriting character recognition system that will be used to read students and lectures Handwriting notes. The development is based on an artificial neural network, which is a field of study in artificial intelligence. Different techniques and methods are used to develop a Handwriting character recognition system. However, few of them focus on neural networks. The use of neural networks for recognizing Handwriting characters is more efficient and robust compared with other computing techniques. The paper also outlines the methodology, design, and architecture 0 of the Handwriting character recognition system and testing and results of the system development. The aim is to demonstrate the effectiveness of neural networks for Handwriting character recognition.

Hung-Hsuan Lin and I-ChenWu in their study "An Efficient Approach To Solving The Minimum Sudoku Problem" focused on an open problem to find the minimum-clue Sudoku puzzles, also commonly called the minimum Sudoku problem [2]. Solving the problem can be done by checking 5,472,730,538 essentially different Sudoku grids independently or in parallel. In the past, the program CHECKER, written by McGuire, required about 311 thousand years on one-core CPU to check these grids completely, according to our experimental analysis. This paper is to propose a more efficient approach to solving this problem. We design a new algorithm, named disjoint minimal unavoidable set (DMUS) algorithm, to help solve the minimum Sudoku problem more efficiently. After incorporating the algorithm into the program and further tuning the program code, our experiments showed that the performance was greatly improved by a factor of 128.67. Hence, it is estimated that it only takes about 2417 years to solve the problem. Thus, it becomes feasible and optimistic to solve this problem by using a volunteer computing system, such as BOINC.

Agnes M. Herzberg and Ram Murty in their research article "Sudoku squares and chromatic polynomials" interprets the nine by nine Sudoku puzzle as a graph coloring problem [3]. Viewed this way, they can generalize the puzzle to arbitrary size. They compute the chromatic number of the resulting graph, and they estimate the number of “Sudoku squares” of any given size.

Shamsul K Khalid and Mustafa M Deris, purposed “A Systematic Redundancy Approach in Watermarking Using Sudoku" [4]. Digital watermarking is one of the most important techniques employed to protect digital contents. Copyright information embedded in the digital contents may become undetectable due to compression and additive noise attacks introduced into a watermarked image. A general strategy to overcome such attacks is to embed redundant watermarking to improve the survivability of the watermark. However, current approaches in redundant watermarking is generally not designed in a systematic way. In this paper, a systematic redundancy approach in watermarking using Sudoku is proposed. The approach is based on the property of Sudoku's permutation that provide tightly related, redundant copies of watermark pieces discretely distributed to different hiding planes. Using the classic 9X9 Sudoku puzzle, the proposed approach has been implemented and tested with Gaussian, compression, Poisson, speckle, low pass filter, high pass filter and contrast attacks using standard images. The result indicates sustained survivability of the watermark under common attacks.

Some hobbyists have developed computer programs that will solve Sudoku puzzles using a backtracking algorithm, which is a type of brute force search. Backtracking is a depth-first search (in contrast to a breadth-first search), because it will completely explore one branch to a possible solution before moving to another branch. Although it has been established that approximately 5.96 x 1126 final grids exist, a brute force algorithm can be a practical method to solve Sudoku puzzles A brute force algorithm visits the empty cells in some order, filling in digits sequentially, or backtracking when the number is found to be not valid.

OpenCV (Open-Source Computer Vision Library) is an open source computer vision and machine learning software library. OpenCV was built to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in the commercial products. Being a BSD-licensed product, OpenCV makes it easy for businesses to utilize and modify the code. The library has more than 2500 optimized algorithms, which includes a comprehensive set of both classic and state-of the-art computer vision and machine learning algorithms. These algorithms can be used to detect and recognize faces, identify objects, classify human actions in videos, track camera movements, track moving objects, extract 3D models of objects, produce 3D point clouds from stereo cameras, stitch images together to produce a high resolution image of an entire scene, find similar images from an image database, remove red eyes from images taken using flash, follow eye movements, recognize scenery and establish

markers to overlay it with augmented reality, etc. OpenCV has more than 47 thousand people of user community and estimated number of downloads exceeding 18 million. The library is used extensively in companies, research groups and by governmental bodies. Along with well-established companies like Google, Yahoo, Microsoft, Intel, IBM, Sony, Honda, Toyota that employ the library, there are many startups such as Applied Minds, VideoSurf, and Zeitera, that make extensive use of OpenCV. OpenCV's deployed uses equipment in China, helping robots navigate and pick up objects at Willow Garage, detection of swimming pool drowning accidents in Europe, running interactive art in Spain and New York, checking runways for debris in Turkey, inspecting labels on products in factories around the world on to rapid face detection in Japan.

In image processing, a Gaussian blur (also known as Gaussian smoothing) is the result of blurring an image by a Gaussian function (named after mathematician and scientist Carl Friedrich Gauss) [5]. It is a widely used effect in graphics software, typically to reduce image noise and reduce detail. The visual effect of this blurring technique is a smooth blur resembling that of viewing the image through a translucent screen, distinctly different from the bokeh effect produced by an out-of-focus lens or the shadow of an object under usual illumination. Gaussian smoothing is also used as a pre-processing stage in computer vision algorithms in order to enhance image structures at different scales—see scale space representation and scale space implementation. A Gaussian blur effect is typically generated by convolving an image with a FIR kernel of Gaussian values.

In recent times, with the increase of Artificial Neural Network (ANN), deep learning has brought a dramatic twist in the field of machine learning by making it more artificially intelligent. Deep learning is remarkably used in vast ranges of fields because of its diverse range of applications such as surveillance, health, medicine, sports, robotics, drones, etc. In deep learning, Convolutional Neural Network (CNN) is at the center of spectacular advances that mixes Artificial Neural Network (ANN) and up to date deep learning strategies. It has been used broadly in pattern recognition, sentence classification, speech recognition, face recognition, text categorization, document analysis, scene, and handwritten digit recognition. The goal of this paper is to observe the variation of accuracies of CNN to classify handwritten digits using various numbers of hidden layers and epochs and to make the comparison between the accuracies. For this performance evaluation of CNN, we performed our experiment using Modified National Institute of Standards and Technology (MNIST) dataset. Further, the network is trained using stochastic gradient descent and the back propagation algorithm [6].

3. METHODOLOGY

3.1 Image Processing

Grey Scaling

The three basic levels of grey level transformation involve linear, logarithmic and power-law transformation. Linear transformation in grey scaling includes simple identity and negative

transformation. The second linear transformation is negative transformation, which is an invert of identity transformation. In negative transformation, each value of the input image is subtracted from the L-1 and mapped onto the output image. Gray Scaling has been deployed to detect the contour over the project. Better Computer vision shall be attained using the grey scaling. Gray scaling is done using the formula as,

RGB[A] to Gray: Y ⟵ 0.299 * R + 0.587 *G + 0.114 * B …..(Equation 1)

Where, Y is the pixel value for given pixel position

R is intensity of Red color at given pixel position

G is intensity of Green color at given pixel position

B is intensity of Blue color at given pixel position

Gaussian Blur

When we blur an image, we make the color transition from one side of an edge in the image to another smooth rather than sudden. The effect is to average out rapid changes in pixel intensity. The blur, or smoothing, of an image removes "outlier" pixels that may be noise in the image. Blurring is an example of applying a low-pass filter to an image. In computer vision, the term "low-pass filter" applies to removing noise from an image while leaving the majority of the image intact. A blur is a very common operation we need to perform before other tasks such as edge detection. There are several different blurring functions in the skimage. filters module, so we will focus on just one here, the Gaussian blur. In short, we need to gaussian blur the image to reduce noise in the thresholding algorithm. The Gaussian blur algorithm implemented over the project utilizes the mathematical model. The formula of a Gaussian function in two dimensions is

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \text{.....(Equation 2)}$$

Where σ is the standard deviation of Gaussian distribution(usually taken as 1)

x is the distance from the origin in the horizontal axis

y is the distance from the origin in the vertical axis

The aforementioned formula gives 5*5 low pass Gaussian filter as,

$$\frac{1}{273}\begin{bmatrix} 1 & 4 & 7 & 4 & 1 \\ 4 & 16 & 26 & 16 & 4 \\ 7 & 26 & 41 & 26 & 7 \\ 4 & 16 & 26 & 16 & 4 \\ 1 & 4 & 7 & 4 & 1 \end{bmatrix}$$

Figure 1: 5×5 low pass Gaussian filter

Adapting Thresholding

Adaptive thresholding calculates the threshold value for smaller regions of 11*11 px and therefore, there will be different threshold values for different regions. The mean of these different region is calculated and threshold value is calculated respectively. Thresholding is a type of image segmentation, where we change the pixels of an image to make the image easier to analyze. In thresholding, we convert an image from color or grayscale into a binary image, i.e., one that is simply black and white. This would make our image preprocessing task simpler to process.

$$dst(x,y) = \begin{cases} maxValueis \;\; src(x,y) > T(x,y) \\ 0 \qquad\qquad otherwise; \end{cases}$$

……(Equation 3)

Where,

dst(x,y) = destination image

src(x,y) = source image

T(x,y) = Threshold value calculated individually for each (x,y) pixel as mean(blockSize * blockSize of neighbour - 2)

3.2 Main Frame Extraction

Contour Detection

Contour detection simply identifies the bounded areas over the image in user input. In simpler words, there could exist multiple bounded areas available in the image. This might include the sudoku puzzle header and Puzzle frame itself. Contour detection simply identifies these bounded areas from the image. First one is source image, second is contour retrieval mode, third is contour approximation method. And it outputs a modified image, the contours and hierarchy. contours is a Python list of all the contours in the image. Each individual contour is a NumPy array of (x,y) coordinates of boundary points of the object.

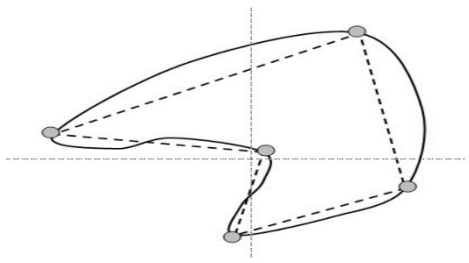


Figure 2: Polygon approximation of a contour

Maximum Puzzle Frame Determination

The non-essential aspects include the text that comprises heading and other non-digit characters that are not useful. Maximum Puzzle Frame thus identifies the biggest contour. After contour detection, different pre-defined polygons are drawn inside the contour using polygon approximation method. Then areas of different polygon are calculated respectively. The largest area of the polygon is selected as a frame. User submitted images might comprise non-essential aspects of sudoku as well. Also, the contour sometime may require the perspective transformation if the image captured has been skewed essential transformations are carried out.

Perspective Transform

The image orientation could be skewed or inclined at any angle i.e. the captured image may not be horizontally captured. To address the situation the perspective transform has been deployed so that the image is aligned appropriately for easier processing of the image. Perspective transform hereby shall result into the formation of 900*900 pixel image.

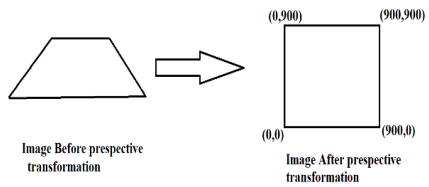


Figure 3: Perspective Transformation of an Image

3.3 Small Grid Segmentation

In order for any digital computer processing to be carried out on an image, it must first be stored within the computer in a suitable form that can be

manipulated by a computer program. Most commonly, the image is divided up into a rectangular grid of pixels, so that each pixel is itself a small rectangle. Being specific to the project, out of 900*900 pixel image extracted previously now the grid with 100*100 pixels are identified and 4px*4px of images are clipped away. Clipping has been done so that the lines of the grid are removed. Now these clipped square boxes are resized over 28*28 pixels, this could be visualized as the detection of Sudoku digits with the least number of edges in the image.

3.4 Convolution Neural Network

The project hereby deploys the CNN in the digit identification. Deploying the MNIST dataset, the model has been trained thoroughly, the train test data has been splitted for the precise result of the model. Now once trained, model has been fed with the data i.e. images that needs to be predicted from the model in the form of text. In other words the digit from image needs to be identified and returned back as text. Once identifying the digits, the text file has been prepared accordingly to the identified digits and is exported for further processing. These exported data comprise an array, where empty image or image with no digits are identified as 0 and rest are identified according to the actual digits. The array comprises of 9*9 dimensional data. Now these data are exported using JSON file format. From the input, the first network starts with a convolution whose filters_size is equal to 5*5 is implemented. It has followed by another convolution with the same filters_size. These two convolutions are followeby a Max_pooling with pool_size equal to 2*2 and then a drop_out with 0.25 probability to switch neurons off.

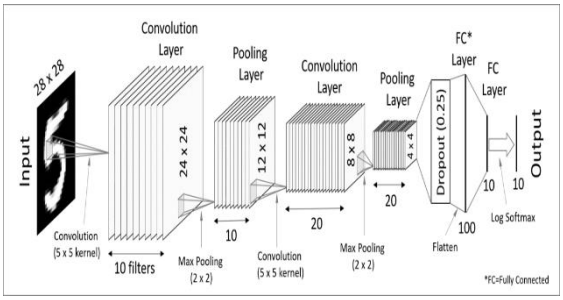


Figure 4: Convolution neural network model

3.3 Genetic Algorithm

Initialize population

At first, we determine all possible value for the cells that do not contain given values in the starting point. Then initialize population by filling that particular empty cell through determined possible value. Here, we have 1,000 initial population at the start and later on the population will be change through mutation and crossover operation but the size of the population remains same as 1000. Increased or decreased on the basis of fitness value convergence.

Fitness function

As always, coming up with the proper fitness function for the genetic algorithm is the greatest challenge. The way we determined the fitness function was using three tables(Row table Column table Square table) .The fitness algorithm first goes through each column of the Sudoku and the unique number contained in the cell is added to the ColumnMap. After an entire column is traversed, the algorithm looks at the count of the ColumnMap . If every key in the column is unique, then the ColumnMap contains a total of 9 values. If the column contains a few duplicates,

the total count in the ColumnMap will always be less than 9. The count can then be used as a representative fitness of uniqueness for a particular column. By adding this number for all columns, we can come up with a fitness for uniqueness of columns. We can then perform the same exact technique for determining row uniqueness. The RowMap is populated with keys from each cell in a row of the Sudoku grid. If the row is entirely unique, then the RowMap will contain 9 entries. The same technique is also used for each 3x3 cell grouping (shown in figure 1). The SquareMap is populated with cell values for this square table.

Fitness function for each column/row/square:

$$\text{Fitness value} = \frac{1.0}{((10 - Uniqueness)/9.0)}$$

……(Equation 4)

i.e. Uniqueness is No. of unique entity in each chromosome

As, fitness value for each column is calculated, then they are summed up and store in fitnessCloumns. Similarly, total fitness value of row and square are summed up and store them in fitnessRows and fitnessSquares respectively. Then fitness value for the population is calculated as,

CurrentFitness = fitnessColumns * fitnessRows * fitnessSquares ……(Equation 5)

Selection

After the calculation of fitness value for each population, population are arrange on descending order based on their fitness value. Then we use the selection rate of 50%, so top 500 population with highest fitness value are selected and remaining are removed.

Crossover

Through the selected 500 population we performed the crossover operation on them in order to generate new solution. At first two population are selected on the hierarchical order then single-point crossover technique is applied to generate new child. This process is repeated until desire number of child are produced i.e. 500 for our project.

Mutation

In certain new solution is formed, then some of their genes can be subjected to a mutation based on mutation rate i.e. 0.5.At first mutation value is calculated for each genes as,

Mutation value is calculated as,

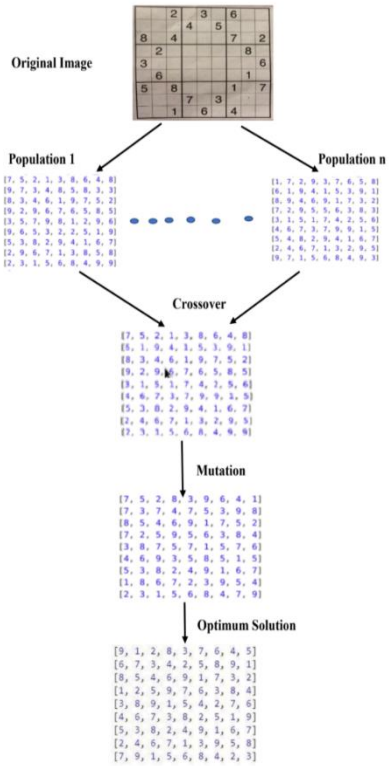
$$Mutuation\ Value = \frac{(i + j)}{18}$$

……(Equation 6)

Where, i =Gene row position

j =Gene column position

Then if calculated mutation value is greater than mutation rate, that gene is flipped by the possible value so that our algorithm can come to a better solution efficiently.



4. RESULT

The final result and output of the project were analyzed and compared with the expected output after the successful completion of our project. When the aforementioned fitness function along with 50% mutation rate and 50% selection rate were used then at about 43 generations, the desired output of sudoku were observed. We tried to give various types of file format but the system threw an error expect for a desired image file. Puzzle was detected and solved with the help of provided sudoku image file. And in the absence of puzzle, frame can't be extracted thereby threw an error. Continuing this, pixel size of 28*28 was sent to the model in order to recognize the digit and so it did. The model couldn't able to predict and recognize the number when there was a hazy and a vague image. Grids were assigned to zero in the case of empty data. At the sudoku solving stage, a unique solution is provided when there were at least 24 predefined numbers. If the values in the same row or in the same column or in the same sub grid are same thereby violating the constraints of sudoku game then error were broadcasted with an inappropriate input. Finally, the result which won among the fitness value in the different population of genetic algorithm, came out to be the solution of the given respective sudoku problem. The graph of prediction accuracy of neural network up to 10 epoch is shown in figure 5.

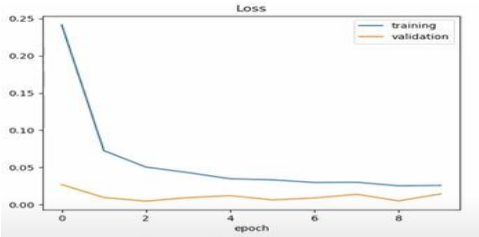


Figure 5: Graph of accuracy versus epoch

The graph of loss vs epoch is shown in figure 6.

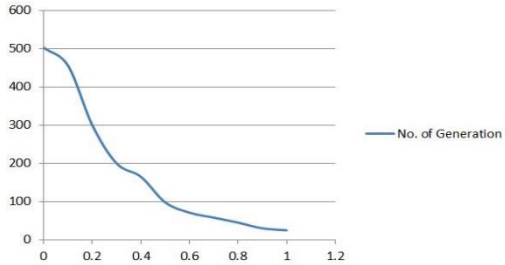


Figure 6: Loss vs Epoch

Analyzing above two graphs, we trained our model for 10 Epoch.

The graph for selection rate and Number of generation for optimum solution is shown in figure 7:

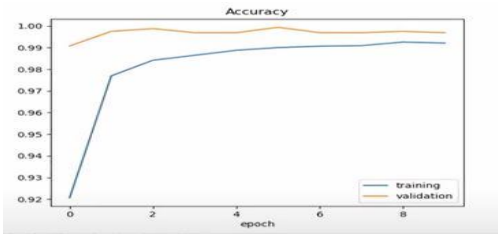


Figure 7: Graph of selection rate vs no. of generations

Here in figure 7

Y axis= No. of Generation

X axis= Selection Rate

The graph for selection rate and time complexity is shown below:

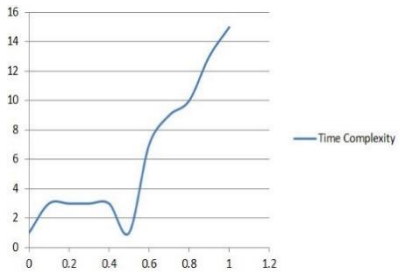


Figure 7: Selection rate Vs Time Complexity

Here in figure 8

Y axis= Time

X axis= Selection Rate

Analyzing above two graphs,0.5 selection comes out to be appropriate one since we got our output with minimum generation of population and with lesser time complexity.

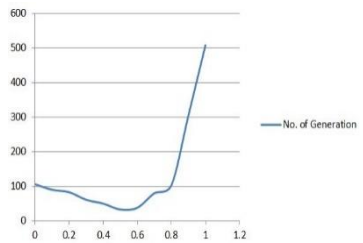


Figure 8: Mutation rate Vs Number of generation

Here in Figure 8,

Y axis= No. of Generation

X axis= Mutation Rate

Observing above graph, approximate mutation rate came to be 0.5 as the best rate.

of their role in eliminating the problems in the building permit approval system.

5. CONCLUSION

The final result of our project has been displayed on the browser. User are capable of uploading the Sudoku image that needs to be solved through the front end, once the image gets uploaded over the system several processing steps over the system are displayed as well. This would allow user to have better understanding over the system. Finally, the compiled output image is displayed back to the user again. Thus, using the portal one can solve the Sudoku problem easily with the least time being spent.

REFERENCES

[1] S. K. A. Khalid, M. M. Deris, and K. M. Mohamad, "A systematic redundancy approach in watermarking using sudoku," 2014. doi: 10.1109/ICITCS.2014.7021723.

[2] OpenCV Team, "OpenCV," 2022. https://opencv.org/about/

[3] R. K. Mohanta and B. Sethi, "A Review of Genetic Algorithm application for Image Segmentation," *International Journal of Computer Technology & Applications*, vol. 3, no. 2, 2007.

[4] J. Matthews and S. Baker, "Active appearance models revisited," *Int J Comput Vis*, vol. 60, no. 2, 2004, doi: 10.1023/B:VISI.0000029666.37597.d3.

[5] F. Siddique, S. Sakib, and M. A. B. Siddique, "Recognition of handwritten digit using convolutional neural network in python with tensorflow and comparison of performance for various hidden layers," 2019. doi: 10.1109/ICAEE48663.2019.8975496.

[6] A. E. Eiben, "Introduction to Evolutionary Computing," *Assembly Automation*, vol. 24, no. 3, 2004, doi: 10.1108/aa.2004.24.3.324.1.

Biogas for Clean Energy Consumption and GHG Emission Reduction

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Abstract

This study analyses the biogas for clean energy consumption and GHG emission reduction in two ecological regions - Hill and Terai – of Nepal. Biogas is methane-rich gas mostly used for cooking in rural households in Nepal. Biogas is interrelated with energy consumption and associated greenhouse gas emissions. The unsustainable use of emission-intensive biomass cooking fuel and other commercial fuels are the major sources of GHG emissions. If biogas is produced and used to its full capacity, it can replace other cooking fuels in the household. The main objective of this study was to observe the existing production and use status of biogas to explore the new pattern of energy consumption and associated GHG emission reduction. This research was carried out in Chitwan and Lamjung districts, representing both Terai and Hill regions of Nepal. Biogas household survey, key informant interview, and direct field observations were used for data collection, while Statistical Package for Social Sciences (SPSS), Volumetric Methane Prediction (VMP), and Long-Range Energy Alternative Planning System (LEAP) Energy Environment Modal were used for data analysis. The result showed that if the biogas completely replaces other cooking fuels, it reduces energy consumption by 40% and GHG emission up to 19 tCO_2e per year. It is mostly from saving on fuelwood burning, by 31.8 GJ/household in the Chitwan/Terai and 19.3 GJ/household in Lamjung/Hill from 2012-2040 compared with a non-biogas household.

Keywords

Biogas, energy consumption, SPSS, VMP, LEAP, GHG emission reduction

1. INTRODUCTION

1.1 Biogas

Biogas basics

Biogas is methane-rich gas produced through the anaerobic decomposition of organic matter. Cattle dung is the most used feedstock at GGC 2047 domestic type biogas digester in Nepal. Biogas is a renewable clean energy source that is mostly used for cooking in rural households in Nepal. Domestic biogas plants seem highly potential to reduce the unsustainable use of biomass cooking fuel, however, the production and use of biogas should be enough to fulfill the daily cooking energy needs of the biogas household. The production capacity of a biogas plant depends on the quality and quantity of feedstock used.

The capacity of a biogas plant in terms of theoretical biogas production efficiency depends on (i) plant size (feeding of the prescribed quantity of feedstock); and (ii) actual daily feeding. Mostly used domestic plants in Nepal are the size of 4 m^3, 6 m^3, 8m^3, and 10m^3. The size of a 1 m3 capacity plant requires 6 kg of cattle dung per day and each kg of dung produce up to 40-liter biogas. One adult cow gives an average of 8 kg dung per day, So, at least 3 cows need to rear to feed into a 4 m3 size biogas digester daily, and on the same basis for other sizes plants. The actual biogas output can be assessed based on the

gas being used per day, considering that a biogas stove burning at full capacity consumes 400 liters (0.4 m^3) of gas per hour [1] [2]. Hence, a family of 5 members uses biogas daily for two meals, breakfast and afternoon tea/snacks. The methane and energy content in biogas are determined by the biochemical composition of the feedstock. High protein content feedstock produces higher methane content biogas while rich organic fat content feedstock produces biogas with higher energy content [3].

Besides type and quantity of feedstock, several factors affect the rate of digestion and biogas production capacity, including temperature, carbon-nitrogen (C/N) ratio, hydraulic retention time (HRT), organic loading rate (OLR), dilution and consistency of inputs, pH value of the input mixture, toxicity, altitude and precipitation [4], [5], [6].

Production and use of biogas in the world

There is a strong potential role for biogas in the transformation of the global energy system. In 2019, global biogas production had an equivalent energy content of 1.43 exajoules whereas the production was only 0.29 exajoules in 2000 [7]. Production and use of biogas have also been increasing as a source of bioenergy to achieve Sustainable Development Goals (SDG) in many ways. [8]. It is forecasted that biogas production will nearly be doubled by 2030 [9].

Production and use of biogas in Nepal

Biogas is one of the promising renewable energy sources in Nepal. Total biogas potential households in Nepal are estimated to be 1.93 million, out of which 57% are expected in the Terai, 37% in the Hill, and the remaining 6% in the Mountain (Table 2) [10]. Although almost all the districts in Nepal now have access to biogas systems, less than 30% of the total potential has been covered yet.

Table 1: Geographical region-wise biogas potentiality and % of biogas plants constructed by 2014 (Source: [10])

Region	Potential biogas households	Number of biogas plants constructed	% of total potential covered
Mountain	123900	2050	1.6
Hill	7,23,600	1,65,698	22.9
Terai	1,089,000	162,839	14.9

Production and use of biogas in Chitwan and Lamjung districts

Installation of biogas plants in both districts was started in 1992/93. The total number of biogas plants installed in Lamjung and Chitwan was 9,623 and 17,798, respectively (Table 2).

Table 2: Total number of biogas plants installed in Chitwan and Lamjung districts (Source: [10],[11])

District	Total number of households	Potential number of households suitable for biogas	Total number of biogas plants installed by 2014
Lamjung	42,048	14,246	9,623
Chitwan	132,345	57,115	17,798

The number of annual biogas plant installations in the districts has been relatively steady over the past decade after increasing in the 1990s (Figure 1). The demand for biogas plant construction remains encouraging, with more than 400 biogas plants installed in Lamjung, while more than 800 biogas plants were constructed in Chitwan in 2014 [10]. However, both districts showed a

general decline in biogas plant installation from 2011.

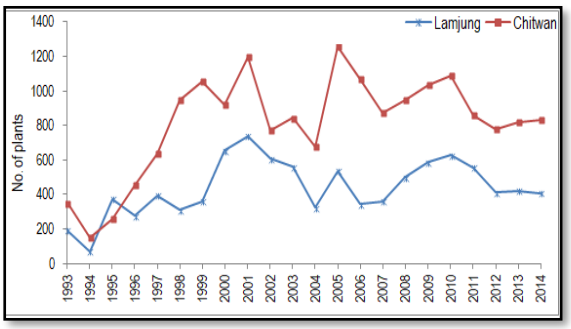

Figure 1: Trend of Biogas Development in Chitwan and Lamjung (Source: [1])

1.2 Energy consumption

Global energy consumption patterns

IEA [12] declared that clean energy transition can reduce consumers' energy bills through managing energy-efficient improvements like the use of biogas biofuels [9]. Global energy consumption rebounded with a 5% growth in 2021, after a 4.5% decline in 2020, in the context of the global pandemic. However, it is estimated that global energy consumption in 2040 will be 56% higher than in 2010. Moreover, a study revealed that energy demand may double in the first half of this century mostly because of use in developing countries, as they use low-quality fuels as GDP and energy consumption trend (Figures 2 & 3). The amount of energy consumed per unit of GDP in Nepal is 1.8 times higher than India, 4.5 times in Bangladesh, and 4.5 times the world average [13]. This figure suggests that it has significant potential to increase both- its use for energy production and energy efficiency [14].

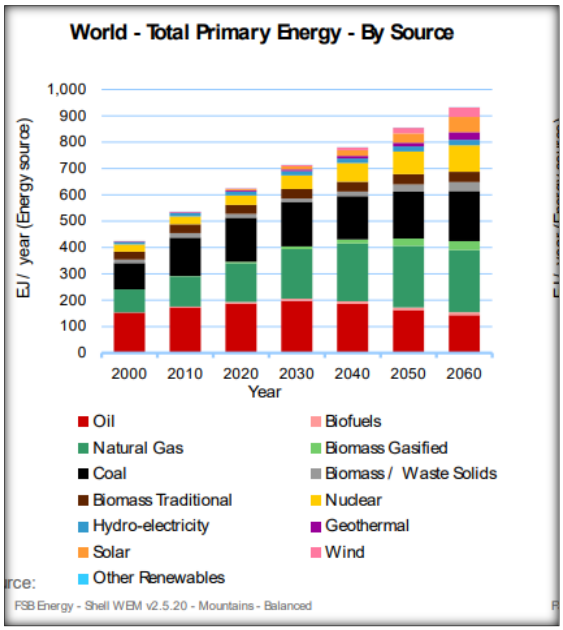

Figure 2: World energy status (Source: [12])

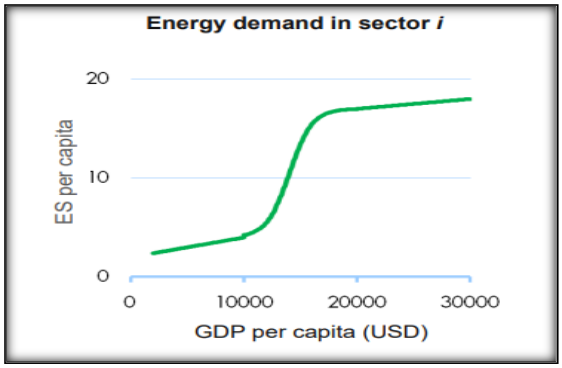

Figure 3: Energy Service (ES) /demand per capita versus GDP per capita (Source: [13])

IEA also reported that bioenergy accounts for roughly one-tenth of the world's total primary energy supply today. According to Net Zero Emissions (NZE) by 2050, biogas provides clean cooking access for 400 million people in 2030, and total biogases demand rises to 5.5 EJ [12].

Nepal's energy consumption patterns/ trends

"From 2000 to 2013, Nepal's energy consumption grew 27%, from 8.04 to 10.17 million tonnes of oil equivalent (mtonne), and consumption is projected to continue to increase, driven by a growing population and increased

economic production" [15] [13]. Seventy percent of the total primary energy supply in Nepal in 2017 was biomass [16]**.** More than 80% of total final energy consumption was used in the residential sector (Figure 4).

Table 3: Energy Consumption Trend in Nepal (Source: [16])

Fuel type	**2014/15**	**2015/16**	**2016/17**	**2017/18**
Firewood	71.2	65.8	67.6	62.5
Agriculture residue	3.5	3.2	3.3	3.1
Cow dung	3.7	3.4	3.5	3.3
Biomass Total	**78.4**	**72.4**	**74.5**	**68.9**
Coal	4.6	5.2	4	2.79
Petroleum Products	10.8	16.2	13.8	18.7
Electricity	3.7	3.9	4.1	4.0
Renewable	2.5	2.3	3.5	3.2
Total Energy in Mtoe	**11,768**	**12,866**	**8,257**	**9,019**

Around 70% of biogas developed today is used for power and heat, 20% is for cooking purposes and the other 10% is upgraded to biomethane. More than half of biogas production today takes place in Asia, which also has the largest growth potential given the availability of significant volumes of organic feedstocks such as crop residues and rising levels of municipal solid waste.

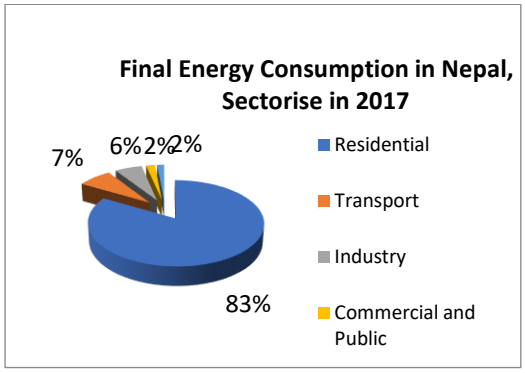

Figure 4: Energy consumption pattern in Nepal (Source: [16])

In 2019, the primary energy consumption of Nepal increased from 0.05 quadrillion btu in 2000 to 0.15 quadrillion billion tonnes unit (btu) in 2019 growing at an average annual rate of 6.49%. Most of the population in Nepal lacks access to clean and safe methods of cooking [16], [17]. The residential sector consumed almost 84% of the total energy consumption in Nepal 2017/18), where about 85% of the residential energy is consumed by the rural population who represent about 80% of the country's population [18]. Thus, the rural population still depends on biomass resources to meet their energy demand.

Energy use pattern in Chitwan and Lamjung

Following the trend of the national energy consumption pattern, fuelwood is the major source of energy used for cooking and heating in both districts (Table 4). About half (49.1%) of the total households in Chitwan district use fuelwood as the major source of cooking fuel. followed by LPG (39%) and biogas about 9.2%. though kerosene, cow dung, and electricity are used for cooking by only 0.75%, 0.16%, and 0.18% of the total households, respectively [11]. Similarly, about 70% of the total households in Lamjung use fuelwood as their major source of energy for cooking which is followed by LPG (19%). Biogas is the third major source with about 10% of the total households in Lamjung using biogas for cooking. Kerosene, cow dung, and electricity are used for cooking by only 0.4%, 0.14%, and 0.13% of the total households**,** respectively [11].

Table 4: Energy Consumption in Chitwan and Lamjung District, Nepal (Source: [11])

	Chitwan		Lamjung	
	Cooking		Cooking	
Fuelwood	49.1		70	
LPG	39		19	
Biogas	9.2		10	
Electricity	0.18		0.13	
Kerosene	0.75		0.4	
Cow dung	0.16		0.14	

1.3 GHG emissions

Global GHG emission status

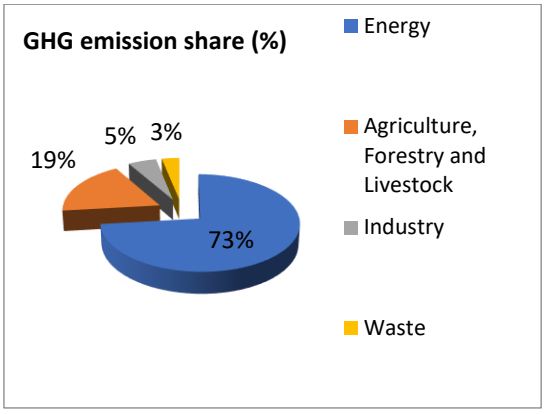

Figure 5: Global GHG emission by sector (Source: [12])

Globally, around 50 billion tonnes of greenhouse gases are emitted each year. Global energy-related carbon dioxide emissions rose by 6% in 2021 (36.3 billion tonnes), their highest ever level, as the world economy rebounded strongly from the Covid-19 crisis and relied heavily on coal to power that growth [12]. But, most of the emission sources are fossil fuel combustion and industrial processes.

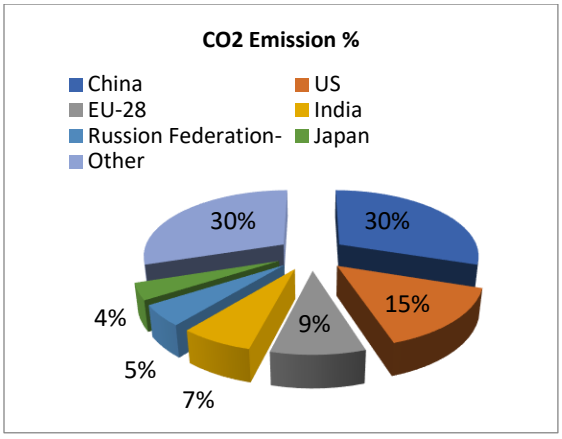

Figure 6: Global CO_2 emission in 2014 (Source:[19])

It has been reported that: "Biogas has the potential to reduce global GHG emissions by 3,290 to 4,360 Mt CO2 eq., which is equivalent to 10-13% of the world's current greenhouse gas emissions. Generally, biogas is a clean gas that comparatively does not produce GHG emissions except for some methane gases released from the biogas plant. Methane gas is 25 times more dangerous than CO2 emission [20], [21]. Hence GHG emission from biogas plant is also counted.

Nepal's GHG emission status

Nepal has ratified the Kyoto Protocol from the UNFCCC, which considers the justifiable use of resources to limit or reduce the emission of gases that contribute to global warming (MoPE, 2004). A study by [22] revealed that about 4.17 million tCO2e can be mitigated by deploying RETs in Nepal, and biogas has the potential to mitigate about half of it by replacing traditional woody fuels which have the highest emission factor. Per capita, the GHG emission rate in Nepal is decreasing from 2005 to 2020, though it is predicted to be increased after 2025.

Table 5: Energy consumption and GHG emission status of Nepal (Source: [22])

Index	2005	2010	2015	2020	2025	2030
Per capita energy (GJ)	15	16	16	17	19	23
Energy per household (GJ)	76	79	78	78	13	17
Share of Renewable (%)	11.7	11.9	11.2	12.3	15.4	22.1
Per Capita GHG production (kg)	474	459	420	392	508	672

The CES (2013) predicted that the per capita GHG emissions increase from 200 kgCO_2e in 2005 to 240 kgCO_2e in 2030. Nepal emitted 51.2 million tonnes of GHGs in 2018. The total GHG emission contribution of Nepal is very modest (0.025%) compared to the global annual emissions [23]. Nepal's contribution to global CO_2 emissions from fuel combustion in 2013 was only 0.01%, which was just 0.21% and 0.11% of India and Asia's emissions [24].

Although Nepal is one of the lowest GHG emitters in the world, the country is highly vulnerable to climate change impacts [25]. It ranks fourth on the climate change vulnerability index as being at extreme risk from climate change effects due to a high level of climate change risk exposure and low adaptive capacity. The key determining factors in the ranking are poverty, population pattern, development, natural resource management, agriculture dependency and conflicts, and adaptive capacity [26]. The majority of GHG emissions in Nepal are derived from the unsustainable use of firewood for household energy applications and petroleum fuels for the transport and industrial sectors [27].

1.4 Research problem, objectives, and rationale of the study

More than 70% of the total primary energy consumption in Nepal is biomass. Unsustainable use of fuelwood and other cooking fuel are the main causes of GHG emissions. Biogas is a clean renewable source of energy which can be produced at the household level by using simple technology and at low cost. Total potential biogas households in Nepal are 1.3 million but less than 30% of total potentiality has been covered yet. Moreover, it is reported that biogas households are using other cooking fuels as alternative energy sources as biogas is not produced enough to fulfill their daily cooking energy needs. It is obvious that once the use of biogas production is enough to replace emission-intensive other cooking fuels it directly impacts on entire energy consumption pattern. However, the study of the existing status of domestic biogas production; the pattern of biogas consumption; the way of biogas production increment, and its impact on clean energy consumption; and associated GHG emission reduction in the present context and even up to far future has not been done yet. Hence, the main objective of this study was to assess the existing condition of biogas production & use in that particular biogas household to analyze the impact of biogas on clean energy consumption and associated GHG emission reduction. The findings of this study would be useful beyond the country where similar conditions exist.

2. RESEARCH METHODOLOGY

This research included quantitative and qualitative data gathered from both primary and secondary sources. Two districts of Nepal, namely, Lamjung from the Hill region which extends up to the High Himalayas, and Chitwan from the Terai region were selected for this study (Figure 7). The selected districts represent the two distinct regions in terms of biogas production which depend upon temperature, energy use practices, fuel costs, availability of feedstock, subsidy policy, and remoteness. Both districts have more than 20-year history of biogas installation [28].

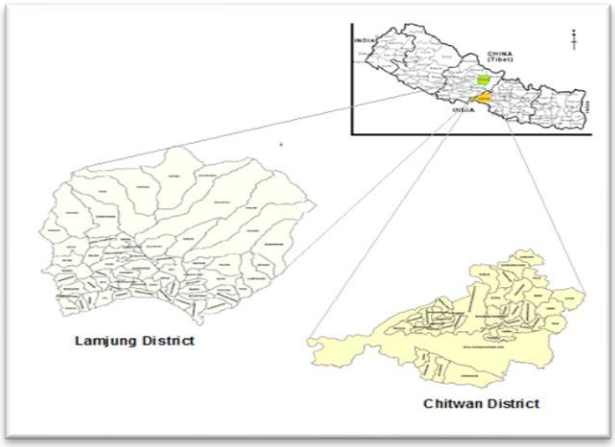

Figure 7: Map of Nepal showing the two study districts

2.1 Sampling

A circular systematic sampling method was used to select the survey households. For each district, the total number of biogas households (N) was then divided by the sample size (n) to obtain the interval (*i*).

$$n = \frac{Nz^2p(1p)}{Nd^2+z^2p(1-p)} \quad \text{(Equation 1)}$$

where,

n = Sample size

N = Total population size

z = Confidence level (at 96% level, z = 1.96)

p = Proportion of samples on population estimate (95%)

d = margin of error (+/- 3.4%, expressed as a proportion, i.e., 0.034)

The original sample size given by the above equation was 157 for both districts.

2.2 Data collection methods

Figure 8: A household survey in Lamjung district

Figure 9: Biogas Plant Observation in Chitwan District

Biogas household surveys with formal and informal discussion, interview, and site observation methods were adopted for primary

data collection. A thorough literature review was applied for secondary information and model application.

2.3 Data analysis methods

A comprehensive analysis of household energy consumption patterns for cooking before the use of biogas, and changes in the consumption and quantity of fuels after the use of biogas, were analyzed to examine the role of biogas in replacing conventional fuel sources. Analyzing the changes in energy use patterns after the use of biogas is important for measuring the potential and real benefits of biogas systems. The data were analyzed using Microsoft Excel and Statistical Package for Social Sciences (SPSS) for statistical data analysis of surveyed households, Volumetric Methane Prediction (VMP) model for biogas plant efficiency increment analysis, and Long-Range Energy Alternative Planning System (LEAP) model for assessing the impact of biogas systems on energy consumption and GHG emissions reduction.

In VMP Model the effect of co-digestion of dung with agricultural residues to increase a plant's production capacity was analyzed and calculated to identify how much methane (CH_4) could be produced per kg Volatile Substate (VS) % in any feedstock (both in mono and co-digestion condition) with different (a,b,c,n) biochemical composition per unit size of biogas digester per day by using Bushwel's equation :

$$\text{BMP } (m^3\ CH_4/\text{kg VS}) = 22.4 * \frac{\frac{n}{2}+\frac{a}{8}-\frac{b}{4}-\frac{3c}{8}}{12n+a+16b+14c}$$

…….. (Equation 2)

LEAP is a bottom-up energy environment model which is a widely used modeling tool for the study of integrated energy policy analysis and climate change mitigation assessment [29].

The four different scenarios were generated in LEAP based on energy use information and related policy conditions such as biogas and subsidy policy: 1) reference or business-as-usual; 2) improved production efficiency; 3) increased subsidy; and 4) integrated scenario (with the cumulative effect of improved biogas production and increased subsidy scenarios (Figure 10).

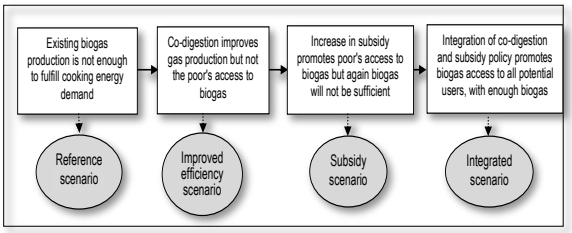

Figure 10: The logic connecting the alternative scenarios to the reference scenario

Key assumptions in LEAP model

The *Key assumptions* for the scenario analyze and comprise demographic variables (population, population growth rate, households, and household size), microeconomic data (GDP, GDP growth rate, per capita income/growth), existing and potential biogas households and feedstock potential (dung and crop residues) for the studied districts and the representative regions. The demographic details were taken from the National Population and Housing Census 2011 [11]. It is assumed that the population growth rate, household growth rate and household size remain the same over the study period for all the scenarios.

The demand analysis consists of final energy demand in which energy consumption is calculated as the product of total activity level and

final energy intensity at each given technology branch (Equation 2) [29].

$(\text{Energy demand})_{b,s,t} = (\text{Total activity})_{b,s,t} \times \text{Energy intensity})_{b,s,t}$ ……..(Equation 3)

Where *b* is the branch, *s* is the scenario and *t* is the year (from base year [0] to the end year).

The environmental emissions are calculated as the product of energy consumption and emission factor for each technology, year, and pollutant (Equation 3) [30], [31].

$(\text{Emission})_{t,y,p} = (\text{Energy consumption})_{t,y} \times (\text{emission factor})_{t,y,p}$ ……..(Equation 4)

Where *t* is technology, *y* is year and *p* is a pollutant.

The IPCC Tier 1 default emission factors contained in LEAP were used for the emission analysis. The environmental emissions or effects were expressed in terms of GHG emissions using the default global warming.

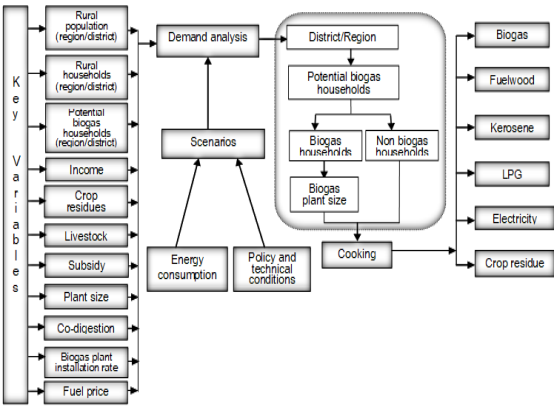

Figure 11: Conceptual framework for analysing energy consumption and GHG emission in LEAP

3. RESULTS

3.1 Existing status of energy consumption in Chitwan and Lamjung before and after biogas

The study showed that although fuelwood was the most prevalent energy source before the installation of biogas plants, biogas changed the energy use pattern, successfully substituting the fuelwood and other biomass sources in both districts.

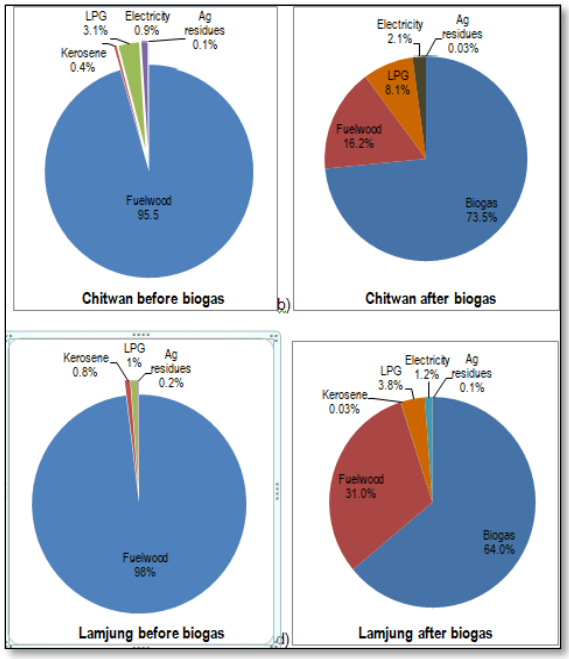

Figure 12: Biogas demand and consumption pattern in Chitwan and Lamjung

The demand and consumption of biogas in the surveyed households were analyzed to identify the daily biogas deficit. Households reported a peak energy demand for cooking between 7:00 am and 8:00 am and 7:30 pm and 8:30 pm (Figure 12). The existing biogas production was usually not enough to fulfill the cooking energy needs of a household all year round. Biogas deficit was higher during winter due to lesser gas production in colder temperatures. On average, biogas

fulfilled 87% and 79% of the cooking energy needs of a household in summer and 60% and 49% of the demand in winter in Chitwan and Lamjung, respectively. Users were using multiple sources of energy for a meal.

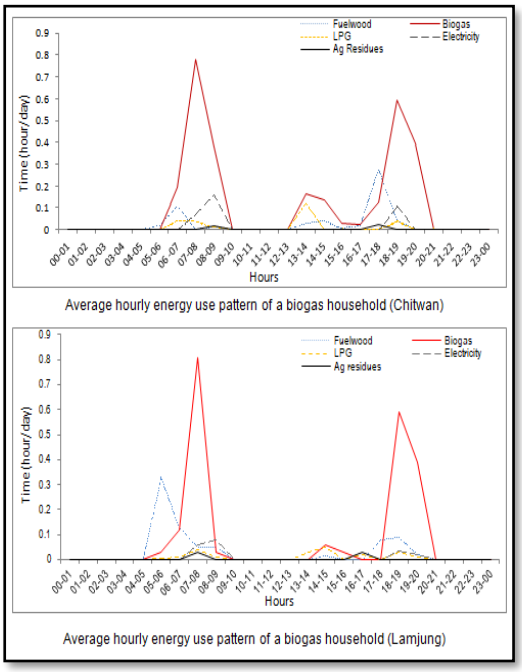

Figure 13: Average daily biogas demand and consumption per household in Chitwan and Lamjung

Figure 14: Using three energy sources for cooking a meal in Lamjung

Reasons for lower biogas production

Respondents mentioned more than one reason for lower gas production. The lower temperature was felt as the main reason for less gas production during winter in 76% and 87% of households in Chitwan and Lamjung, respectively (Table). Similarly, insufficient feedstock, lower than the prescribed amount, fed into the digester was considered another major reason in 49% of households in Chitwan and 46% of households in Lamjung.

3.2 Biogas production increment due to co-digestion

This study suggests that co-digestion of mixed feedstock could be the best solution for underfed domestic biogas plants to increase biogas production. Co-digestion of crop residues with dung and human excreta could increase biogas yield by approximately 50-150% depending on the proportion of the co-substrates and temperature. It is assumed that this amount of biogas increment will be enough to replace other emission cooking fuels of the biogas household every day.

3.3 Impact of biogas on energy consumption pattern in both districts

The energy consumption after the installation of biogas is mainly driven by the activity level and impacts of various scenarios. In the reference scenario, the total final energy consumption in the potential biogas households for cooking from all fuels is projected to decrease by 506 TJ from 2012-2040 in Chitwan with an average annual reduction of 0.8%, and 72 TJ in Lamjung with an average annual reduction of 0.4% in the same period (Table 8.10). The reduction in total energy

consumption is due to the reduction in inefficient fuelwood consumption replaced by biogas.

Table 6: Final energy demand projection of biogas households in Chitwan and Lamjung under different scenarios in LEAP for selected years by plant size (TJ).

Fuels	2012	Reference		Improved efficiency		Subsidy		Integrated	
		2020	2040	2020	2040	2020	2040	2020	2040
Chitwan									
Electricity	2.7	3.8	6.5	6.5	17.0	4.0	8.4	7.3	26
LPG	8.4	12.1	24.5	2.2	2.3	13.2	35.9	2.0	-
Fuelwood	2485	2310	1840	2096	1295	2207	1004	1930	-
Biogas	106	137	225	213	401	154	359	246	668
Crop residue	0.05	0.03	-	0.03	-	0.04	-	0.03	-
Total	2602	2463	2096	2318	1715	2378	1407	2184	694
Lamjung									
Electricity	0.3	0.5	1.0	4.1	9.9	0.5	1.1	4.6	15
LPG	1.0	1.4	2.6	0.01	0.02	1.4	3.3	0.03	-
Fuelwood	642	618	550	427	271	603	431	337	-
Biogas	47	52	64	79	109	54	82	82	137
Crop residue	0.12	0.08	-	0.06	-	0.08	-	0.06	-
Total	690	672	618	510	390	659	518	424	152

Total fuelwood energy consumption is estimated to decrease by 645 TJ with an average annual reduction rate of 1.1% in Chitwan and by 92 TJ with an average annual reduction rate of 0.6% in Lamjung in the reference scenario from 2012-2040. The total consumption of biogas is predicted to increase by 2.7% per annum from 106 TJ in 2012 to 225 TJ in 2040 in Chitwan and 1.1% per annum from 47 TJ to 64 TJ in Lamjung in the same period.

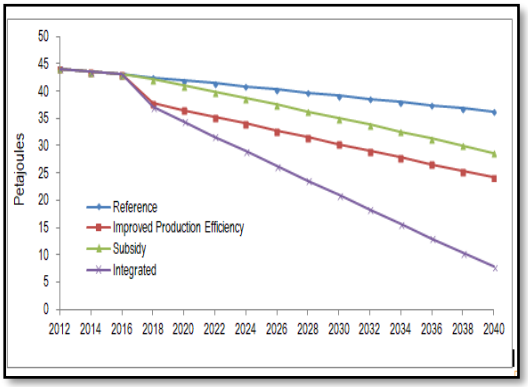

Figure 15: Final energy demand projection of potential biogas households from all fuels in the Lamjung district for the four scenarios respectively in LEAP

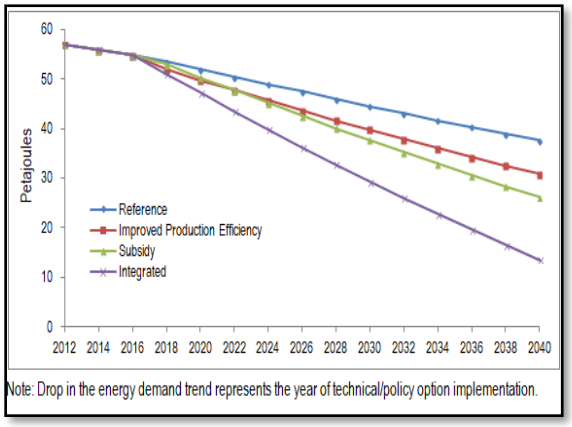

Figure 16: Final energy demand projection of potential biogas households from all fuels in the Chitwan district for the four scenarios respectively in LEAP

As in the case of the surveyed districts, the most striking feature in the final energy demand prediction for the Lamjung (Figure 14) and Chitwan (Figure 15) is the significant decrease in demand in the improved biogas production efficiency and integrated scenarios as a result of increased availability of biogas after co-digestion of crop residues with dung.

Saving energy after the use of biogas

Comparison of total predicted energy consumption of potential biogas households in the studied districts and both regions with and total energy consumption after the installation of biogas plants across all scenarios. This saving is mainly due to the reduction in the burning of inefficient fuelwood and the use of efficient cooking fuel such as biogas and electricity, which illustrates the impact of biogas technology in reducing the energy demand of user households. If the biogas completely replaces other cooking fuels, it reduces energy consumption by 40%.

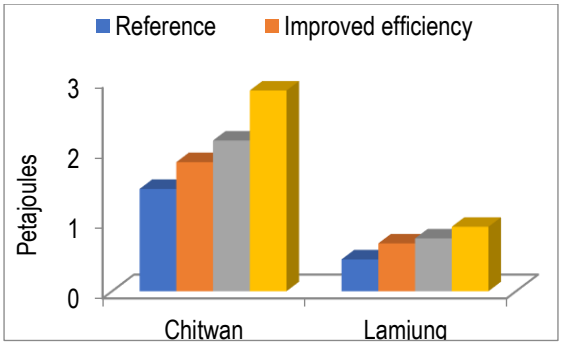

Figure 17: Saving on total energy consumption (GJ) Projection after the installation of biogas plants compared with no biogas household

3.4 Impact of biogas on the GHG emissions reduction

Biogas is a lower carbon fuel and it can reduce GHG emissions from the domestic sector by replacing the burning of emissions-intensive fuels with efficient fuels/stoves. The replacement of traditional biomass and petroleum fuels has a significant impact on environmental emissions reduction. If the current trend of fuelwood consumption continues, the total GHG emissions in the reference scenario are predicted to decrease by 0.72%/year from about 22,500 tCO_2e in 2012 to 18,300tCO_2e in 2040 in Chitwan, and by 0.42%/year from 5,800 tCO_2e in 2012 to 5,100 tCO_2e in Lamjung (Table 11).

Table 7: GHG emissions projection of potential biogas households in Chitwan and Lamjung by fuel-type under different scenarios for selected years (tCO2e)

Fuels	2012	Reference		Improved efficiency		Increased subsidy		Integrated	
		2020	2040	2020	2040	2020	2040	2020	2040
Chitwan									
LPG	575	831	1670	146	154	899	2454	135	0
Fuelwood	21,598	20,084	16,005	18,220	11,250	18,186	8,723	16,772	0
Biogas	319	399	677	643	1210	463	1082	740	2,013
Crop residue	0.4	0.3	0	0.2	0	0.4	0	0.2	0
Total	22,492	21,314	18,352	19,010	12,614	20,548	12,259	17,648	2,013
Lamjung									
LPG	65	92	179	1.8	1.5	96	228	1.0	0
Fuelwood	5,578	5,369	4,777	3,708	2,349	5,244	3,750	2,930	0
Biogas	141	155	193	237	329	162	248	247	412
Crop residue	1	0.7	0	0.5	0	0.7	0	0.5	0
Total	5,785	5,617	5,149	3,948	2,680	5,502	4,226	3,179	412

The emissions are predicted to reduce further in the integrated scenario to about 2,000 tCO_2e (8.3%/year) in Chitwan and 400 tCO_2e (9%/year) in Lamjung in the same period. The total emissions from the burning of fuelwood are projected to decrease by about 21,600 tCO_2e in Chitwan and about 5,600 tCO_2e in Lamjung in the integrated scenario from 2012-2040. The total emission from biogas is predicted to increase by about 1,700 tCO_2e (2.7%/year) in Chitwan and 270 tCO_2e (1.1%/year) in Lamjung in the same period when all potential households have access to biogas. The predicted emissions from fuelwood in the integrated scenario are virtually zero in 2040 in both districts and regions, as none of the biogas households are expected to use fuelwood for cooking.

3.5 Total global warming mitigation potential (GMP)

Total Global Warming Mitigation Potential was calculated by considering emission from both energy and non-energy sector by using the following equation.

GMP = GHG emissions from burning of conventional fuels + reduction in GHG emissions from forest cleared for fuelwood + reduction in GHG emissions from the decomposition of unfed dung + reduction in GHG emissions from replacing chemical fertilizers - GHG emissions from methane leakage from biogas plants……..(Equation 5)

The GMP of biogas plants from all sources increases significantly with the increase in the

number of biogas plants. Total GMP in a 100-year time horizon (including both energy and non-energy related emissions) of all the biogas plants installed in the reference scenario is estimated at 410,000 tCO_2e in Chitwan and 143,000 tCO_2e in Lamjung in 2040 (Table 10). This is projected to further increase to 1.04 million tCO_2e and 309,000 tCO_2e, respectively, in the integrated scenario when all the potential biogas plants are installed and biogas (and electricity to supplement biogas deficit replaces all conventional fuels.

Table 9: Total global warming mitigation potential of biogas plants in different scenarios including energy as well as non-energy emissions (1,000 tCO_2e)

District/ Region	2012	Reference		Improved production		Increased subsidy		Integrated	
		2020	2040	2020	2040	2020	2040	2020	2040
Chitwan	194	248	410	326	621	278	660	377	1039
Lamjung	91	102	143	178	248	104	160	185	309

The total GHG emission mitigation potential of a co-digested biogas plant from both energy and non-energy sector sources, such as replacing emission- intensive fuels; avoiding deforestation for fuelwood; decomposition of dung for biogas production; and bio-slurry to replace chemical fertilizers in 2040 are projected to be about 16.7 tCO_2e in Chitwan and 19.3 tCO_2e in Lamjung.

4. DISCUSSION

This study assumed that co-digestion of dung with crop residue at different mixing proportion increase biogas production up to 150%. This finding is consistent with [34], [35] [36] [37] that reported an increase in biogas yield of 50-200% more than single feedstock digestion, depending on plant operating condition and co-substrates used. [38] Moreover, if the biogas completely replaces other cooking fuels, it reduces energy consumption by 40%. Although specific studies on the impact of biogas on reducing energy consumption could not be found, this study's finding is consistent with the finding of other studies on renewable energy technologies, that use of efficient energy sources reduces the consumption of inefficient traditional fuels and hence on total energy consumption [39] [32] [33] [40]. Similarly, the average annual rate of GHG emissions reduction after improving plant efficiency through co-digestion of mixed feedstocks in Lamjung is higher than in Chitwan because increased biogas production is projected to replace more fuelwood in Lamjung. These findings are comparable with the findings of [41], (Shakya & Shrestha, 2006), [43], [44] because they did not take into account the improved production efficiency of the plants and non-energy sector emissions.

5. CONCLUSION

The use of biogas is directly proportional to high clean energy consumption and GHG emission reduction, hence has strong nexus between them. Insufficient biogas production has been identified as one of the major constraints for the wider replication of domestic biogas technology. The increased biogas production efficiency through co-digestion of cattle dung with crop residues is enough to replace the existing use of other cooking fuels. Hence, this increment in all the potential households can increase the saving on total annual energy consumption up to 46.2 GJ in Chitwan district and 57.1 GJ in Lamjung district by substituting all of the traditional fuels. Regarding GHG emission, the mitigation potential per plant is lower in Lamjung compared

with Chitwan in the reference and increased subsidy scenario but higher in the improved production and integrated scenarios. Moreover, the GHG emission mitigation potential of a co-digested biogas plant from both energy and non-energy sector sources, such as avoiding deforestation for fuelwood, decomposition of dung and bio-slurry replacing fertilisers by 2040 is projected to be about 16.7 tCO2e in Chitwan/Terai and 19.3 tCO2e in Lamjung/Hill. However, only about 5% of households reported using slurry to replace fertilisers and hence the reduction in emissions would be less than the projection. The GHG emissions due to the methane leakage from biogas plants are significant at about 1.02 tCO2e/year/plant. This is higher than the GHG avoidance from burning of traditional fuels substituted by biogas though it is much lower compared to the GHG avoidance from both energy and non-energy sector sources.

6. RECOMMENDATIONS

Digestion of dung with human excreta only as currently practiced in Nepal, however, has no significance in improving biogas production. Feedstock insufficiency has been identified as one of the major reasons for lower biogas production. Relevant biogas companies should therefore carefully assess the feedstock availability beforehand to ensure that a newly constructed plant will not be under-fed. Similarly, extending awareness and training on co-digestion to potential users should be seriously considered for the option and smooth operation of co-digested plants. Lastly, the GHG emissions due to the methane leakage from the biogas plant should also be taken as a precautionary measure as it is about 1.02 tCO2e/year/plant.

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REFERENCES

[1] BSPNepal, "Biogas plant owner manual (in Nepali). Biogas Support Programme.," BSP-Nepal, Kthmandu Nepal, 2012.

[2] P. Ghimire, "Final report on technical study of biogas plants installed in Bangladesh. A report submitted to national program on domestic biogas in Bangladesh.," Dhaka, Bangladesh, 2005.

[3] U. Werner, U. Stohr and N. Hees, "Biogas plants in animal husbandry.," 1989.

[4] U. Z. L. S. M. N. &. B. E. Balasubramaniyam, "Biogas production in climates with long cold winters," Wageningen University, the Netherlands,, Wageningen, 2008.

[5] A. Karki, J. Shrestha and S. Bajgain, "Biogas as renewable source of energy in Nepal: Theory and development. Kathmandu, Nepal:," Biogas Support Programme Nepal., 2005.

[6] B. Nagasami and K. Ramasami, "Biogas production technology: An Indian perspective.," Coimbatore, India:, 2010.MoWS, “M&E Framework for water

supply system Functionality and Sustainability indicators.," Nepal, 2016.

[7] A. Viancelli, W. Michelon and E. Emahdy, "urrent Efforts for the Production and Use of Biogas Around the World.," *Biofuel and Biorefinery Technologies,*, vol. 9, 2019.

[8] B. K. McCabe and T. Schmidt, "McCabe, Bernadette K. and Schmidt, Thomas (2018) Integrated biogas systems: local applications of anaerobic digestion towards integrated sustainable solutions. Technical Report.," IEA Bioenergy, 2018.

[9] IEA, "Outlook for biogas and biomethane: Prospects for organic growth," IEA, Paris, 2020.

[10] BSPNepal, "District and fiscal year wise production of biogas plants (Unpublished). Kathmandu, Nepal:," BSPNepal , Kathmandu Nepal, 2015.

[11] CBS, "National Population and Housing Census 2011. National Report," Central Bureau Statisticas, Nepal, 2012.

[12] IEA, "IEA (2021), World Energy Outlook 2021, https://www.iea.org/reports/world-energy-outlook-2021," Paris.

[13] "NEEP. (2015). Nepal Energy Efficiency Programme. Retrieved from http://energyeficiency.gov.np/article-component3", 2015

[14] "ADB.. Energy Outlook for Asia and the Pacific. Manila: Asian Development Bank," 2015.

[15] "NEA. (2016). A Review in Review: Fiscal Year 2015/2016. Kathmandu: Nepal Electricity Authority", 2016

[16] ADB, "Energy Sector Assessment Strategy and Road Map," 2017.

[17] SE4All, "Global Tracking Framework. Sustainable Energy for All. Retrieved from : presentation title: future medium 24pt emboldened Up to Three Lines All Capital or Title Case (biee.org)," 2015.

[18] S. KC., S. Khanal, P. Shrestha and B. Lamsal, "Current status of renewable energy in Nepal: Opportunities and challenges.," *Renewable and sustainable energy review*, vol. 15, pp. 4107-4117., 2011.

[19] T. Boden, G. Marland and R. Andres, "National CO2 Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-201Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Departm," 2017.

[20] S. Bakkaloglu, "Quantification of Methane Emission from UK Biogas Plants. Waste Management. Volume 124, Pp. 82-93.," 2021.

[21] C. Scheutz and A. M. Fredenslund, "Total methane emission rates and losses from 23 biogas plants," *Waste Management*, vol. 97, pp. 38-46, 2019.

[22] CES, "Final report on study on role of renewable energy technologies in climate change mitigation and adaptation options in Nepal. Retrieved from Lalitpur, Nepal:," 2013.

[23] MoPE, " Initial national communication to the conferrence of the parties of the United Nations framework convention on climate change. Retrieved from Kathmandu, Nepal: http://unfccc.int/resource/docs/natc/nepnc1.pdf," 2004.

[24] IEA, " International Energy Outlook. Paris: International Energy Agency.," 2012.

[25] MoEST, "Climate change and UNFCCC negotiation process. Retrieved from Kathmandu, Nepal:," 2012.

[26] Maplecroft, "Climate change vulnerability index. Retrieved from http://maplecroft.com/about/news/ccvi.html," 2014.

[27] WECS, "Energy Sector synopsis report Nepal. Retrieved from Kathmandu, Nepal: www.wec.gov.np," 2010.

[28] BSPNepal, "Biogas Development in Nepal," BSP-Nepal, Kathmandu, Nepal, 2013.

[29] SEI, "An introduction to LEAP: Tools for sustainable energy analysis. Retrieved from http://www.energycommunity.org/default.asp?action=47," 2013.

[30] R. Kadian, R. Dahiya and H. Garg, " Energy-related emissions and mitigation opportunities from the household sector in Delhi. Energy Policy, 35(12), 6195-6211.," 2007.

[31] SEI, " LEAP User Guide for LEAP version 2008. Retrieved from Somerville:," 2010.

[32] J. Z. N. L. M. D. &. F. D. Lin, "Achieving China's target for energy intensity reduction in 2010: An exploration of recent trends and possible future scenarios. Retrieved from Berkeley, USA:," 2006. [Online].

[33] Malla, "Household energy consumption patterns and its environmental implications: Assessment of energy access and poverty in Nepal..," *Energy Policy,* vol. 61, pp. 990 - 1002, 2013.

[34] H. Moller, S. S. and B. Ahring, "Methane productivity of manure, straw and solid fractions of manure," *Biomass and Bioenergy,* vol. 26, pp. 485-495, 2004.

[35] T. Poulsen, A. Nizami, R. Rafique, G. Kiely and J. Murphy, "How can we improve biomethane production per unit of feedstock in biogas plants?," *Applied Energy,* vol. 88, no. 6, pp. 2013-2018, 2011.

[36] R. Omar, R. Harun, T. Ghazi, W. Azlina, A. Idris and R. Yunus, "Anaerobic treatment of cattle manure for biogas production. In Proceedings of Annual Meeting of American Institute of Chemical Engineers," Philadelphia, USA, 2008.

[37] A. Sahito, R. Mohar and K. Brohi, "Sahito, A. R., Mahar, R. B., & Brohi, K. M. (2014). Anaerobic co-Digestion of canola straw and buffalo dung: Optimization of methane production in batch experiments," *Mehran University Research Journal of Engineering & Technology,* vol. 33, no. 1, pp. 49-60, 2013.

[38] "Anaerobic biodegradability and methane potential of crop residue co-digested with buffalo dung," *Mehran University Research Journal of Engineering and Technology,* vol. 32, no. 3, pp. 509-518, 2013.

[39] B. Limmeechokchai and S. Chawana, "Sustainable energy development strategies in the rural Thailand: The case of the improved cooking stove and the small biogas digester," *Renewable and sustainable energy reviews,* vol. 11, no. 5, pp. 818-837., 2007.

[40] S. Pokhrel, "An econometric analysis of energy consumption in Nepal.," *Energy Policy*, vol. 35, pp. 350 -361, 2007.

[41] S. Dhakal and A. Raut, "Dhakal, S., & Raut, A. K. (2010). Potential and bottlenecks of the carbon market: The case of a developing country Retrieved from http://www.scopus.com/inward/record.url ?eid=2-s2.0-77953685470&partnerID=40&md5=6cb," *Energy Policy*, vol. 38, no. 7, pp. 3781-3789, 2010.

[42] S. Shakya and J. Shrestha, "Contribution of renewable energy technologies for GHG mitigation in Nepal. Paper presented at the First national conference on renewable energy technology for rural development, 12 - 14 October 2006, Kathmandu, Nep," 2006.

[43] P. Pokhrel, "Pokharel, S. (2007b). Kyoto protocol and Nepal's energy sector. Retrieved from http://www.sciencedirect.com/science/article/pii/S0301421506003594," *Energy Policy*, pp. 2514 - 2525, 2007.

[44] N. Chaulagain and R. Laudari, "Chaulagain, N. P., & Laudary, R. (2010). The environments of the poor in the context of climate change and the green economy - Alternative energy linking climate and environment consideration Proceedings of Nepal country workshop on Environments of the Po," 2010.

Building Permit Approval System: A Case Study of Kirtipur Municipality

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Abstract

In Nepal, the level of building code implementation is different in different municipalities and each municipality has a different building permit process. No research is done about the effectiveness of the building permit approval system in the local authority in Nepal. The study was conducted to review the effectiveness of the building permit approval system in Kirtipur Municipality. The research presents and discusses the findings from one of the methods used to measure effectiveness of the system. Fifty (50) questionnaires have been made to the house owner or the Principal Submitting Person (PSP) of the private building registered on FY 2076/77 or later. Four problems were identified from literature review relevant for Kirtipur Municipality and two problems were identified from group discussion with the house owners of ward number nine of Kirtipur Municipality. Most of the respondents felt that ineffectiveness of the building plan approval process was due to lack of transparency, information gap regarding Building permit process and delay to send notice by the ward. The causes of lack of transparency were found to be deficiency of complaint mechanism, discrepancy of the basis of designer, step of floor plan approval is not disclosed and delay in decision. The causes of the problem with the information gap regarding building permit process were building permit procedures not accessible via phone, responsible officials are not friendly to give information and building permit procedures not accessible via website. The problem of delay to send notice by the ward was delay to make site visits by the ward engineer, delay to send report by the ward engineer and due to reshuffling of engineers in ward offices.

Keywords

Building permit, local authority, transparency, complain mechanism, information gap

1. INTRODUCTION

1.1 Background

Housing as one of the basic needs is the fundamental right of all people guaranteed by the constitution of Nepal. Housing being a material asset and psychosocial symbol of achieved status, people construct private housing investing all their lifetime earnings. The migration of people is increasing in urban areas for better income opportunity, education, health, safety and other services. Later on, people want to reside in their place of migration which increases the demand of housing in urban areas. The social pattern of Single family from Joint family has increased the demand of no of residences in Nepal. We can see the division of Building vertically to distribute it to the number of Sons in a house. Residing in self-owned residence is a matter of pride in Nepalese society. Constructing a self-owned house is the dream of every individual. From the 1990s the government has acknowledged the need for the private sector's involvement in fulfilling housing needs in the country by enacting the Joint Apartment Act 1996.

There are a number of project delivery systems in the construction industry. Traditional methods, design-built methods and engineering-procurement-construction (EPC) are the most

common. These days the design-built method is one of the modern methods of project management and delivery. Construction involves multi-stakeholders to complete. The role and responsibilities are dependent on each other. Performance of one party has a tremendous effect on the other. Clients have been argued to be the most important construction industry participants as they initiate and fund the construction process from inception to completion [1]. There are three distinct types of building construction mechanism in practice in Nepal, prevalence of owner-built structures is seen [2]. In Nepal people own their own plot of land and construct a Building in it. Generally, contractors are selected on a per square feet rate, material is self-managed by the owner, building permit is taken from local authority and building is built. It gives the owner the responsibilities in terms of time, cost and quality.

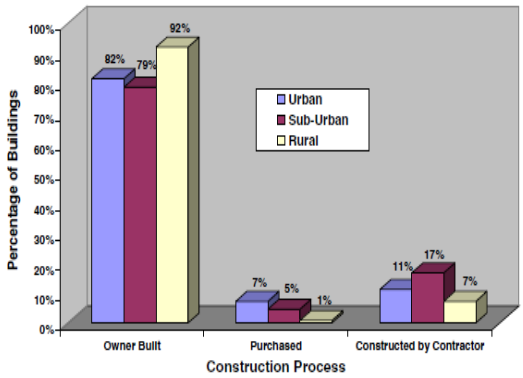

Figure 1: Building Construction Process for Residences in Kathmandu Valley [2]

There is poor institutional and technical capacity within the local authorities for implementing the building permit process [2]. The owner faces problems from the phase of floor plan approval up to receiving of completion certificate. Submission of building plans to the local or municipal authority for approval is very tedious and time consuming. The time involved ranges from a few weeks to months. The submission process of the building plans to the government authorities requires the authorities to check in details on the design for building by-laws compliance or non-compliance. It poses a major problem because the owner has difficulty to estimate the actual time required for a building project due to the uncertainty of the time taken for building plan approval. In developing countries, the difficulties and challenges are present alongside a general situation of socio-economic stress, chronic resource shortages, institutional weaknesses and a general inability to deal with the key issues [3].

1.2 Objective

The objectives of the research are as follows.

- To identify problems faced by building owners during Building permit approval and their possible solutions.

1.3 Rationale of Study

The purpose of this research is to explore the prevailing problems faced by private sector building owners during building permit approval and suggest the strategy to minimize them. The study will explore the effectiveness of the Building permit approval system in Kirtipur Municipality. Problems faced by private sector building owners will be identified which will help to make a strategy for making the Building permit approval system effective. The explorations of causes of problems will allow each stakeholder to be aware of their role in eliminating the problems in the building permit approval system.

2. METHODOLOGY

2.1 Research Design

Research design is "a logical plan for getting from here to there, where here may be defined as the initial set of questions and there is some set of conclusions about these questions" [4]. The study was conducted in several phases: literature review, questionnaire development, data collection, data analysis, findings, discussion and conclusion. Selection of papers relevant to the building permit approval were obtained and reviewed. Keyword search was used to identify the selected papers. (Copper, 2010) argued that secondary research channels such as Journals, proceedings and government reports grant useful information for the primary research.

The research method used in this research is qualitative case studies. The method used in this research is descriptive. The research consists of three parts, a basic survey of problems faced by the clients and their causes based on questionnaire and interview studies, the second part where challenges faced during the building permit process of other countries are studied. Third, the conclusion of problems faced by private sector Building Owners during the building permit process and their causes are identified. Fourth, recommendations are given with an emphasis on problem solving.

The research methodology is mostly qualitative in nature, and was conducted through the use of semi-structured questionnaires. The samples were selected through stratified random sampling. During this research visits on recently completed and under construction private residences in Kirtipur Municipality were performed for case study and collection of data from questionnaire survey and observations.

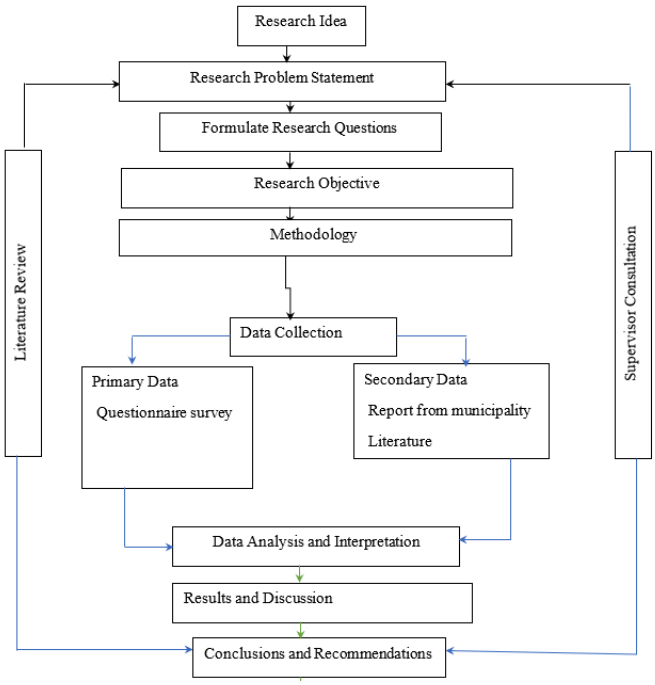

Figure 2: Flowchart of research methodology

2.2 Study Population

The Buildings that get registered for building permit from Kirtipur Municipality in the fiscal year 2076/77 or later will be studied in this research. For the purpose of calculation of sample size, the applications that got registered in the FY2076/77 are used. The building act, 2055 has provisioned the duration of construction of building to be two years, so the data from the last two years was used to calculate the sample size. The number of buildings that got registered were 509.

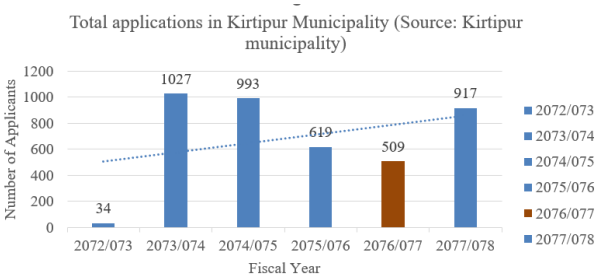

Figure 2: Total applications in Kirtipur Municipality (Source: Kirtipur municipality)

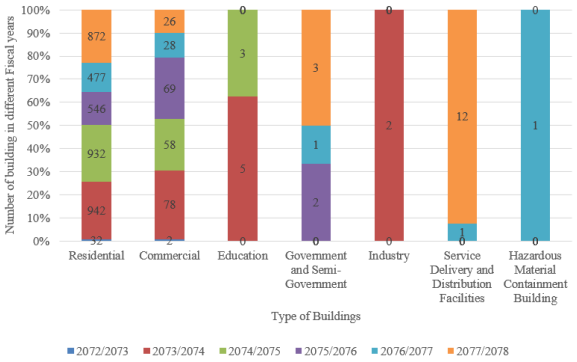

Figure 3: Building Type in Kirtipur Municipality (Source: Kirtipur municipality)

2.3 Sample Size

The sample size obtained for Kirtipur municipality was equally distributed to all the 10 wards of the municipality. A stratified random sampling method was used for the number of minimum sample size for questionnaire survey. The sample size is determined by using the formula used by Krejcie & Morgan in their 1970 article "Determining Sample Size for Research Activities"[5]. The formula used for these calculations is:

$$Sample\ Size(n) = \frac{X * X * N * P * (1 - P)}{(ME * ME * (N - 1) + (X * X * P * (1 - P))}$$

Where, n = Required sample size, X^2 = Chi square for the specified confidence level at 1 degree of freedom, N = Population size, P = The population proportion, ME = Desired Margin of error (expressed as a proportion)

According to Kirtipur Municipality the number of registered applications for Building permit in the fiscal year 2076/77 was 509. On considering population proportion as 0.5, the value of marginal error as 0.1 and the confidence interval of 10%, the value of chi-square is 2.706. From the calculation the sample size is achieved as 49.82 and the sample for questionnaire survey is taken as 50.

2.4 Questionnaire Design

Questionnaire regarding challenges faced during receiving completion certificate. Following problems in floor plan approval were extracted from literature review which is relevant with the process of floor plan approval in Nepal.

1. Lack of knowledge
2. Lack of transparency
3. Unofficial payment
4. Ineffective communication

The process of floor plan approval of Kirtipur Municipality was studied and the meeting with the engineers and responsible bodies of the municipality was held and the aforementioned problems were extracted.

1. Rejection of application
2. Delay to send notice by the ward

2.4 Validity and Reliability

As human beings are the primary instrument of data collection and analysis in qualitative research, interpretations of reality are accessed directly through observations and interviews. Thus, we are closer to reality than if a data

collection instrument had been interjected between us and the participants [6]. There are four types of triangulations, the use of multiple methods, multiple sources of data, multiple investigators or multiple theories to confirm emerging findings [7]. Here internal validity is addressed by triangulation. Triangulation validates the data through the use of household questionnaires, key informant interviews, and observations. Cronbach alpha was used to test consistency of the questionnaire. Higher the value of alpha, the more reliable the questionnaire are. Researchers have indicated 0.7 to be an acceptable reliability coefficient. The Cronbach's alpha. coefficient for the questionnaire is given in Table below.

Table 2: Reliability Statistics

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No of Items
0.819	0.805	30

2.5 Data Collection

Primary data are the base of the research. More the actual figures collected from the primary data will be the precise of the study. For the collection of primary data, following methods will be used:

a) Questionnaire survey- Semi-structured questionnaire survey was conducted with the private sector building owner. List of issues was prepared to guide the structured questionnaire with the house owner. Total 50 questionnaires were conducted.

b) Observations –The observation of the Buildings owned by the interviewee and their construction stages were noted.

Secondary data were collected from the literature study of national and international articles about the floor plan approval process and the challenges faced. The published journals, reports, internet/websites related to Building permits are another source of data that is involved in this research.

3. RESULTS

Descriptive strategy was used for data analysis and the end product being richly descriptive. The analysis of the data involves identifying recurring patterns that characterize the data. Findings are the recurring patterns or themes supported by the data from which they were derived [6].

Demographic Information Gender: Among 50 respondents, Majority of the respondents in this survey were male 76% while few were female 24%. This shows that males are more involved in Building permit process than females.

Level of Education: The majority of the respondents (44.2%) have completed their bachelor's degree. 27.9% respondents have completed their diploma level education and 23.30% respondents have completed their master's degree. Few respondents (4.6%) were found to have education of certificate level.

Building Category: As per Building act there are four categories of building types that are class A, class B, class C and class D. The randomly sampled buildings under study were under class B and class C. There were 28 no of class B buildings, which were 56 percent of total population. There were 22 no of class C buildings, which were 44 percent of total population.

Construction Stage of Building: Maximum number 22 of the buildings were completed which were 44% of the sample size. Thirteen (13) number or 26% of the buildings were DPC completed. Twelve (12) numbers or 24% of the buildings were completed. The least number 3, or 6% of the sampled buildings were ongoing foundation works.

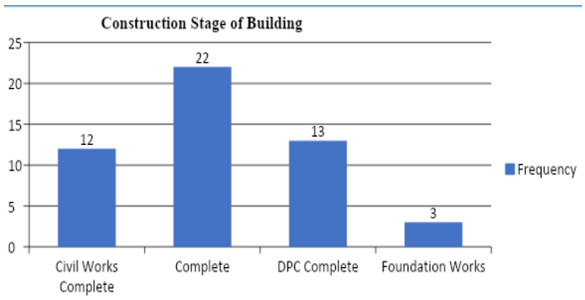

Figure 3: Construction Stage of the building

Time required for building permit approval: The average time taken for granting the building permit approval as mentioned in Nagarik Bada Patra is two months. As per our study, it shows that only 54% of building owners got building permit approval on time, whereas 26% approvals were granted in between 3 to 5 months,12% were approved within six to eight months, 6% were approved within nine to eleven months and 2% of building got approval after one year.

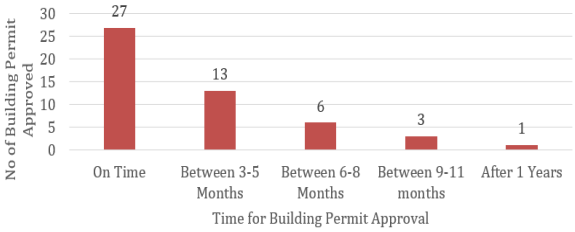

Figure 4: Time required for building permit approval

Problems Faced by Owners: The problems faced by building owners were asked to rate in the category of very low, low, average, high or very high.

Table 3: Frequency of rating of problems faced by Owner

S.N.	Description		Very low	Low	Average	High	Very high	Total	Highest frequency
1	Information gap regarding Building permit process	N	1	13	13	19	4	50	High
		%	2.0	26.0	26.0	38.0	8.0	100.0	
2	Rejection of application	N	11	22	4	6	7	50	Low
		%	22.0	44.0	8.0	12.0	14.0	100.0	
3	Lack of transparency	N	0	5	17	18	10	50	High
		%	.0	10.0	34.0	36.0	20.0	100.0	
4	Ineffective communication	N	1	16	9	18	6	50	High
		%	2.0	32.0	18.0	36.0	12.0	100.0	
5	Unofficial payment	N	12	35	0	1	2	50	Low
		%	24.0	70.0	.0	2.0	4.0	100.0	
6	Delay to send notice by the ward	N	3	9	17	16	5	50	Average
		%	6.0	18.0	34.0	32.0	10.0	100.0	

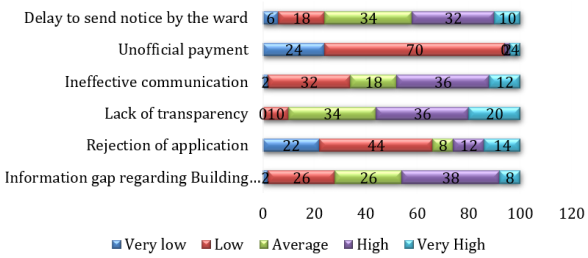

Figure 5: Frequency of rating of problems faced by Owner in %

Information gap regarding building permit process: Majority of the respondents (46%) rated the problem of information gap regarding building permit process as High. Similarly, 26% of respondents have rated the problem as average and 28 % of total respondents have said that the problem regarding building permit process is low. Since, most of the respondents have rated high; there is a major problem with the information gap during the building permit process.

Rejection of application: Most of the respondents (66%) have rated the problem of rejection of approval from ward/municipality during building permit process as Low. 12% and 14% of total respondents rated the problem as High and Very High respectively. Whereas, only 8% of respondents have an average rating for the problem faced due to rejection of application. In general, most of the respondents have low ratings for the problems faced due to rejection of application therefore this problem can be considered less significant or insignificant.

Lack of transparency: 56% of the total respondents have rated high for the problem of lack of transparency in the building permit process approval. 34% has rated average and 10% has rated Low for the same problem. Majority of the respondents have rated that lack of transparency is the major problem faced by the building owners during the building permit process.

Ineffective communication: The problem of ineffective communication has been rated high by 48% respondents. 32% respondents have rated low and 12% respondents have rated average.

Unofficial payment: Most of the respondents (94%) have responded that there is no problem of unofficial payment during the building permit approval process. Only 6% was rated high for the same parameter. The problem of unofficial payment can be considered insignificant as the majority of respondents has rated low.

Delay to send the notice by the ward: 42% of respondents have rated high for the problem of delay to send notice by the ward. 34% respondents have rated average. 18% respondents have rated Low and 6% respondents have rated Very Low for the particular problem. Delay to send notice by the ward is a significant problem

4. DISCUSSION AND CONCLUSIONS

Forty-six (46) percent Building owner received floor plan approval within time mentioned by Municipality (two months) from the date of registration of application. Fifty-four (54) percent Building owner received floor plan approval late than the time mentioned by Municipality (after two months) from the date of registration of application. Among the problems faced by private sector building owners during building permit approval are lack of transparency, information gap regarding building permit process and the delay to send notice by the ward. The causes of lack of transparency were found to be deficiency of complain mechanism, discrepancy of the basis of designer, step of floor plan approval is not disclosed and delay in decision. The causes of the problem information gap regarding building permit process were building permit procedures not accessible via phone, responsible officials are not friendly to give information and building permit procedure not accessible via website. The problem of delay to send notice by the ward was delay to make site visit by the ward engineer, delay to send report by the ward engineer and due to reshuffling of engineers in ward offices.

5. RECOMMENDATIONS

Following recommendations are made to make the Building permit system effective.

- Queuing system should be introduced to enhance transparency in the Building permit approval system.
- Information regarding the Building permit system should be updated on the website and be accessible to the general public.
- Sufficient staff should be provisioned in the ward office to enable site visit and sending reports in time.

REFERENCES

[1] CBS, "Waste management survey of Nepal 2013," Thapathali, Kathmandu, Nepal, 2013.

[2] S. Prasain, "How Nepal, a country of farmers, became a food importer over the years," *The Kathmandu Post*, Kathmandu, Nepal, Feb. 02, 2022.

[3] IFFCO, "Nano Urea (Liquid) Fertilizer," 2022.

[4] D. Dasgupta, K. Kumar, R. Miglani, R. Mishra, A. K. Panda, and S. S. Bisht, "Microbial biofertilizers: Recent trends and future outlook," in *Recent Advancement in Microbial Biotechnology: Agricultural and Industrial Approach*, 2021. doi: 10.1016/B978-0-12-822098-6.00001-X.

[5] S. Adarsh, S. Mathew, A. S. Roshni, K. T. Gopika, V. Nirosha, and A. P. Arya, "Phyto-accumulators to mitigate micronutrient deficiency in organic farming," *International Journal of Agricultural Sciences*, vol. 13, no. 1, 2022.

[6] N. Griffiths, "Best practice guidelines for using poultry litter on pastures," 2011.

[7] M. K. Maharjan and S. P. Lohani, "Municipal Solid Waste Management in Nepal: Opportunities and Challenges," *Journal of the Institute of Engineering*, vol. 15, no. 3, 2020, doi: 10.3126/jie.v15i3.32185.

[8] N. M. John, S. O. Edem, N. U. Ndaeyo, and B. A. Ndon, "Physical composition of municipal solid waste and nutrient contents of its organic component in Uyo Municipality, Nigeria," *J Plant Nutr*, vol. 29, no. 2, 2006, doi: 10.1080/01904160500464836.

[9] P. Dhakal, S. Devkota, and R. H. Timilsina, "Factors affecting the adoption of biofertilizers in Chitwan District, Nepal," *J Pharmacogn Phytochem*, no. SP1: 3050-3054, 2018.

[10] S. Dulal, "Waste to value with biogas in Nepal. How to increase the demand for biogas and scale up commercial plants to reduce LPG imports," *Nepali Times*, Kathmandu, Nepal, Jun. 01, 2022.

[11] W. B. Smith, M. Wilson, and P. Pagliari, "Organomineral Fertilizers and Their Application to Field Crops," in *Animal Manure: Production, Characteristics, Environmental Concerns, and Management*, 2020. doi: 10.2134/asaspecpub67.c18.

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.

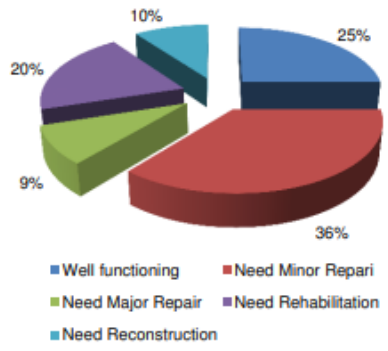

Figure 1: Functionality Status of Water Supply System

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

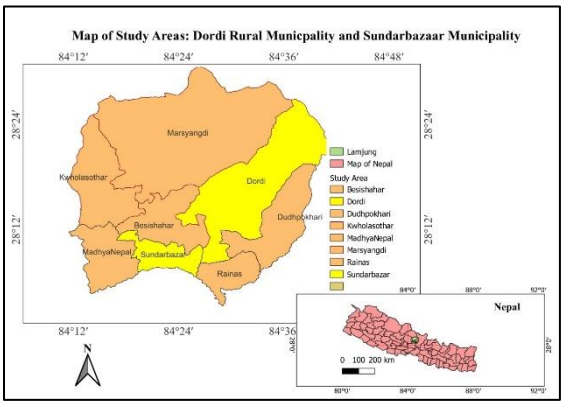

Figure 2: Location of study areas

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

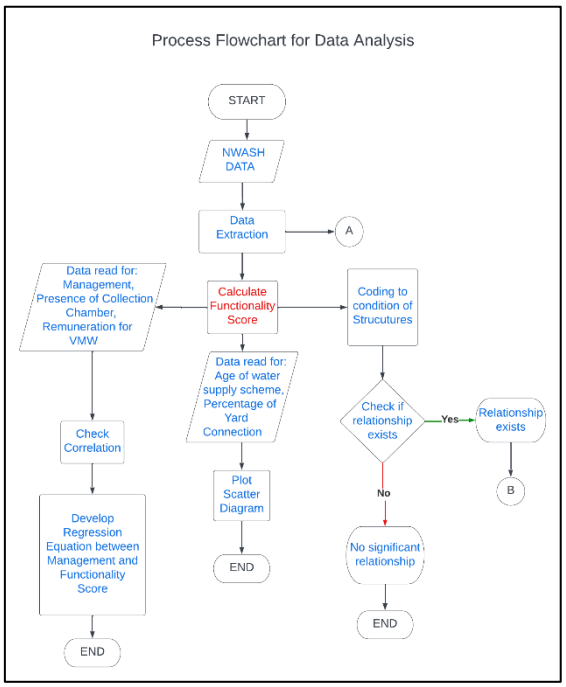

Figure 3: Data analysis flowchart

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.

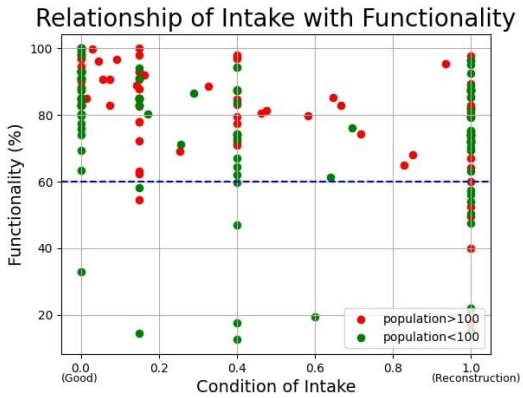

Figure 4: Relationship between repair condition of intake and functionality

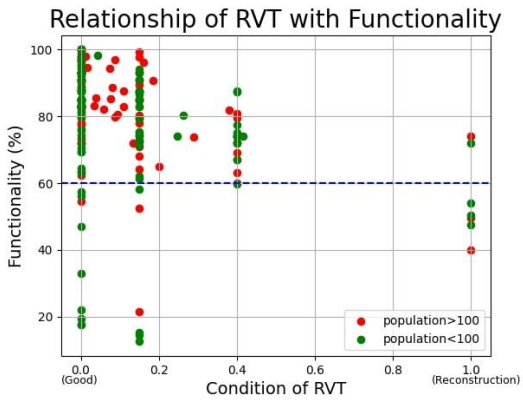

Figure 5: Relationship between condition of RVT and functionality

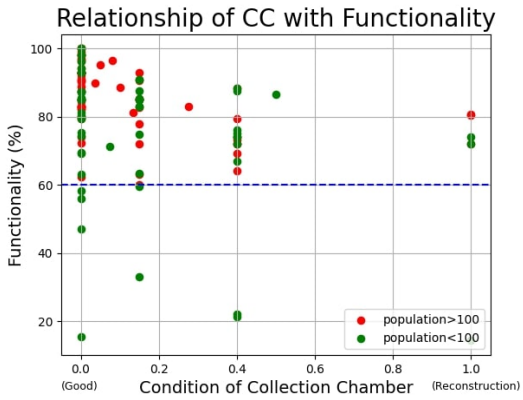

Figure 6: Relationship between condition of CC and functionality

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

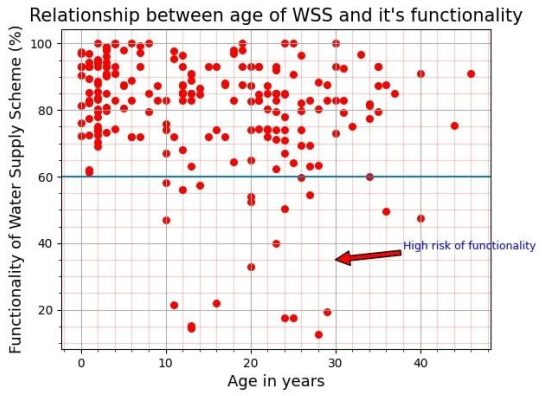

Figure 7: Relationship between age and functionality of water supply scheme

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

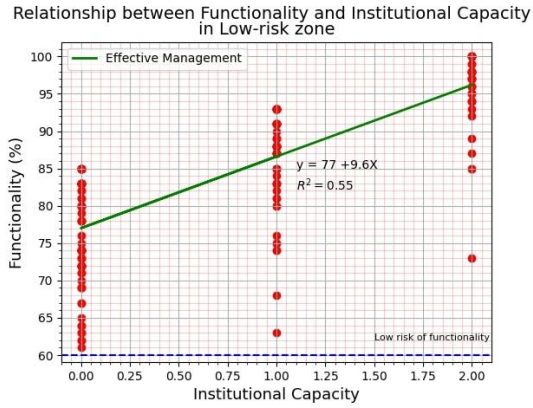

Figure 8: Relationship between functionality and institutional capacity

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

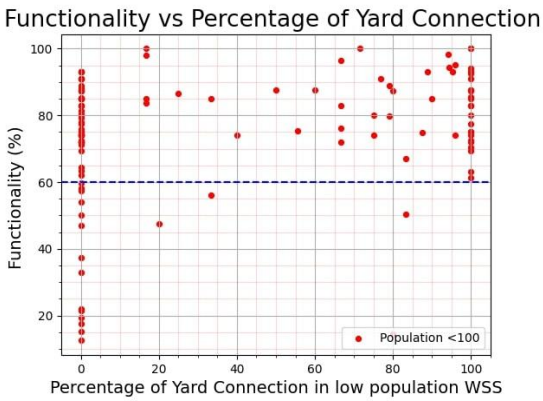

Figure 9: Relationship between functionality and yard collection

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.

REFERENCES

[1] JMP, "Progress on Sanitation and Drinking Water : 2020 update," Geneva/New York, 2021.

[2] K. Onda, J. Lobuglio, and J. Bartram, "Global access to safe water: Accounting for water quality and the resulting impact on MDG progress," *Int J Environ Res Public Health*, vol. 9, no. 3, 2012, doi: 10.3390/ijerph9030880.

[3] UN, "Report of Interagency and expert group on Sustainable Development Goal Indicators," Geneva, Switzerland, 2016.

[4] S. J. Marks, E. Kumpel, J. Guo, J. Bartram, and J. Davis, "Pathways to sustainability: A fuzzy-set qualitative comparative analysis of rural water supply programs," *J Clean Prod*, vol. 205, 2018, doi: 10.1016/j.jclepro.2018.09.029.

[5] L. K. Koestler, "Improving Sustainability using incentives for Operation and Management: The concept of water-person-years," *Waterlines*, vol. 29, no. 2, 2010.

[6] J. Combs, "From the editors: Big samples and small effects: let's not trade relevance and rigor for power," *Academy of Management Journal*, vol. 53, no. 1. 2010. doi: 10.5465/amj.2010.48036305.

[7] MoWS, "M&E Framework for water supply system Functionality and Sustainability indicators.," Nepal, 2016.

[8] T. Kativhu, D. Mazvimavi, D. Tevera, and I. Nhapi, "Influence of multiple uses of water on the sustainability of communally-managed rural water supply systems in Zimbabwe," *Journal of Water Sanitation and Hygiene for Development*, vol. 11, no. 1, 2021, doi: 10.2166/washdev.2020.173.

Enabling Solar Mini-grid Development for Off-grid Electrification in Nepal

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Abstract

Because of technological advancement and declining costs of the technologies, solar photovoltaic (PV) based mini-grids in the recent days are gaining popularity as a means to provide electricity to off-grid communities especially in the developing countries. Nepal has been implementing solar mini-grid projects to non-electrified rural areas to achieve the target of electricity for all by 2023. The scope of implementation and sustainable operation of such mini-grid projects in rural area is interdisciplinary in nature. This paper presents technical, social, financial aspects along with key issues of 100kWp solar mini-grid project in one of the rural villages of Nepal. The insights from the paper can support to design solar mini-grid program for sustainable electricity supply in remote areas.

Keywords

Solar Mini-grid, Energy Storage System, Real Time Monitoring, Sustainability

1. BACKGROUND INFORMATION AND RESEARCH ACTIVITIES

1.1 Background and Objective of the Study

Nepal has huge potential to develop low carbon economy through its ample abundance of renewable energy resources such as solar energy, biomass, mini or micro hydro, wind energy etc. These renewable energy resources offer great opportunities to enhance energy security and for the environmental sustainability. Although hydropower development is the national priority and will be taken as the lead energy resources of Nepal, the other renewable energy resources are essential to complement and meet the objectives set by Government of Nepal (GoN) for enabling energy mix in the total national energy supply.

Decentralized renewable energy services have been emerged as cost competitive solutions for electrification to non-electrified areas because of both declining cost of the technologies and development of efficient end use devices [1]. On comparing individual energy system, the mini-grid project can offer greater opportunity to increase productive energy uses (PEU) and thus enhances possibility of larger income generation in rural community [2–4][5]. This has increased inclination of development agencies towards support to mini-grid program especially to off-grid areas of the developing countries for achieving Goal-7 of the United Nation's Sustainable Development [6][7][8][9]. Despite some provisions of enhancing end uses thereby generating income at local level, the businesses in mini-grid electrification domain are still not attractive and requires financial support in developing countries [10][11]. Hence, various

schemes of financial support are being deployed to implement mini-grid electrification programs. Similarly, intervention of different business approaches; technical innovations for implementation as well as for operation and maintenance have also been emerged in different parts of the world.

In this paper, we present and analyze experiences of implementation of solar mini-grid projects in rural community of Nepal by considering a case study. First, we will briefly provide information on the recent updates on the electrification status in the country and the government's key policies and plans to achieve Nepal's commitment towards sustainable development goal-7 (SDG-7) for universal access to electricity to all by 2030. Second, we will present general idea of solar mini-grid projects that have been promoted by Alternative Energy Promotion Centre (AEPC) with the support of Asian Development Bank (ADB) under South Asia Sub Regional Economic Cooperation (SASEC), Power System Expansion Project. As a case study, we will review one solar mini-grid project to share experiences on four main dimensions: technical, social, economic, and operation and maintenance. We will also provide key issues and challenges that were experienced in various stages during and after implementation of the solar mini-grid project.

1.2 Energy Consumption and Electrification

Nepal's energy resources are broadly divided into three categories of traditional, commercial and renewable energy. The traditional energy includes solid biomass fuels derived from plants and animals. The commercial energy includes electricity and petroleum products. Nepal completely depends on import for its required petroleum products. The demand of petroleum products has been proliferating and the trend remains same in future under business-as-usual scenario. Figure-1 shows the distribution of energy consumption by three major categories of energy resources in the year 2020/21.

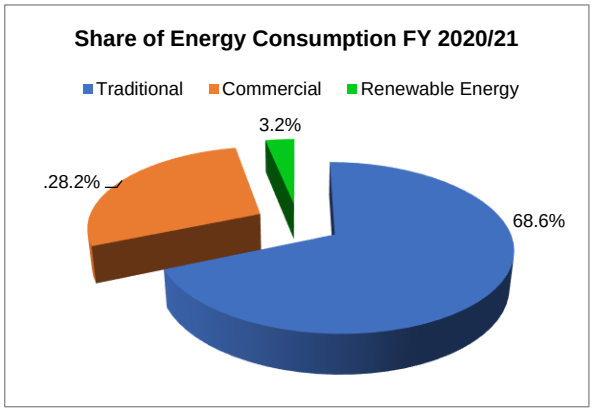

Figure 1: National energy consumption of FY 2020/21

In the total energy consumption for the fiscal year 2020/21, the share of traditional biomass, commercial and renewable energy were 68.6%, 28.2% and 3.2% respectively [12].

The electricity access in Nepal has been reached to 93% of the total population through on-grid and off-grid services [13], where the latter has been reached to 7% of the total population. The desk study by AEPC shows that grid extension has been reached to around 9% of those populations who earlier were provided with off-grid sources like micro or mini hydro and solar PV. The remaining 7% of population have still no access to electricity, mainly in two provinces namely Karnali and Sudurpaschim where building national grid infrastructure has been real challenge due to difficult geographical terrain and its remoteness (Fig-2). The multi-tier framework

analysis shows that, about 30% of total population have electricity services of below Tier-3 and only 47.3% grid connected population has access to 24 hours electricity [14].

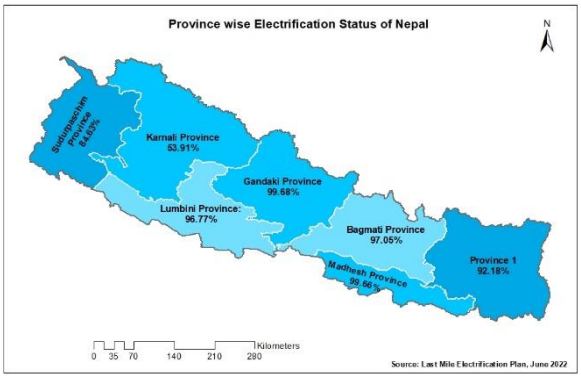

Figure 2: Province-wise electrification status

Nepal Electricity Authority (NEA) is the government owned utility company which has been providing national grid electricity services through generation, transmission and distribution of electricity to its consumers. Likewise, AEPC has been promoting renewable energy technologies to provide access to clean lighting and clean cooking solutions in rural areas since last 25 years. At present, both the institutions have been working under the purview of the Ministry of Energy, Water Resources and Irrigation (MoEWRI).

1.3 Rationale of solar power development in the national energy mix

Solar energy is one of the most promising resources that use abundant and free energy from the sun having clean, inexhaustible and environment friendly nature. Nepal, being located in favorable latitude, receives ample solar radiation. The average solar radiation varies from 3.6 - 6.2 kWh/m2/day with 300 sunny days in a year [15]. The commercial potential of solar power for grid connection of Nepal is estimated to be 2,100 MW [16].

Solar PV has been considered effective technology for rural electrification of large part of the rural population seeking considerably low amount of electrical energy. The operation and maintenance cost of diesel generators for those remote locations is too high. Small hydro power plants need specific topographical conditions that are only found near a small percentage of end users' settlement. Solar power generating systems do not need fuel or extensive infrastructure, it is easy and quick to install for all kind of applications. This option is found to be viable solution to meet basic energy needs in many locations of the country that are scattered with no access to national grid. Hence, the government has aimed to promote solar PV for electrification to non-electrified households in remote areas. Further, in view of energy security, it has been envisioned to develop 5 to 10 % electricity generation to national grid from renewable energy sources including solar PV [17].

2. METHODOLOGY

The primary information for the study is acquired from one of the mini-grid projects that was implemented by AEPC. Here, the primary data were gathered from real time technical monitoring, personal interview with the government line agencies and the stakeholders' consultations by conducting site visit to mini-grid project site. Data analysis was carried out basically for the real time energy generation and consumption balance of solar mini-grid project.

The secondary data were collected from policy, guidelines and relevant studies carried out in past. The relevant documents developed by NEA, AEPC, MoEWRI, MoF along with reports published by International Energy Agency, were mainly referred for this study.

2.1 GoN subsidy policy for solar mini-grids

As per the renewable energy subsidy policy of Nepal, the solar mini-grid projects will be eligible to receive subsidy if the site is not accessible by national grid power supply and no other means of electrification exists.

The 90% upfront capital subsidy to solar mini-grid system is provisioned for the solar mini-grid power plant up 250kWp installed capacity when it is owned by the respective local government. The local government unit is the third level of government division in Nepal.

The support to energy service company (ESCO), Cooperatives and Users Committee is up to 60% upfront subsidy for the solar mini-grid power plant up to installed capacity of 100kWp [18].

2.2 Solar Mini-grid Promotion by AEPC

AEPC initiated first solar-wind hybrid mini-grid project in 2011 by the support of ADB, and further replicated large numbers of micro-grid systems in various part of the country. AEPC has been implementing solar mini-grid special program to provide electricity service of at least of Tier-3 level to off-grid households where no alternative potential of micro or mini hydro exists. The electricity service of Tier-3 level refers to have at least 8-hours electricity per day which includes at least 3-hours per evening, capacity sufficient to power medium loads above 200Watt and can afford a basic consumption of 365kWh per year [19]. Till date more than 30 solar mini-grids of cumulative capacity above 1.2MWp have been implemented serving to more than 6,000 households and powering more than 150 small scale rural enterprises.

AEPC implemented ADB supported SASEC Project (2015-2021), under which nine solar mini-grids with the cumulative capacity 565kWp were successfully completed. By following guidelines of project selection criteria, the site selection and feasibility assessment of mini-grid project was carried out by AEPC in coordination with Local Governments (LGs) and users' communities.

The technical standards for solar photovoltaic system components used in Nepal are guided by Nepal Photovoltaic Quality Assurance (NEPQA) and Renewable Energy Test Station (RETS) Nepal conducts testing of PV components as per NEPQA guidelines. In addition, during procurement of major system components such as solar PV modules, energy storage system or batteries, PV controllers and solar inverters international quality test certifications have been provisioned as mandatory requirement. Following are the key innovative approaches adopted for implementation of solar mini-grid projects.

- All single phase and three phase consumers are connected through pre-paid energy meters ensuring timely collection of energy tariff.
- Power conditioning devices (i.e. controllers and PV inverters/Battery Inverter) are integrated in the mini-grid systems that allow system to efficiently operate in off-grid mode as well as provision to connect into the

national grid power line when grid power supply will arrive in the village in future.

- The technical standards of the power distribution network are required to be of at least national grid quality and standards so that the present off-grid power transmission and distribution network is grid compatible for future grid integration.
- As long as the telecom data network or internet services are available to the remote sites, the real time data can be monitored and analyzed through the web-portal space given by the respective manufacturers of power conditioning devices integrated in these solar mini-grid projects.

In terms of financing mix, the upfront subsidy of 90% of the total project cost has been provisioned whereas the remaining 10% has been raised from local community as an equity investment. The land required for installations of hardware and powerhouse construction have been managed by the community. Prior to implementation, the formation of cooperatives with inclusive representation of women and disadvantaged group at community is made mandatory. Such cooperatives are made responsible for raising equity, monitoring during construction, exploring business opportunities, tariff management and conflict management. Various capacity building activities have been conducted by AEPC through the social mobilizer in community to enable them to execute their obligations. The supplier and installer companies have been selected by following standard procurement and bidding procedures. The provisions of operation and maintenance to provide on-site services for 3-years by the installer company have been integrated in the bidding documents. On having such provisions, it has envisioned to have effective transfer of skills and knowledge from Installer Company to hosting cooperatives.

2.3 Case study of 100kWp Gutu solar mini-grid project

2.3.1 Site information

The site is located at 390 m above sea level having its geographical coordinates $28^0$54’30”N and $81^0$19’15.3”E. The Gutu village is located at the western part of the Surkhet district in Karnali province (Figure 3).

Figure 3: Site Location

The project was completed in one-year time from the beginning of its project cycle including procurement process and is in its operation phase till now. The field visit, real time remote system monitoring and performance analysis of the case were intended to acquire project related information through possible means within the intended research study time frame.

During the feasibility study, the proposed site was selected considering various village clusters in the proposal to efficiently distribute power through isolated grid line as demonstrated in the below map showing service area (Figure 4).

Figure 4: Gutu Solar Mini-grid service clusters map

During the field visit for data and information collection, informal meetings with the local stakeholders were conducted to understand operational issues and challenges.

2.3.2 Solar resource assessment of the site

The local environmental resource assessment of the site is the preliminary input for the technical design and feasibility analysis of the PV mini-grid projects. The solar resources for PV energy production are 1,727kWh/m^2/year global horizontal irradiation and 1,907kWh/m^2/year global tilted irradiation at 28º optimum tilt angle of the solar PV array towards south direction [20]. The annual average solar PV energy output at the site was estimated to be 1,430kWh for each kWp PV installed capacity forecasted through simulation tool (Solargis).

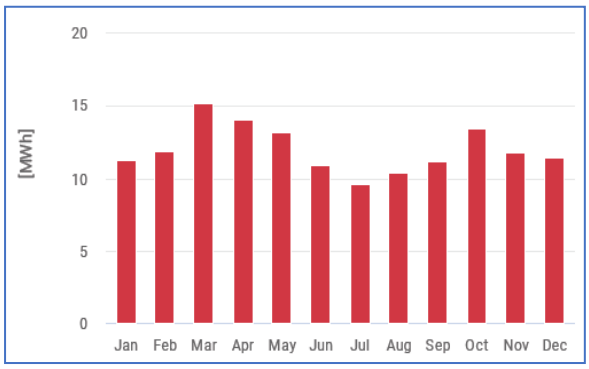

Figure 5: Estimation of monthly PV Output of 100kWp

By using Solargis application tool, the average monthly solar PV output has been estimated (Figure 5). It is observed that the month of March and October do have highest PV production, whereas July has the lowest energy yield condition.

3. RESULTS AND FINDINGS

3.1 Salient features of solar mini-grid

The power generation system includes 100kWp solar PV array, 768kWh energy storage system (battery bank), 100kW PV grid-tie inverters, 72kW off-grid/battery inverters and a multi-cluster control system.

The DC power produced by 100kWp solar PV array converts to 3-phase 400Vac through two units of each 50kW PV grid-tie inverters that are synchronized with the AC bus bar. PV string inverters serve day-time electrical loads as well as deliver energy for battery bank charging through battery inverters. The core of the system components inside powerhouse are solar PV inverters, battery inverters, multi-cluster control system and the OpzV series valve regulated lead acid (VRLA) battery bank. There are 12 battery inverters (four clusters of each three inverters stacked) connected to the multi-cluster box. Each battery inverter provides 6kW rated capacity with cumulative capacity of 72kW. In this configuration, the battery inverters are not connected into grid or diesel generator at the moment, and they perform function of battery charging and energy supply to village loads. In order to optimize battery charging and PV direct power supply to the day-time loads, the PV inverters and battery inverters do communicate to

each other. There are four battery banks of each 4,000AH@C10 at 48V nominal voltage. The total capacity of energy storage system is 768kWh battery bank. The battery banks and inverters are wired to the DC switch board with MCCBs and battery fuses. The charging system is comprised of 100kW of three phase PV grid-tie inverter technology with inbuilt solar maximum power point tracker (MPPT) charge controllers which are synchronized together with the battery inverters as demonstrated in the block diagram (Figure 6).

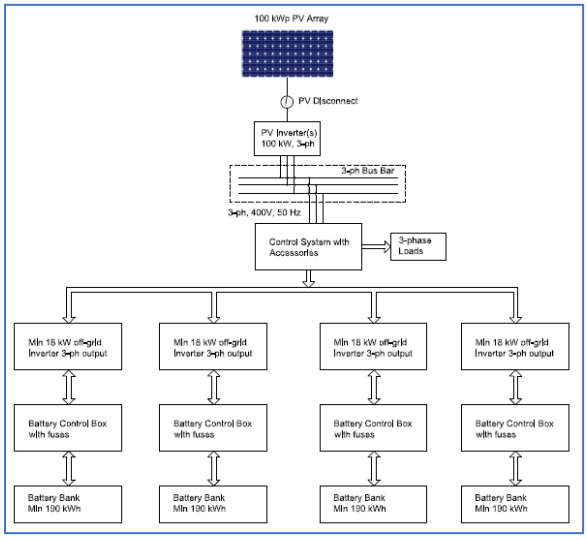

Figure 6: Power generation system block diagram

On the 3-phase bus-bar, the output feeder cables are connected to supply power to village power transmission and distribution network. The electricity produced by solar PV system has been transmitted through low voltage three phase 400V AC and single phase 230V AC as required by the demand of household and other loads. The data manager device is used for the system monitoring and control purpose which is connected with the cluster battery inverters and PV string inverters via multi-cluster communication interface. Figure-7 and Figure-8 depict ground mounted 100kWp PV array together with a powerhouse, energy storage battery system and power conditioning devices.

Figure 7: Powerhouse and 100kWp PV array

Figure 8: Battery bank and inverters inside powerhouse

3.2 Analysis of energy production and consumption

During its first year of operational phase, the real time remote monitoring has been conducted in order to analyze monthly energy production and consumption balances. It is observed that the day-time consumption or PV direct consumption is 37% of total production which basically provides energy service to business enterprises and public institutions in the day-time. Out of total annual energy consumption, 63% of the energy has been supplied through battery energy storage system (ESS) in the evening and morning hours. The actual PV energy production of this off-grid solar mini-grid varies from day to day because of the following two key factors:

CASE-1 (energy surplus): When there is no day-time electricity demand and battery bank is also fully charged, the solar PV plant will not produce energy.

CASE-2 (energy deficit): When day-time load is high, battery bank is poorly charged or discharged, the PV plant will produce its maximum capacity to meet direct-loads or day-time electricity demand as well as to charge the battery bank system.

Figure 9 illustrates total monthly energy production, amount of energy used for battery charging and the amount of energy served from PV direct loads in the day-time without going through battery bank.

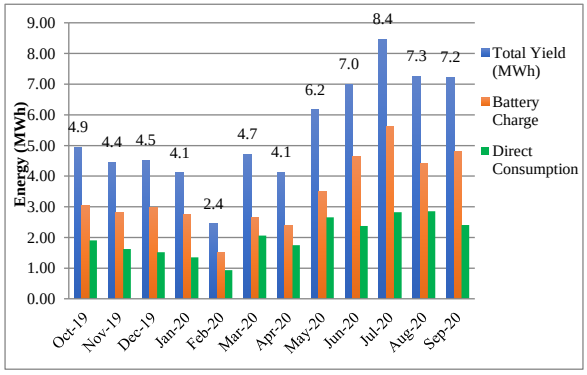

Figure 9: Energy production-consumption of Gutu SMG

Figure 10 shows typical daily load curve of power supply and consumption pattern traced through real time system monitoring. In this daily load curve, power consumption pattern in a particular day (11, Jul, 2020) corresponding to the day-time PV power production is presented.

The night-time electrical load varied in between 12kW to 17.5kW which had been served through the battery bank, where the battery state of charge came down to 63% from 88% during evening peak hours. The system started power production from 5:45AM and peaking at 10:15AM when it was producing 66.83kW real power from a 100kWp solar PV array. The day time loads were directly served through PV inverter without seeking any additional power from ESS and battery inverter during 5:45AM to 5:50PM.

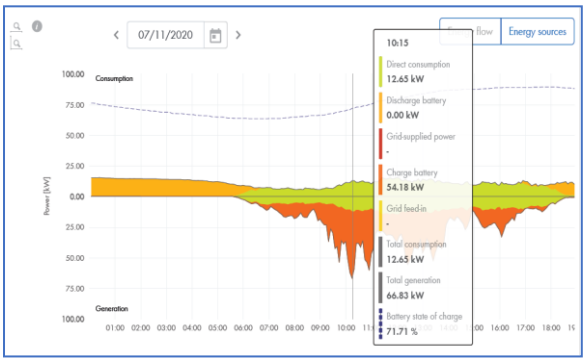

Figure10: Daily energy balance scenario of Gutu SMG site

3.3 Social mobilization

AEPC has supported to enhance institutional capacity of the users committee (UC). The locally formed UC had been capacitated to convert into a legal entity of energy service provider Cooperative in order to conduct energy business. The capacity development included technical trainings to the system operator, tariff management and account keeping of the mini-grid energy business to maintain financial transparency as well as operational sustainability.

3.4 Social and financial aspects

The households connected to national grid system in the semi-urban and urban area have access to grid electricity without contributing to the upfront investment who pay only monthly electricity tariff. The investment cost of solar mini-grid is also high compared to other comparable energy

service technologies. Therefore, as social justice, the government has made special provision of providing up to 90% investment subsidy to remote and rural households for implementation of off-grid solar micro/mini-grid project. The off-grid projects are more of social projects than the commercial projects serving rural communities with the lighting and basic electricity services. The 90% of the project investment cost of Gutu SMG had been subsidized by AEPC whereas the remaining 10% of the upfront cost has been contributed by both communities and Chaukune rural municipality (Local Government).

The solar mini-grid has been serving to 344 households, 30 productive energy use (PEU) demands, 10 public service institutions, grocery shops within the Gutu village market center. The operation cost covers expenses of system operator, office expenses and funds for repair and maintenance. The operation cost (general administration and repair) is inflated over a period with the inflation rate of the project life cycle. The total upfront investment of the project is NRs 56.55 million. The cost includes all the power generation and distribution components, powerhouse, pre-paid energy meters, miniature circuit breakers (MCBs), LED lights for end users as well as operation and maintenance (O&M) costs for 3-years. The financial analysis has been carried out for the 10% equity investment excluding value added tax (NRs 5.005 million). The estimate shows that the payback period for 10% equity is 4 years with the project internal rate of return (IRR) of 25% at the levelized cost of energy NRs 9.0 per kWh (Tables-1 and Table-2 indicated input parameters of financial analysis).

Table 1: Inputs to financial analysis

Parameters	Values
Project financial analysis period (years)	10
Plant capacity (*kWp)*	100
Number of households	344
Numbers of commercial entities	30
Inflation (%)	8.3
Depreciation (years)	10
Discount rate (%)	5
Insurance Premium (%)	1
Revenue default rate (%)	10% in year 1st& 2nd, 5% thereafter

Table 2: Average tariff for mini-grid consumers

Customer category	Energy (kWh)	NRs/kWh
(i) Domestic		
Minimum tariff	*10*	*150*
>minimum tariff	*1*	*15*
(ii) PEU		
Minimum tariff	*20*	*400*
>minimum tariff	*1*	*20*

Although the initial estimate was made on the basis of above figures, the UC takes need-based decisions after consultation with AEPC and related stakeholders. Afterwards, the tariff was revised with NRs 13 per kWh for domestic consumers on top of monthly service charge NRs 50. Similarly, NRs 18, NRs 21 and NRs 25 for 16Amp single phase, 32Amp single phase and 25/32Amp three phase consumers respectively.

3.5 Operation and maintenance

AEPC provided various types of technical, financial and managerial trainings before the system were handed over to the local community. As provisioned, the installer company has the responsibility to keep system operation and to provide maintenance services for the first three

years. The cost associated with operation and maintenance for the first three years has been covered by the initial project implementation contract between AEPC and the installer company. A potential candidate from the same village had been trained as an operator of the project from the installation phase to undertake responsibility for operation, daily or routine maintenance, pre-paid energy meter recharge, energy logbook maintaining and distribution line maintenance. The operator has been paid on monthly basis (NRs 13,00 per month) by the installer company who works as full time mini-grid system operator on-behalf of the company, at least for the first three years. The installer company does routine maintenance on quarterly basis in order to do preventive and corrective maintenance of the SMG. Beyond the first three years of maintenance period, the users committee may extent technical service of the same company through signing annual maintenance contract.

3.6 Key issues and challenges

The key issues and challenges encountered during project implementation and operation phases are:

- The detailed feasibility study and energy demand survey was conducted in 2015 thereby estimating service to 107 households and other end users. Total recommended solar mini-grid system size was 39kWp solar PV. However, during the community consultation in 2017 for the implementation plan under AEPC-SASEC project, total 344 households (107 old houses and 237 new houses) had to cover as recommended by the local government, because of which a 100kWp system was suggested. Hence, an increased system size of 100kWp capacity was considered for the implementation which was commissioned in May, 2018. The temporal difference between survey study and actual field implementation may result variation of estimated energy users which may lead difficulty for collecting capital cost (community equity part).
- Gutu SMG site was observed as potential site for economic activities because of which 5% energy growth rate was considered in the initial design. Nevertheless, after one year of implementation the energy demand was increased more than the expected rate. Public institutions as well as energy based PEU demands are increased in the Gutu market center, the migration of some energy end users happened from the adjoining village settlements and summer season loads (fans, refrigerators) were owned by the large number of end users those who did not demand that in initial site survey. Hence, the system has required to do power-cut in some days of summer season in order to avoid the issues of the power plant overload and technical faults.
- The historical data monitoring demonstrates that, the majority of plant shut-down occurred during the first six months of SMG operation, whereas first two years average shutdown was recorded up to 8.7% of the total time.
- One of the technical issues identified is load unbalance of three phase power which causes disruption in power due to plant shutdown by phase overload.

- Although the online real time remote system monitoring has been set up, but due to poor telecom network in remote villages and lack of internet service provider or WIFI connection, the remote data monitoring has still been challenging.
- Despite provisioning of local operator for both day-to-day operation and maintenance of the solar mini-grid system and to make communication with Installer Company for handling technical difficulties, it was observed that the training provided to operator was inadequate for handling with computer, data monitoring and diagnosing minor problems. Therefore, it is advisable to develop effective criteria while selecting operator and to provide refresher trainings continuously to keep up the operational capability of the operator.
- One of the challenges to isolated solar mini-grid is switching of energy users to the national grid mains line when grid arrives in the village. If this case encountered in future, the UC of Gutu SMG has plan to bulk purchase electricity from NEA grid and distribute locally through the same Cooperative to run local community electrification program and also do the grid connection of the solar mini-grid.

4. CONCLUSIONS

The study provides a window into various aspects of solar mini-grid systems such as technical, socioeconomic and financial in rural areas of Nepal. There have been good evidences of a significant progress in the community rural electrification schemes by the mini/micro hydro and solar or solar/wind hybrid mini-grid technologies in the recent years. The motivation for off-grid energy projects aimed to increase local economic activities, access to modern form of electricity for the households as well as community services to operate electrical appliances, medium of communications that are essential for day-to-day activities. The solar mini-grid systems are proven to be effective and sustainable tool to provide modern energy services to the off-grid communities of Nepal that are far from the national grid electricity system.

The case study demonstrates that, with a certain fixed capacity it is often difficult for solar PV mini-grid system to provide 24/7 electricity service and fully sufficient electricity. Except for increasing system capacity, the amount of electricity generated from solar PV system generally is not fully capable of meeting unlimited electricity demand such as energy services above Tier-3 level. Hence, the overall management of solar PV power stations in terms of technical, financial, human resource, and institutional capacity building is critical to improving the reliability of electricity service and sufficiency of electricity supply.

REFERENCES

[1] IRENA. Renewable Power Generation Costs in 2017, Vol. B. Abu Dhabi: 2018

[2] Pueyo A, DeMartino S. The impact of solar mini-grids on Kenya's rural enterprises. Energy Sustain Dev 2018; 45:28–37.https://doi.org/10.1016/j.esd.2018.04.002.

[3] Azimoh CL, Klintenberg P, Wallin F, Karlsson B, Mbohwa C. Electricity for development: Mini-grid solution for rural

electrification in South Africa. Energy Convers Manag 2016;110:268–77. https://doi.org/10.1016/j.enconman.2015.12.015.

[4] Ulsrud K, Winther T, Palit D, Rohracher H, Sandgren J. The Solar Transitions research on solar mini-grids in India: Learning from local cases of innovative socio-technical systems. Energy Sustain Dev 2011;15:293–303. https://doi.org/10.1016/j.esd.2011.06.004.

[5] Bhandari KR, Adhikari NP. Grid Integration of Solar and Solar/Wind Hybrid Mini-Grid Projects: A Case of Solar/Wind Hybrid Mini-Grid Project Implemented by AEPC. J Inst Eng 2020;15:42–8. https://doi.org/10.3126/jie.v15i3.32004.

[6] Madriz-Vargas R, Bruce A, Watt M. A Review of Factors Influencing the Success of Community Renewable Energy Mini-grids in developing countries. Sol Res Conf 2015:1–11.

[7] Nam K-Y, Zhai Y. Guidebook for Deploying Distributed Renewable Energy Systems. Manila: Asian Development Bank; 2019.

[8] World Bank. Reliable and Affordable Off-Grid Electricity Services for the Poor 2016:1–7.

[9] UNDP and ETH Zurich. Derisking Renewable Energy Investment: Off-Grid Electrification 2018.

[10] Bhattacharyya SC. Mini-grids for the base of the pyramid market: A critical review. Energies 2018;11. https://doi.org/10.3390/en11040813.

[11] Knuckles J. Business models for mini-grid electricity in base of the pyramid markets. Energy Sustain Dev 2016;31:67–82. https://doi.org/10.1016/j.esd.2015.12.002.

[12] Economic Survey 2020/21, Ministry of Finance, Government of Nepal

[13] Nepal Electricity Authority, A year in review -fiscal year 2020/21, Nepal 2021.

[14] ESMAP/WB. Nepal - Multi-Tier Framework for Measuring Energy Access Household Survey (MTF) 2017. 2019. Https: //doi.org/Ref. NPL_2017_MTF_v01_M.

[15] Government of Nepal, Water and Energy Commission Secretariat, Singha Durbar, Kathmandu(2013),*National Energy Strategy of Nepal.*

[16] Alternative Energy Promotion Centre (AEPC) Nepal, *Solar and Wind Energy Resource Assessment (SWERA, 2008).*

[17] White paper 2018, Ministry of Energy, Water Resources & Irrigation, Government of Nepal

[18] Renewable Energy Subsidy Policy 2022, Alternative Energy Promotion Centre, Government of Nepal.

[19] ESMAP/The World Bank, Technical Report, Multi-tier Framework for Energy Access, https://www.worldbank.org/en/topic/energy/publication/energy-access-redefined.

[20] Global Solar Atlas, Online resource assessment tool prepared by SOLARGIS, ESMAP.

Energy Consumption and Demand Projection of Manufacturing Industries in Kathmandu Valley

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Abstract

This paper analyzes present energy consumption by industrial sector within Kathmandu Valley. Initially, author has gone through intensive literature review and prepare questionnaire. Kathmandu Valley is considered as hub of economic sectors. There are large numbers of industries therefore Sample Distribution method is applied to select location. Out of 1,372 industries, 239 industries have been visited to collect data regarding various energy sources available, technologies used, manufactured final products etc. Collected data is compiled using MS-Excel. It was found that total energy consumption by manufacturing industries in Kathmandu Valley is 16.4 PJ. Diesel is the main energy sources which contribute about 37.21% of total energy consumption. The energy demand is projected from base year 2019 to 2050 using MAED energy model tool. The energy demand for manufacturing industries in Kathmandu Valley is estimated to grow from 16.4 PJ in 2021 to 50 PJ at low growth rate (3.95%), 116 PJ at medium growth rate (7%) and 524 PJ at high growth rate (12.7%). However, the demand of diesel and electricity will increase from 38% and 6% in base year to 60% and 14% respectively by 2050.GHG emission in 2021 was 1,249.6 thousand metric tons and it is expected to increase by 2050 at low growth, medium growth, and high growth is 3842.8 thousand metric tons, 8890 thousand metric tons, and 40,043 thousand metric tons respectively.

Keywords

Energy Consumption, Industrial sector, Energy Scenario Development, GHG Emission

1. INTRODUCTION

Energy is vital for the development of the country economics useful in formulating plan and policies. In Nepal, the use of traditional fuel dominates the energy consumption at 67% followed by imported fuels (petrol, diesel, LPG, kerosene, coal and furnace oil) 27% [1]. The high use of traditional fuels not only creates the unnecessary burden on the forests in Nepal, but also releases several greenhouse gases in the atmosphere. Similarly, the use of imported fuel is increasing at an alarming rate, which creates burden in the country's economy.

While looking at the energy consumption in different economic sectors, the residential sector consumes 80% of the overall energy consumption while the industrial sector consumes around 8% of the energy [1]. When compared to the global scenario of energy consumption by sector, the industrial sector consumes 23% while the residential sector consumes 20% of the total energy consumption respectively [2]. The gross value added by the industrial sector to the country's economy at basic price is at 51% [3]. The lower share of energy consumption in industrial sector while contributing more than 50% of the country's economy suggests that with

increase in energy consumption in industry, the country's economy can also be improved. Coal is major source of energy consumption in industrial sector in Nepal which produces enormous quantity of hazardous GHGs gases [4]. However, electricity source of energy in industrial sector is in increasing trends [1].

Kathmandu Valley is one of the industrial hubs in Nepal with 1,372 manufacturing industries registered according to the Department of Industry, Nepal. This study aims to determine the energy consumption in various sub-sectors of the manufacturing industry by end use and fuel type.

2. STATEMENT OF THE PROBLEM

Sustainable Development Goal (SDG) 9 targeted that industrial sector has to increase the share of energy consumption up to 25% and shift the nation from least developing country to middle by 2030 [5]. It requires tremendous consumption of energy resources and more energy efficient technology to achieve the targeted goal. However, there are not enough study that analyzes long term plan for energy consumption and GHG emissions at local city level. The economic activities are increasing in Kathmandu Valley with increasing population and the numbers of operational industries. Therefore, it is essential to carry out long term analysis regarding energy consumption and demand projection for industrial sector in Kathmandu Valley.

3. OBJECTIVE OF STUDY

- To determine the present status of energy consumption in industrial sector of Kathmandu valley
- To estimate the energy demand of all type of energy up to 2050 AD at 5 years interval in industrial sectors
- To access the emissions due to the consumption of various fuels in industrial sector

4. METHODOLOGY

Research methodology is a way to solve research problem systematically and appropriately [6]. Figure 1 indicates the methodology adopted to carry out this research.

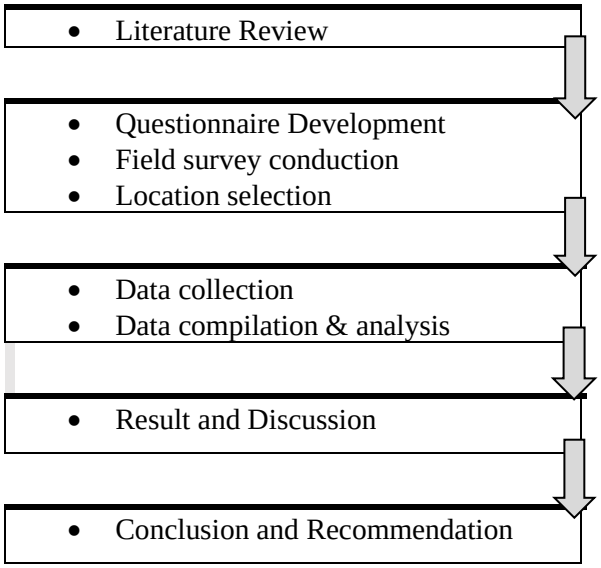

Figure 1: Methodological chart

4.1 Literature Review

Extensive literature review was conducted to calculate energy consumption by industrial sector. Relevant documents, plan, policies and guidelines regarding energy resource, potential, supply, demand and consumption from various secondary sources and institution has been collected and reviewed.

4.2 Questionnaire Development

The information acquired from literature review reports has been used to design questionnaires. The questionnaire has included various parameters such as annul energy consumption by sources, technologies used, fuel cost, efficiency of equipment, and emissions.

4.3 Sample Size Determination

According to Department of Industry, there are 1,021 numbers of manufacturing industries in Kathmandu Valley. Therefore, it was impossible to collect energy data from all the industries therefore; sampling method was applied to determine appropriate sample size. For sample size proportionally determination, it was designed with 95% level of confidence, 5% margin error and 5% non-response rate for the manufacturing industries. The sample size will be calculated using Krejci and Morgan formula [7],

$$n = \frac{\chi^2 \; x \; p \; x \; qxN}{e^2 \; (N-1) + \chi^2 x \; px \; q}$$

where,

χ^2 = chi-square for specific confidence level (95%)

p = probability of success

e = margin of error

N = Population size

n = required sample size

Non-response rate: Total non-response rate is assumed as 5%, which considers non-respondent and unavailable unit.

Hence, total sample size = $n + 5\% \; of \; n$

4.4 Location Selection and Field Survey

After questionnaire development, and sample size proportionally determination, location has been selected to conduct field survey. Locations to collect data are different classification of industries categorized by Nepal Standard Industrial Classification (NSIC) within Kathmandu Valley. Then, the survey has been conducted in 239 various manufacturing industries as shown in Table 1. During field survey phase, primary data regarding energy consumption has been collected by interview and observation. And, the secondary data such as electricity bill, machine log book, generator log book etc. has also been collected from the record.

Table 1: Number of samples collected in different industries

NSIC	Collected Sample Number
Cement, Bricks, Concrete and Clay products	15
Chemical Products, Rubber, Glass and Plastics/ Lubricants	35
Electrical and Electronic products	5
Food, Beverage and Tobacco	29
Mechanical Engineering, machineries, Iron and steel and other metals	28
Miscellaneous (Jewelry, musical instrument, sporting goods, toys etc.)	38

Paper, Publication & Printing, Furniture & Fixtures	48
Textiles, Readymade Garment & Leather Products	41
Grand Total	**239**

4.5 Data Collection, Compilation and Analysis

The energy consumption data collected from manufacturing industries by field survey was further compiled using MS Excel. During this phase, the error and invalid data were eliminated. Then, the compiled data has been analyzed which proceed for result and conclusion.

5. RESULTS AND CONCLUSION

5.1 Total Energy Mix

Final energy consumption by manufacturing industries in Kathmandu Valley is 16.4 PJ. Figure 2 shows the share of various fuels consumption in manufacturing industries in Kathmandu Valley. It was found that industrial sectors are highly dependent on fossil fuel. It accounts for about 67% of total energy consumption while biomass and electricity contribute 27% and 6% respectively. Diesel is the main source of energy consumption in industrial sector. It accounts about 37.21% share of total energy consumption. After diesel, coal is most consumed energy source which contributes 21.5% share of total energy consumption. Furthermore, fuelwood, agriculture residue, furnace oil and others occupied shares of 14.5%, 12.5%, 5.4% and 2.6% respectively.

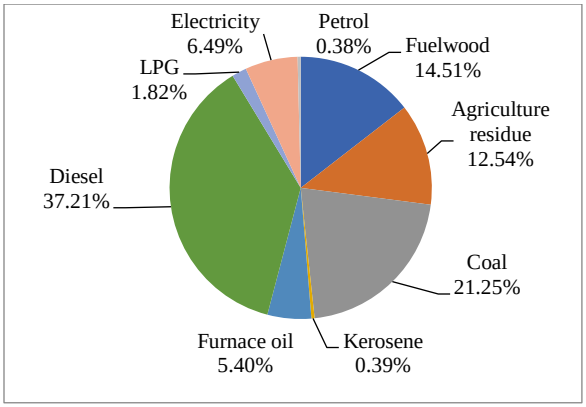

Figure 2: Share of energy consumption by fuel types

5.2 Energy Consumption by End-use

In industrial sector, boiler, process heat and motive power are major process under which final products are manufactured. It was found that 36.86% of total energy is consumed for process heat which is followed by boiler (34.84%), motive power (25.84%) and others (2.5%). Mostly, coal and fuelwood are used for process heat in cement, brick, food and beverage industries. Meanwhile, diesel and electricity is also used for process heat and motive power in chemical and plastic industries. It seems uses of biomass (fuelwood and agricultural residue) are still higher for boiler but consumption of coal is being replaced by electricity and diesel.

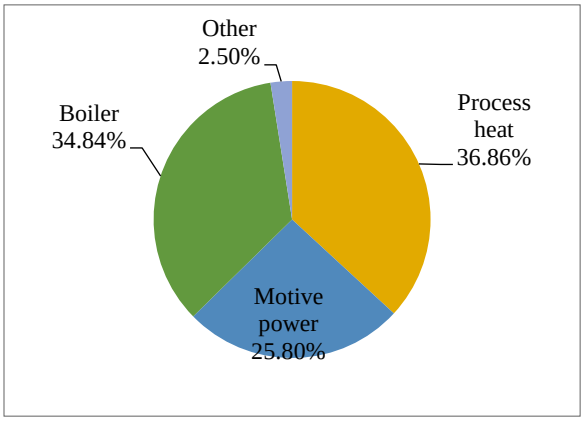

Figure 3: Share of energy consumption by end use

5.3 Energy Consumption by Category-wise

According to NSIC, manufacturing industries are classified in several categories among which food, beverage and tobacco (39%) consumes highest energy as shown in Figure 4.

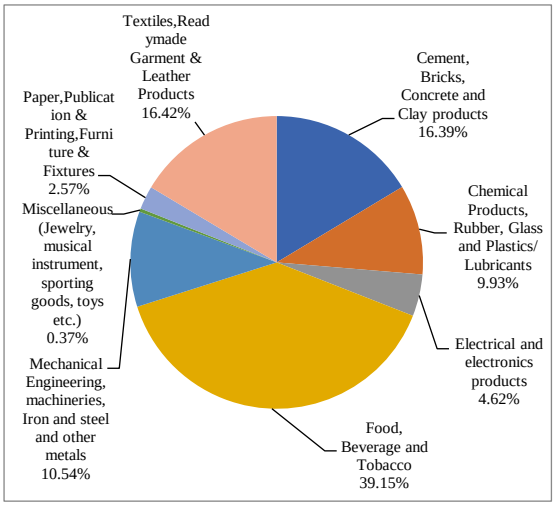

Figure 4: Share of energy consumption by industries wise

Then, cement, brick, concrete and clay product and textile, readymade garment and leather product both accounts about 16% of total energy consumption which is followed by mechanical engineering, iron and steel and other metal (10.5%), chemical products, rubber, glass and plastic (10%) and remaining others.

5.4 Energy Scenario Development

In order for scenario development, different sets of possible future energy demand have been considered are Low Growth Scenario, Medium Growth Scenario and High Growth Scenario.

Low Growth Scenario

Low growth was considered as the average growth rate of GDP for manufacturing industries of Nepal within a decade. The assumptions for this scenario are:

- Average growth of 3.95%
- The share of each demand technology in the supply energy for future year will be same as base year

Medium Growth Scenario

For medium growth scenario, the growth rate has been considered as the targeted growth rate of GDP by SDG. The assumptions for this scenario are:

- Average growth of 7% [5]
- The share of each demand technology in the supply energy for future year will be same as base year.

High Growth Scenario

For high growth scenario, the growth rate is considered as the targeted growth of GDP for manufacturing by the 15th plan. The assumptions of this scenario are:

- Average growth of 12.7% [8]
- The share of each demand technology in the supply energy for future year will be same as base year.

Policy Scenario

Major assumptions for policy scenario are:

- Average growth of 7%
- For boiler,
    - ❖ Penetration of 100% share of electric boiler in food beverage and tobacco by 2050
    - ❖ Penetration of 100% share of electric boiler in textile and leather by 2050

- Penetration of 100% share of electric boiler in chemical rubber and plastic share by 2050
- Penetration of 100% share of electric boiler in wood products and paper by 2050

5.5 Energy Demand Projection

The total energy demand for industrial sector from base year 2021 to 2050 is expected to grow at average annual growth rate of 3.95% from 16 PJ in 2021, 23 PJ in 2030 and 50 PJ in 2050 which has increased in more than three folds. Similarly, at medium growth rate, the total energy demand for industrial sector is expected to grow from 16 PJ in 2021 to 30 PJ in 2030 and 116 PJ in 2050. Meanwhile, the total energy demand for industrial sector from base year 2021 is expected to grow from 16 PJ in 2021 to 30 PJ in 2030 and 116 PJ in 2050. Then, the total energy demand is expected to grow from 16 PJ in 2021 to 29 PJ in 2030 and 106 PJ in 2050.

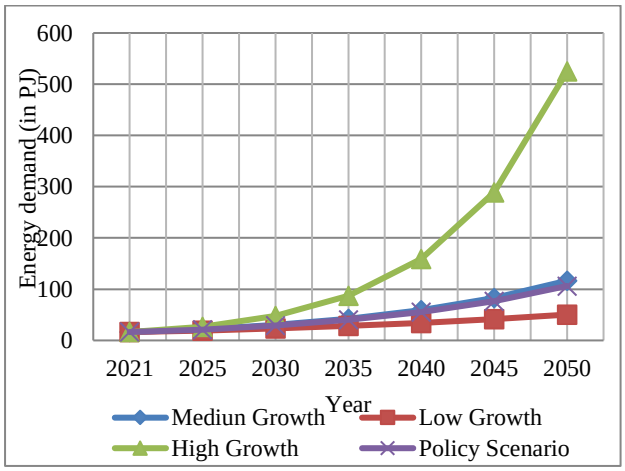

Figure 5: Comparison of energy demand projection at low, medium, high and policy scenario

5.6 GHG Emissions

GHG emission was 1,249.6 thousand metric tons and would increase to 1770.8 thousand metric tons, 2297 thousand metric tons and 3665 thousand metric tons in 2030 while, this would increase to 3842.8 thousand metric tons, 8890 thousand metric tons and 40,043 thousand metric tons in 2050. However, at policy scenario GHG would increase from base year to 2163 thousand metric tons in 2030 and further it would increase to 6,964 thousand metric tons in 2050. In comparison with reference and policy scenario, it seems the growth rate of emission would decrease by 2050 where GHG would be controlled significantly.

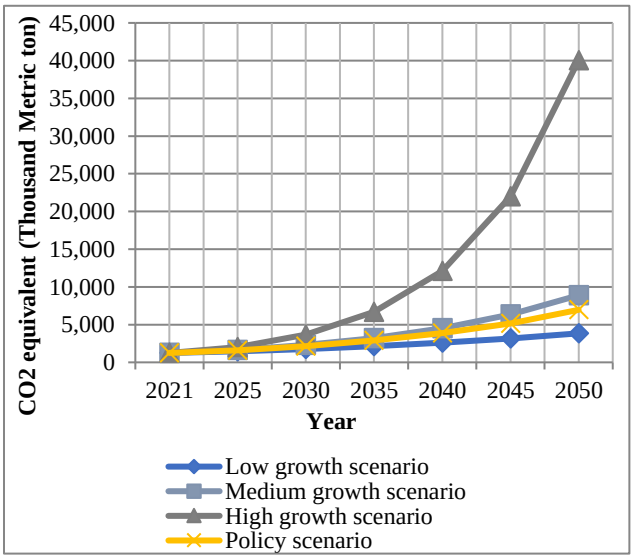

Figure 6: Comparison of GHG emissions projection at low, medium, high and policy scenario

6. CONCLUSION

- Total energy consumption of manufacturing industrial sector in Kathmandu Valley is 16.4 PJ. Industrial sector accounts 67%, 27% and 6% share of total energy consumption fossil fuel, biomass and electricity respectively.
- 36.86% of total energy is consumed for process heat which is followed by boiler

(34.84%), motive power (25.8%) and others (2%)

- Among several categories of industries, food, beverage and tobacco has major energy consumption types which accounts 39% of total energy consumption.
- The energy demand for manufacturing industries in Kathmandu Valley is estimated to grow from 16.4 PJ in 2021 to 50 PJ at low growth rate (3.95%), 116 PJ at medium growth rate (7%) and 524 PJ at high growth rate (12.7%).
- In policy scenario, penetration of 100% electric boiler by 2050 results as the share of biomass (28%) and coal (21%) in 2021 will decrease to 4% and 15% respectively by 2050. However, the demand of diesel and electricity will increase from 38% and 6% in base year to 60% and 14% respectively by 2050.
- GHG emission in 2021 was 1,249.6 thousand metric tons and it is expected to increase by 2050 at low growth, medium growth, high growth and policy scenario is 3842.8 thousand metric tons, 8890 thousand metric tons, 40,043 thousand metric tons and increase to 6,964 thousand metric tons respectively

7. FURTHER RESEARCH AREA

This paper represents total energy consumption in industrial sector in Kathmandu Valley. Further research can be conducted to find energy consumption in other economic sector such as residential sector, transport sector, commercial sector, agriculture sector and construction and mining sector.

REFERENCES

[1] M. o. Finance, "Economic Survey 2020/21," Ministry of Finance, Kathmandu, Nepal, 2021.

[2] IEA, "Largest end uses of energy by sector, selected IEA countries," International Energy Agency, Paris, 2021.

[3] CBS, "National Economic Census 2019," Central Buerue of Statistic, Kathmandu, Nepal, 2021.

[4] T. R. B. Khem Gyanwali, "Demand Side Management in Industrial Sector of Nepal," in *Proceedings of IOE Graduate Conference*, Kathmandu, 2013.

[5] NPC, "Nepal's Sustainable Development Goals - Status and Roadmap: 2016-2030," Government of Nepal, National Planning Commission, Kathmandu, 2017.

[6] C. Kothari, Research methodology: method and techniques, 2004.

[7] K. &. Morgan, "Determining Sample Size for Research Activities," 1970.

[8] National Planning Commission, "The Fifteenth Plan," Government of Nepal, National Planning Commission, Kathmandu, 2020.

Impact of Using Audio-Visual Aids in Online Teaching-Learning System

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Abstract

An online teaching learning system is a digital-based technology for virtual classes by using computer-type appliances. Digital-based Audio-Visual (A-V) aid is considered an effective tool for online teaching learning system as it stimulates, motivates, and focuses learners' attention during the instructional process. This research explored the opinions and experiences of both teachers and students on the effective use of A-V aids in online teaching learning classes, based on their online teaching-learning practices, in an Academic Institution in Nepal from June to December 2020. Google survey forms (Online) were made available to all the teachers and students from different programs/faculties at Himalaya College of Engineering, affiliated to Tribhuvan University, Nepal. The collected data from the survey were analyzed by using basic statistical tools and the data was presented the results graphically. The study showed that the majority of the teachers and students have positive perceptions on their impact of using A- V aids, however, the range of agreement was varied based on different course contents, faculties and perceptions of the respondents.

Keywords

Online classes, audio-visual aids, level of agreement, quality education delivery

1. INTRODUCTION

1.1 Background

An online or virtual learning is a system that creates an environment designed to facilitate teachers' management of educational courses for their students, especially by using computer appliances [1]. It is obvious that quality of education depends on effective teaching-learning pedagogy where the effectiveness of class depends on many factors like use of quality technology, content, delivery capacity of the teachers, and participation and level of understanding of the students. Use of appropriate teaching learning apps like Zoom, Microsoft Teams, and teaching learning materials or A-V aids like Power point, Digital notes, Video clips, Google sites, You-tube channels is an important factor for effective teaching- learning pedagogy [2]. A research showed that on an average, students retain 25-60% more when learning online compared to only 8-10% in a classroom (Forum 2020). This might be due to the increased ability of students to grab the matters faster while using A-V aids. However, quality of A-V aids including many other factors like – network capacity, electricity supply, quality of materials, presentation skill, confidence level of teachers determined the quality of online classes.

The recent COVID-19 pandemic had resulted in schools and universities being shut down all across the world, so the education delivery mechanism had been changed dramatically from the physical traditional method to virtual classes by using digital platforms. Most of the academic institutions in Nepal also had been experiencing

an online virtual teaching system ever since the pandemic arose. While getting access to the right technology, learning online can be more effective in several ways [3]. Online teaching systems may never totally replace the traditional experience; however, it is also undeniable that the technology-based online teaching-learning mechanism provides a major impact compared to traditional lessons even in the way of pursuing formal education in a new normal situation.

Many studies have been done about the impact of A-V aids in virtual teaching methods [2], [4], [5], and all suggested that audio-visual aids are considered as important teaching-learning material. However, none of the studies have been done yet by combining both teachers' and students' experiences context-wise, faculty wise and by considering all those influencing factors together. Hence, this study aimed to fulfill those knowledge gaps in the area based on the range of agreement data retained from the respondents.

1.2 Objectives

The main objective of this study was to identify the effective use of A-V aids in online teaching-learning systems both from teachers' and students' experiences. This study assessed the level of agreement and experiences of teachers and students from different faculties and in different contexts.

1.3 Conceptual Framework

The A-V Aids represents the independent variable while quality delivery with an effective & efficient teaching-learning process acts as the dependent variable. The hypothesis set as: 'Visual aids have a positive and significant relation with enhancing the learning process. Besides the defined curriculum, the effectiveness of online classes is determined by many factors where the motivation of students for learning is also important (Figure 1).

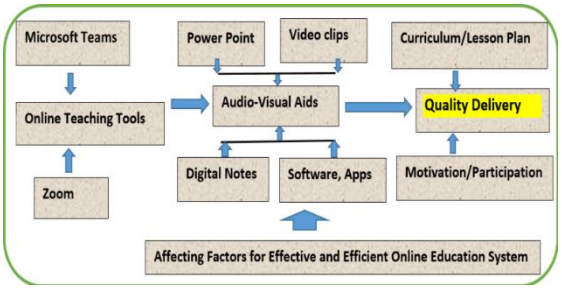

Figure 1: Conceptual framework of the study

2. LITERATURE REVIEW

Learning is a complex process as it happens as an outcome of afresh attained skills, principles, perception, knowledge, facts, and new information at hand [6]. It can be reinforced with different teaching/learning resources because they stimulate, motivate as well as focus learners' attention for a while during the instructional process [5]. A virtual learning environment, which is also known as a 'Learning Management System' in North America is a system that creates an environment designed to facilitate teachers' management of educational courses for their students, by using computer appliances. For the first time, Starr Roxanne Hiltz [7] in 1986 describes 'Virtual Classroom' as a 'Computer-Mediated Communication system for University Education system' and came into practice in a progressive manner. The material like models, charts, film strips, projectors, radio, television, maps etc. are called instructional aids which are used in the classroom to encourage learning and make it easier and more motivating [8].

The use of visual aids in the teaching-learning process has multifarious values [9] as 'visual aids

need to stimulate and cognize thinking| [10]. Likewise, visual aids give chance speakers to make a more professional and consistent performance. Visual aids are those devices that are used in classrooms to encourage students learning process and make it easier and more interesting. Visual aids are the best tool for making teaching effective and the best dissemination of knowledge. Audio-Visual (A-V) aids are the best tool for making teaching effective and the best dissemination of knowledge [2] and [5], and level of motivation [3].

Moreover, 'A-V aids are those instructional devices that are used in the classroom to encourage learning and make teaching-learning process more effective, easier, and interesting [2]. According to Burton "Visual aids are those sensory objects or images which initiate or stimulate and support learning". Kinder, S. James; describes visual aids as "Visual aids are any devices which can be used to make the learning experience more real, more accurate and more active".

There is a famous Chinese proverb "one seeing or sight is worth a hundred words" which means that - if we hear we forget if we see we remember, and if we do something we know it" which means that use of A.V aids [2]. Another study showed that e-learning requires 40-60% less time to learn than in a traditional classroom setting because students can learn at their own pace, going back and re-reading, skipping, or accelerating through concepts as they choose [11]. Nevertheless, the effectiveness of online learning varies amount age groups. A study showed that people generally remember 10% of what they ***read***, 20% of what they *hear*, 30% of what they *see*, 50% of what they *hear* and *see*, 70% of what they *say*, and 90% of what they *say* as they *do* a thing [5]. So, there is no doubt that technical devices have a greater impact and dynamic informative systems. Likewise, research [12]indicated the psychology of visual aids as under, 1% of what is learned is from the sense of *taste*, 1.5% of what is learned is from the sense of *touch*, 3.5% of what is learned is from the logic of *smell*, 11% of what is educated is from the logic of *hearing* and 83% of what is learned is from the sense of *sight*.

However, it is very important to maintain the quality of A-V Aids while using it [13]. Visual aids must be visible to the whole class; tapes of speeches and sounds should be confirmed for correct volume and quality in the actual environment in which they will be used [14]. All calligraphy and illustration must be large and adequate to be seen easily by the students farthest from the aids', and colors should provide clear contrast and easily be visible. [5]. Using A.V aids in teaching, on the one hand, enhance teachers' lesson plans and give students additional ways to process subject information as they supplement the work of the teacher and help in the study of the textbooks", and they concretize the knowledge, on the other hand, to be presented and help in making learning experience apple real, living and vital [2].

Taking the perception of both teachers and students as respondents is necessary for this study. The role of teachers in effective teaching is important as integrating technology into the classroom as a teacher prepares lessons that use technology in meaningful and relevant ways. Technological aids should support the curriculum rather than dominate it. Technology should assist

the teacher in creating a collaborative learning environment [4] as [14] says that the integration of technology into the curriculum means using it as a tool to teach academic subjects and to promote higher-order thinking skills of the students. Nevertheless, there are challenges to online teaching-learning systems mainly some students without reliable internet access and/or technology struggle to participate in digital learning. To get the full benefit of online learning, there needs to be a concerted effort to manage all facilities effectively.

3. METHODOLOGY

3.1 Sampling

In this research, purposive sampling techniques were used for the collection of information from the particular individuals who had the specific knowledge as such type of knowledge has been required for quantitative research. The targeted population for this research is the teachers and students of Himalaya College of Engineering, affiliated with Tribhuvan University, Nepal. Online Google Survey forms with MCQs were made available for data collection. In total 17 teachers and 170 students (in1:10 ratio) altogether from Civil Engineering, Architecture, Computer & Electronics, and CSIT faculties did attempt the survey. The answers to the questions were based on respondents' experiences in online teaching learning classes from June to November 2020.

3.2 Working Approach

A different set of Google survey forms with MCQs were provided for teachers and students to assess the variances of views and use of visual aids between teachers and students from different groups and faculties. A mixed method approach was adopted for this research (Figure 2).

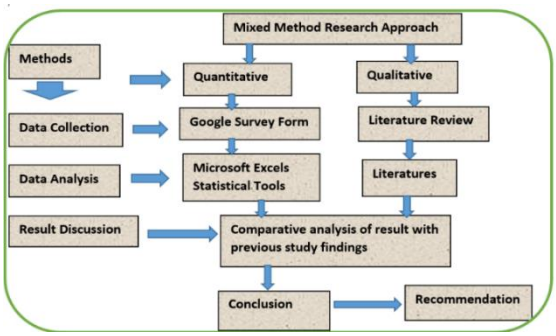

Figure 2: Study approach

3.3 Data Collection

The required data for the analysis were collected as answers to survey questions.

3.4 Data Analysis

Microsoft Excel and Statistical tools were used for simple statistical analysis. Bar chart, Pie chart, and previous research findings were used for result presentation and discussion.

4. RESULTS

4.1 Teachers' Responses in Survey

The result (Table 1) showed that 100% of the respondent teachers agreed on the fact that A-V aids increase students' level of understanding; improve quality delivery; presentation skills; teachers' hardship, time and effort as the materials can be used in Multi-places and times.

Table 1: Teachers' responses

SN	Questions to Teachers	Teachers' Responses					
		Disagreed	Agreed				
		0	1	2	3	4	5
1	Increase teachers' confident level.	1	0	1	6	5	4
2	Required less memory capacity (as most of the matters are well included in the material)	3	1	2	2	7	2
3	Level of students' active participation in classes.	1	3	5	3	4	1
4	Students' level of understanding (that is known from the discussion at the end of the session)	0	0	0	6	8	3
5	Quality delivery of message	0	0	1	4	10	2
6	Presenter's presentation skills:	0	0	3	1	10	3
7	Teachers hardship- more time and effort consuming	0	0	0	1	6	10
8	Hassle in management	2	1	1	0	9	4
9	Can use same material in multi-places and times	0	2	1	3	5	6
10	Problem during electricity cut off and poor internet connection	1	0	0	2	6	8
11	Concern about copy-right and plagiarism issues	2	1	1	2	3	8

4.2 Students' Responses in the Survey

The result in Table 2 showed only 67% of the respondent students agreed with the fact that A-V aids increase students' level of understanding. However, 75% of the respondents agreed that the use of A-V aids increases: a) level of concentration in class; and b) increase students' presentation skills and confidence in expressing what they learn. Only 71% of the students agreed that it increases student's confidence level, while more than 90% of the students agreed that A-V aids were not effective during the electricity cut-off and poor internet connection.

Table 2: Students' responses

SN	Questions to Student	Disagree	Agree				
		0	1	2	3	4	5
1	Increase students' confidence level	49	40	35	33	11	2
2	We are able to concentrate in class:	42	45	36	30	13	4
3	Level of understanding has increased:	56	42	33	25	13	1
4	Problem during electricity cut off and poor internet connection	14	11	14	19	31	81
5	Students presentation increased level of understanding and to express what student learned:	43	27	47	31	16	6

4.3 Teachers' Perception of the Effective Use of A-V Aids

The results showed that all of the teacher respondents fully agreed (i.e., 0% disagreed) on the fact that the use of A-V aids influences on teaching quality as it: (a) increases teachers' confidence level; (b) requires less memory capacity; and (c) increase students' active participation during classes. Maximum 37% of the teachers' respondents showed their agreed level up to 60% in case (a); 50% of the students showed their agreed level up to 80 % in case (b); and 31 % showed their agreed level up to 40% in case (c) condition mentioned above.

However, there are some negative aspects that affect quality delivery while using A-V aids such as (i) Hassle in management; and (ii) Problems during electricity cut-off and poor internet connection. A maximum of 60% of the total respondents showed their agreed level up to 80% in case former case and 50% showed their agreed level up to 100% in the latter case. Moreover, plagiarism and copyright issues are also a matter of consideration for effective use of A-V aids where 7 to 53 % of total respondents showed their agreed level from 20 to 100% respectively (Figure 3).

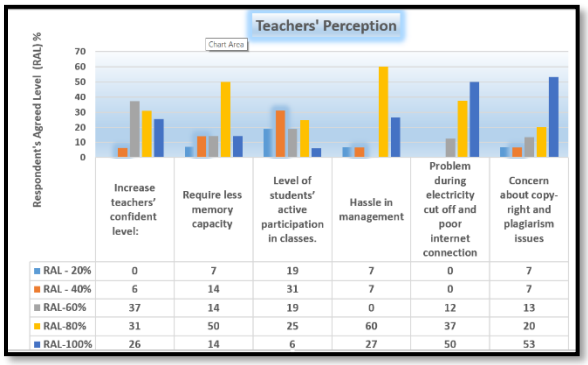

Figure 3: Teachers' perception

4.4 Faculty- wise Teachers' Responses

Faculty-wise teachers' responses results (Figure 4) showed that 11% of the total student respondents from BCE, 14% from BCT, 13% from BEX, 14% from BArch, 20% from CSIT, and 50% from BCA faculty *did not* agree on the fact that the use of A-V aids increases teachers confidence level. This showed that the level of disagreed percentage from BCE to CSIT is in the 10 - 20% range while for BCA is up to 50%. Likewise, none of the teachers *disagreed* (i.e., 100% *agreed)* with BArch and BCA. for the fact that the use of A-V aids in teaching impact on classes during electricity cut-off and an internet connection, and Hassle in management was 100% *agreed* by BCT, BArch, and BCA. Similarly,

Copyright and plagiarism issues were *agreed upon* by 100% of the respondents from BCT, BEX, and BCA. Overall, 22% of the total respondent students in BCA (double than other cases) *disagreed* that teachers required less memory capacity to use A-V aids in virtual classes than in the traditional system.

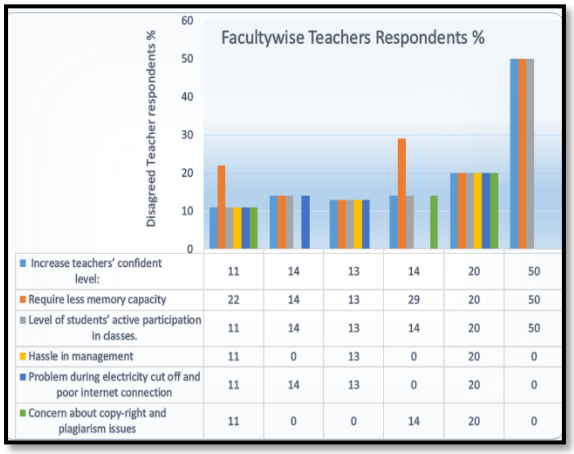

Figure 4: Faculty-wise Teachers' Responses

4.5 Students' Perception

The use of A-V aids affect on learning process through many aspects, mainly by increasing their degree of confidence; concentration; understanding; presentation skills; and confidence in expression what they learn. However, the cons of using A-V aids in a virtual teaching-learning system are that students face problems during electricity cut-off and poor internet connection.

The study results also (Figure 5) showed that 7 to 37% of the total student respondents showed their agreed level up to 80%, and 1 to 52% of the total respondents showed their agreed level up to 100% for the positive benefits of using A-V aids. Similarly, 1 to 34% of total respondents agreed on the fact that A-V aids increase students' confidence level; 3 to 35% of total respondents agreed for an increased level of concentration in class, 1 to 37% of total respondents agreed for an increased level of understanding; and 6 to 37% of total respondents agreed for increased presentation skill and confidence in expression. However, 7 to 52% of total respondents with 100% agreed level (RAL) mentioned that there is a problem to use A-V aids during electricity cut-off and poor internet connection problems.

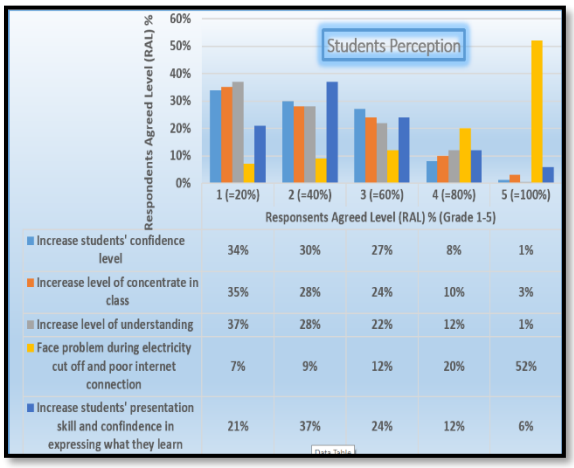

Figure 5: Students' Perception

4.6 Faculty-wise Students' Perception

Results as in Figure 6 showed that 33% of the total students from BCE, 27% from BCT, 32% from BEX, and 16% from BArch *did not agree* with the fact that the use of A-V aids increase students' confidence level. It is clearly seen that percentage of disagreed students from BCE is more than double that from BArch but the results from BCT and BEX are almost in a similar range. similarly, 27% of total students from BCE, 23% from BCT, 21% from BEX, and 24% from BArch arch *did not agree* with the fact that the use of A-V aids increases students' level of concentration in class, where the percentage of disagreed students are more than 20% in all cases. Likewise, the largest percentage of students, ranging from

21 to 42%, *disagreed* with the fact that the use of A-V aids increases students' level of understanding. in the same way, the maximum percentage of students (31%) from BCE and the minimum percentage of students (12%) from BArch *did not agree* that the use of A-V aids increases students' presentation skills and confidence.

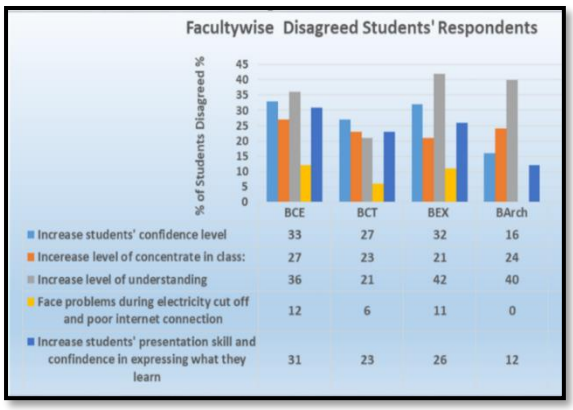

Figure 6: Faculty-wise students' perception

On contrary, none of the students from BArch disagreed (that means 100% of the students *agreed*) that electricity cut-off and poor internet connection create problems in online class while using A-V aids.

5. DISCUSSIONS

Most of the findings of this study are supported by the results of earlier studies. For example, according to [2], most of the students agreed that the use of A.V aids is more effective in the learning process at the university level. Likewise, as per [5] 70% of the students and teachers agree that the visual aids help in motivation and 75% of the students and teachers agree that the visual aids help in clarification of contents under research. Another study showed that 92.6% of the students agreed that they understand more effectively with the use of audio-visual aids [15]. This might be because students pay more attention to visual classes while they see and hear properly.

Supporting the findings of this study, a study on 'The use of PowerPoint Presentations at the Department of Foreign Language Education in the Middle-East' [16] concluded that students learned better if the course material was presented through some visual tools. They also reported that teachers believed that PowerPoint presentations made the content more appealing; therefore, they helped them take students' attention. The results of [17] showed that students exposed to Power-Point presentations preferred more than the textbook presentations. Similarly, [18] reported a number of benefits including increased motivation, improvement in self-concept and mastery of basic skills, more student-centered learning, and engagement in the learning process. [19] from his 17 social studies concluded that teachers held a variety of views towards technology integration.

6. CONCLUSION

The outcome of the above discussion suggests that the appropriate use of AV aids is useful to students as well as teachers. The result of this study supported the hypothesis: 'The use of A.V aids is important for effective teaching-learning processes' as it motivates both the teachers and students to bring changes in the classroom environment through many influencing factors associated together.

However, the common effort of students, teachers, parents, management team, and the government in the case of public institutions is required to adopt the appropriate technology. Teachers' interest-based training programs

should be designed in a way to promote the use of aids in the classroom. The support from parents, management, and the government should be provided to initiations to manage the fund. Teachers should get feedback from students on whether AV aid used has a positive impact on their learning or not. Examining students' results is also a way of evaluating the learning outcomes. Aids used must be able to attract the involvement, participation, and discussion among students in the classroom so that they would be able to relate the aid with the subject matter. Parents who are also aware of the importance of aids in teaching should convince other parents and teachers as well so that their children could attain a quality education.

REFERENCES

[1] M. N. Manusamy, "Use of online technology for multimedia education," *Information Sservices & Use,* vol. 25, no. 3, pp. 249-256, 2006.

[2] S. Rasul, Q. Bukhsh and S. Batool, "A Study to Analyse the Effectiveness of Audio Visual Aids in Effective Teaching Learning Process at University Level," *Procedia - Social and Behavioral Sciences,* vol. 28, pp. 78 - 81, 2011.

[3] F. S. Lari, "Impact of using Power Point Presentation on Students Learning and Motivation in Secondary Schools," *Procedia - Social and Behaviour Sciences,* vol. 98, pp. Pp. 1672 - 1675, 2014.

[4] A. Ranasinghe and D. Leisher, "The benefit of integrating technology into the classroom," *International Mathmatical Forum,* vol. 4, no. 40, pp. Pp. 1955 - 1961, 2009.

[5] G. Shabiralyani, K. S. Hasan, . N. Hamad and N. Iqbal, "Impact of Visual Aids in Enhancing the Learning Process Case," *Journal of Education and Practice,* vol. 6, no. 19, 2015.

[6] L. L. Adeyanju, ""Perceived Effects of Freshmen's Attitude to the Use of Audio Tape in Instruction.","," 1997.

[7] S. R. J. K. &. T. M. Hiltz, ""Experiments in group decision making communication process and outcome in face-to-face versus computerized Conferences.," *" Human Communication Research,* vol. 13, no. 2, pp. 225-252, 1986.

[8] A. Rather, Esseentials Instructional Technology, Darya Gunj, New Delhi, India, 2004.

[9] M. Mohanty, "Educational technology. "Educational technology. New Delhi: Rajouri Garden," 2001. [Online].

[10] N. Kishore, "Educational Technology," Abhishek , Publication , 2003.

[11] B.H.B, "retrieved, "Facts and stas that reveal the power of learning retrieved from https://www.shiftelearning.com/blog/bid/301248/15-facts-and-stats-that-reveal-the-power-of-elearning#:~:text=According%20to%20a%20Brandon%2DHall,way%20workflow%20is%20not," [Online].

[12] L. Cuban, "Computers in the Classroom, Cambridge MA.," Harvard University Press, 2001.

[13] R. J. M. Chorley, "Models in Geography," 1996.

[14] Koc.M., " ". Implications of learning theories for effective technology integration and pre-service teacher training: A," Journal of Science

Education," *ournal of Science Education,* vol. 2, no. 1, pp. 1- 16.

[15] R. Nivethitha, R. Gayathri and V. Priya, "Awareness of Audiovisual Aids in Education," *Drug Invention Today,* vol. 10, no. 6, 2018.

[16] E. Ozaslan and Z. Maden, "The use of Power Point Presentations at in the Department of Foreign Language Education at Middle East," *Middle Eastern & African Journal of Educational Research,* no. 2, 2013.

[17] G. Corbeil, "Can PowerPoint Presentations Effectively Replace Text-books and Blackboards for Teaching Grammar? Do Students Find Them an Effective Learning Tool?," *CALICO Journal,* vol. 24, no. 3, pp. Pp. 631 - 656, 2007.

[18] J. Stepp-Greany, "Student perceptions on language learning in a technological environment: Implications for the new millennium.," *Language, Learing and Technology,* vol. 6, no. 1, pp. Pp. 165 -180, 2002.

[19] Y. Zhao, "Social Studies Teachers' Perspectives of Technology Integration," *Journal of Technology and Teacher Education,* vol. 15, no. 3, pp. Pp. 311 - 333, 2007.

Parametric Study on Post-tensioned Concrete Box Girder Bridge in Earthquake

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Abstract

In this research comparative study of rectangular and trapezoidal sections of post tensioned box girder for same width, depth and loading conditions is done. For this research, a three-dimensional finite element (FE) model of two-lane Box Girder Bridge made up of prestressed concrete has been developed using commercially available software CSiBridge v23.3.1. Three dimensional 4-noded shell elements have been employed for discretization of domain and to analyze the complex behavior box girders. The linear analysis has been carried out for moving load with maximum eccentricity at mid span. Also. the study intends to present the parametric study for deflections, longitudinal bending moment, shear force, consumption of concrete and stiffness for these cross-sections. And draw fragility curve to identify the probability of exceedance for the defined damage state conditions.

Keywords

Concrete box girder, push over analysis, time history analysis, fragility analysis

1. INTRODUCTION

A box girder is a bridge in which the main beams comprise girders in the shape of hollow box. The girder normally comprises either prestressed concrete, structural steel, or a composite of steel and reinforced concrete. The box girder bridge type is linked to providing construction methods and maximizing material use for a given span. As the span increases, the dead load also increases, which is a crucial aspect. Box girders or cellular structures have been created as a result of the removal of unneeded components from sections in order to reduce dead load. Better torsion resistance is provided by box girders, which is advantageous in particular if the bridge deck has a curved in plan [1]. Additionally, because two webs enable the use of broader and therefore stronger flanges, larger girders can be built. This permits longer spans. This type of superstructure is generally used for spans between 20 to 50 m.

The box section also possesses high bending stiffness and there is an efficient use of the complete cross-section. Due to its structural effectiveness, superior stability, greater serviceability, cost-effectiveness during construction, and appealing aesthetics, box girders have become widely accepted in the motorway and bridge systems [2]. Due to its 3-D behavior, which includes bending, distortion, and torsion in both the transverse and longitudinal directions, the study and design of these box girder bridges is relatively complicated. Box beam structures are well suited to bridges with large curvature because of their excellent torsional resistance [3]. They can be built as single, double, or multi-cell structures using box girders in various geometries, including circular, trapezoidal, and rectangular.

The general objective of this research is to determine the overall performance of prestressed

Box Girder Bridge of different span and sections with constant depth. Similarly, the specific objectives have been listed below:

- To analyze the structural behavior of post-tensioned concrete Box Girder Bridge for different sections with varying span.
- To determine the structural capacity of the bridge pier by nonlinear static analysis and structural demand using nonlinear dynamics analysis excited by different ground motion time histories.
- To quantify the seismic vulnerability of the bridge for different deck sections with the help of fragility curves.

2. METHODOLOGY

A finite element analytical model of different cross-section i.e., Trapezoidal and Rectangular box girder of different span length were modeled in CSi Bridge v23. Parametric study of different models was done for different load case such as dead load, live load (IRC Class 70R loading) and Gorkha earthquake. Also, comparative study for different cross section of box girder was done by fragility curve analysis [4]. Both structural demand and capacity was calculated in terms of displacement ductility which is the ratio of maximum top pier displacement and the rebar first yield displacement. Push over analysis is performed in order to evaluate the structural capacity. Also, Time history analysis is performed in order to evaluate the structural demand considering the three different ground motion data (Gorkha, Kocaeli and Northridge) [5]. Comparative study of both girder section was done by considering probability of exceedance for slight, moderate, extensive and collapse damage states respectively due to Maximum Considered Earthquake and Design Basis Earthquake [6].

3. MODELING

3.1 Superstructure modeling

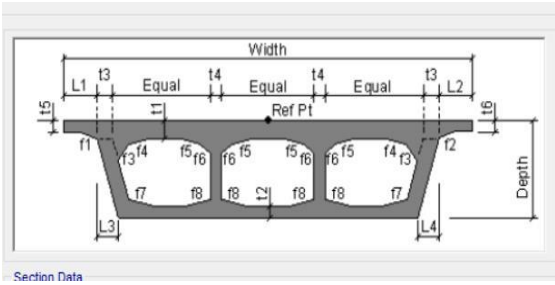

Figure 1: Typical section detail of Trapezoidal box girder

Table 1: Section details for box girder

Description	Trapezoidal	Rectangular
Total depth (m)	2.4	2.4
Top width (m)	10.2	10.2
Bottom width (m)	6.04	7.2
Top Slab Thickness (t1) (m)	0.35	0.35
Bottom Slab Thickness (t2) (m)	0.25	0.25
Exterior Girder Thickness (t3) (m)	0.35	0.35
Exterior Girder Bottom Offset (L3 & L4) (m)	0.58	0.58
Overhang Length (L1 & L2) (m)	1.5	1.5
Horizontal fillet (f1,f2,f4,f5,f7,f8) (m)	0.6	0.6
Vertical fillet(f1,f2,f4,f5,f7,f8) (m)	0.125	0.125
Overhang Outer Thickness (t5 & t6) (m)	0.25	0.25
Cross-sectional Area (m^2)	6.437	6.856

The bridge used in this study is a prestressed concrete, two Lane Bridge with carriageway width 7.2 m with 1.5 m footpath on both sides. It consists of two spans continuous over a pier cap. The dimensions of the bridge are verified as per “Post Tensioned Box Girder Design manual”, Federal Highway Administration (U.S. Department of Transportation).

3.2 Substructure modeling

Multicolumn pier with circular cross section with diameter 1.3 m and clear height 6.5 m is used in bridge. Thirty numbers of longitudinal reinforcement of 32 mm diameter and stirrups of 12 mm diameter at 150mm c/c spacing are used as shear reinforcement. Cap beam of length 10.5m is used having cross section of 2m × 1m at edge and 2m × 2m at center. Grade of concrete is M25 and that of reinforcing steel is Fe500.Degradation of stiffness of member due to cracking of concrete, yielding of reinforcement due to flexural yielding and strain hardening can be represented using fiber [6].

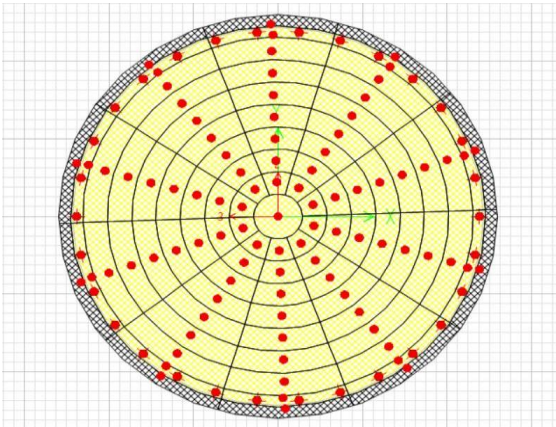

Figure 2: Fiber distribution in cross section of pier

3.3 Loading placement

Since it is noted that the critical moment is generated for Class 70R wheeled vehicle loading; therefore, parametric study was done by placing Class 70R wheeled vehicle loading. Two loading cases are considered for each bridge model, eccentric IRC Class 70R loading, bridge dead load and earthquake load.

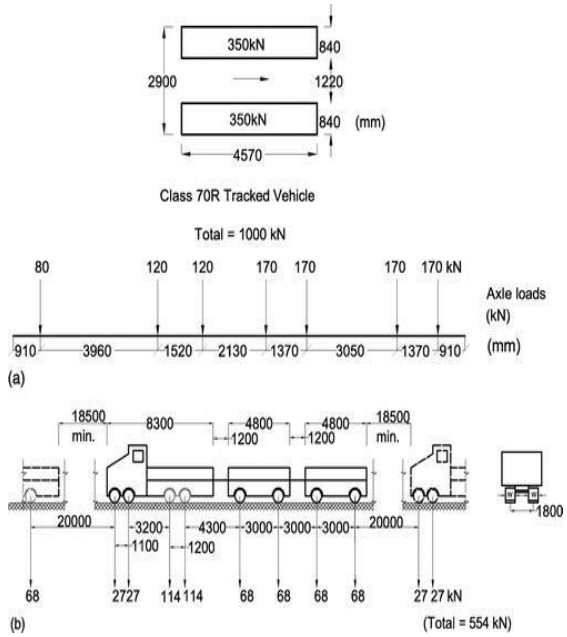

Figure 3: Longitudinal and transverse positioning of IRC Class 70R loading

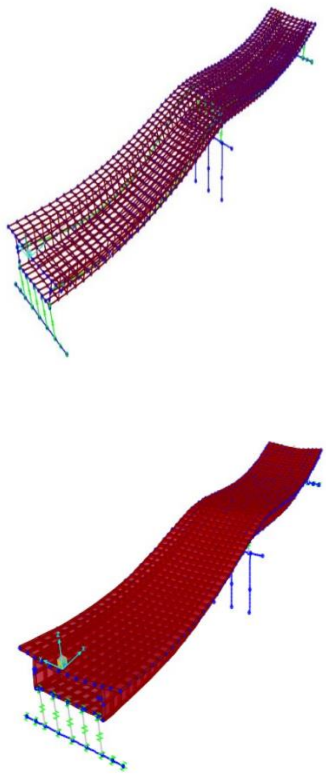

Figure 4: Deformed shape of trapezoidal and rectangular box girder model

4. RESULTS AND DISCUSSION

In the parametric study two cross sections namely rectangular and trapezoidal for different span of box girder are analyzed. The result obtained for various span of bridges are compared for different loading configuration dead load (self-weight) live load (IRC Class 70R) and earthquake load. The loads are placed in accordance with IRC: 6-2000, Standard Specification and Code of Practice for road and bridge.

4.1 Along U1 direction

The span of the bridge is aligned along U1 direction. The E-W component of the Gorkha Earthquake is considered for the analysis of all the bridge model in U1 direction. The output time step considered was 0.05 sec with 1200 steps and total time of 60 sec. The results obtained are summarized below:

Table 2: Bending moments for different span length

Span (m)	Trapezoidal	Rectangular
30	56222.73	59286.34
45	69288.9	76479.4
60	99776	118154

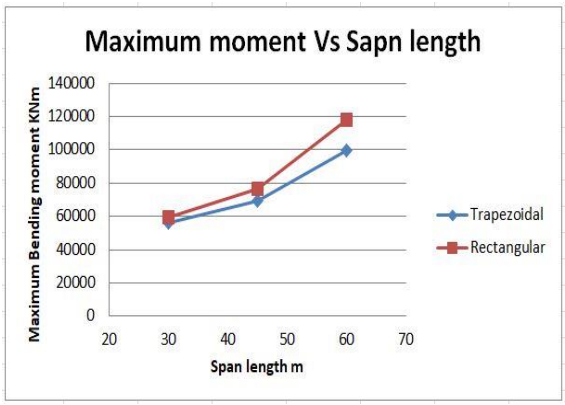

Figure 5: Maximum Bending moment of different span length

Table 3: Shear force for different Span length

Span (m)	Trapezoidal	Rectangular
30	-3417.67	-3524.87
45	-3665.204	-3874.29
60	-4364.32	-4656.2

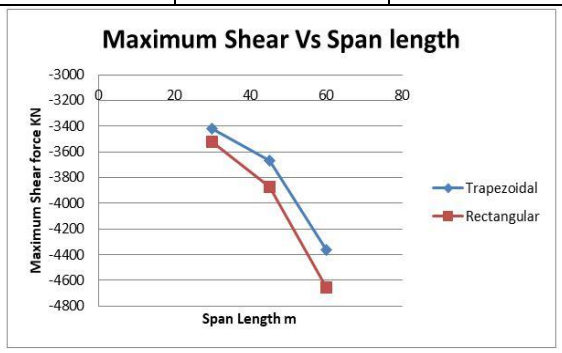

Figure 6: Maximum Shear force of different span length

Table 4: Deflection for different span

Section	Span (m)	Displacement (m)
Trapezoidal	30	0.0039
	45	0.0049
	60	0.0064
Rectangular	30	0.0036
	45	0.0043
	60	0.00528

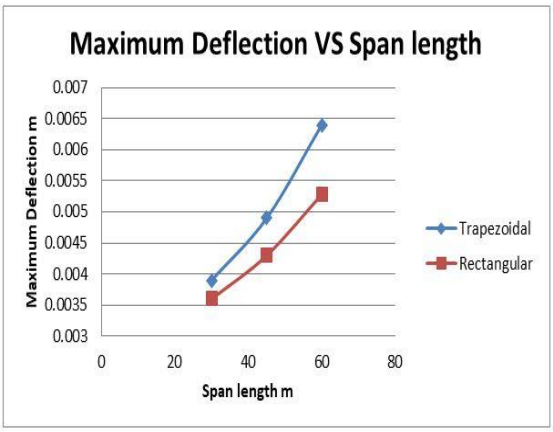

Figure 7: Maximum Deflection of top flange for different span length

Result of Cross-section Variation:

From the result obtained, it can be concluded for a constant depth of bridge model, the maximum bending moment of trapezoidal is 5.44%, 6.03%, and 8.33% less than rectangular models of spans 30m, 45m and 60m. The maximum shear force of trapezoidal is 3.13%, 6.17%, and 11.2% less than rectangular models of spans 30m, 45m and 60m.The nodal displacement of trapezoidal is 7.69%, 12.24%, and 17.5% more than rectangular models of spans 30m, 45m and 60m.

Result of Span Variation:

From the result obtained, it can be concluded for a constant depth of bridge model, the maximum bending moment increases by 29.76% and 56.34% when span varies from 30m to 45m and 45m to 60 m respectively and maximum moment of Trapezoidal section increases by 23.24% and 44.93%. The maximum shear force increases by 35.18% and 64.75% when span varies from 30m to 45m and 45m to 60 m respectively and maximum shear of Trapezoidal section increases by 28.34% and 57.23%.

4.2 Push over analysis

From Pushover curve for pier with Trapezoidal deck section, the maximum base shear is 2705.798 KN, maximum base shear for pier with rectangular deck section is 2905.798KN. Median ductility capacity for all damage states are higher for pier with Trapezoidal section.

Table 5: Quantification of damage states

S.N.	Trapezoidal section			Rectangular section		
Damage states	Displacement (mm)	Ductility Ratio(μd)	Median Ductility Capacity (Sc)	Displacement (mm)	Ductility Ratio(μd)	Median Ductility Capacity (Sc)
Slight/ Minor Damage	8	1	1.56	11	1	1.36
Moderate	17	2.12	5.62	19	1.72	3.95
Extensive	73	9.12	12.49	68	6.18	9.635
Complete	127	15.87	15.87	144	13.09	13.09

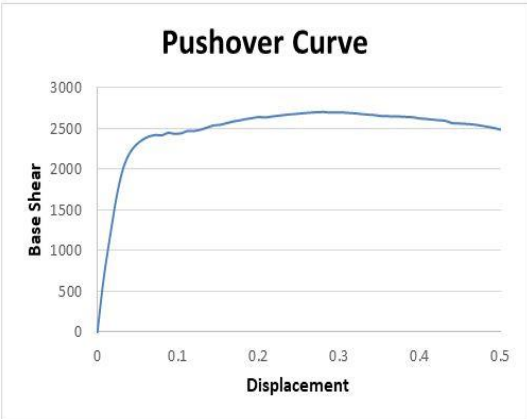

Figure 8: Push over curve for trapezoidal section

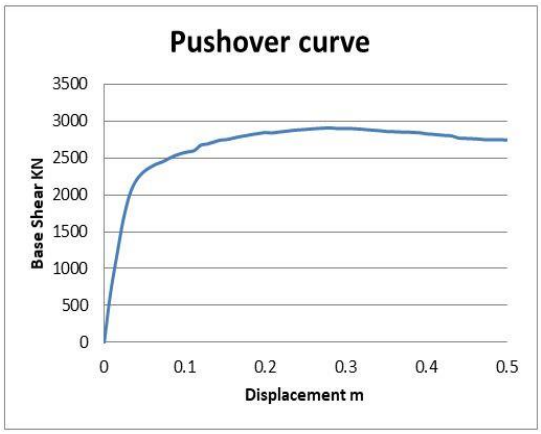

Figure 9: Push over curve for rectangular section

4.3 Time history analysis

Three numbers of ground motion records are used during the analyses which are Gorkha, Northridge and Kocaeli. Twenty number of time histories data are generated by scaling each ground motion from 0.1g to 2g at the interval of 0.1g. These generated time histories are subjected to modeled bridge at foundation level in transverse and longitudinal direction altogether having 60 numbers of time history analyses for each bridge pier. Maximum displacement time history of pier top due to ground motion subjected in both longitudinal and transverse directions are monitored. In all cases maximum displacement is more in transverse direction so all displacement values used in further calculation are of the transverse direction.

4.4 Regression analysis

Displacement ductility and Peak ground acceleration are plotted on ordinate and abscissa respectively in this analysis. The result of this analysis is trend-line for the plotted 60 numbers.

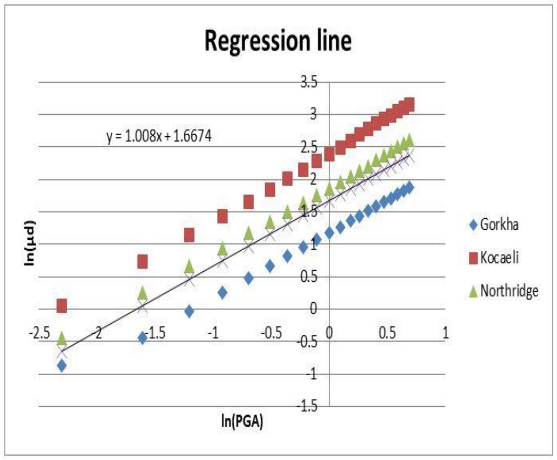

Figure 10: Regression analysis of Time History Results for Rectangular deck bridge pier

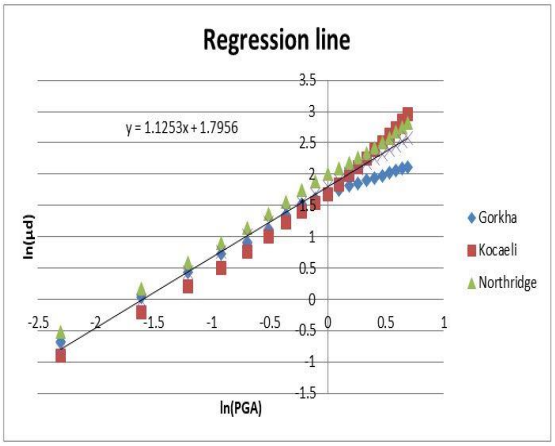

Figure 11: Regression analysis of Time History Results for trapezoidal deck bridge pier

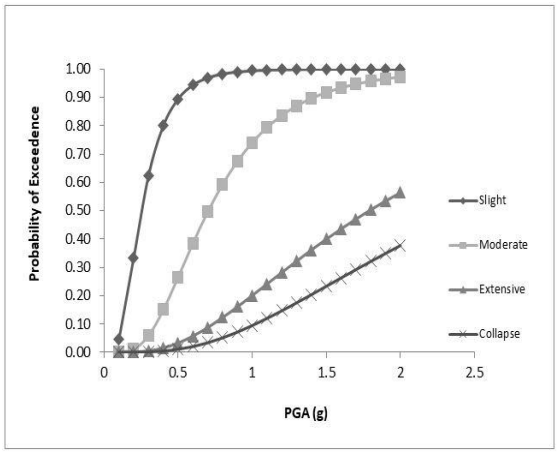

Figure 12: Fragility curve for rectangular deck section pier

These are the trend-line equations for Rectangular and Trapezoidal deck section bridge pier. These Equations are used in the fragility analysis for determining displacement ductility for arbitrary value of PGA.

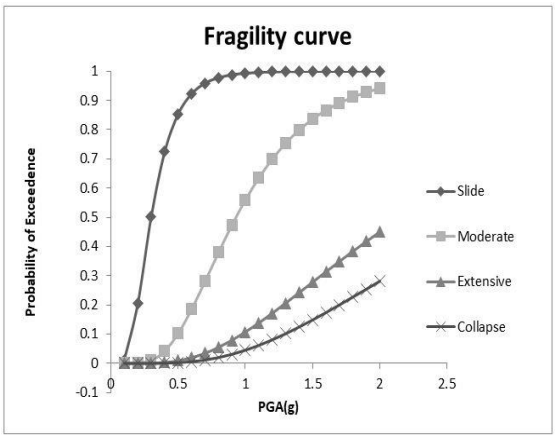

Figure 13: Fragility curve for Trapezoidal deck section pier

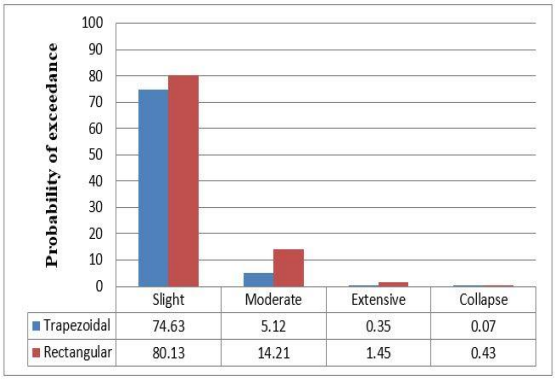

Figure 14: Probability of exceedance for design basis earthquake

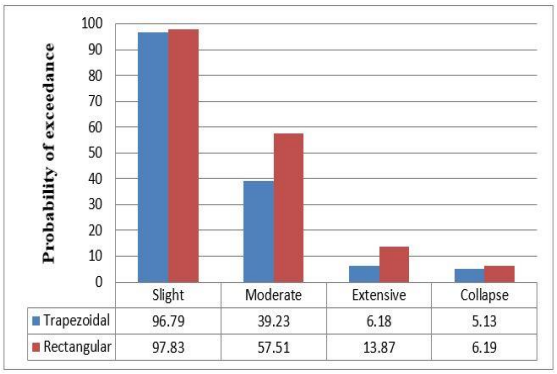

Figure 15: Probability of exceedance for Maximum Considered Earthquake

We analyze the different box girder bridges with different cross-sections for different number of spans. From the result of nonlinear time history analysis, the maximum shear force and maximum bending moment of rectangular box girder is higher than that of trapezoidal box girder section. This is because of the stiffness of the bridges and center of gravity lies different for both sections of girders. And, nodal displacement is higher in a trapezoidal box girder hence the rectangular box girder section is the stiffest one.

From the span variation result, when the span varies from 30 m to 45 m i.e., increase by 50% then the maximum bending moment, maximum shear force and maximum nodal displacement increase by only less than 50%. Also, when the span length varies from 45 m to 60 m i.e., increase by 33.33% then all the response parameters increased by greater than 50\%. Hence, from span variation for the given section of the box girder, 45 m span length is the effective one.

From the fragility curve analysis, the probability of exceedance for rectangular box girder section is higher as compared to the trapezoidal one for all damage states i.e., slight, moderate, extensive and collapse in both design basic earthquake and

maximum considered earthquake. This is because the center of gravity for trapezoidal section lies above as compared to rectangular section and difference in stiffness for the sections. Hence the rectangular section bridge is vulnerable as compared to the trapezoidal section bridge when the seismic event is happened. Seismic vulnerability of bridges can be assessed using fragility curves obtained using analytical methods of formulation [7].

5. CONCLUSION

The result presented highlight the effect of span length and the cross-sectional shape on the behavior in terms of deflection, bending moment, shear force and fragility curve analysis in different box girders.

1. Among the rectangular and trapezoidal cross-section box girders for all span length, the deflection is higher in trapezoidal section thus it can be concluded that rectangular section is stiffest section.
2. Bending moment and shear force in rectangular sections are higher than in trapezoidal sections for all span length.
3. From span variation, as the span increases the deflection, shear force and bending moment increases which is not in linear proportion and 45m span is effective one.
4. The probability of exceedance of rectangular deck section pier are 80.13%, 14.21%, 1.45% and 0.43% for slight, moderate, extensive and collapse damage states respectively due to Design Basis Earthquake.
5. The probability of exceedance of rectangular deck section pier are 97.83%, 57.51%, 13.87% and 6.19% for slight, moderate, extensive and collapse damage states respectively due to Maximum Considered Earthquake.
6. The probability of exceedance of trapezoidal deck section pier are 74.63%, 5.12%, 0.35% and 0.07% for slight, moderate, extensive and collapse damage states respectively due to Design Basis Earthquake.
7. The probability of exceedance of trapezoidal deck section pier are 96.79%, 39.23%, 6.18% and 5.13% for slight, moderate, extensive and collapse damage states respectively due to Maximum Considered Earthquake.
8. Probability of failure of trapezoidal deck section pier is less as compared to rectangular deck section pier having same pier and foundation.
9. Hence, seismic vulnerability of bridges can be assessed using fragility curves obtained using analytical methods of formulation.

REFERENCES

[1] J. Karim, “Behavior of a two cell prestressed concrete box girder bridge.,” McGill University, Montreal, Canada, 1988.

[2] P. D. Bhawar, M. R. Wakchaure, and P. N. Nagare, “Optimization of prestressed concrete box girder.,” *Int J Res Appl Sci Eng Technol*, vol. 4, no. 3, 2015.

[3] P. Kumar and B. Shilpa, “Dynamic analysis of box girder bridges with several spans

under longitudinal seismic excitations," *International research journal of Engineering & Technology*, 2016.

[4] M. Priestly, "Development of fragility curve for simply supported bridge using analytical method of fromulatuon," 2001.

[5] PEER, *PEER Ground Motion Database*. 2022.

[6] K. R. Karim and F. Yamazaki, "Effect of earthquake ground motions on fragility curves of highway bridge piers based on numerical simulation.," *Earthq Eng Struct Dyn*, vol. 30, no. 12, 2001.

[7] A. Kibboua, F. Kehila, H. Bechtoula, Y. Mehani, and M. Remki, "Development of fragility curves for seismic evaluation of a reinforced concrete bridge," *Second European Conference on Earthquake Engineering and Seismology, Istanbul*, 2014.

Stabilization of Silty Soil using Cement as Primary Binder and Epoxy Resin as Admixture

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Abstract

This research aims for the assessment of the influence of cement and epoxy resin on the stabilization of silty soil. Cement is used as a primary binder and epoxy as an admixture to stabilize the soil by increasing its compressive strength. Disturbed soil samples near the bank of Bagmati river, Chyasal were sampled through excavation. Laboratory tests show that the soil is silt with low plasticity. A Standard Proctor test is done to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) is done so that the quantity of cement and epoxy required for mixing with the dry soil can be calculated. Cement of proportions (5%,10%,15%) by total weight of dry soil have been used as a primary binder and epoxy resin of proportions (1.25%,2.5%,5%) by total weight of soil as an admixture to prepare soil samples for stabilization for a curing period of 7, 14, 28, 56 and 90 days and the unconfined compressive strength of those samples were determined accordingly. In this paper, the unconfined compressive strength of soil before and after stabilization have been compared. In this research, it is seen that the compressive strength of the stabilized soil drastically improves with the increase in proportions of combination of both cement and epoxy resin. Also, the research shows that the compressive strength increases with increase in curing period.

Keywords

Stabilization, Cement, Epoxy Resin, UCS test

1. INTRODUCTION

The damaged road condition of the valley, shrinkage and swelling potential of silt and clay beneath the Kathmandu valley, earthquake seismic zone V and other such geo-hazards have made Kathmandu valley more susceptible for inducing the deformation and various failures in the soil. Due to these reasons, it is necessary to apply technique to improve bearing capacity, in-situ and engineering properties of soil. Also, fine grained soil possesses high swelling potential and low strength [1]. Hence, one of the techniques for solving such geo-technical problems is soil stabilization. Soil stabilization is a ground improvement technique to improvise the weak geotechnical properties of soil. Soil stabilization removes cost of excavation and backfilling [2]. One of the methods of soil stabilization is chemical stabilization [3]. Normally, chemical stabilization is preferred for fine grained soil. Chemical stabilization uses chemical additives with soil to improvise soil strength properties and remove moisture [2]. We used cement as primary binder due to its high binding capacity and epoxy resin as admixture due to strength gaining capacity by polymerization.

There are many researches done on fine-grained soil and epoxy resin. In the research by [4], it is shown that epoxy resin is very effective for ML

(silt of low plasticity), MH (Silt of High Plasticity) and CH (clay of high plasticity) soils. [5]showed the soil samples with mixture of soil-cement and soil-cement-resin mixed increased with increasing the contents of cement and resin as well. According to research done by [6], type of soil was one of the important factors for compressive strength increase. The research had been conducted with cement contents of 3%, 5% and 7% by weight where the compressive strength was increased on increasing the cement content as well as with increase in curing period from 7 days to 28 days by two times for ML soil which can be presented by power curve. The paper [7]supports the theory that hydrolysis and hydration are the primary reactions in a clay-cement interaction where lime could initiate attack of clay particles and cause breakdown of amorphous silica and alumina. [8]suggested that the combination of highly plastic Kaolin clay and Ordinary Portland Cement requires lower pH at higher temperatures to produce secondary cementing material CSH (Calcium Silicate Hydrate). [9], [10]showed that epoxy resin is an organic polymer consisting of carbon and oxygen atoms that improves the strength of fine-grained soil drastically. [11]suggests that blends with higher percent of bio-epoxy leads to conversion of other ether groups which results in process of co-polymerization which weakens strength of materials though. [12] used CH and ML soil with 3,7,28 days of curing period with 0%, 0.5%, 1.0%, 1.5% and 3% polymer.

Polymer stabilizer reduces soil erosion drastically and increases strength significantly [13]. Also, with addition of polymer MDD increases and OMC decreases [12].

This research determines the effectiveness of the combination of cement with epoxy resin on various proportions according to water-cement ratio and epoxy-water ratio for optimum strength for silty soil.

2. MATERIALS

2.1 Natural Soil

The soil was extracted from Himalaya College of Engineering, which lies at the riverside of Bagmati River. The extracted soil was classified as Silt of Low Plasticity (ML) on the basis of Unified Soil Classification System (USCS). Particle size distribution was done by IS-2720 code. Similarly, Liquid limit, Plastic limit and Plasticity Index of soil were found out in accordance with AASTHO T89-90 and T90-96 testing procedures.

Gravel	% Retained on 4.75 mm	11.09%
Sand	%passing 4.75 mm and retained on 75 micron	82.50%
Fines	% passing 75 micron	6.40%
% passing 425 micron		38.32%

Table 1 Particle size distribution

In-situ Moisture Content	17.92%
Bulk Density	1,793.826 kg/m^3
Specific Gravity	2.61
Liquid Limit	28.25%
Plastic Limit	25%
Plasticity Index	3.25%
Maximum Dry Density	1725.5 kg/m^3
Optimum Moisture Content	18.375%
Soil Classification	Silt of Low plasticity (ML) USCS Classification

Table 2 Index properties of soil

2.2 Cement

Cement is a binding material which on mixing with water gets hydrated and the main cementitious property is exhibited by the calcium silicates: C_3S and C_2S. The calcium hydroxide obtained from hydration of cement further reacts with pozzolanic materials to form further cementitious materials. Cement Stabilization helps to remove fatigue failures caused due to repeated deflection of asphalt surface [14].

2.3 Epoxy Resin

Epoxy resin are organic compounds in which a single oxygen atom is bonded with two carbon atoms [15]. Epoxy resin used contained of 1:1 Hardener and Epoxy resin respectively which was stirred and mixed thoroughly. Epoxy Resin being an organic polymer, starts to polymerize when mixed with hardener due to which the soil gains high strength under compression loading by the formation of a strong epoxy structure. Epoxy resin forms 3-dimensional cross-linked network forming cross-linked structure which enhances strength and mechanical properties [15]. Polymers improves soil properties by increasing adhesion between soil grains [16].

3. SOIL SAMPLE PREPARATION AND EXPERIMENT

Mixing of soil with different cement and epoxy resin contents was done according to the BS 1924- 1274 standards (British Standards Institution 1924). At first, the parent soil was oven dried and passed through a 425 micron sieve. Water equal to the OMC was added whereas, cement was added in proportion of either 5, 10 and 15% of the total mass of soil. Similarly, epoxy resin was added in either proportion of 1.25, 2.5 and 5% of the total mass of soil and mixed thoroughly. This makes altogether of 10 combinations of cement and epoxy resin which are shown in Table 3. Two samples were prepared for each combination to obtain average data, which makes it 20 samples for a single curing period. So, a total for 100 samples were prepared for all curing periods of 7, 14, 28, 56 and 90 days. The homogeneous mixture was then compacted by a constant force of 20kg in the cylindrical mold of Harvard Miniature Compaction Apparatus in three layers by blowing 25 times in each layer. Then it was wrapped in plastic to prevent exposure to moisture. Before 3 days of testing, the samples were unwrapped and cured in natural surrounding for the allotted period. As for cement stabilization of silt, for better testing and low cost, unconfined compressive strength test is carried out [17]. Unconfined Compressive Strength tests were carried out on the samples according to the ASTM D1633 (ASTM 1983) standard on their respective time schedule and results were noted.

Figure 1: Brittle failure after testing of sample of high cement and epoxy resin content

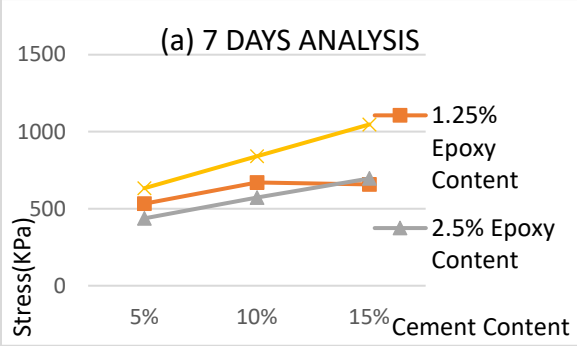
Figure 2: Unconfined Compressive Strength test of Samples

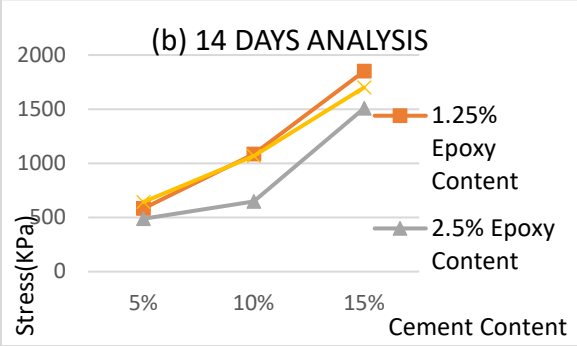
Table 3: Percentage of constituents in soil samples for each curing periods

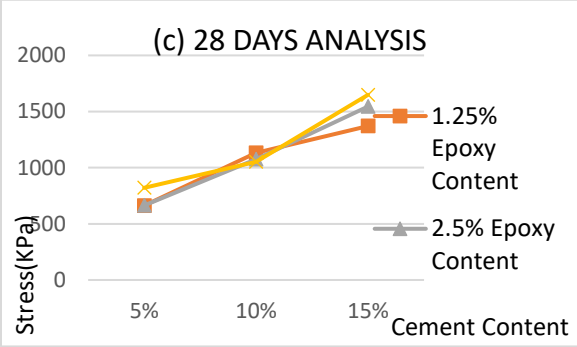
Samples	Total % of soil	% of dry soil	% of water	% of epoxy resin	% of cement
A	100	84.475	15.522	0.00	0.00
B	93.75	79.195	14.552	1.25	5.00
C	92.5	78.139	14.358	2.50	5.00
D	90	76.028	13.970	5.00	5.00
E	88.75	74.972	13.776	1.25	10.00
F	87.5	73.916	13.582	2.50	10.00
G	85	71.804	13.194	5.00	10.00
H	83.75	70.748	13.000	1.25	15.00
I	82.5	69.692	12.806	2.50	15.00
J	80	67.580	12.418	5.00	15.00

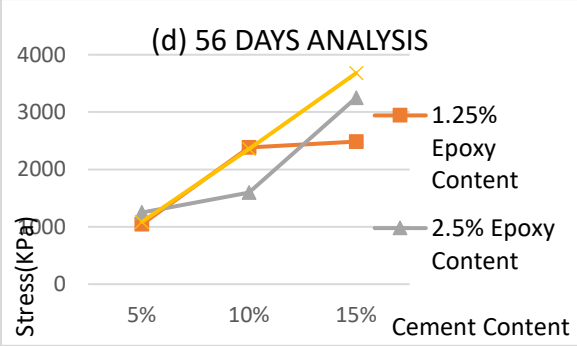
4. RESULTS AND DISCUSSIONS

4.1 Comparison of strength of stabilized samples at 7 days, 14 days, 28 days, 56 days and 90 days









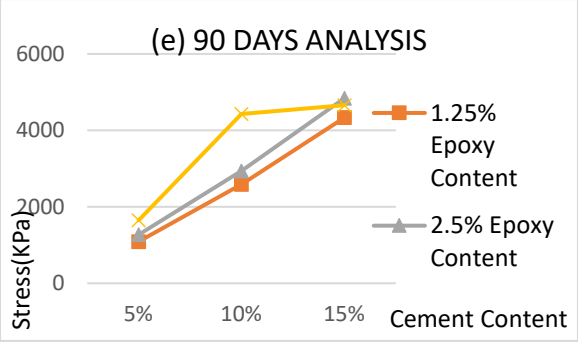
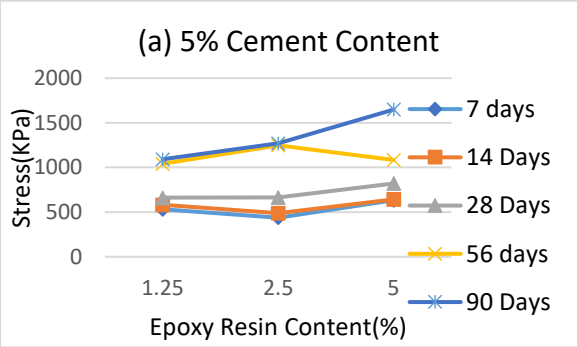
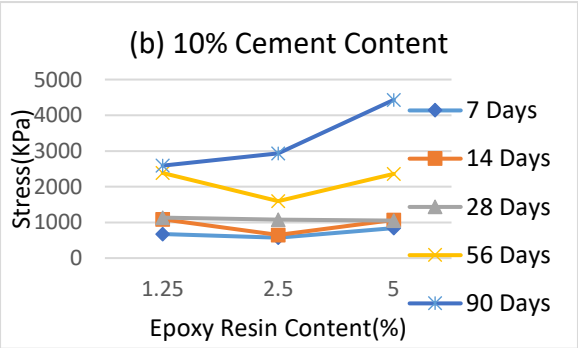


Figure 3: Plot of Unconfined compressive strength Vs Cement content for soil samples (a) 7 Days Analysis of varying epoxy content with varying cement contents; (b) 14 Days Analysis of varying epoxy content with varying cement contents; (c) 28 Days Analysis of varying epoxy content with varying cement contents;
(d) 56 Days Analysis of varying epoxy content with varying cement contents; (e) 90 Days Analysis of varying epoxy content with varying cement contents

4.2 Comparison of stress for various content of epoxy resin with at various cement contents





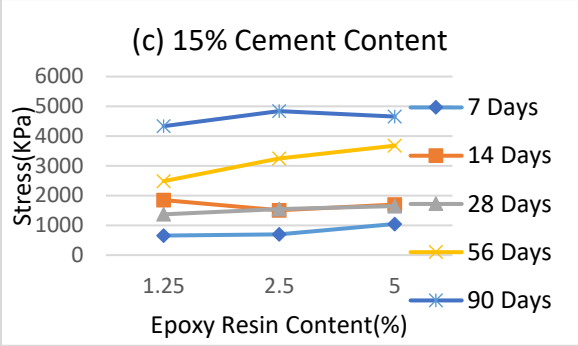


Figure 4: Plot of Unconfined Compressive Strength Vs Epoxy resin content for soil samples prepared with (a) 5% cement; (b) 10% cement; (c) 15% cement for five different curing periods

From these graphs of Figure 3 and Figure 4, it is noticed for 7 days period, the samples with only 5% epoxy resin content for all proportions of cement show drastically increase in strength. Also, till 14 days curing period, the strength increased with high level of epoxy resin and samples with low level of epoxy resin do not vary largely. On 28 days curing period, it can be distinctively seen, for any cement content, the samples of any epoxy resin content show similar increase in strength. For, 7 days, 14 days and 28 days, in all these curing period, cement content have been major factor for drastically increase in strength. Primary binder is more responsible for increase in strength due to properties such as hydration, formation of secondary products etc.

However, the status of strength changes in 56 days and 90 days. In 56 days and 90 days. In 56 days and 90 days, for 5% cement contents, the strength is similar with any proportion of epoxy content. However, the strength rises with increasing epoxy resin content for 10% and 15% cement content. The ultimate strength is acquired with highest epoxy resin and cement contents. The samples used to undergo brittle failure at

higher curing periods for higher Cement content and ERC (Figure 5). This concludes, till 28 days of curing period, cement (primary binder) is more responsible for increase in strength and then after, the polymerization property of epoxy resin (admixture) increases strength of the samples. Improvement in strength also relate to improvement in strength means change in engineering properties of soil such as settlement characteristics, shear structure, permeability, swell potential in fine grained soil [18].

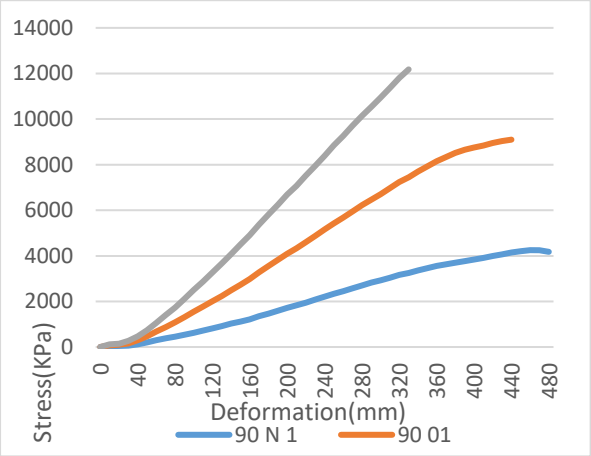


Figure 5: Brittle failure of samples at 90 days curing period after reaching a peak point.

4.3 Comparison of stress of stabilized soil sample for various percentages of cement and epoxy resin for 7, 14, 28, 56 and 90 days

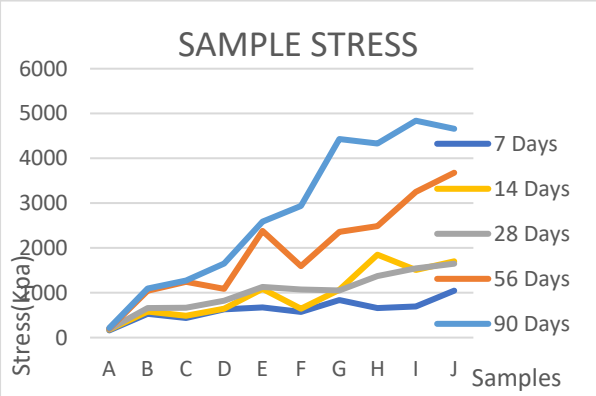


Figure 6: Sample stress variation

Samples are named according to the mixing proportions which is mentioned in table 3. The above graph shows that the maximum strength for the stabilized soil sample is observed frequently near the 9th and 10th samples (samples I and J). The maximum strength is obtained at 90 days of curing. This graph shows that the strength of the soil sample increases with the increase in the number of days of curing and proportions of cement – epoxy content.

4.4 Comparison of stress for unstabilized soil, minimum stabilization proportion and maximum stabilization proportion

As compared to the soil without cement and epoxy content, there is an increase in stress for both minimum proportions (5% cement and 1.25% epoxy resin) which is sample E and maximum proportions (15% cement and 5% epoxy resin) of cement and epoxy resin which is sample P. Also, there is a significant increase in stress for the sample containing any content of either or both cement and epoxy resin for all curing periods.

Hence, it can be concluded that the addition of cement and epoxy resin has successfully stabilized the soil.

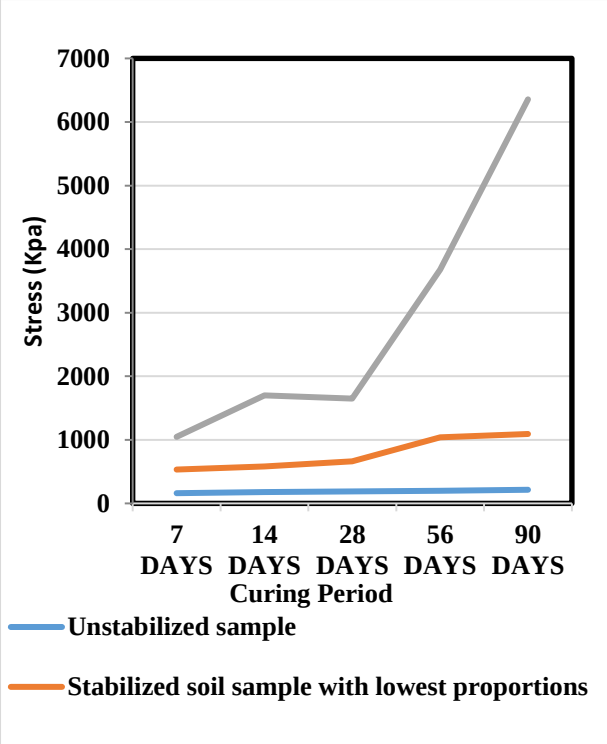


Figure 7: Comparison of stress for un stabilized and stabilized soil samples with minimum and maximum proportions

5. CONCLUSION

1. The compressive strength increased on 5%, 10% and 15% cement proportions with varying proportions of epoxy resin of 1.25%, 2.5% and 5% on all cement proportions.

2. The optimum unconfined compressive strength was obtained at 5% epoxy and 15% cement proportion by weight at highest curing period which is 4658.58% increase in strength compared to strength of wet sample.

3. The strength of stabilized soil was increased on increasing the curing period. The highest Unconfined Compressive Strength was recorded at 90 days followed by 56 days, 28 days, 14 days and 7 days respectively similar as results from [7], [8].

4. The compressive strength increased with increasing cement-epoxy resin content which has similar results with [8], [10].

5. At higher curing periods, the cement-epoxy stabilized sample has a brittle failure nature.

In this research, the stabilization of silty soil with cement and epoxy resin is investigated and the effects of stabilization are measured by the Unconfined Compressive Strength (UCS) test. It is found the addition of epoxy resin to primary binder cement increases the strength by a considerable magnitude. The effect of curing period is also dominant as the strength of a soil sample cured for 90 days is much higher than a soil sample cured for 7 days. The addition of cement causes the pozzolanic reactions to occur and consume a large quantity of water, which if existed as a free solution, would prohibit to some extent the chemical reactions of epoxy resin with hardener. The cement performed better till 28 days of curing period meanwhile epoxy performed better after 28 days of curing period. These results showed that cement and epoxy resin can be effectively used in many fields including pavement layers (road construction), retaining walls, deep soil mixing, earthquake engineering, soil foundation engineering etc. However, further research on this can be carried out to study its economic aspect before application.

6. ACKNOWLEDGEMENTS

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providing us the material and Himalaya College of Engineering for permitting us to extract natural soil. We would also like to thank staffs of Himalaya College of Engineering for supporting and helping us during our research.

7. CONFLICT OF INTEREST

The authors declare that they have no conflict of interest. All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Shishir Dhakal, Sandesh K.C. and Utsav Chimariya, Saurav Shrestha and Suvarna Singh Raut. The draft of the manuscript is written by Shishir Dhakal and all authors commented on the draft of the manuscript, hence revising the draft to final manuscript. All authors read and approved the final manuscript.

REFERENCES

[1] C. Turan, A. Javadi, R. Vinai, N. Shariatmadari, and R. Farmani, "Use of class C fly ash for stabilization of fine-grained soils," in *E3S Web of Conferences*, 2020, vol. 195. doi: 10.1051/e3sconf/202019506001.

[2] M. A. Patel and H. S. Patel, "A Review on Effects of Stabilizing Agents for Stabilization of Weak Soil," *Civil and Environmental Research*, vol. 2, no. 6, 2012.

[3] N. S. Kalidas, "Strength Characterstics of Stabilized Embankment Using Fly Ash," *IOSR Journal of Mechanical and Civil Engineering*, vol. 11, no. 4, 2014.

[4] M. Melhem, "Compression strength of Treated Fine-Grained soils with Epoxy or Cement," *International Journal of Geotechnical and Geological Engineering*, vol. 13, no. 2, 2019.

[5] A. R. Estabragh, M. Naseh, I. Beytolahpour, and A. A. Javadi, "Strength of a clay soil and soil-cement mixture with resin," *Proceedings of the Institution of Civil Engineers: Ground Improvement*, vol. 166, no. 2, 2013, doi: 10.1680/grim.12.00014.

[6] S. I. Haralambos, "Compressive Strength of Soil Improved with Cement," 2009. doi: 10.1061/41023(337)37.

[7] A. Herzog and J. K. Mitchell, "Reactions accompanying stabilization of clay with cement," *Highway Research Record*, vol. 36, 1963.

[8] D. Chian, "Cement stabilization in clayey soils considering clay types, sand impurities and curing temperature," 2017.

[9] A. Ajayi-Majebi, W. A. Grissom, L. S. Smith, and E. E. Jones, "Epoxy-Resin-Based Chemical Stabilization of a Fine, Poorly Graded Soil System," *Transp Res Rec*, vol. 1295, 1991.

[10] C. A. Anagnostopoulos, "Strength properties of an epoxy resin and cement-stabilized silty clay soil," *Appl Clay Sci*, vol. 114, 2015, doi: 10.1016/j.clay.2015.07.007.

[11] A. Derahman and Z. Z. Abidin, "Mechanical properties of bio-epoxy resins and synthetic epoxy resins blends," *IOP Conf Ser Mater Sci Eng*, vol. 1176, no. 1, 2021, doi: 10.1088/1757-899x/1176/1/012005.

[12] P. K. Kolay, B. Dhakal, S. Kumar, and V. K. Puri, "Effect of Liquid Acrylic Polymer on Geotechnical Properties of Fine-Grained Soils," *International Journal of Geosynthetics and Ground Engineering*, vol. 2, no. 4, 2016, doi: 10.1007/s40891-016-0071-5.

[13] D. Nihad Bahaaldeen Salih and N. B. Salih, "Geotechnical characteristics correlations for fine-grained soils," in *IOP Conference Series: Materials Science and Engineering*, 2020, vol.

737, no. 1. doi: 10.1088/1757-899X/737/1/012099.

[14] F. Bell, *Engineering Treatment of Soils*. CRC Press, 1993.

[15] J. C. Capricho, B. Fox, and N. Hameed, "Multifunctionality in Epoxy Resins," *Polymer Reviews*, vol. 60, no. 1. 2020. doi: 10.1080/15583724.2019.1650063.

[16] T. v Bheemasetti, T. Tabassum, B. N. Lingwall, and R. Rahman, "Evaluating Erosion Potential of Stabilized Fine-Grained Soils," 2020.

[17] S. Pu *et al.*, "Mechanical and Microscopic Properties of Cement Stabilized Silt," *KSCE Journal of Civil Engineering*, vol. 24, no. 8, 2020, doi: 10.1007/s12205-020-1671-0.

[18] N. J. Meegoda and P. Ratnaweera, "Compressibility of contaminated fine-grained soils," *Geotechnical Testing Journal*, vol. 17, no. 1, 1994, doi: 10.1520/GTJ10078J.

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