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From the Editor's Desk

In the last few years the number of research activities at Nepal Engineering College (*nec*), conducted by the students and faculty members have increased several folds, compared to the similar activities five years ago. The involvement level of the students and faculty members of the college in different international projects has elevated in a similar fashion. The number of quality graduate theses in different programs conducted by the college improved noticeably in the last few years. All these activities have created a wealth of data, information and knowledge; the content of this issue of SCITECH-Nepal is a testament to Nepal Engineering College's incessant quest to improve quality academic environment. After successfully completing all the academic and research programs in the midst of the Covid-19 global pandemic, Nepal Engineering College is embarking on a range of international collaborative programs, and expanding its network across the Asian and European institutes. The overall outputs of these programs will indeed expose the students and faculty members to new areas of research. The college recently established new links with Nepal based industries which, again, is expected to enhance *nec* students' access to new technologies. I am confident that the readers of this issue of SCITECH-Nepal will definitely find the published research articles of value for the time. With the original paper contribution from the researchers, we intend to keep on improving the quality of the Journal with each new issue.

Hari K. Shrestha

Chief Editor:

Prof. Dr. Hari Krishna Shrestha

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Facial Gesture based Learning Application for Children with Autism of Nepal

Sachin Shrestha¹, Amit Shah², Niraj Dhakal³, Pawan Dhakal⁴

Department of Electronics and Communication Engineering

Nepal Engineering College, Bhaktapur, Nepal

E-Mail ID: ¹sachins@nec.edu.np, ²amits@nec.edu.np, ³nearoz998@gmail.com, ⁴pawan12430@gmail.com

KEYWORDS

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ABSTRACT

Autism is a neurodevelopmental disorder that causes a wide range of impairments in social communication and leads to restricted and repetitive behaviours. The development of the ICT based platforms that could aid them to improve vocabulary in a playful manner seems very crucial in the current era. This paper focusses on a desktop-based application that will aid children with autism to learn new words in a playful environment. The application was developed as a game desktop app in which a character within the game made movements like walk left, walk right, jump etc based on the facial gesture of the children. As such the system was designed with facial gesture recognition and tracking functionality. In the backend, image processing-based facial gesture tracking algorithm was carried out within the video captured from web-cam and generated audio output as per the achievements of the character within the app. In the front-end part, the desktop app showed a character which made movements based on the facial gesture of the user. Also, different fruits will appear on the screen randomly, which when touched by the character would generate audio, speaking the name of the fruit in Nepali language. The application was tested among 5 neurotypical persons and 2 children with autism. The confidentiality of the children was maintained and that the permission from the parents as well as the therapists and special educators of the children with autism was also taken prior to the tests. The accuracy with the movement of the character with the facial gesture was in the range of 90%. The tests showed that the children with autism found the application interesting and that they could learn few words with such applications with rigorous training sessions.

INTRODUCTION

Autism spectrum disorder (ASD) is a neuro-disability that typically appears during the first three years of life [1]. It is characterized by deficits in social interaction and communication accompanied by repetitive and restricted patterns of behaviour and interest [2]. There has been a big rise in the prevalence rate of autism as stated by the Centers for Disease Control and Prevention (CDC) [3]. Figure 1 presents the graphical overview of the rise in the prevalence of autism in the United States of America over the years (2004-2020), as reported by the CDC [4].

Statistics in Nepal

In 2018, Michelle Heys conducted a survey among 4098 children of rural areas with ages between 9 to 13 [5]. He had used the Nepali- version of an autism screening tool called Autism Quotient-10. The study showed the prevalence rate of autism 3 per 1000

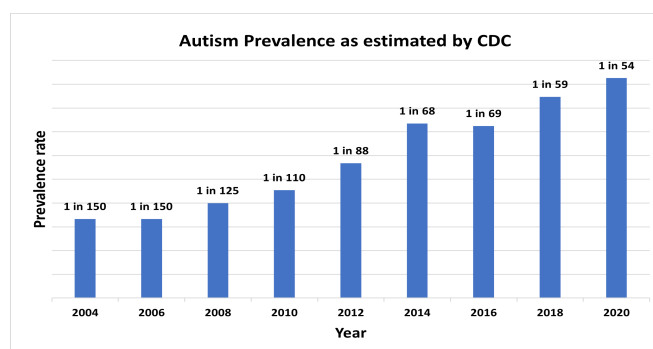


Figure 1: Autism Prevalence Estimated by CDC

children. The annual report (2076-2077) of Autism Care Nepal Society (ACNS) [6] [7] showed that 822 cases of autism had been diagnosed at ACNS so far by the end of June 2020. The graph of the total cases of autism is shown in Figure 2. Within the fiscal year 2076/77, 130 cases of autism had been diagnosed at ACNS.

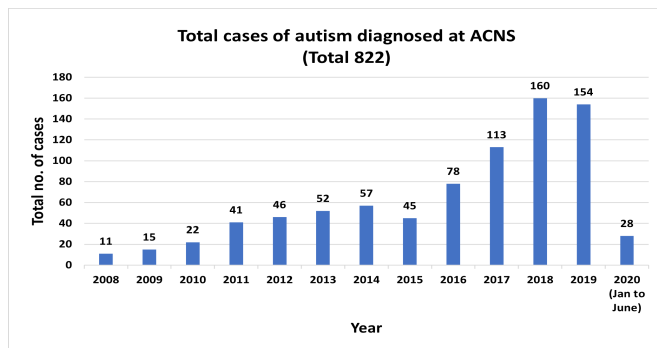


Figure 2: Autism Cases Diagnosed at ACNS since 2008

ICT based Learning Platform for Children with Autism of Nepal

The technology-based interventions to improve ASD core deficits are being used and are gaining popularity with the usage of technologies like mobile computing, virtual reality, robotics etc [8]. Virtual reality (VR) based training has also been found to be useful to improve social skills [9] and so different developments have been made in virtual reality (VR) based applications to improve the skills of people with ASD. Research has been done where VR is tested for teaching street-crossing skills [10]. Visual Activity Schedules are created to support children with ASD by presenting a sequence of events that are going to happen in relation a specific task either during an activity or throughout the day [11]. This has proved to highly promote the independence and predictability for children with autism, and has helped with transitioning between activities [12]. Social Stories are also very popular among the children with ASD and are considered one of the best tools to enhance their social skills [13]. These are short stories and are with fun and easy ways to describe certain situations, events or activities. They aim to teach children with ASD about certain situations or events, such as dressing up, and also preparing them for new events, such as moving house. Different android applications [14] [15] have been developed to create Visual Activity Schedules [16] and Social Stories [17].

In the context of Nepal, so far, no developments have been made for ICT based teaching learning platforms were developed for children with autism. Nepal is more inclined toward the usage of low-tech devices so far [18]. Eye pupil tracking system-based app option selection was researched for the people with cerebral palsy of Nepal [19]. At ACNS, with support from UNICEF, an android app named, Beautiful Mind had been developed [20]. The app had different sections for parent and children. For children, different engaging activities like drawing board, colour fillers etc. were present. However, the app couldn't reach its full potential and that it couldn't run across different devices. In 2020, ACNS launched a new android app, ACNS Sunaulo Bihani [21], that could be beneficial for the children with autism (CWA) as well as their parents and caretakers. The app includes different sections targeting communication, sections with social stories and different videos. These limited applications showed the immense need for autism related education technologies in Nepal.

METHODOLOGY

The flowchart of the system is shown in Figure 3. The hardware part of the system consisted of a different hardware unit of laptop beside the main processor, like web-cam to capture the real-time video, monitor screen to display the front-end and a speaker to generate the audio. The desktop application was developed using Python version 3.6.4.

Video Capture

The webcam is used to capture the real-time video frames of the user. OpenCV library [22] was used for the extraction of video frames and their processing.

Face Detection

The face within the video frame was detected in real-time using feature descriptor called HOG (histogram

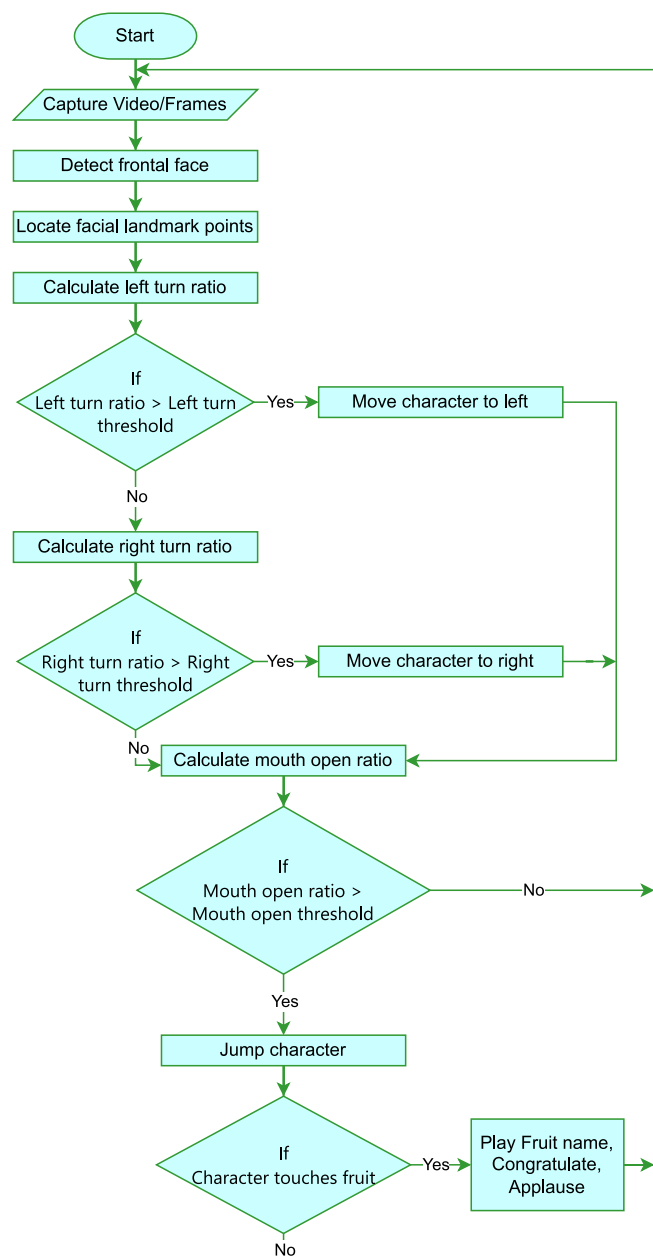


Figure 3: Flowchart of the System

of oriented gradient) and sliding window detection technique. A sliding window is a two-dimensional rectangular box of a fixed width and height and slides across an image. The system could judge whether the tonal distribution of a face within a frame of an input video was a face or not by the analysis of the histogram [23].

Face Selection Algorithm

The decision algorithm for single face selection from multiple faces in a frame is shown in Figure 4. For the detection of human faces within an image frame, HOG and sliding window methods were useful [24] [25]. The system applied frontal face detection method of the dlib library for the calculation of the number of faces present within the given frame. For single face within the frame, the system would track and operate on that face. For multiple faces, further operations were carried out with respect to that of the previously operated face. The locations of each of the faces were calculated and compared with the location of previously operated face and the closer face would be selected for further operations.

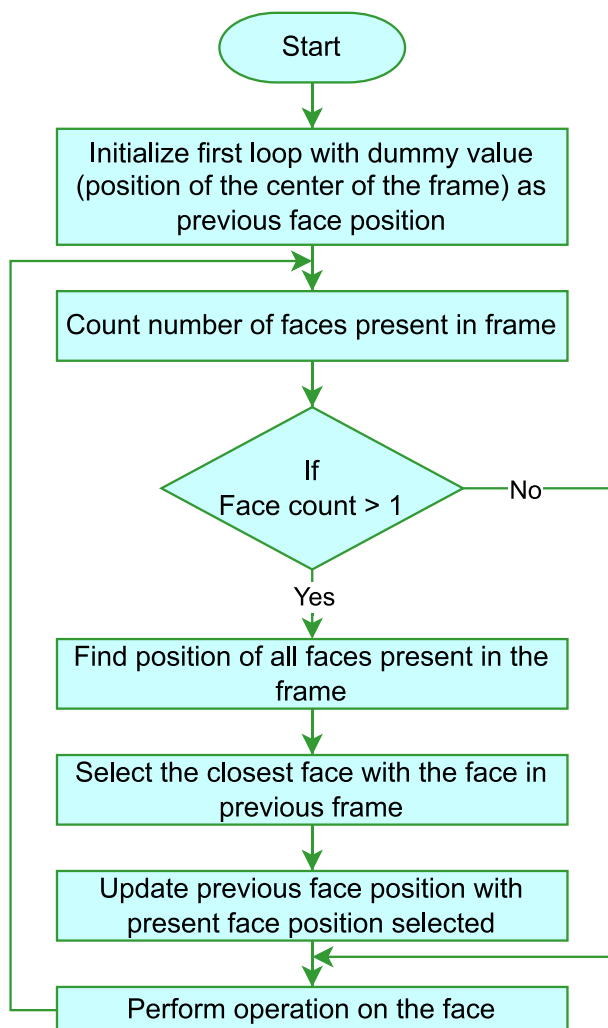


Figure 4: Decision Algorithm for Single Face Selection

Facial Landmark Points Detection

Various facial landmark points were detected by

using different image enhancement techniques. A library called dlib [26] portrayed 68 landmark points on the various positions of the detected face in order to represent a face. After obtaining the numbering of each landmark point on the face, facial gestures such as opening of mouth, left or right turn of face were identified.

Facial Gestures

Within the desktop app, three major facial gestures were defined; left turn and right turn of the face to move the game character to left and right respectively, and opening of mouth to make the character jump. The left or right turn of the face was identified by calculating the left turn ratio value and right turn ratio value respectively. Next, the opening of the mouth was identified by calculating the mouth open ratio value. The threshold values for each of these gestures were calculated by hit and trial method.

Ratio Calculation

Left Turn Ratio: The distance between landmark point 17 and landmark point 46 was calculated and the distance between landmark point 17 and landmark point 13 was taken as reference. The left turn ratio was then calculated as:

$$\text{Left turn ratio} = \frac{\text{Distance between points 17 and 46}}{\text{Distance between points 17 and 13}}$$

Right Turn Ratio: The distance between landmark point 1 and landmark point 37 was calculated and the distance between landmark point 1 and landmark point 5 was taken as reference. The right turn ratio was then calculated as:

$$\text{Right turn ratio} = \frac{\text{Distance between points 1 and 37}}{\text{Distance between points 1 and 5}}$$

Mouth Open Ratio: The distance between landmark point 52 and landmark point 58 was calculated and the distance between landmark point 49 and landmark point 55 was taken as reference. The mouth open ratio was then calculated as:

$$\text{Mouth open ratio} = \frac{\text{Distance between points 52 and 58}}{\text{Distance between points 49 and 55}}$$

Character Jump

The character showed the effect of gravity i.e., acceleration and deceleration during the jump. Such effect was achieved by varying the vertical position of the character during the jump as per the value of acceleration due to gravity, g , whenever the gesture, open mouth was detected.

Fruits Display

The images of different fruits were displayed within the front-end of the app in sequential order. At a time one fruit would appear in the screen and when the character touched the fruit, next fruit at some random distance were displayed.

Voice Output

If the character touched the fruit by jumping, a voice

output was generated via speaker. The output audio was a pre-recorded and stored audio file, with respect to the fruit. For an example, if the fruit 'orange' was touched by the character, the audio file saying "Suntala" would be played. A pre-recorded congratulatory voice and applause audio would also be played upon the successful touch. A python library, playsound [27], was used for playing audio.

User Interface

The user interface (UI) of the desktop app is shown in Figure 5.

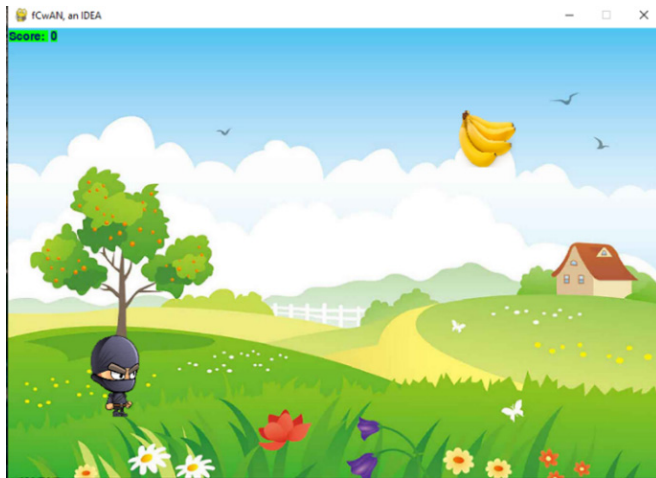


Figure 5: User Interface of App

The UI had an image background, a game character and a fruit. The users had to turn their head right or left to move the character and open their mouth to jump the character.

RESULTS AND ANALYSIS

Performance Evaluation Protocol

Different tests were done to calculate the values of true positive (TP), true negative (TN), false positive (FP) and false negative (FN). The four major tests were done; face turned left, face turned right, face kept still and mouth opened. For each of these cases, 100 observations were made to calculate previously mentioned performance parameters.

The evaluation protocol to calculate those values for the face turned left, right and kept still are shown in Table 1.

Table 1: Protocol for TP, FP, TN, FN for Face Turned Left & Right

Type	Description
TP	Character moved left and right when face was turned left and right respectively.
FP	Character moved left and right when face was turned right and left respectively or when face wasn't turned either side.
TN	The character didn't move when the face wasn't turned left or right.
FN	The character didn't move even when face was turned left and right.

The evaluation protocol to calculate those values for open mouth are shown in Table 2.

Table 2: Protocol for TP, FP, TN, FN for Mouth Open

Type	Description
TP	Character jumped when mouth was opened.
FP	Character jumped when mouth wasn't opened.
TN	Character did not jump when mouth was closed.
FN	Character did not jump when mouth was opened.

The five different performance parameters, specificity (Sp), sensitivity (Se), precision or positive predictive value (PPV), negative predictive value (NPV) and accuracy (Acc) were calculated. Also, a 2x2 confusion matrix was generated for the values of TP, FP, TN and FN. For the testing purpose, instead of using people with autism, 3 male healthy persons of age 22 were chosen.

Facial Movement Tracking

The observed values and the calculated values after

Table 3: Result obtained from different movements

Parameters	Gesture		
	Right	Left	Jump
TP	92	92	91
FP	4	0	2
TN	98	100	96
FN	2	4	5
Specificity	0.96	1	0.98
Sensitivity	0.98	0.96	0.95
PPV	0.96	1	0.98
NPV	0.98	0.96	0.95
Accuracy	0.97	0.98	0.96

100 different observations are shown in Table 3.

The confusion matrix after 100 different observations

Table 4: Confusion matrix for facial movement detection

Actual Class	Detected Class		
	Right	Left	Jump
Right	92	0	2
Left	0	92	4
Still	4	0	99

for left and right movement of character for left and right turn of face is shown in Table 4.

Next, the confusion matrix after 100 different observations for the jump of the character with opening and closure of mouth is shown in Table 5.

From Table 3, it could be concluded that the system had detected right and left movement of the face

Table 5: Confusion matrix for open mouth detection

Actual Class	Detected Class	
	Jumped	Not Jumped
Jumped	91	5
Not Jumped	2	96

and the opening of mouth with 96.93%, 97.95% and 96.39% accuracy respectively. In average, the accuracy of the system was 97.09%.

Associated Delays

The character could move from one corner to the another within the frame of size 800 by 600 with continuous detection of either left or right face turn was 8.080 seconds. The total time for the character to make a jump and fall to the ground was 2.256 seconds. These delays will be helpful in future to measure the alertness of the users.

User Interface

The priority was given to the simplicity and ease in interaction during the design of the user interface (UI). The user interface was shown in Figure 5. The character of the game made its movement either left or right based on the turn of the face to either left or right respectively. With such head gestures, users could navigate the character to desired position within the UI. In order to eat the fruit, the character needed

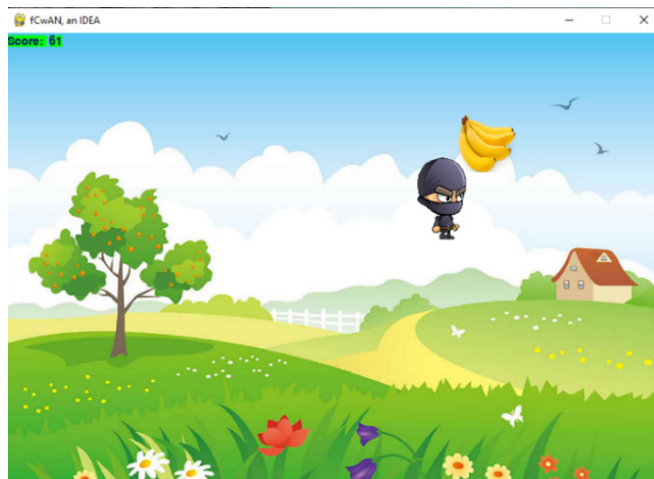


Figure 6: Character Jump to Eat the Fruit

to jump and touch the fruit and for the jump of the character, user had to open their mouth. The jumping action of the character to eat the fruit is shown in Figure 6.

When the character touched the fruit, a new random fruit would appear in a random place as shown in Figure 7. At the same time, the score would also increase.

Impact Analysis

The impact of the system to users was analysed by testing the system first with five neurotypical children.

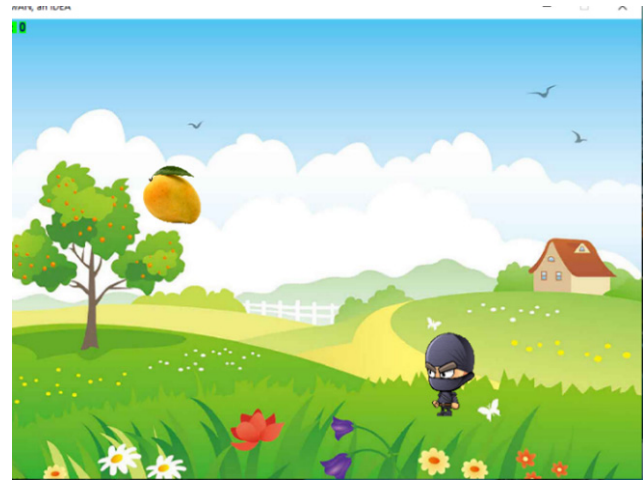


Figure 7: Next Fruit Appeared on the Screen

Four different parameters like age, learning time, performance and entertainment were considered. Three people that included one of their teachers,

Table 6: Impact analysis of the App

Age	Learning time (in minutes)	Time spent on playing (in minutes)	Total score secured	Entertainment (out of 5)
11	1	5	22	4
13	Less than 1	4	45	4.5
8	3	8	15	4
9	2	7	20	4
4	3	15	32	5

one of their parents and one of the project team members were chosen for the evaluation of the entertainment level of the child. The evaluations were based on their expression, excitement and also a query to them. The observations are shown in Table 6.

During the test on two individuals with autism, different responses were observed. The impact of the app on highly varied depending upon their intellectual abilities and their past experiences with laptops. The first individual showed higher interest in the game than the second child. He tried his best to catch the fruit and was pronouncing the name of the fruit after he made the gaming character touched it. The second individual got excited on knowing that he could control the jump of the character by his facial gesture. In overall, it could be concluded

Table 7: Observation data of the CWA

Age	Ability/ level	Performance	Involvement
15	Verbal (2 to 3 words)	Scored 27 within 25 min	Intermediate
15	Non-verbal, hyperactive	Scored 4 within 10 min	low

that the system excited them and could grab their attention for a certain period and was helpful in teaching a few words as well as to connect with the app. The observation during the test on children with autism is shown in Table 7.

However, it was also observed that the children didn't feel ease with head turn as they can't see the character movement when their face is turned in certain directions. This became more prevalent with the children with autism as they lost their attention when their face turned too far. Hence, the other head movement like tilt can be more effective.

CONCLUSION

This paper discussed desktop application that introduced a game that could be helpful for the children to teach them new words. The system had the sensitivity of 97.87%, 95.83% and 94.79% for right turn, left turn and mouth open respectively. Likewise, specificity of 96.07%, 100% and 97.95%. The accuracies were obtained as 96.93%, 97.95% and 96.39% respectively. The time for character to move from one corner to another was 8.080 seconds and the jump time (ground-peak-ground) was 2.256 seconds. The system was found to be effective when tested with the neurotypical children as well as with the children with autism to teach them few words. Thus, it can be concluded that the system can be a foundation for the enhanced learning for people with autism to identify and learn the names of different objects.

Since the system is basically a desktop application, its usage was limited to the laptop. However, this can easily be built in a more portable system like raspberry pi with smaller processing units. Also, the system can be enhanced in the future with additions of other functionalities such as login, session limit, alertness calculation, verbal communication etc and also with the experimentation with other head movement rather than the head turns.

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ABOUT AUTHOR(S)



(Sachin Shrestha) has completed his Masters in Information and Communication Engineering from IOE, Pulchowk Campus. He has been involved in teaching profession for the last 15 years and is currently working as Associate Professor at Nepal Engineering College, Changuarayan, Nepal. His research interests are ultra-low powered system design, biomedical signal processing, embedded system design, image processing and high-tech system design for disability



(Amit Shah) has completed his Masters in Information and Communication Engineering from IOE, Pulchowk Campus. He has been involved in teaching profession in engineering colleges for 19 years and is currently working as Associate Professor at Nepal Engineering College, Changuarayan, Nepal. His research interests are bio-signal processing and high-tech system designs for disability



(Niraj Dhakal) has completed his Bachelor's Degree in Electronics and Communication Engineering from Nepal Engineering College, Pokhara University. He has done projects in his college life related to high-tech assistive technology for disability.



(Pawan Dhakal) has completed his Bachelor's Degree in Electronics and Communication Engineering from Nepal Engineering College, Pokhara University. He has done projects in his college life related to high-tech assistive technology for disability.

Impacts of Micro Hydropower Plant on Rural Livelihood: A Comparative Analysis of Households in Lamjung District

Sujit Ghimire ^{a,1}, Khem Raj Sharma ^{b,2,✉}

^aTransmission Directorate, Nepal Electricity Authority (NEA), Kathmandu, Nepal

^bSamunnat Nepal Guthi, Kathmandu, Nepal

Email ID: ¹sujit.ghimire150@gmail.com, ²khemrajonline@gmail.com

KEYWORDS

Micro Hydropower
Livelihood Assets
Rural People
Lamjung
Electricity

ABSTRACT

This study aims to assess the impacts of micro-hydropower on rural livelihood assets in Ghamrang, Mapping, and Ghiche villages of Lamjung district. The livelihood assets were taken from the Department for International Development (DFID) sustainable livelihood framework, which include human, natural, financial, social, and physical capital. The main instruments used for primary data collection were household interviews, key informant interviews, and focused group discussions. Access to electricity has increased the enrollment of children in formal School and has motivated them to study. It has positive effects on the villages in multi-dimensional ways such as lighting, operating television, radio, and computer. Similarly, electricity has indirectly forced the people in modern agriculture such as farming black cardamom. Rural electrification has also provided opportunities to get the latest and useful information to the rural people; they got news and views of national and international importance and got useful tips for their occupational betterment from radio and television. Results revealed that the people in electrified areas were more socially active and got involved in community organizations. It was evident that micro-hydropower has played a positive role in improving the livelihood assets of rural people in the study area.

INTRODUCTION

Hydropower in the form of electrical energy is obtained from the generators coupled with turbines, which converts hydraulic energy into mechanical and electrical energy. Hydropower with an installed capacity of less than 1000 Kilowatts (KW) is classified as micro-hydropower [1]. Due to geologically complex terrain along with technical, economic, and financial reasons of the country, Nepal Electricity Authority (NEA) is unable to connect grid based electricity systems all over the country [2]. Micro-hydro was widely initiated during the decade of 1960s in Nepal. The Micro-hydro was widely initiated during the decade of 1960s in Nepal. Micro Hydropower is environment friendly, cheaper in operation, and maintenance cost that provide opportunity for rural electrification; and affordable, and renewable source of energy for lighting, and rural enterprise development. Micro-hydropower projects are initiated as assistance to villagers and are not treated as revenue generating projects for the nation. They are usually built under Government subsidies. In addition, being a community-based project, many rural households are being added for lighting their houses through these MHPs and it has

helped to preserve the surrounding local environment [3]. Energy generated from micro-hydropower could be used for small and medium scale enterprises like sewing machines, welding shops, rice mills, computer institutes, and telecommunication centers at local level, which create employment opportunities and enhance rural communities' economic and social status [4].

METHODOLOGY

Study Area

The study was conducted in Lamjung district in the Gandaki Province of the Federal Democratic Republic of Nepal. The study area is about 80 km north-east of Pokhara, Kaski. It was decided to study three electrified villages in Kwholasothar Rural Municipality of Lamjung District, Ghamrang, Mapping, and Ghiche, as well as a non-electrified village, Gilung.

Data Collection

Primary Data

Primary data were collected from the field study. The tools used for primary data collection for this study

were Household Interviews, Key Informant Interviews (KIIs), and Focused Group Discussions (FGDs). Questionnaires for the field survey were developed. Collected data were verified by key informant interviews. The KII was done with a few selected key-personnel in the study area.

Household Interview: There were a total 155 households in the electrified villages and 151 households in the non-electrified village. The sample size was calculated by using statistical formula mentioned below [5].

$$n_0 = \frac{z^2 * p * (1 - p)}{e^2}$$

Where, $z = 1.645$: taking confidence level of 90%

p = degree of variability; taking 0.5

e = level of precision; taking $\pm 10\%$

For small population the sample size can be adjusted by using formula

$$\text{Adjustable sample size, } n = \frac{no}{1 + \frac{no - 1}{N}}$$

Where, N = Total number of households

To obtain an unbiased result, 48 samples of households were fixed from both electrified and non-electrified villages.

Key Informants Interview (KII): The KII was conducted for the verification of received data from household interviews. KIIs were done with the Chairman and Operator of micro hydro plant, teacher of secondary school, Chairman of Kwholasothar Rural Municipality Ward Number 8, leader of Mother Group, and Retail Shops in the study area. Number of key informants was fixed based on information facilitation.

Focused Group Discussion (FGD): From electrified villages, a Micro Hydropower Functional Group was selected for FGD, and a self-created second group was considered from non-electrified villages.

Secondary Data

Most of the secondary data were collected from reviews of articles, journals, reports and published documents. The literature -- both published and unpublished -- was taken for review.

RESULTS AND DISCUSSION

Impacts of Micro Hydropower Plant on Livelihood Assets

Human Capital

One of the important livelihood assets is Human Capital; it represents the skill, knowledge, education, and health status of the rural people.

Impact on Education: According to the interviewed key informants, most of the rural people were not able to contribute money for an expensive source of lighting such as kerosene, dry cell batteries et al.

With sufficient light from electricity, students were able to do homework and study at night time; due to this, children were motivated to enroll in schools of electrified villages. They also said that the rural children did not have sufficient time for doing homework during daytime. This indicates that electricity can directly influence the education status of the rural community.

Effect on Children's Study Hours: According to the respondents from non-electrified villages, their children used kerosene lamps while studying at evening and nighttime, but by this system, they cannot study for a long time due to deficiency of enough kerosene for lighting. However, the electrified villagers opined that the performance of their children had improved in school due to an increase in the study hour at night. Therefore, the electricity from MHP plays a positive role to improve the children's duration of study at home.

Women Empowerment: Survey reveals that women respondents from electrified villages have sufficient knowledge and ways about electricity facilities; they have been able to manage their time in different productive work. More women from electrified villages were involved in some productive activities such as small grocery shops, modern agriculture, Cardamom farming, and small business. The electric light also makes it comfortable at night time especially for women and children. Due to sufficient electric light at night time, women were involved in cleaning and drying of Cardamom till late hours. Cultivation of Cardamom has been introduced as a commercial crop in the area.

Impact on Income Source of Households: Survey data reveals that 43% of households are depending on agriculture in electrified villages because people have been engaged in Cardamom farming. Local farmers mentioned that prior to electricity supply the cleaning and drying of raw Cardamom was delayed and got expensive due to lack of workers but now with sufficient light from electricity the cleaning & drying of Cardamom was done easily at night time. The main income source of non-electrified households mainly depends on remittance from foreign employment and they are not interested in engaging in small business activities at the local level. Hence, it can be concluded that the Ghamrang MHP has contributed to involve the people in modern agricultural activities especially black cardamom farming.

Impact on Knowledge and Skill: The use of electrical instruments has contributed to multiple changes in the children's behaviors. People said that they found a change in their thinking after use of electrical devices. Survey data showed that in electrified villages 96% of people used electronic devices such as TV, radio and computer. By using Television, people can listen as well as watch the things happening on a national and international level. Learning by seeing is faster and easier than only hearing. Only 41 % of people used those devices in the non-electrified village using energy from home-solar systems and Dry cell batteries. It can be concluded that due to electricity

people were close to the media, they were interested in new technology.

Natural Capital

Natural assets denote the natural resources stock from which resource flows and services are made useful for livelihoods. In the rural development context depletion and degradation of renewable resources such as forest, land, and water is the central interest. So, in questionnaires for natural capital more focus was put on the exploitation of forest area, water, environmental services, and dependency on it.

Respondents of electrified villages revealed that Ghamrang MHP has created the awareness of proper watershed management and regeneration to secure sustainable use of water. Moreover, electricity replaced the Kerosene and firewood burning for lighting in villages and contributed to the reduction of emission of smoke. They also pointed out that before the construction of MHP there were problems of soil erosion and landslides around the powerhouse area. No landslides and soil erosion occurred around the powerhouse area since the construction of MHP as MHP had carried out slope protection works to protect its powerhouse. Hence, Micro hydropower played an important role in the conservation of forest, land, and water in Ghamrang village of Lamjung district.

Sources of Energy for Cooking: Firewood is a major energy source for cooking in both electrified and non-electrified villages. There was no significant difference between the percentage of the households who used firewood for cooking in electrified and the non-electrified village. Due to insufficient power production from Ghamrang MHP for cooking purposes, the pattern of firewood consumption has not changed. Respondents from the electrified villages had opinion that micro-hydro has contributed to protect forest areas especially some trees from the forest areas, which used to be used for lighting purpose before the installation of micro hydropower. It also indirectly supports the protection of the environment.

Sources of Energy for Lighting: All the households from electrified villages used electric energy for lighting. However, in the non-electrified village the major source of energy for lighting was the solar-home system where 20 households had installed it out of 48. Some households in the non-electrified village used kerosene and candles for lighting. The pattern of use of a source of lighting energy for the non-electrified area has been presented in figure 1. It was found that

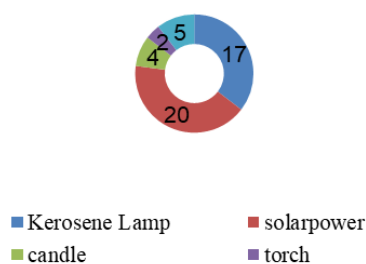


Figure 1: Number of households used energy for lighting purposes in the non-electrified village

during the survey the initial installation cost of solar panels was about NPR. 25,000 per set, so all of the households could not afford to install the solar-home system. The survey reveals that the electrified villages are illuminated at night and do not need another source of lighting but in the non-electrified village, it is just the opposite.

Financial Capital

Cash in hand, savings, liquid assets, and access to credit in the form of loan, pensions, and remittances are the fundamental financial capital for rural households. Financial assets are particularly important because money can readily be converted into other assets.

Economic Status of Village People: In the study area, both electrified and non-electrified villages, most of the people living are Gurung and they have different kinds of lifestyle and the culture. Most of the households in an electrified village were involved in modern agriculture. As said earlier, people revealed that black cardamom farming is the main cash crop for income generation. Besides that, Paddy, Maize, Potato, and Buckwheat were also cultivated. The volume of local food production was low, on average local food is sufficient for feeding the villagers just 6 months. They managed food for the remaining period from outside the village. Furthermore, most of the economically active young people were working in foreign countries. They sent money through the remittance to the village, which was another source of income in that area. Some Gurung youth were also employed in the Indian army. Most of the young people in the area have a tendency to work outside the village. Some of the pension-holders, women, and children are living in the village. The settlement was densely housed and the houses are roofed with corrugated galvanized iron sheets, which is a sign of economic wellbeing. At start, the respondents said that MHP has given sufficient light at nighttime so they got engaged in cleaning and drying the raw black cardamom at nighttime.

Annual Income: The above discussion reveals that the major source of income of the electrified village is agriculture and non-electrified villages have received remittances from foreign employment. From the households survey it was found that in the electrified village most of the higher-income-generating households earned money from selling black cardamom. But, in the non-electrified village major income depends on remittances from foreign employment. Figure 2 also shows that the annual income is more in the electrified village as compared

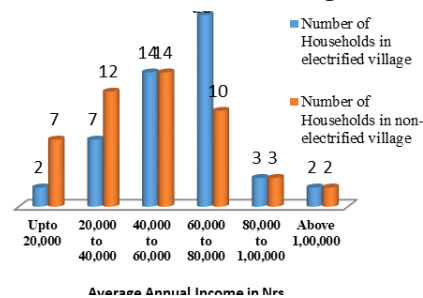


Figure 2: Average annual income of electrified and non-electrified households

to non-electrified village. Hence, micro-hydropower has directly or indirectly contributed to the increase the annual income of rural households in the study area.

Per Capita Income: Total average per capita income is calculated by dividing the total income by the total population of the surveyed area. The total income of an electrified village is slightly higher than a non-electrified village. The gross per capita income at the national level is 866.48 US\$ (In 2017) which also included the income of people living in an urban area. The gross per capita income of an electrified village has been calculated as NRS. 48388.34/-. However, a non-electrified village has a per capita income of NRS. 37437.30/- in 2017. Survey data revealed that agriculture was the major occupation of the people in Ghamrang village. More than 80 % of farmers revealed that the involvement of villagers has increased towards the black cardamom farming after establishing MHP in Ghamrang. So, it can be concluded that electricity has played an indirect role in the income generation in the rural area and promoting modern commercial farming.

Social Capital

In the livelihood framework, social assets encompassed the analysis of the membership of formal groups, decision-making, leadership, social inclusion, and organization development in the study area.

Female Involvement in Community Organization: It was found that people in an electrified area were more active in social work and they were interested in getting involved in different organizations of the community. Figure 3 indicates that 35% of the female population was involved in the community organization from an electrified village which was only 12% from the non-electrified village. In an electrified village, women were encouraged to participate in monthly meetings. There were only four community meetings conducted in a non-electrified village but eight meetings were conducted in an electrified village in 2017. According to the female respondents, participation in community meetings has improved their confidence level. Hence, it can be concluded that the involvement of women in community based organization has been considerably increased in an electrified village as compared to a non-electrified village.

Micro Hydropower Functional Group: Reference

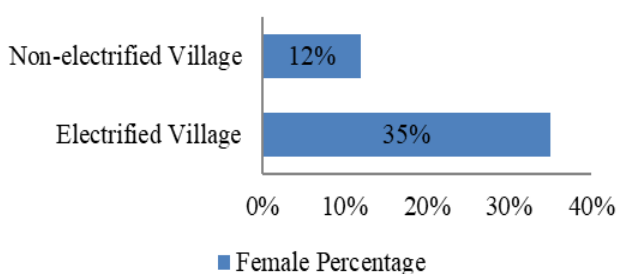


Figure 3: Female Involvement in community organization

[6] shows that the Community Organization (CO) is established by the representation of one male and one female from each household. One member from each CO is selected and sent to the functional group. In the functional group, the Chairperson and the manager are chosen from the members of a functional group. These people play a great role in the whole life cycle of the project, from the beginning of the planning to the management of the micro-hydro plant.

The Ghamrang MHP Functional Group was established by the participation of one male and one female from each beneficiary household. Eleven members of a functional group have been selected from the community organization with a minimum of five female members. The Chairperson was selected by those eleven members of the Functional Group.

Physical Capital

Physical assets are infrastructure and goods needed to support livelihood. Physical infrastructure included the use of electricity further its linkage with basic tools such as transportation, communication, drinking water, source of energy, and market-condition. Physical assets can be regarded as manmade assets that can substitute natural capital in many circumstances. In a livelihood framework, the physical capital of local communities was also studied. In physical assets, attempts have been made to examine the impact of electricity on communication, health status, family planning, and market availability.

Use of Mobile Phone: Now-a-day mobile phones are generally affordable, easy, and important communication devices. Mobile phones help to contact their relatives from the rural area to an urban area or other places. It was observed that among the people of non-electrified villages they have difficulties in charging their mobile phones. Usually, they charge their phones in 3-4 days from neighboring electrified villages or from the houses with installed solar power. Survey data revealed that only 65% of households have mobile phones in the non-electrified village. But 92% of households use mobile phones in electrified villages. Thus, a significantly high percentage of people used mobile phones in electrified villages due to access to a charging facility from micro-hydropower.

Media: People are getting access to television and FM radio which have provided instant information covering the latest news. Due to the free and clear television signal available in mountainous areas of Nepal, the trend of use of TV is increasing day by day. During evening time villagers generally get together to share news and details about social activities in the study area. This has contributed creating social harmony among the village people.

It was evident that frequent uses of media in both electrified and non-electrified villages were TV and Radio. Survey data shows that 80% of households from the electrified village are using television as a major source of media which was only 32% from non-electrified households. Similarly, 78% of households were using radio in non-electrified villages whereas only 52% of households in an electrified village

were using radio. Various things were learned and gained from watching television. Access to media helped to increase awareness about family planning, communicable diseases, and health care of the people in electrified villages. Hence, electrification has immensely promoted the use of visual media in this rural area.

Market: Electric light allows shops in the village to remain open till late evening, thus increasing their business hours. Also, the availability of loans from the local savings and credit group has allowed shop owners to expand their undertaking.

Health: Due to availability of electricity from the MHP better health service from an electrified village of the study area has been provided as compared to the non-electrified village. As per the field survey in 2018, 76% of people from a non-electrified village had visited hospitals in 2017; this was 14% more than the electrified village. Common cold and fever were common health problems faced by the rural people in the study area. Some people irrespective of an electrified or a non-electrified village suffered health problems like blood pressure, diabetics and other minor heart problems.

CONCLUSIONS

This study was focused on assessing the contribution of micro-hydropower plants on improving the rural livelihood assets in a typical rural area in the mid hills of Nepal. Two rural settlements of the Lamjung district of Gandaki province, with and without micro-hydropower plants were selected for the study. In this study, five main livelihood assets were compared which were human, natural, financial, physical and social capital of the people in the study area.

Based on the survey result, electricity has contributed to promote education in these rural areas. People from electrified villages were more empowered in terms of using electronic devices such as TV, radio, and mobile phones. Women from electrified villages were involved in various productive activities such as Cardamom planting and processing. Electricity has also played an important role to enhance the skill, knowledge, education, and health status of rural people. Micro hydropower has encouraged the people in productive activity in order to make them financially better off resulting in improved livelihood. Most of the people from electrified villages were actively participating in social organizations. Thus, this study comes to conclude that the Ghamrang MHP has played a positive role in improving the livelihood assets of the rural people.

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ABOUT AUTHOR(S)



(Sujit Ghimire) has completed M.Sc. in Interdisciplinary Water Resource Management from Pokhara University in 2019. He is currently working as an Engineer in Nepal Electricity Authority (NEA) since January 2019. His fields of research interest are Water Resource Management and Hydropower development.



(Khem Raj Sharma) has received his PhD in Soil and Water Engineering from Central Luzon State University, Philippines in 1992 and Master of Engineering from University of Philippines in 1983. He has over 45 years of experience in the field of water development projects especially in construction, irrigation and water supply. He worked as a research director in the Department of Irrigation of Government of Nepal for over a decade. Currently Dr. Sharma is working as a Visiting Professor in Nepal Engineering College. He is a board member of Samunnat Nepal Guthi, Kathmandu, Nepal.

Domestic Waste Generation and Management Practices in Birtamode Municipality, Jhapa, Nepal

Pratistha Bhurtel^{a,1,✉}, Robert Dongol^{b,2}

^aGolden Gate International College, Tribhuvan University, Nepal

^bNepal Engineering College, Pokhara University, Nepal

· EMail ID: ¹email1@nec.edu.np, ²robert@nec.edu.np

KEYWORDS

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Household
Socio Economic
Waste Composition

ABSTRACT

Urbanization and increasing population are push factors for increased waste generation thereby adding complications in its management. Birtamode Municipality is a newly formed municipality where solid waste management is becoming a huge challenge. Therefore, this paper presents the status of solid waste generation, composition and management practices in ward number 2 of the municipality. The solid waste was collected from the surveyed households (determined by Cochran's formula), selected following systematic sampling method. Additional information was gathered from key informant interview and literature review. A total of three hundred and forty (340) households were surveyed through a questionnaire to elicit information on the socio-economic characteristics of the respondent households that contribute in waste generation, handling and management. The average waste generation and average waste per capita generation was found to be 0.414 kg/HH/day and 0.100 kg/person/day respectively. The major waste composition was dominated by organic (82.96 %) followed by plastic (10.98 %), paper (2.76 %), bottle/glass (1.25 %), metal/tin (0.33 %), textile (0.37 %), rubber (0.25 %) and others (0.29 %). The highest fraction of waste generation was observed in upper middle socio-economic group. The waste generation at household is directly proportional to household's family size ($P=2.89E-19$, $r=0.08338$), education ($P=0.006931$, $r=0.032$) and house type ($P=0.034051$, $r=0.05311$). However, other variables like days, ethnic group, occupation, and gender did not show any significant effect on waste generation. Majority (91 %) segregate their waste, of which 11.11 % respondent compost their organic waste; 88.56 % burn the plastic and paper; 35.94 % reuses the textile; glass and E-waste are mostly buried and thrown. 69.93% respondents showed their willingness to pay for the better waste management services. It was found that municipality collects waste irregularly from market area and therefore only household near main roads can receive the service of waste collection.

INTRODUCTION

Waste comprises of discarded substances from households, industries, chemical industries, and health care services. If any other substances exist, found or disposed in an environment that could cause adverse effect on environment are called waste [1]. Solid waste management is a challenge for the city authorities in developing countries mainly due to the increasing generation and changing of waste stream, the burden posed on the municipal budget because of the high costs associated to its management, the lack of understanding over a diversity of factors that affect the different stages of waste management and linkages necessary to enable the entire handling system functioning [2]. Municipalities have the responsibilities for Solid Waste Management, ever since it has been accounted as the job of the government. The municipality of developing nation has always been facing a problem to meet the objective set by the government "they often face problems beyond the ability of the municipal authority to tackle" [3]. Developing nations face huge problem then

developed nations in the case of waste management. "The challenge of urban solid waste is particularly peculiar to developing countries, where resources are limited but urbanization is occurring rapidly" [4]. In Nepal, only few municipalities have proper landfill for the final disposal of waste. For the sound management of solid waste, it is important to know the waste characteristics [5]. The determination of size and type of landfill needed is based on the volume, characteristics of waste generated and adoption of waste reduction practices at households, community and municipality level. Solid Waste Management and Resource Mobilization Center (SWMRMC) had carried out baseline survey to collect the SWM baseline information at national level in 2003 for the first time and second time in 2016. The total municipal waste composition showed that the highest fraction was organic matter and dominant fraction was paper products in institutional waste in Nepal [6]. The waste remains no more waste if it is properly managed and valued. Besides this, effective local governance system, level of awareness and sharing of responsibility are

also equally important for effective and efficient solid waste management [7].

MATERIALS AND METHODOLOGY

The study area lies in Jhapa district of the Province number 1 of Federal System of the country. It is situated at 122 m elevation and is located at latitudes 26.629307" and longitudes 87.982475". The selected ward number 2 of the municipality spreads over an area of 17.7 sq.km. The total households of study area is 3,042 with population 17,420 [8].

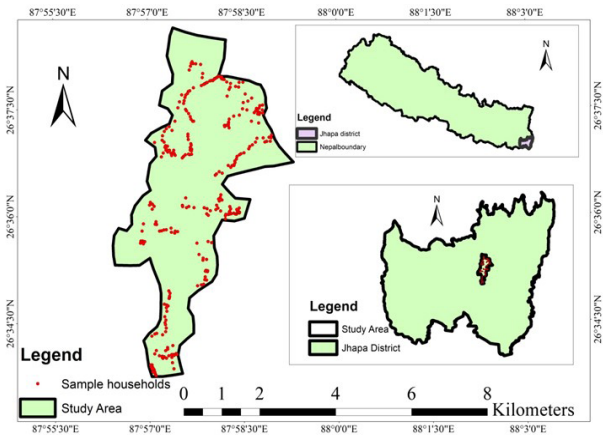


Figure 1: Map showing detail of study area

The study started with the determination of the required sample size using Cochran’s formula [9] for household survey, mainly to collect the information on family size, income and expenses and practices of 3 R principles etc. as shown in equations (i) and (ii), and then the required number of samples was proportionately divided based on the types of houses within ward 2.

$$n_0 = z^2 p q / e^2 \dots\dots\dots (Eq. i)$$

Where, z = Confidence level (95%) = 1.96
 e = Level of error (%5)
 $p = q = 0.5$

$$Sample\ size\ (n) = \frac{n_0}{1 + \frac{n_0}{N}} \dots\dots\dots (Eq. ii)$$

Where, N = no. of household

The required number of samples was selected through systematic sampling method for which sampling interval was calculated with the help of the equation (iii).

Sample interval (N) = total number of household in the ward/ total number of required sample size .. (Eq. iii)

Each household was given two different plastic bags to put the organic and inorganic waste generated within 24 hours separately [10] [11]. The respective plastic bags were collected next day and characterization of the waste was done. The waste collection was carried with the same households where the questionnaire survey was conducted. A total of 340 houses were surveyed for the household waste generation collection, where each household was provided with two polythene

bags. Although, 340 households were initially part of the study, waste was collected from 306 houses only because few households forgot to put the waste in the provided bags. Similarly, Key Informant Interviews were also conducted with the representatives of the key agencies responsible for the waste management to assess the challenges and opportunities towards proper management of solid waste in the municipality. Research reports, articles and unpublished reports were referred for the secondary information and data related and relevant to the study.

For the processing and analysis, the data collected was collated and analyzed using inferential statistical techniques. These include chi square test, correlation and multiple regression analysis to achieve the objectives of the study.

- The chi- square test measures the significant effect between the selected socio-economic variables and the quantity of waste generated in the study area.
- The multiple regression analysis was used to examine the effects of the changes in the independent variables over the dependent variables. The R2 was also reported to measure the goodness of the fit of the model.

RESULTS AND DISCUSSION

Waste Generation and Composition

The composition of waste was organic waste (82.96 %) followed by plastic (10.98 %), paper (2.76 %), metal/ tin (0.33 %), textile (0.37 %), dirt (0.76 %), bottle/glass (1.25 %), rubber (0.25 %) and others (0.3 %). Table 1 presents the various amount of waste generated by the households on daily basis. In Birtamod, per capita waste generated was 100 gm/person/day that is nearly like the baseline data study conducted for 60 new municipality of Nepal which showed that the per capita household waste generation was 115 gm/ capita/day [6]. The waste generation rate of Nepal is 0.12 kg capita-1 day-1 [12]. The result showed that the per capita waste generation was little lower may be because the study area is in rural area. Literature shows that most of the solid waste composition in the developing countries is biodegradable organics. In India, Bangladesh and Sri Lanka the percentage of organic waste was found to be 65 %, 78 %, and 65 % respectively (ADB, 2011). Rates in other studies are 0.4 kg capita-1 day-1 [13], 0.4 kg capita-1 day-1 [14], 0.52 kg capita-1 day-1 [15], 0.52 Kg capita-1 day-1 [16], 0.66 kg capita-1 day-1 [5], 161.2 gm capita-1 day-1 [11], 115 gm capita-1 day-1 [6]. Socio-economic status of the

Table 1: Amount of daily waste generated

Amount of waste/ day (kg)	No. of house	Percentage (%)
Less than 0.5 kg	231	75.49
0.5-1 kg	59	19.28
1-2 kg	16	5.22
Total	306	100.00

households also influences the municipal solid waste generation in Bangladesh [3].

Statistical analysis of different parameters

Waste from the 306 households were analyzed and measured in kg/capita/day by dividing the total wastes in wet weight basis by the number of people residing in each household. The average family size of the sampled households of ward 2 was calculated to be 4.2. The per capita waste generation was 100 gm/person/day. The total household solid waste generation equals to 1.26022 tons/day. The median value of the data is lower than the mean. This is consistent with the positively skewed distribution of waste data. From the histogram (Fig: 2), average household waste generation was 0.414 kg/day. The kurtosis value is positive and <3 showing the data is highly peaked and random distribution of generation rate. The corresponding standard deviation was 0.333.

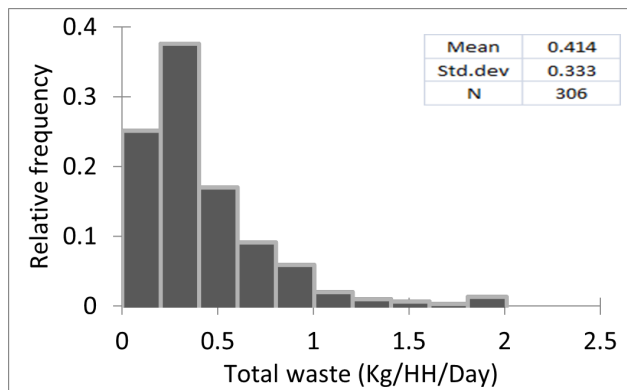


Figure 2: Histogram of daily waste

Educational background was significant with positive coefficient value of 0.032213 showing that waste generation increases with the increase in the educational background (Table 2). The family size socio-economic variable is also positive and significant at 5 %. Finally, family income is also significant but the coefficient $2E-06$ is not high. Therefore, it does not show any positive relation. From table 2, house type, family size, education and income were found to be the significant at 5 % among the other socio-economic variables such as (gender, ethnic group and occupation). Furthermore, it is insignificant and there

Table 1: Chi-square analysis of different between socioeconomic variables and amount of total household waste generation

Socio-economic Variables	Degree of freedom	X2 Calculated	Significant level
Education	14	23.7053	0.04972**
House type	6	12.2908	0.05579 **
Occupation	14	21.409	0.0916
Gender (waste handling)	8	7.7876	0.4545
Ethnic group	12	10.9185	0.5359
Family size	10	75.9028	0.0000 **
Income	20	55.5847	3.356e-05**

is no strong correlation between gender, ethnic group and occupation based on the ($P>0.05$).

The household waste generation rate went up with larger families (Fig. 3). From the statistical data the waste generation of household was found to be significant: $2.89E-19$ with family size. The results are corroborated with the finding [5]. A strong correlation between waste generation rate and the family size in their studies was recorded [3].

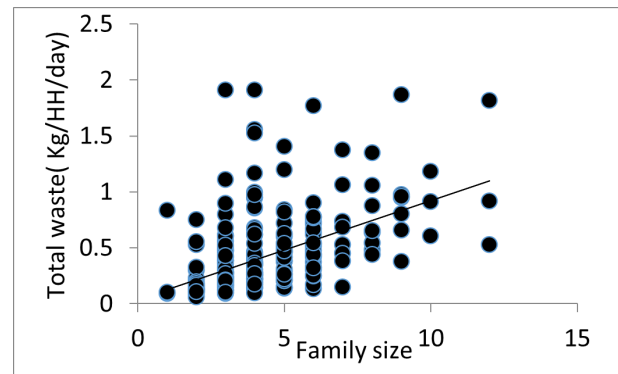


Figure 3: Family size and waste generation

The waste generation was found to be significant with income: 0.025 but the nearly zero coefficient value showed no any high increase or decrease in the dependent variable due to change in independent variable i.e. this particular study does not find a positive correlation between income and wastes generated. The difference in the economic strata of the houses with the income level showing positive relation between income and waste generation [5]. The relation between the waste and income was not positive may be due to the more percentage of respondent with middle income and the waste generation being high in middle income socioeconomic group. The waste generation was found to be significant with house type with positive coefficient 0.05311. This showed that with the increase in the house type from mud to cement the waste generation has significantly increased. The education level was however significant with positive correlation.

Table 3: Physical composition of HSW by different socio-economic group (%)

	LSEG	LMSEG	MSEG	UMSEG	HSEG
Organic	11	43.23	26	12.14	2.25
Plastic	1.12	6.11	2.43	1	0.1
Paper	0.25	1.03	1.23	0.1	0.15
Metal	0.08	0.12	0.02	0.14	0
Textile	0.08	0.15	0.13	0	0.04
Dirt	0.01	0.36	0.33	0.015	0.04
Bottle	0.05	1	0.12	0	0.2
Rubber	0.003	0.2	0.05	0	0
Other	0.14	0.07	0.14	0	0

Note: LSEG: Lower socio-economic group; LMSEG: Lower middle socio-economic group; MSEG: Middle socio-economic group; UMSEG: Upper middle socio-economic group; HSEG: Higher socio-economic group

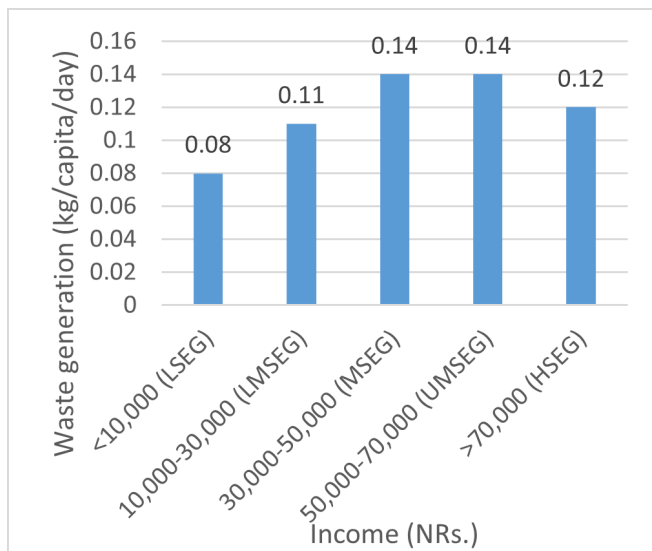


Figure 4: Average per capita waste generation by different socio-economic group

The fraction of both organic and plastic waste was seen to be highest in Lower middle socio-economic group (LMSEG) (Table 3).

The difference in the waste generation may be due to a variation in the consumption pattern and high percentage of the households in middle income group. The highest per capita waste generation was observed in the upper middle socio-economic group and lowest per capita waste generation was observed in the lower socio-economic group (Fig. 4).

It was found that there was no significance difference between days of week and waste generation. ($F_{6, 296}=1.322$, $P\text{Value}=0.2472$) (Fig. 5). Similarly, there was also no significance difference between ethnic group and waste generation. ($F_{6, 299}=1.091$, $P\text{Value}=0.3677$) (Fig. 6). Only the difference was observed in Aadibasi with lowest waste generation among the Ethnic group. The waste generation in Aadibasi was found to be low with p -value $7.82e-11$. The lowest waste generation in Aadibasi may be due to the consumption pattern or tradition way of waste management. Aadibasi also includes the Shantal group that is observed to be the

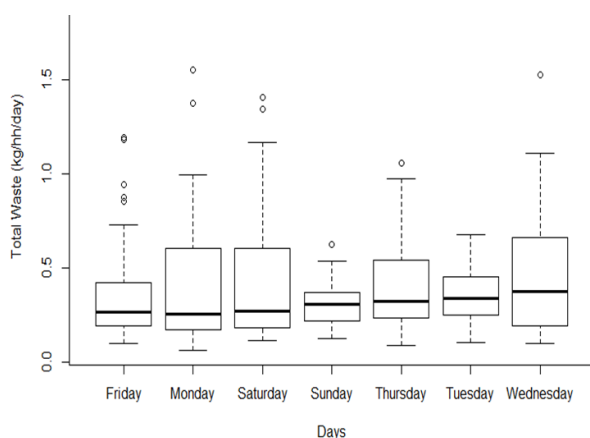


Figure 5: Box-Whisker plot of Household Waste generation with days of week

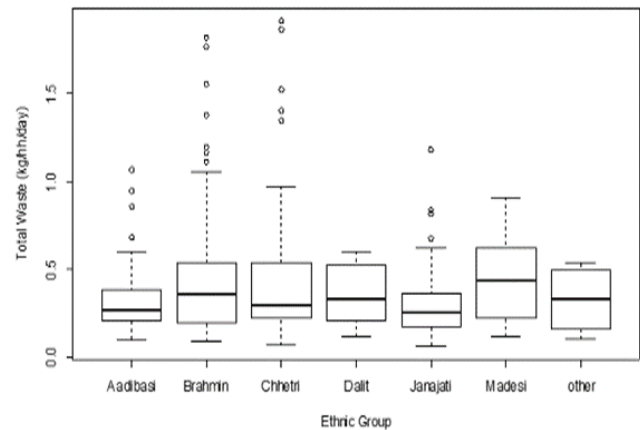


Figure 6: Box-Whisker plot of Household Waste generation with Ethnic group

lowest income generators among the entire ethnic group and still follows the traditional lifestyle like living in a mud house, consumption of some typical fauna and flora species etc.

The $R^2 = 0.30$ of the multiple regression implies that only 30 % of solid waste generation is explained by the variables such as roof type, education background, family size and family income (Table 4). In addition, it

Table 4: Multiple linear regression analysis of the socioeconomic variables and household solid waste generation

	Coefficients	Standard Error	t Stat	P-value
Intercept	-0.270	0.091296	-2.95872	0.003334
Income	2E-06	8.78E-07	2.280825	0.023257
Education	0.032213	0.011848	2.718865	0.006931
Roof type	0.05311	0.024944	2.129183	0.034051
Family size	0.08338	0.00867	9.616576	2.89E-19

* $R^2=0.30$, Significant level at 0.05

also indicates that there are some other factors that could affect household solid waste generation apart from the socio-economic variables like lifestyle, consumption behavior or seasons.

WASTE MANAGEMENT PRACTICES

Waste management at household level

Waste management practices such as composting, burning, reusing, collecting, and restoring at households are common. The table 6 represents the percentage of households with waste management practices for different types of waste. Of the respondents, 91 % segregate the waste where 11.11%

Table 5: Gender involve in waste handling

	Household number	Percentage
Male	27	9
Female	179	59
All the members	16	5
Both	84	27

Table 6: Management of various types of solid waste at the households

Organic waste	Dump into pit	Compost	Feed animals	Throw		
	44.44	11.11	30.71	13.73		
Plastic and paper waste	Burn	Sell	Throw	Collect	Bury	Reuse
	21.24	19.28	7.18	14.05	2.28	35.94
Glass/bottles	Sell	Throw	Collect	Bury		
	1.96	40.84	10.13	47.05		
E Waste	Throw	Sell	Collect	Bury		
	47.38	16.01	14.37	22.22		

Note; All the values are in percentage.

compost; 21.24 % burn the plastic and paper; 35.94% reuses the textile; 47.05 % bury the glass, E-waste was mostly buried and thrown. 69.93% showed willingness to pay and 30 % were reluctant to pay for the better waste management services. Mostly females are involved in waste management at households. There are very few households where both male and female members of the family are equally involved in the waste management (Table 5).

Waste management at Birtamode Municipality

Birtamode Municipality has been managing solid waste and sanitation activities. The waste collection is done within the core urban wards of the municipality (ward number 1, 3, 4 and 5) with total households of 10,057 leaving 8,340 households of ward number 2, 7, 8, 9 and 10. Roadside waste is collected on daily basis by the tractors. Around 2.5 – 3 tons of waste is collected every day from the service area. There is no waste transfer station or permanent dumping side. The in-use dumping site is 500 m away from the core area. Birtamode Municipality is involved in transporting the collected waste using tractors. Birtamode Municipality has neither issued directives nor operate any compost plant for reducing the organic waste and also for resource recovery for the residual organic waste. There is not any separate solid waste management section in the municipality office. The solid waste in the municipality has been managed by 11 sweepers, 3 drivers with no technicians and supervisor. Some of the aspects that must be focused were awareness among the people, collaboration with Government and Non-Government Organizations, lack of equipment and vehicles. The major challenges are lack of technical manpower even after the availability of the resources, urbanization and increasing waste in the core area, roadside waste dumping and littering of waste by the people. The present dumping site is situated in a small area and nearby the road that is necessary to be replaced by permanent landfill site in the future. If these problems can be addressed, the waste can be managed properly and can be handled in a better way.

CONCLUSION

Housing roof type, family size and education are the significant factors among the socio-economic variables with positive contributions to household solid waste generation whereas ethnic groups, days of a week and occupation are not significant factors. It is

also necessary to focus on strict rules and regulations to manage the waste along the municipal territory. Similarly, lack of trained manpower and technicians, lack of awareness in the public who dump waste on the roadside and litter everywhere and difficulty in finding a permanent landfill are significant hurdles for proper waste management. Solving these problems is essential for a effective waste management system. Since the waste generation is dependent on various factors which were not considered in this study such as lifestyle and other need to be studied either independently or in cohort to indicate their magnitude of influence on the variation and on trend of waste. Resource recovery from the waste needs to be materialized at the municipality level through the formulation and implementation of the policy as local authority has been bestowed with the power to formulate and implement the needed policy at their own.

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ABOUT AUTHOR(S)



(Pratistha Bhurtel) had received her master's degree from Golden Gate International College and participated in many waste related volunteering programs. She has participated in research program "Cultural Landscape and Environmental Changes in the Himalayas" conducted by joint collaboration of Department of Geography and City & Regional Planning of California State in ACAP region. She has worked in organization with developmental background and citizen science program (CORAM-Community Rainfall Measurement) carried by ISET Nepal and RECHAM Consult.



(Robert Dongol) holds M.Sc. degree in Environmental Engineering and Management from Asian Institute of Technology in 2007. He is an Associate Professor at Nepal Engineering College (*nec*) and coordinate M.Sc. Interdisciplinary Water Resource Management (iWRM) program at its center for Postgraduate Studies. Prior to joining *nec*, Mr. Dongol had worked as an Research Associate in Sida funded ARRPET project. Mr. Dongol was also the team leader of IDRC South Asia Water (SAWA) Leadership Program on Climate Change (2017-2021).

Perceived Health Consequences of Wastewater Use in Urban Agriculture: A Case of Golmadhi in Bhaktapur

Puja Rai ^{1,✉}, Dharma Raj Bagale²

Department of Civil & Rural Engineering

Nepal Engineering College, Changunarayan, Bhaktapur, Nepal

Email ID: ¹yumiawaicha@gmail.com, ²dharmarb@nec.edu.np

KEYWORDS

Wastewater
Water Treatment

ABSTRACT

Wastewater is widely used for irrigation in Kathmandu Valley despite the lack of adequate treatment facilities. The farmers may experience mild to serious health impacts from using polluted water for irrigation. This study examines the perceived health consequences of the wastewater use in Golmadhi, Bhaktapur. Field observations, farmers survey, and key informant's interviews were carried out to get an overview of how they perceive the associated health implications. The study shows that the farmers in Golmadhi use raw wastewater and/or diluted wastewater due to the absence of other reliable sources and as a continuity to old wastewater use practice. The health problems such as fever, headache, and itchiness were also reported, but could not be directly associated with wastewater use. Wastewater use should not be prohibited as it is being practiced traditionally and it provides the livelihood for many households. Therefore, it is suggested that the farmers need to be made aware of the health guidelines that prohibit the cultivation of vegetables that are meant to be consumed raw. The gaps in the knowledge of the true extend of informal wastewater use must be addressed by the government through detailed assessment.

INTRODUCTION

People perceive the use of wastewater differently in different places. Some consider it as a valuable resource while others perceive it negatively because of the health risks associated to its use [1]. Wastewater is especially valued for its reliability, in arid regions, besides the added benefits from contained nutrients [2], whereas, in humid regions like Nepal, wastewater agriculture is largely the result of the unplanned pollution of irrigation sources with wastewater [3].

Wastewater irrigation in the Kathmandu Valley is widespread but poorly documented in practice, however, systematic documentation is not found on the extent of direct and indirect use, globally [4]. The Kathmandu Valley is a metropolitan area with poor wastewater disposal infrastructure surrounded by agricultural lands. Existence of informal irrigation with lack of adequate wastewater treatment facilities and low rainfall during the dry winter season has led to extensive use of wastewater for agriculture [4]. Centralised collection and treatment of sewage is proved to be ineffective in the Kathmandu Valley and decentralised alternatives like small-scale

constructed wetlands for hospitals, individual houses, and schools are small-scale options and cannot solve the overwhelming wastewater disposal problems [4]. However, properly managed wastewater irrigation can be used to mitigate the polluting effects of municipal wastewater discharge to local water bodies [5]. The quality of wastewater used varies from diluted wastewater to raw sewage. Rutkowski et al. (2007) carried out a study in two different municipalities of Kathmandu Valley and found that the farmers were experiencing mild to serious health impacts from using polluted water for irrigation.

This paper seeks to elucidate the perceived health consequences of wastewater use in urban agriculture.

LITERATURE REVIEW

Health hazards are often associated with wastewater use. Several researchers found that the health risk of using wastewater was real but [6] claims that farmers can manage it with their income. The "itai-itai" disease originated in Japan is due to irrigation of rice paddies with highly contaminated water [7]. In Pakistan, studies indicated higher hookworm infections in farmers and farm workers who used wastewater for irrigation than

Table 1: Summary of Health Risks related with the Use of Wastewater for Irrigation

Group Exposed	Health Threats		
	Nematode Infection	Bacteria/Viruses	Protozoa
Consumers	Significant risk of Ascaris infection for both adults and children with nrtreated wastewater	Cholera, typhoid and shigellosis outbreaks reported from use of untreated wastewater; seropositive responses for Helicobacter pylori (untreated); increase in non-specific diarrhoea when water quality exceeds 104 thermotolerant coliforms/100 ml	Evidence of parasitic protozoa found on wastewater-irrigated vegetable surfaces, but no direct evidence of disease transmission
Farm workers and their families	Significant risk of Ascaris infection for both adults and children in contact with untreated wastewater; risk remains, especially for children, when wastewater treated to <1 nematode egg per litre; increased risk of hookworm infection in workers	Increased risk of diarrhoeal disease in young children with wastewater contact if water quality exceeds 104 thermotolerant coliforms/100 ml; elevated risk of Salmonella infection in children exposed to untreated wastewater; elevated seroresponse to norovirus in adults exposed to partially treated wastewater	Risk of Giardia intestinalis infection was insignificant for contact with both untreated and treated wastewater; increased risk of amoebiasis observed with contact with untreated wastewater
Nearby communities	Ascaris transmission not studied for sprinkler irrigation, but same as above for flood or furrow irrigation with heavy contact	Sprinkler irrigation with poor water quality (106–108 total coliforms/100 ml) and high aerosol exposure associated with increased rates of infection; use of partially treated water (104–105 thermotolerant coliforms/100 ml or less) in sprinkler irrigation is not associated with increased viral infection rates	No data on transmission of protozoan infections during sprinkler irrigation with wastewater

for those who do not use wastewater irrigation [8]. Many diarrheal outbreaks have been often associated with wastewater-irrigated vegetables [9]. Dermatitis and fungal infections were found to be associated with occupational exposure to raw wastewater in Hanoi, Vietnam [10]. The health risks related with the use of wastewater for irrigation is shown in Table 1.

Wastewater contains valuable nutrients that can increase crop yields and save on artificial fertilizers, but expanding formal reuse is typically complicated by weak coordination, complexity in the inter-operability of policies and regulations, and difficulties in identifying and managing the real and perceived health risks associated with reuse [11].

METHODOLOGY

The study was carried out in Golmadhi area of Bhaktapur municipality having 4437 inhabitants, which consists of 2217 males and 2220 females as per the 2011 census. It was conducted through a literature review, field observations for familiarization, a survey of farmers for examining their perception of wastewater use and associated health implications and, interviews of key informants for validating the results. The key informants interviewed were the local health officials; authorities of local governments, etc. The randomly sampled 24 farmers were interviewed using a structured questionnaire that addressed land holdings systems, cropping patterns, irrigation practices, their awareness and consumption practices of agricultural products, and perceived health consequences of wastewater use. The interviewed

farmers, both male and female, belong to different ethnic groups mostly from the Newar community.

RESULTS ANALYSIS

Irrigation Practices

Two types of land ownership are found in practices in the study area viz., self-owned (52%) and tenanted (48%). Most farmers use raw wastewater from nearby domestic wastewater open channel downstream or plugged sewer line of waste in upstream during dry months, and wastewater mixed river water during monsoon. However, some use groundwater from nearby well for sowing the seeds.

Cropping pattern

In Golmadhi it is found that the average time used for land preparation was 16 working hours for approximately ½ ropani lands (i.e. 0.025 hectares [1]. Multiple cropping is especially practiced in these areas, based on crop cultivation season. Wastewater use in the area has created opportunity for year round vegetable production. The summer crops in Golmadhi were paddy in low lands and vegetables in uplands. While in winter, the vegetables were planted in both up and low land. The major vegetables grown are cauliflower, garlic, onion, radish, and green leafy vegetables. Similarly, in spring season, particularly green pumpkin pods and other leafy vegetables are grown by the farmers.

Source of irrigation water and its reasons

The water sources used were chosen for two reasons:

- i) Availability or its acceptance, and
- ii) Inaccessibility of alternative water sources.

The river water in Bhaktapur was found to be accessed mainly through river water pumping during monsoon and through natural gravity flow from nearby domestic wastewater channels during dry months when the river water discharge is very low. Most of the interviewed farmers responded that they use wastewater because no other option is available while only a few of them responded that they prefer wastewater use for its high crop yield and reliability. Wastewater users revealed there was high investment cost and failed attempts of groundwater extraction due to which they preferred wastewater over groundwater. Wastewater users associated positively with both river diluted and raw wastewater use.

Perceived Health Consequences

Health consequences of wastewater use can have two routes-

- i) Health consequences emerging from exposure to wastewater carrying relevance to producers who come in contact of wastewater, and
- ii) Health consequences emerging from consumption of produce using wastewater. It was found that most of the farmers use raw wastewater for irrigation which resulted in some minor diseases such as fever, hookworm, itchiness, and rashes.

The educational level also has influenced the perception of farmers on the use of raw wastewater, as most of the farmers were below basic education level. This might be the reason they do not know about the cause of the disease. Due to lack of education, they also do not know about the mitigation measures. Elderly farmers were open in talking about health problems while young farmers, despite having a proper understanding of diseases, showed reluctance to discuss. Farmers viewed the contact with wastewater and its foul smell as the major causes of health problems and they had a poor understanding of the transmission pathways of diseases. In Golmadhi some farmers responded that their exposure to wastewater for a long time made them immune to wastewater diseases. In a study by [1], itchiness, hookworm, and fever were found as major diseases as shown in Figure 1.

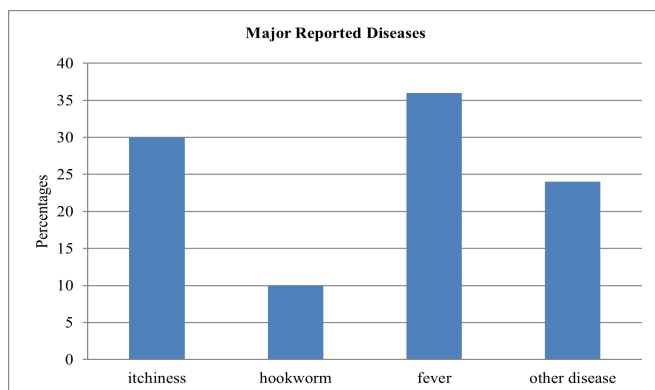


Figure 1: Major Diseases Reported in Golmadhi
(Source: Karki, 2018)

DISCUSSIONS

In Golmadhi, wastewater irrigation supported most of the farming households. There is a huge plot of land adjacent to the river and a little further adjacent to a closed sewer line. Renting of pumps was also found to exist in practice. As stated by [12], in Golmadhi wastewater irrigation is the only available reliable source for the production of fresh vegetables and, farmers in Golmadhi could easily overcome seasonal variations of water availability and they generated income for better livelihoods because of possibilities to cultivate the high-value vegetables close to the city [4].

Diarrhoea, ascariasis and schistosomiasis are among the major wastewater-related diseases that cause a significant burden of diseases and potentially lead to death [13]. In this study, it was found that the farmers complained of health issues like skin itching, rashes, etc., but none considered it important to take safety precautions while using wastewater for irrigation and also were not sure if these illnesses were directly linked to wastewater use, but the perception of an association was fair.

During the study, it was observed that the raw domestic waste was directly mixed to the Hanumante River. Therefore, waterways are generally most at risk of the harmful effects of wastewater.

CONCLUSIONS

Wastewater is used by farmers for irrigation in Kathmandu Valley, due to traditional practice, the absence of alternatives, and its nutrient value. In Golmadhi, Bhaktapur wastewater is the only available reliable source of water for the production of fresh vegetation. It is perceived that people have some minor skin diseases like itching and rashes, which would be eliminated by adopting safety measures. Some of the safety measures listed by [13] includes: i) wastewater treatment, ii) crop restriction, iii) wastewater application techniques that minimize crop contamination (e.g. drip irrigation), iv) withholding periods to allow pathogen die-off after the last wastewater application, v) hygienic practices at food markets and during food preparation, vi) health and hygiene promotion, vii) medication (e.g. anti-helminthic drugs) and immunization, viii) use of personal protective equipment (PPE), ix) disease vector and intermediate host control, x) reduced vector contact, xi) restricted access to irrigated fields and hydraulic structures.

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ABOUT AUTHOR(S)



(Puja Rai) is an undergraduate student in Civil and Rural Engineering; Nepal Engineering College affiliated to Pokhara University. She has keen interest in research especially related to water resources and involved in different projects in college life.



(Dharma Raj Bagale) is an Agricultural Engineer, and holds a Master's Degree in Interdisciplinary Water Resources Management from Pokhara University, Nepal. He also has another Master's Degree in Rural Development from Mid-western University, Nepal. He is currently affiliated to Nepal Engineering College as Assistant Professor.

Sustainability Assessment of Community Constructed Wetland based Wastewater Treatment Plants in Kathmandu Valley

Bibhusan Kumar Khadka ^{1,✉}, Robert Dongol²

Nepal Engineering College, Pokhara University, Nepal

Email ID: ¹khadkabibhusan@gmail.com, ²robert@nec.edu.np

KEYWORDS

Constructed wetlands
Sustainability
Kathmandu Valley

ABSTRACT

The paper presents the results of sustainability assessment of three community constructed wetland-based wastewater treatment plants of Kathmandu Valley namely Desai Gaun, Sano Khokana and Sunga. The sustainability assessment was based on the four dimensions - technical, socio-environmental, financial, and institutional, for which Multi Criteria Analysis approach was used. Participatory tools such as focus group discussion, household questionnaire survey, key informant interview and field observations were used to collect the information and values were assigned to the core factors and sub-factors of each sustainability dimension against the set weightage. The cumulative percentage was compared against the sustainability ranking developed by WaterAid. All the three systems were found sustainable technically. Sano Khokana and Sunga are institutionally sustainable with a presence of a strong institution looking after the system. Desai Gaun is not sustainable from two sustainability dimensions. Sunga system falls far below in the socio-economic dimensions of sustainability. Financial is the weakest sustainability dimension for all the three systems. The systems at Sunga and Desai Gaun fall under "Not Sustained" whereas that of Sano Khokana falls under "Sustained but at Risk".

INTRODUCTION

Sewerage from community and institution is discharged directly into the rivers without any prior treatment. In a developing country like Nepal, huge centralized systems for sewerage treatment were found to be unsuitable and inappropriate due to associated high cost of spare parts, utility bills, chemical additives, and lack of trained manpower [1]. Conventional wastewater treatment technologies are based on highly optimized physical, chemical and microbial processes whose cost effectiveness varies with loading rate [2]. As an alternative, constructed wetlands, unlike energy intensive and expensive central approaches, are operated nearby the source of wastewater. Though it treats comparatively small amount of wastewater, the beauties of constructed wetland are their intrinsic simplicity, low investment cost, easy operation, high efficiency, and low maintenance cost [3]. After the successful operation of the first constructed wetlands at Dhulikhel Hospital [4], many other constructed wetland systems were installed at different locations including hospital, schools, university, and communities and even at household levels depending on the volume of wastewater generated from these

sources. As constructed wetlands are cheap and require low maintenance cost, it can be successful in a low-income country like Nepal [3]. Though constructed wetlands being valuable assets, the sustainability of the constructed wetlands is always questionable. Few of the existing constructed wetlands are partially performing at community level. Although the decision to install the constructed wetlands was a good step toward sewerage treatment but due to lack of proper supervision, few have stopped functioning, various issues associated with them such as lack of awareness of constructed wetland technology, it is often difficult to convince people that it will work, to make them invest on constructed wetland, unavailability of local materials to construct, carelessness in taking care of simple operation and maintenance requirements such as checking for blockage in the pipes and lack of priority for city governments, private industries or institutional to treat wastewater due to lack of strong legislation and standards. Even the performance of constructed wetlands at individual households and institutional level is not as per anticipated [5].

METHODOLOGY

Description of the selected wastewater treatment systems

The study was carried out in three constructed wetlands in Kathmandu Valley. One community based constructed wetlands each from Kathmandu, Bhaktapur and Lalitpur districts was selected. The details of constructed wetlands provided in Table 1.

Table 1: Selected wastewater treatment systems

Age	Desai Gaun wastewater treatment plant	Sano Khokana wastewater treatment plant	Sunga wastewater treatment plant
Date of Construction	2014	2008	2006
Design discharge	-	Varies between 10-15 m ³ /d	50 m ³ /d
Beneficiaries	240 Households	34 Households	84 Households
Location	Gokarna, Kathmandu	Sano Khokana, Lalitpur	Sunga, Bhaktapur

Field observation

Direct field observation was made at the selected constructed wetlands to assess the physical status of the entire system, operating condition and visible constraints and flaws in the operation.

Focus Group Discussion

Focus Group Discussions with locals were carried out to draw and triangulate the information regarding environmental benefits, reduction in the use of freshwater consumption and positive benefits, acceptance of the wetlands, and draw information on institutional capacity and its effectiveness. Three FGDs in each three selected sites were conducted.

Key informant interview

The key informant interviews were conducted onsite and offsite. The key informant interviews were conducted with the operation and maintenance members of the selected constructed wetlands. The monthly tariff collected was retrieved from the records of the user's groups of the constructed wetlands as well as from the local people during household

questionnaire survey. The onsite key informants were asked to provide the monthly operation and maintenance cost of the system, effectiveness of the User committee, use of treated water and fund availability, availability of trained manpower, coordination and linkage of the community and the knowledge transfer, gender, and social inclusion in the program. The offsite key informant interview was conducted with the personal working in this field for a longer period.

Retrieval of old records

Key informant or the user committee were requested to provide the information on the collection of tariffs, availability of fund, undertaken provision for the system replacement fund. The secondary data available for the selected constructed wetlands was retrieved from the various sources both published and unpublished.

Wastewater sampling

As the constructed wetland is one of the components of Decentralized wastewater treatment system (DEWATS), the sampling of the wastewater was done after each unit of the DEWATS system to determine the treatment efficiency of each unit. The parameter analysed and the standard procedure followed is shown in Table 2.

Data analysis

Multi Criteria Analysis (MCA) method was adopted for sustainability assessment and the value was compared with the sustainability index given by Water Aid for Water, Sanitation and Hygiene (WASH). The application of MCA method for sustainability monitoring of WASH projects is instrumental to solve the complex process. Each sustainability dimension is significantly governed by many factors and sub-factors. Various factors and sub-factors ensuring sustainability were identified and given certain score (Table 3) through close consultation with the experts and prevailing norm if any [6]. Reasonable sub factors were identified carrying the discussion with them and the identified sub factors were given the final weightage which was taken as the average of the two-weightages given by the practitioner and expert. In field, the value against each sub factors were given on participatory way and the value were converted to same value by unitary method.

Table 2: Wastewater Quality Parameters and Methods Adopted for their Analysis

S. No.	Wastewater quality parameter	Methods
1	pH	4500 H+ B. Electrometric method, APHA 21st edition
2	Turbidity	2130 B. Nephelometric method, APHA 21st edition
3	Total Suspended Solids	2540 C. APHA 21st edition
4	Biological Oxygen Demand	5210 B. 5-Day BOD Test, APHA 21st edition
5	Chemical Oxygen Demand	5220 B. Open Reflux, Titrimetric Method, APHA 21st edition
6	Phosphate	4500-P E. Ascorbic Acid Method, APHA 21st edition
7	Ammonia	4500 NH ₃ F. Phenate Method, APHA 21st edition

Table 3: Sustainability weightage to core factors and sub factors

Sustainability Dimensions (Total Score 100)	Core factors to assess sustainability dimensions	Sub-factors to assess core factors
Technical (20)	Physical status of the system (20)	Absence of unauthorized connection (2) Provision of primary treatment unit (2) Provision of secondary treatment unit (2) Even distribution of wastewater in constructed wetland (2) Provision of sludge removal unit (2) Removal of weeds and solid waste (2) Smell emanation (2) Filter media is not clogged (2) Regulated water level in bed (2) General appearance (2)
Institutional (40)	User committee (26) Operation and maintenance of the system (14)	Basis for formation of user committee (5) Frequency of meeting of user committee (5) Linkage with local authority and other agencies (5) Training and external support (4) Role of women in decision making process (3) Provision of knowledge transfer among successive user committee (4) Responsible for daily O&M (4) Capacity/skill of caretaker or operator (4) Provision of incentives to caretaker (3) Frequency of involvement of caretaker (3)
Socio-environmental (20)	Acceptance of the system (8) Use of treated water (4) Environmental benefits (8)	Perception of user on technology (2) Perception of user on quality of treated water (2) Fulfilling the objective (2) Users informed about system (2) Purpose of use of treated water (Included for information and analysis) Satisfaction of use of treated water (4) Absence of bad odor (4) Absence of water related disease (2) Change in nearby water bodies (2)
Financial (20)	Collection of tariffs (14) Availability of fund (6)	Monthly tariff charged (Included for information and analysis) Efficiency of tariff collection (6) Tariff sufficient to carry O&M (4) Availability of savings (4) Means of external fund source (6)

RESULTS AND DISCUSSIONS

The four sustainability dimensions of the three treatment plants studied are discussed hereunder.

Technical Aspect

In all the three plants, there was no unauthorized connection. In Desai Gaun there has been no cleaning of the system since the beginning whereas in Sano

Khokana, the removal of weeds is done on a weekly basis. In Sunga there is no provision of removal of weeds. In Sano Khokana and Desai Gaun, pipes are fixed in level with cement concrete which results in uniform distribution of wastewater over the bed. The flow is regulated in all the three sites. All the three systems were in operating condition and a normal smell persist in all the three systems (Field Observation).

The sludge drying bed was a compulsion in Sunga WWTP as the location of the system is in sloppy area, making the desludging tedious by the means of vehicle. As a result, the treated water is discharged into nearby Siddhikali rivulet. There is no sludge drying bed in Desai Gaun wastewater treatment plant due to lack of land space and during planning itself it was decided to desludge by using the tanker. The treated water is then discharged directly into the Bagmati River as the outlet pipes are located far below the community residence. In Sano Khokana there is a biogas plant, two co-composting fields, anaerobic baffled reactor (ABR) and horizontal constructed wetland followed by a pond for the storage of the treated water. There are six biogas users in the Sano Khokana WWTP including the president, and these users operate the system. From the co-composting fields, manure is extracted and is used for agricultural land. In this system, people are using the treated water for fish farming and agriculture.

Institutional dimension

In Desai Gaun, 240 households are connected to the system. According to the president, from each house one man and one woman were present during the formation of user committee. The user committee was formed based on mutual understanding and agreement of all community members. The user committee consists of 9 members including 4 women and 5 men. Those who were active and have good image in a community were selected as the user committee members. The user committee used to have a meeting twice or sometimes even thrice a month after the installation of the system at 2014 A.D. but from 2017 A.D. meeting of user committee has not been held. According to the president of the system, meeting had been called for the fourth time during this period, but no members of the user committee showed any interest. According to the user committee members, even the president was not active aside from calling a meeting; there were no such provision to enforce for the meeting of user committee by the president. It seems like no one among the user committee have interest on the system. According to the president, if any minor problem arises then maintenance is carried out with the interest generated from the savings done by user committee. The amount for wages received by individuals during the construction phase was collected and saved with a vision that, it would be used for the system operation and maintenance. c. If any major problem arises then president (on individual basis) seeks help of the municipality. The local Municipality has been providing required financial support when the system requires huge maintenance cost. If money is to be borrowed from the finance, then president calls the meeting and the responsible user committee members fulfill the official requirements for the retrieval of the money. Training on waste management was provided by the Society for Operation Minimum Needs (SOMNEED). The training was provided 5-6 times to women, but the training was not provided after the 2015 April 25 A.D earthquake. Women have effective role in decision making process to some extent, but the operation

and management of system is totally dependent the president alone. There has been only one user committee since the installation of the system. There was a caretaker till April 2017 A.D. The president and member of user committee are serving as a caretaker voluntarily whenever problem arises in the system. If any maintenance is required, labor is hired on daily wage basis to carry maintenance of the system.

In Sano Khokana wastewater treatment plant responsible, confident, and dedicated ones from the society were selected in the user committee. According to the president, to make the user committee representative members of user committee were selected from each small toll in the society. The user committee meeting occurs only when problem arises in the system. A proposal from user committee to Lalitpur Metropolitan to support the system is not yet finalized. Lumanti, a national based non-governmental organization is responsible to carry needed maintenance of the system. An awareness program was conducted by Lumanti on importance, need, operation and sustainability of biogas to the people. In Sano Khokana wastewater treatment plant, there are 11 members in the user committee including 4 women and 7 male. Women are equally treated in decision making. There is informal transfer of knowledge acquired by the president and user committee members during the gathering of people in Bhoj, Guthi and Bhajan Mandal. Biogas users carry out daily operation and maintenance of the system as they were trained about the operation of the system. Biogas users are required to pay 250 per month but no one among 6 biogas user pays the charge of biogas and in return takes care of the system including the president.

According to president, in Sunga wastewater treatment plant user committee members were selected from them, who can give time and who were renowned as social workers. According to the president, the user committee meeting occurs every month. But according to the members of user committee, meeting is not conducted consistently. The representatives of Environment and Public Health Organization come and monitor the system. There is no considerable support from the organization except monitoring. There is a designated trained caretaker, who is offered a monthly salary of NRS. 4000. Madhyapur Thimi Municipality provides salary to the caretaker and financial support when proposed by the user committee. There is extreme need of training. Training was provided by Environment and Public Health Organization during the initial phase after the installation of the system. Women are equally treated in decision making process, and there are two women in 7 members of user committee. The knowledge acquired by the president is shared to all members of user committee in meeting.

Socio-environmental dimension

Social benefits

Users of Desai Gaun perceived this system as an excellent technology, as prior to the installation of

DEWATS; the wastewater was directly drained to the Bagmati River. According to the president, after the installation of this system, almost every household-built toilet as the waste generated could be directly connected to the sewers for treatment in the system. Prior to the construction of this system the waste from toilet was drained into the drain, which after accumulating caused bad odor emanation. The accumulated waste used to get cleared only during rainy season. The community was declared open defecation free zone after the installation of this system and now the community is witnessing healthy and clean environment. The treated water is directly drained into the nearby Bagmati River. President confessed that users including himself are not still convinced in using water that comes from toilets and bathroom. The users are not really interested about the system, but they are happy that the waste from their house is drained no matter where it goes.

In Sano Khokana, treatment system is totally fulfilling its objective, as it was expected to manage the household waste by the system which is happening. The users also perceive this system as excellent technology as the treated water is used for fish farming and irrigation of rice and vegetables. In Sano Khokana users are provided information and update about the system. Users are satisfied with the use of treated water, and even wish to have more treated water so that they can use the treated water for their domestic uses.

Meanwhile, People of the Sunga community conceive the treatment system as excellent technology as it prevented their land from sliding down. In Sunga users are informed about the operating condition of the system by the members of user committee. The treated water is not used for domestic purpose i.e. prior to the construction of the system it was expected to use for toilet flushing but due to abundant water in community well, treated water is drained directly into the nearby Siddhikali rivulet. People perceive treated water quality as good as they are draining the treated water to the nearby stream instead of untreated water.

Environmental benefits

The general appearance of the Desai Gaun was dirty as the vegetation were too long which even made difficult to move along the system. There is no problem of odor after the installation of the system. After the installation of the system the accumulation of the waste in the drain is reduced. In all the sites, there are no such evidences that the installation of system has reduced the water related disease. In Desai Gaun, people feel honored that they are discharging treated water to the holy Bagmati river nowadays even though it is in small scale but there are like 35-40 households which are not connected to the system due to the location of their house at lower altitude than the sewer pipe.

In Sano Khokana there are no water bodies, and treated water is collected in a pond which is used for fish farming and irrigation.

In Sunga, prior to the installation of the system

untreated water was drained into the Siddhikali Kholsa but now treated water is drained so that there is no problem of bad odor to the adjacent Bal Premi Secondary School.

Financial dimension

There is no collection of tariffs in Desai Gaun WWTP, according to president, slips were even prepared for the tariff collection, but no users showed any positive interest about paying tariff. Also, in both Sano Khokana and Sunga there is no provision of collection of tariff from users. In Desai Gaun there is a saving of NRS 5.4 lakh (collected and saved from the incentives received during the construction phase) in a finance which generates around NRS 40-45 thousand of interest per year. The generated interest is used to carry minor maintenance required by the system. In Sano Khokana, NRS 2 lakh which is received by local people as by providing labor force during the construction of the system which is collected and then saved for future needs to the system. The saved money was provided to the local individual with a return interest of NRS 20000/annum. The interest generated is used for general maintenance of the system. In Sunga there is a savings of NRS 5000-6000 and the system is totally dependent on municipality for necessary maintenance of the system.

In Desai Gaun, Gokerneshowr municipality provides External fund and when required for the maintenance of the system. Technical officials from the municipality come and estimate the cost of maintenance and provide the estimated financial support to the system. In Sano Khokana, money is collected from the users for minor maintenance, if not sufficient then seeks for donors; Lumanti (Non-Governmental organization) is responsible for carrying major maintenance till this date. Lumanti is carrying major maintenance till this date but user committee is planning to seek help from local government onwards. In Sunga, Thimi municipality is the source of external fund.

Overall sustainability of constructed wetland-based wastewater treatment systems in Kathmandu valley

The technical dimension of all three selected site is above 70% which means the systems are technically sustainable. Amongst three systems, Sano Khokana has obtained higher score in technical sustainability dimension as six households are getting biogas from the system and are involved in daily operation of the system. On the other hand, treated water is collected in a pond where fish farming is done, and from the same pond people extract water for the irrigation of vegetables when required.

Institutional dimension of Desai Gaun is 51.87% indicating the system institutionally not sustainable. The major maintenance is carried out on individual basis by the president and few other user committee members in cooperation of Gokerneshowr Municipality. This shows that the people lack interest on the system. Whereas the institutional dimension of Sano Khokana and Sunga are 74.82% and 72.92% respectively. In Sano Khokana, biogas users are

carrying the operation of the system daily, as they are getting benefits from the system and other few peoples are using the treated water from the pond for domestic purpose. While in Sunga, there is designated caretaker to carry the operation of the system and the president is also frequently available in the necessary instances to the system.

The socio-environmental dimension of Desai Gaun and Sano Khokana are 70% and 83.3% respectively. The sustainability dimension of Sunga is 56.6% which means the system is not socio-environmentally sustainable. There was a problem of landslide before the installation of the system but after the installation of the system the problem of landslide was reduced. Before the installation of the system, it was expected to use the treated water for domestic uses and manure from the sludge drying bed, but the location of the system had hindered the use of both treated water and manure for agricultural land. Instead the treated water is directly drained into nearby Siddhikali Kholsa.

The financial dimension of Desai Gaun, Sano Khokana and Sunga are 61.15%, 61.65 % and 32.9% respectively which means the systems are financially not sustainable. The main reason for all three system being not financially sustainable is lack of tariffs collection. In fact, users are not willing to pay the tariff and there is no such enforcing regulation to make them pay. As a result, there is no generation of revenue from the users. Among three system, Sunga has obtained very less score in financial sustainability in comparison to other system as there is no means of savings and the system is totally dependent to Thimi Municipality for minor maintenance as well. On the other hand, there is a savings in both Desai Gaun and Sano Khokana, which is only sufficient to carry out some minor maintenance of the systems.

The overall sustainability of Desai Gaun, Sano Khokana and Sunga is 61.49%, 76.19% and 60.605% respectively which means Desai Gaun and Sunga wastewater treatment plant are 'Not sustained' and Sano Khokana wastewater treatment plant is 'Sustained but at risk' (Table 4).

Table 4: Overall Sustainability of the Systems

Sustainability dimensions (100%)	Desai Gaun	Sano Khokana	Sunga
Technical	70	90	80
Institutional	51.87	74.82	72.92
Socio-Environmental	70	83.3	56.6
Financial	61.15	61.65	32.9
Overall Sustainability	61.49	76.19	60.605
Sustainability ranking	Not sustained	Sustained but at risk	Not sustained

CONCLUSIONS

Based on the checklist developed and response received from respondents, technical, socio-

environmental, financial, and institutional dimensions of sustainability were analyzed for three constructed wetland-based wastewater treatment system. Out of total sustainability weightage of 100 marks, Sunga, Sano Khokana and Desai Gaun obtained 60.6 %, 76.19 % and 61.49 % cumulative average in overall dimension, respectively. The financial and socio-environmental sustainability dimensions of Sunga have brought the system at risk whereas the institutional and financial sustainability dimensions of Desai Gaun have brought the system at risk. In case of Sano Khokana, the financial dimension has brought the system at risk. Financial dimension, in all the three systems, are relatively poor and is amongst the four sustainability dimensions that pull the entire system below sustainability.

RECOMMENDATIONS

Direct benefits from the system is the key factor responsible for the sustainability of the system [5], biogas and use of treated water in Sano Khokana are the reasons for the frequent operation and periodic maintenance of the system. So, the means of direct benefits should be enhanced to make the users more accountable towards the system. A certain sum of tariff collected by the water supply and sewerage should be allocated for the maintenance of the system. Frequent monitoring of treated effluent should be carried out, which provides timely information if any required to maintain the system/unit.

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ABOUT AUTHOR(S)



treatment system (DEWATS).

(Bibhusan Kumar Khadka) has completed M.Sc. in Interdisciplinary Water Resource Management (iWRM) from Nepal Engineering College in 2019. He is currently working as a Civil Engineer in DUNGESHWOR Rural Municipality, Dadapara-05, Dailekh since January 2020. His research interest is in the field of Decentralized waste water



Postgraduate Studies. Prior to joining *nec*, Mr. Dongol had worked as a Research Associate in Sida funded ARRPET project. Mr. Dongol was also the team leader of IDRC South Asia Water (SAWA) Leadership Program on Climate Change (2017-2021).

(Robert Dongol) holds M.Sc. degree in Environmental Engineering and Management from Asian Institute of Technology in 2007. He is an Associate Professor at Nepal Engineering College (*nec*) and coordinate M.Sc. Interdisciplinary Water Resource Management (iWRM) program at its center for

Study of Rain Attenuation Statistics for Terrestrial Microwave Link in Nepal

Kailash Karki^{a,1,✉}, Amit Shah^{b,2}, Rupesh Dahi Shrestha^{b,3}, Anil Kumar Yadav^{b,4}

^aNepal Telecommunications Authority, Kathmandu, Nepal

^bDepartment of Electronics and Communication Engineering,
Nepal Engineering College, Changunarayan, Nepal

Email ID: ¹kkarki@nta.gov.np, ²amits@nec.edu.np, ³rupeshd@nec.edu.np, ⁴anilky@nec.edu.np

KEYWORDS

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Vertical Polarization
ITU-R

ABSTRACT

While designing a terrestrial microwave link, signal attenuation due to rain comes into vital consideration since raindrops highly absorb and scatter radio waves. For 24 hours signal availability study of rain fade is a major concern. In this paper, terrestrial microwave link degradation (in dB) is calculated for four major cities of Nepal, Biratnagar(26.290N,87.160E), Kathmandu (27.420N,85.220E), Pokhara (28.130N,84.00E), and Surkhet(28.360N,81.370E) using ITU-R model. The eighteen years (2000-2017) of rainfall data obtained from the department of hydrology and meteorology of Nepal is analyzed and the corresponding attenuation level is calculated for the ten-kilometer microwave link having an operating frequency of 18 GHz. Also, attenuation behavior is analyzed for different polarization (horizontal and vertical) of signals. For the microwave link length of 10 Km having an operating frequency of 18 GHz, it is found that horizontally polarized signal encounters 35% more attenuation in comparison to vertically polarized signals.

INTRODUCTION

Congestion in lower frequency bands, as well as demand for increased data rate, has compelled the communication system, designers/stakeholders, to move on to a higher frequency band. The availability of wide bandwidth is advantageous but at the same time, higher frequencies signal greatly suffers from environmental factors like rain, snow, hail, fog, and clouds[1]. Tradeoffs should be maintained for bandwidth availabilities and tolerable rain attenuation. Rain in the radio signal path is the most dominant factor which contributes to the transmission loss for microwave signal. While moving to a higher frequency band the wavelength of the signal will be approximately equal to raindrop size, consequently, rain absorbs the signal as well as scatters the path. Rayleigh and Mie scattering is the main cause of attenuation at a higher altitude of the atmosphere. The signal attenuation is tolerable in case of lower frequency range, whereas full availability of signal is a challenging task at higher frequency range. It degrades the performance of the system limiting the use of high frequency for terrestrial microwave communication systems.

For the microwave link beyond 5 GHz, one needs to take care of the rain attenuation phenomenon. Analysis of the rain attenuation statistics provides valuable inputs for the system designers so as to

design better microwave systems in the future for efficient and reliable link availability. The amount of precipitation in a particular region greatly affects the rain attenuation. Rain rate attenuation has already been studied for several countries like South Korea, Malaysia, India, and so on [2] [3] [4] [5]. A similar type of analysis for Nepal will provide the amount of link margin needed to compensate for the effect which helps the system designers to increase the system availability and link performance. In this paper, the rain rate is calculated for four different cities of Nepal based on the collected data, and the corresponding terrestrial microwave link attenuation is estimated and analyzed from different perspectives. Empirical methods, as well as physical methods, are in use to predict rain attenuation. The unavailability of all the required parameters for modeling shifted the interest of the researcher to go for an empirical method [2]. For the empirical method rain rate distribution for 1-minute integration time is needed to estimate the rain attenuation at that location.

The rain attenuation phenomenon is studied for four major cities of Nepal, namely Biratnagar, Kathmandu, Pokhara, and Surkhet. The eighteen years precipitation data (2000 A.D. – 2017 A.D.) obtained from the Department of Hydrology and Meteorology, Nepal is used for the analysis. Similarly, the thunderstorm factor is taken from the map provided in [6].

LITERATURE REVIEW

Having an area of 147181 sq. km, Nepal elongates from 26° 22' to 30° 27' N and from 80° 04' to 88° 12' E. The altitude of Nepal varies from 60 m to 8848 m from the sea level and thus consists of a wide variety of climates based on altitude and season. The season of Nepal can be classified as pre-monsoon (March to May), monsoon (June to September), post-monsoon (October to November), and winter (December to February) [7]. The main source of precipitation (around 80%) in Nepal is the monsoon. In this season, precipitation ranges from 150 mm to 5000 mm per year. As shown in figure 1, out of four cities, Pokhara consists of the highest annual precipitation. The result obtained after analyzing eighteen years of data shows that the monsoon season contributes to 79.4% of annual precipitation in Nepal whereas the proportion of precipitation in winter is only 2%.

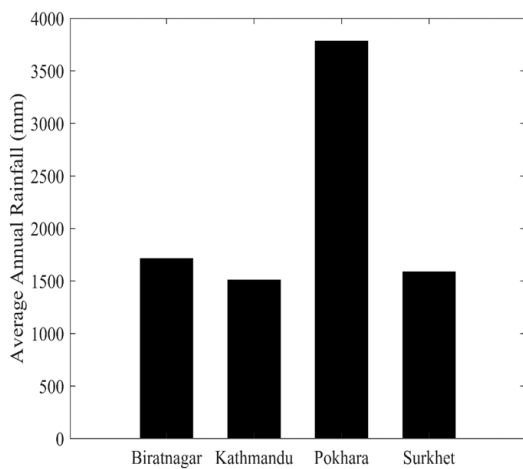


Figure 1: Average annual rainfall distribution

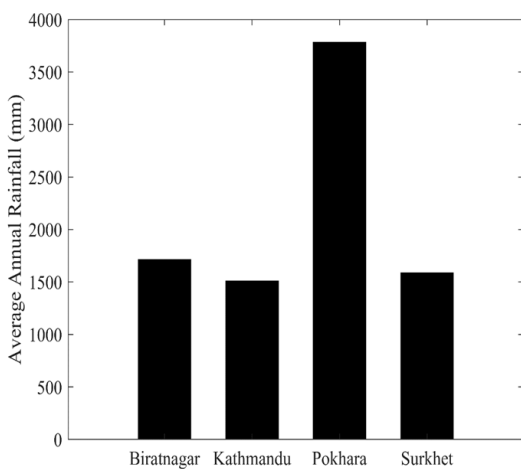


Figure 2: Seasonal contribution (percentage of annual precipitation) over Nepal

For attenuation prediction, rain rate information for lower integration time is needed. International Telecommunication Union (ITU) has suggested the researchers and system de-signers go for a 1-min rain rate [8]. Usually, rain rate data are available for longer integration time (hour, day, month, year) which is suitable for hydrological analysis. A longer integration

time rain rate needs to be converted to a 1-min rain rate using an appropriate model. Based on the available parameters and climatic zone, one needs to choose the appropriate algorithm.

Rather than the total precipitation of rain over an observed time, the rate at which the precipitation is happening plays an important role in communication link design. The cumulative distribution function gives the long-term behavior of rain which is also called the exceedance curve. With the help of the exceedance curve, the percentage of time that the rain-fall rate exceeds a certain value can be calculated.

Number prediction models are available to get the exceedance curve from the information of the annual rainfall amount. Some of the most commonly used prediction models are the ITU-R model [9], the Moupfouma Rain model [10], and Rice-Holmberg (R-H) Rain model [6]. Among them, the R-H model is utilized in this research to estimate the hourly rain rate for 1- minute integration of time. From the information of average annual rain accumulation, highest monthly rain accumulation over the study period, and an average number of thunderstorms in an average year, the R-H model provides the estimation of a one-hour rain rate for different exceedance probabilities.

Mainly in the Himalayan region, the climate is greatly affected by the summer monsoon. Before the monsoon, the atmosphere becomes highly unstable. Thunderstorm reaches the extreme value in this season especially in densely populated countries like Nepal. The result from the study per-formed by [11] indicates that lightning activity begins in March, reaches a peak in May, and starts to decrease in June.

In the case where long-term rain measurements are not available, ITU has proposed a model to estimate rainfall rates for different annual exceedance probabilities. This model uses digital maps that contain monthly total rainfall and monthly mean surface temperature for different locations. But the digital map does not provide the desired accuracy for all the regions due to low resolution of data. For example, it treats Kathmandu and Pokhara as the same place due to the low resolution of data.

Detailed steps of the rain attenuation model given by ITU [9] for long term statistics of rain attenuation are given below:

Step 1: Obtain the rain rate $R_{0.01}$ exceeded for 0.01% of the time (with an integration time of 1 min).

Step 2: Compute the specific attenuation, γ_R (dB/km) for the frequency, polarization, and rain rate of interest.

Step 3: Compute the effective path length, d_{eff} , of the link by multiplying the actual path length d by a distance factor r ,

$$r = \frac{1}{0.477d^{0.633} R_{0.01}^{0.073\alpha} f^{0.123} - 10.579(1 - \exp(-0.024d))} \dots\dots\dots (1)$$

where f (GHz) is the frequency and α is the exponent in the specific attenuation model from Step 2.

Step 4: An estimate of the path attenuation exceeded for 0.01% of the time is given by:

$$A_{0.01} = \gamma_R d_{eff} dB \dots\dots (2)$$

Step 5: The attenuation exceeded for other percentages of time p in the range 0.001% to 1% can be deduced from the following power law:

$$\frac{A_p}{A_{0.01}} = C_1 P^{-(C_2 + C_3 \log_{10} P)} \dots\dots\dots (3)$$

with

$$C_1 = (0.07^{C_0}) [0.12^{1-C_0}]$$

$$C_2 = 0.855C_0 + 0.546(1 - C_0)$$

$$C_3 = 0.139C_0 + 0.043(1 - C_0)$$

where

$$C_0 = 0.12 + 0.4 [\log_{10} (\frac{f}{10})^{0.8}] \text{ for } f \geq 10 \text{ GHz}$$

RESULTS AND DISCUSSION

In this paper, the most important cities of Nepal were considered to find the rain attenuation because most of the microwave communication equipment is set up in these major cities. 1-minute rain rate at 0.01% exceedance level ($R_{0.01}$) for four different cities is calculated using Rice-Holmberg(R-H) model and the rain rate obtained from this model is compared with data directly obtained from the ITU map. The cumulative distribution of the rain rate for 1-minute integration time is shown in figure 3.

The 0.01% rain rates ($R_{0.01}$) of four different cities taken from figure 3 are recited in Table 1, where the maximum $R_{0.01}$, which is 139 mm/hr, is found in

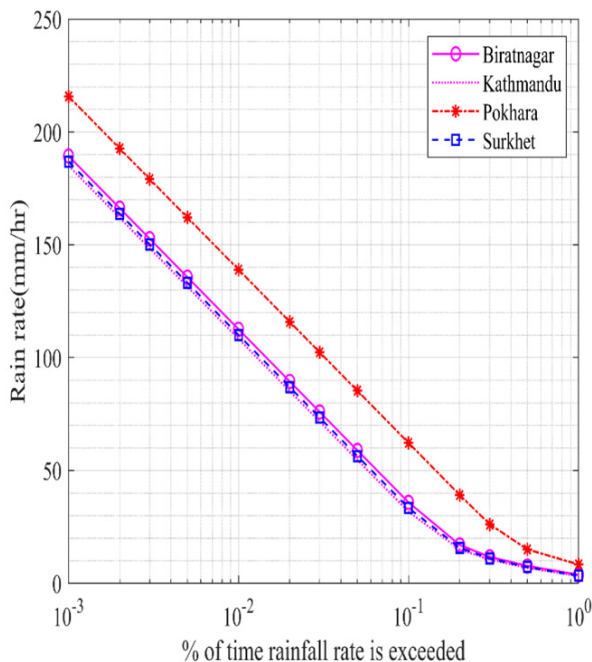


Figure 3: Cumulative rain distribution of Nepal

Pokhara, while a minimum of 110 mm/hr is reported for Surkhet. A significant difference is found between calculated $R_{0.01}$ and $R_{0.01}$ provided by the ITU

Table 1: $R_{0.01}$ for Different Cities

City	Calculated	ITU MAP
Biratnagar	112	90.25
Kathmandu	108	80.64
Pokhara	139	99.93
Surkhet	110	79.874

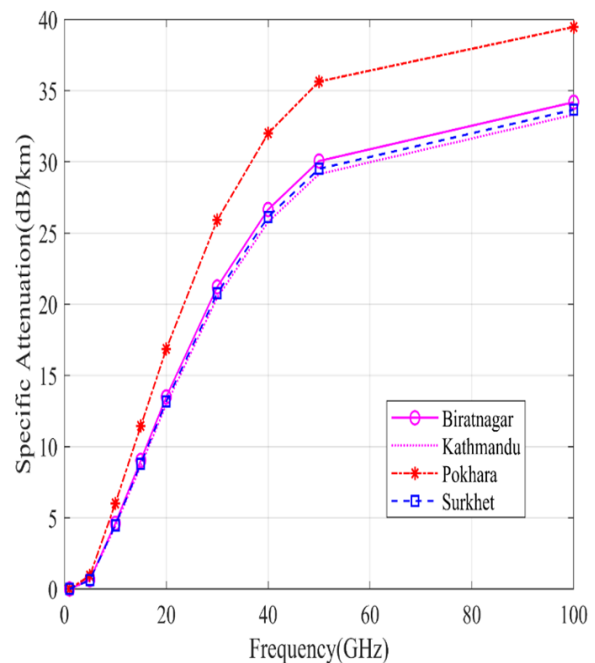


Figure 4: Specific Attenuation for different frequencies in horizontal polarization

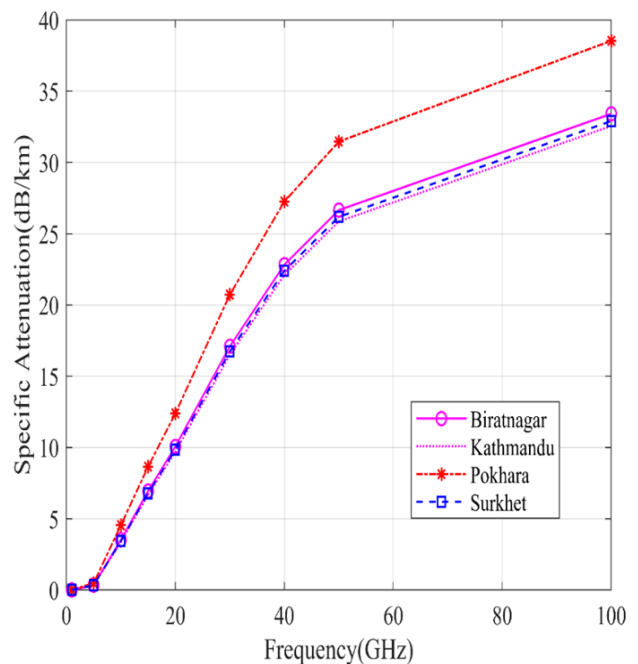


Figure 5: Specific Attenuation for different frequencies in vertical polarization

map [12]. Since the ITU map uses global data, it is less accurate than the calculated value. In calculation, local data has been used. Frequency, distance, rainfall rate,

polarization are the main factors that affect terrestrial microwave link performance.

The fundamental quantity in the calculation of rain attenuation is specific attenuation which provides the attenuation level in each kilometer (dB/Km). For total attenuation, microwave link length should be included. For the above-mentioned four cities, specific Attenuation is calculated for different frequencies which are shown in Figure 4 and Figure 5. Figure 4 shows the variation of specific attenuation for frequency in the case of horizontal polarization whereas Figure 5 gives

the same considering the case of vertical polarization. It is found that specific attenuation increases sharply while increasing frequency up to 50 GHz and rises gradually from 50 GHz to 100 GHz. It also demonstrates that rain attenuation goes up as the precipitation rate for the area is high. Thus, among the considered cities, the highest attenuation is observed in Pokhara and the lowest in Kathmandu. For Pokhara taking 18 GHz of frequency, specific attenuation of 14.68 dB and 10.91dB is recorded for horizontal and vertical polarization respectively. Similarly, for Kathmandu, it is

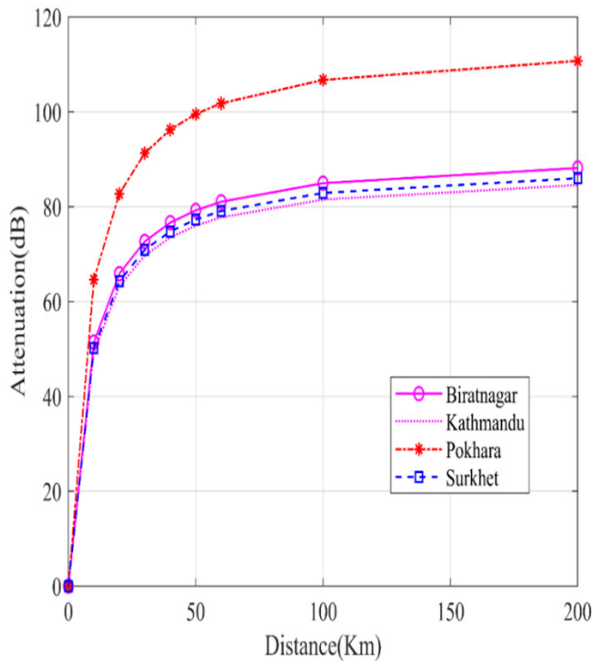


Figure 6: Rain Attenuation for different distances at a frequency of 18 GHz in horizontal polarization

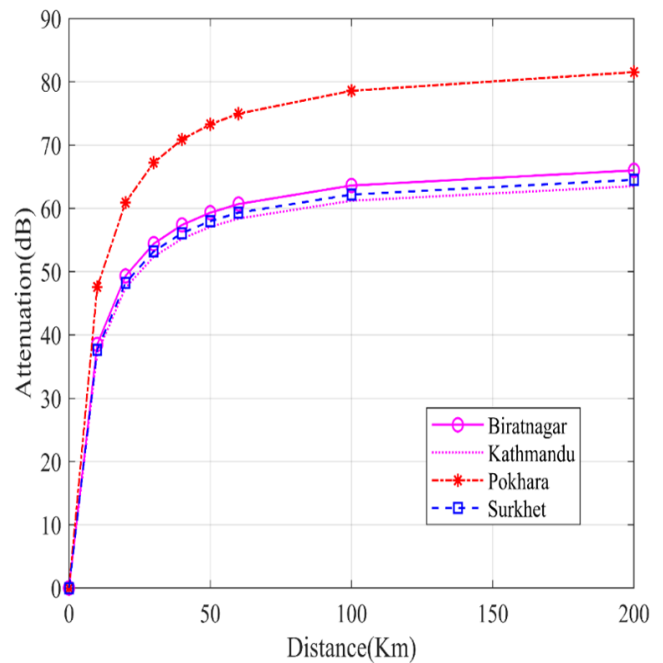


Figure 7: Rain Attenuation for different distances at a frequency of 18 GHz in vertical polarization

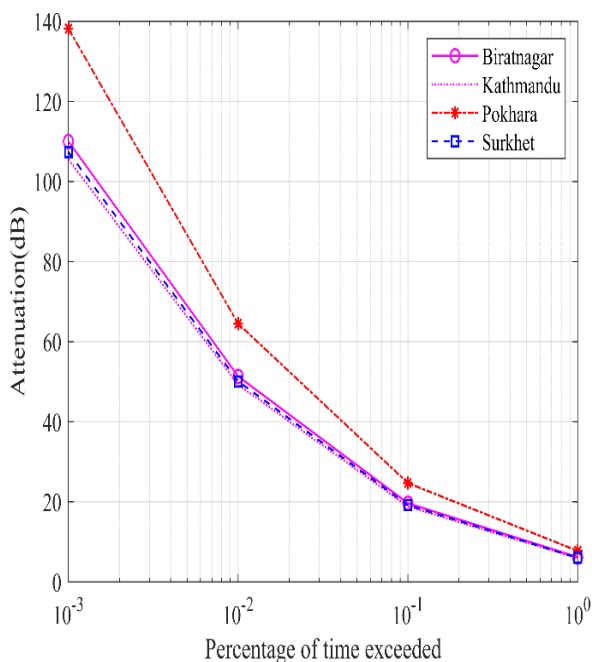


Figure 8: Rain Attenuation for different percentages of time at 18GHz frequency with a link length of 10 Km (Horizontal Polarization)

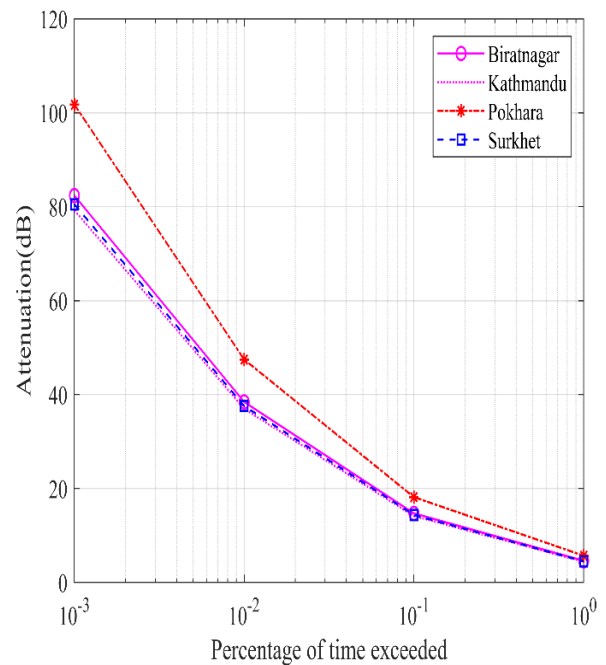


Figure 9: Rain Attenuation for different percentages of time at 18GHz frequency with a link length of 10 Km (Vertical Polarization)

found that vertically polarized signal will face about 3 dB less attenuation compared to the case of horizontal polarization which is 11.23 dB. From the obtained plot, it is evident that the specific attenuation of horizontal polarization is about 1 dB higher compared to 38.53 dB specific attenuation of vertical polarization at 100 GHz in Pokhara.

As stated earlier, the total rain attenuation (in dB) depends on the length of the microwave link considered. Total attenuation can be obtained by integrating the specific attenuation along the path. Figure 6 shows the rain attenuation for different distances for four different cities of Nepal considering a frequency of 18 GHz in the case of horizontal polarization. It appeared that attenuation sharply increases for the first ten kilometers followed by a gradual increase up to the next ten kilometers. After that, attenuation curves remain almost flat for remaining distances. The reason behind the flatness of the curve might be due to the insignificant change in the effective path length of the microwave link. The horizontally polarized signal encounters attenuation of about 64 dB for the first ten kilometers in Pokhara which is highest among the considered cities whereas about 50 dB is reported for Kathmandu. With the help of figure 6 and figure 7, it is found that each city experiences 33.95% less attenuation on an average in vertical polarization compared to horizontal polarization.

CONCLUSION

In this paper, the rain attenuation phenomenon is studied for four different cities of Nepal. The calculations were performed taking the frequency of 18 GHz since most of the microwave link in Nepal uses this frequency. Among the considered cities, Pokhara experiences the highest attenuation whereas least in Kathmandu. For microwave link length of ten kilometers, Pokhara records the highest attenuation which is 64 dB whereas the value is 50 dB for Kathmandu. It is found that the vertically polarized signal will face 25 per-cent less attenuation compared to the horizontally polarized signal. Thus, vertical polarization will be more economic in a city like Pokhara. It is also revealed that there is no significant difference (less than 2%) in attenuation behavior in Kathmandu, Surkhet, and Biratnagar whereas Pokhara needs special attention. Obtained results also indicate that attenuation sharply increases for the first ten kilometers followed by a gradual increase up to the next ten kilometers. Beyond this, the attenuation curve remains almost flat. The result of this paper will serve as a good tool for microwave system designers in Nepal.

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ABOUT AUTHOR(S)



(**Kailash Karki**) obtained his M.Tech degree in Communication and Radar System from KL University, India in 2017. He is currently working as an Assistant Director at the Nepal Telecommunications Authority (NTA). Prior to his appointment at NTA, he was an Assistant Professor at Nepal Engineering College (*nec*). His research interest includes radio wave propagation, ICT policy & regulation, and digital economics.



(**Amit Shah**) has completed his Master in Information and Communication Engineering from IOE, Pulchowk Campus. He has been involved in the teaching profession in engineering colleges for 16 years, currently working as an Associate Professor and Head of the Department of Electronics and Communication Engineering, Nepal Engineering College. His research interest is bio-signal processing and speech processing.



(**Rupesh Dahi Shrestha**) received the BE degree in Electronics and Communication from Nepal Engineering College in 2005 and MSC degree in Information and Communication Engineering from IOE, Pulchowk Campus in 2013. He has experience of more than 16 years in teaching and is currently working as Associate Professor in *nec*. His research interest includes signal and image processing, machine intelligence, and embedded system.



(**Anil Kumar Yadav**) received the BE degree in Electronics and Communication from Tribhuvan University in 2007 and M.Tech degree in Communication Systems from the National Institute of Technology (NIT), India in 2011. He has experience of more than 9 years in teaching and is currently working as Assistant Professor in *nec*. His research interest includes wireless communication, automation, and networking.

Determination of Level of Service: case study of Balkhu-Sanepa Ring Road Section

Sagar Gautam^{a,1}, Thusitha Chandani Shahi^{b,2}

^aAcme Engineering College, Kathmandu, Nepal

^bCenter for Postgraduate Studies, Nepal Engineering College, Nepal

Email ID: ¹ersagar.gasmarthousing@gmail.com, ²thusithacs@nec.edu.np

KEYWORDS

Traffic Flow
Traffic Volume
Urban Road Network
Highway Capacity
Traffic Performance

ABSTRACT

An anticipated traffic flow in an urban road network is creating various problems associated with the speed, delay and congestion. The study aims at the determination of traffic stream flow quality in terms of Level of Service for Balkhu-Sanepa road section in Kathmandu. Speed, flow and density data were extracted from the video-record and analyzed by using statistical tool 'R-programming' (version 3.6.1). Indian Highway Capacity Manual has been taken as the basis for determining the Level of Service for traffic stream. The Level of Service (LOS) of Balkhu- Sanepa road section was found to be 'C'. Percentile speed values have also been determined in this study. The 85th percentile was found as 71.15 kmph which could be recommended for the maximum limit for speed control. The study concluded that the improvement of traffic performance could be initiated for upgrading the LOS to 'B' and percentile speed and maximum traffic volume of road could be adopted for the better planning decisions and design standards.

INTRODUCTION

Traffic congestion is one of the major problems for present global urban scenario for both developed and developing countries. In case of developing countries, planners are looking to reduce congestion by making new infrastructure. Similarly, in developed countries planners are looking how to improve LOS from existing infrastructure.

Traffic density is one of the major traffic stream parameter which could be determined from the fundamental traffic flow models. Furthermore, traffic density is main criterion for the finding the Level of Service of highway sections. Traffic flow models have broadly classified into the interrupted and uninterrupted flow and facility conditions as per the Highway Capacity Manual [1].

Spot speed studies are used to determine the speed distribution of traffic stream at a specific location. Purpose of this study is to establish posted speed limit to observe speed trends of vehicles.

Kathmandu Valley is facing rapid increase in the number of registered vehicles, which results in the higher traffic volume in the road-network. Determination of speed- density relationship and consequently LOS, and spot speed of vehicles might be helpful for design and management of currently upgraded road section and other section of Kathmandu Ring Road.

The main objective of this study is to determine LOS

for Balkhu-Section of Kathmandu Ring Road. Traffic density, space mean speed and percentile speed values have been specifically determined for finalizing the LOS and other recommendations for improving the traffic performances in such urban road network.

LITERATURE REVIEW

Level of Service (LOS) tries to answer how good the present traffic scenario on a given roadway facility. LOS are defined at six levels from "A" to "F" with LOS A depicting the highest level of traffic performance freedom of maneuverability and speed section and comfort as shown in Table I(a). LOS F depict traffic operations that are oversaturated, traffic being on a standstill while LOS E depicts traffic operation at the capacity of the segment. The LOS threshold proposed by Chetan R Patel using clustering technique for Indian road especially heterogeneous mixture of traffic which is given in Table I(b).

Table 1(a): Level of Service with respect to v/c ratio

Level of Service (LoS)	Range of v/c ratio
A	<0.25
B	0.125-0.276
C	0.276-0.479
D	0.479-0.715
E	0.715-1.00
F	>1.00

Source: Patel & G.J, 2012

Table 1(b): Level of Service with respect to v/c ratio

LoS	NFPC	V/C ratio	Service Volume for two Lane Road (PCUs/day)
A	≤ 0.15	≤ 0.25	<7500
B	0.15-0.25	0.26-0.45	7500-13500
C	0.26-0.40	0.46-0.60	13500-17500
D	0.41-0.55	0.61-0.75	17500-23000
E	0.56-0.70	0.76-1	23000-30000
F	> 0.71	> 1	>30000

Source: Indo-HCM

Where,

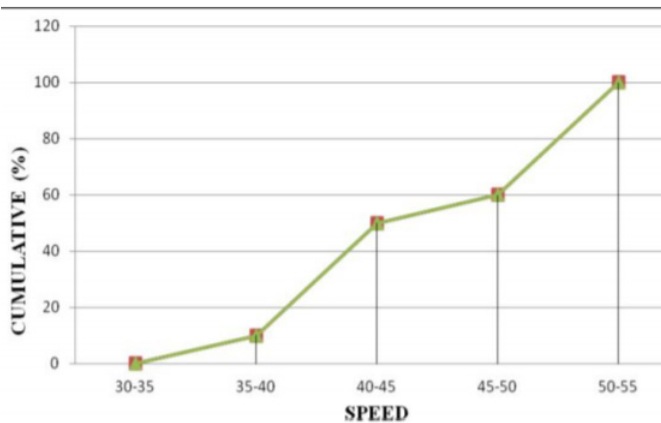
NFPC = number of follower as passenger capacity

V/C = volume capacity ratio

Speed as considered as one of the main factors for traffic flow parameter. It is recommended to conduct study in free-flow condition and duration must be at least one hour and sample size must be of at least thirty vehicles [2]. The larger the sample size, the greater the probability that the data is significant.

- 98th percentile speed: Below this speed 98 percent vehicles move and it is taken as design speed for the geometric design.
- 85th percentile speed: 85 percent of vehicles move below this speed. It is used to establish upper speed limit for traffic management.
- 50th percentile speed: It is known as median speed of vehicles.
- 15th percentile speed: It is used for determining minimum speed limit for major highways.

Figure 1 represents cumulative distribution for trucks



*Figure 1: Illustrative Figure of Cumulative Distribution Curve for Trucks
(Source: Javid & Tarry, 2018)*

RESEARCH METHODOLOGY

The urban traffic flow related data collected from the field observation enabled the entire modelling process. It looks into the problem of traffic behaviour in urban streets. Despite the presence of overhead crossing bridge, some of the pedestrian still use main road for crossing purpose. This affects speed and density of vehicles but precaution was taken during the survey to ignore speed and density of vehicle which were

impeded by pedestrian. Primary data were collected from image analysis of video graphic survey. And from this LOS and percentile speed were determined from R-programming to get the required result.

Study Area

For this purpose of study, Balkhu- Sanepa road section was selected which is illustrated in Figure 2. This route connects major places such as Satdobato, Ekantakuna, Dhobighat, Kalanki etc. Length of this section was considered as 150 m to capture the data of speed, flow and density.



Figure 2: Photograph of study road section

As video graphic method of data was used, a suitable position (which cover distance between entry and exit point) to install camera was required and thus Sanepa Bridge was used for this purpose. The salient features of the road section are shown in Table 2.

Table 2: Salient Features of Road

SN	Salient Features of Road	
1	Name of the Road	Balkhu-Sanepa Road
2	Location	
	• Province	• Bagmati
	• District	• Lalitpur
3	Cross Section	
	• Right of Way	• 62 m
	• Carriage Way	• 8 Lanes
	• Total Length	• 27 Km
4	Total Width/direction	10 m
5	Each lane width	3.5 m

Video was played on laptop screen by magnifying the required length of 150 m road section such that chances of error is minimized (vehicle travel time, vehicle count is minimized).

Steps For Primary Data Collection:

- Reconnaissance survey has been done for spot fixing camera throughout whole day. For this purpose, one day data was observed manually.
- A longitudinal trap length (distance between entry and exit point) of 150 m was adopted to capture

- the data for measurement of speed.
- Marking were made with reflector and double tape to fix the distance between entry and exit point of 150m.
- The video camera was mounted on the tripod stand and was placed at a sufficiently high level to cover the full survey stretch.
- The camera was installed for five days i.e. 5 hours 30 minute each day. Three hours in morning hour (8 am-11 am), two hours thirty minute in evening hour (3 pm- 5:30 pm).
- Flow count was done manually through video.
- For density, on 150 meter distance between entry and exit point the number of vehicles were counted.

Secondary data in this study were taken from the project report for Kathmandu Ring Road Expansion Project Office and Traffic Police Office. In the field survey, time of entry and exit of different vehicles over the length of the road section were recorded and based on the distance between entry and exit point of 150m fixed for each station. 10% of total volume of each mode observed in 15-minute interval was considered for sampling. Recorded video was replayed on large screen monitor and 15 minutes classified traffic flow counts were made [3].

Density changes at every fraction of second, but density corresponding to each and every second is tedious and troublesome to extract. At each 30th second the video was paused and the number of various vehicles at the section is that period was noted down [4]. From extracted density data from the field, Level of Service was calculated of Balkhu- Sanepa road section.

DATA ANALYSIS

Determination of Level of service

Level of Service was determined as per the following sequence:

Two way traffic volume = 1948 PCU/hr

- Lane Distribution = 50/50 (Based on field observation)
- Carriageway width = 7.0 m

Determination of Critical Gap (CG)

$$CG = 74.8 * Q^{-0.45} \quad (\text{Source: Indo HCM, 2017})$$

$$= 74.8 * (1948)^{-0.45}$$

$$= 2.475 \text{ sec}$$

Total Flow is 1948 PCU/h in the traffic stream using PCU for each vehicle type.

$$\text{Number of Follower (NF)} = 0.65 * 1948 = 1266.2 \text{ PCU/h}$$

Calculation of Base Capacity

$$\text{Capacity} = 5082 - 275 * \text{IRI}$$

$$\text{IRI} = 2 \text{ (Pavement management discussion paper)}$$

$$= 5082 - 275 * 2$$

$$= 4532 \text{ PCU/hr.}$$

Also Calculation of Number as Percentage of Capacity

$$\begin{aligned} NFPC &= \frac{NF}{\text{Base Capacity}} \\ &= \frac{1266.2}{4532} \\ &= 0.2793 \end{aligned}$$

From Table 1(b) it was concluded that 0.2793 value lies in range of 0.26 to 0.4. Therefore, Level of Service (LOS) of Balkhu-Sanepa road section was found to be 'C'

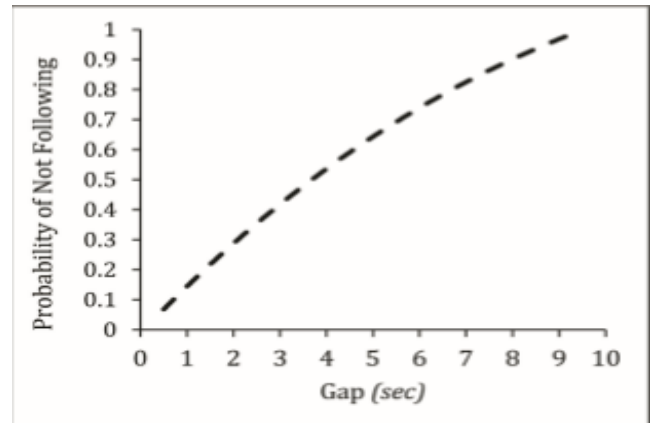


Figure 3: Plot between the gap value and cumulative distribution of Non-Followers (Source: Indo- HCM, 2017)

Percentile Speed of Vehicles

Spot speed study was carried out at 150m stretch of Balkhu-Sanepa road section. Table 3 represents speed data collection of Balkhu -Sanepa section of road.

Table 3: Speed data collection of study road section

Speed (Kmph)	Middle Speed (Kmph)	Frequency	Frequency %	Cumulative Vehicles %
37-43	40	64	1.53	2
43-49	46	442	10.55	12
49-55	52	984	23.48	36
55-61	58	1013	24.18	60
61-67	64	701	16.73	76
67-73	70	471	11.24	88
73-79	76	260	6.21	94
79-85	82	119	2.84	97
85-91	88	78	1.86	99
91-97	94	26	0.62	99
97-103	100	8	0.19	99
103-109	106	4	0.10	100

From Table 3 cumulative speed distribution curve was plotted.

Figure 5 represents speed distribution curve which resembles normal distribution curve. Speed is plotted on x- axis whereas probability density plotted on y-axis.

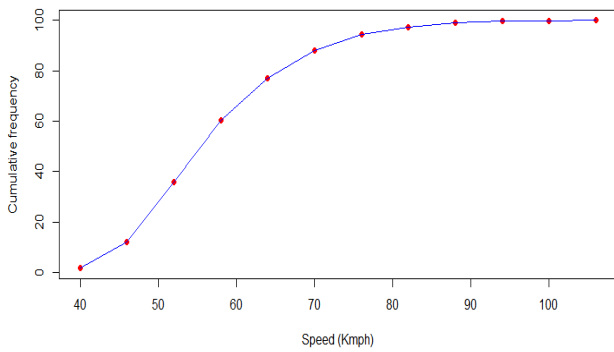


Figure 4: Cumulative Distribution Curve

Table 4: Percentile Speed of Vehicles

Speed (Kmph)	Percentile Speed			
	15th	50th	85th	98th
Vehicle	49.81	58.19	71.15	87.097

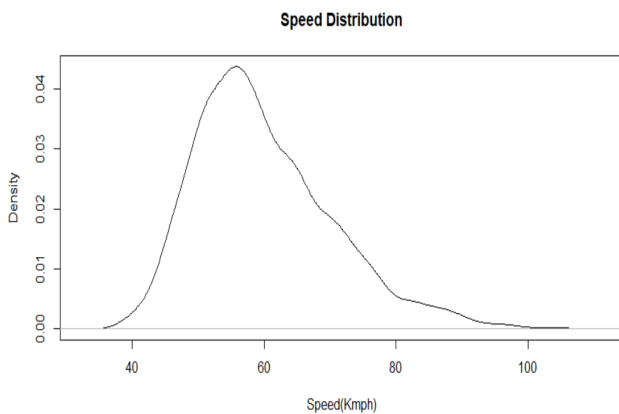


Figure 5: Cumulative Distribution Curve

DETERMINATION OF PEAK HOUR

Table 5: Maximum flow measurement over consecutive days and time

Day and Date	Time	Peak Flow (V/15 min/2 lane)
Sun (15th Dec, 2019)		
Morning	10:00-10:15	501
Evening	5:00-5:15	486
Mon (16th Dec, 2019)		
Morning	10:35-10:50	485
Evening	3:45-4:00	419
Tue (17th Dec, 2019)		
Morning	10:05-10:20	468
Evening	5:11-5:26	468
Wed (18th Dec, 2019)		
Morning	10:39-10:54	532
Evening	4:25-4:40	467
Thu (19th Dec, 2019)		
Morning	9:38-9:53	498
Evening	4:45-5:00	433

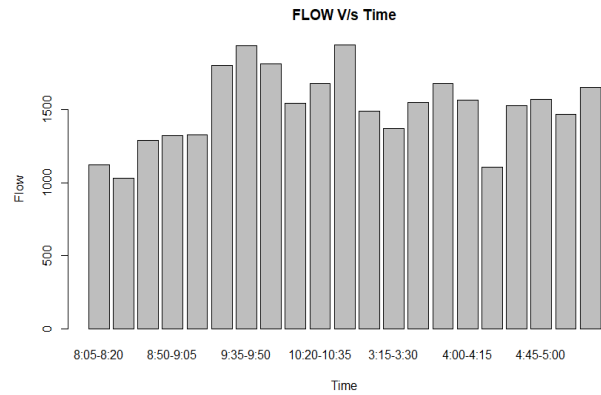


Figure 6: Flow traffic over consecutive 15-min interval

As inspection from above Table 5 and figure 6 gives opportunity to observe maximum flow rate at morning 9Am to 11Am and evening 4Pm to 5:30Pm

CONCLUSION

The study has been conducted for determination of level of service and percentile speed. Data has been taken from Bus, Car, Micro, Motorcycle, Tipper and Truck.

From Indian- HCM 2017 level of service of Balkhu-Sanepa road section was found to be "C" which is realistic as looking into present scenario. The traffic flow was found to be minimum in early morning time and in afternoon. But maximum flow occurs at morning 9 am to 11 am and evening 4 pm to 5:30 pm which can be seen in figure 6. Further, looking into speed data it was found that median speed is 58.19 kmph which is above posted speed limit (50 kmph). So, most of the drivers are violating the posted speed limit of 50kmph, on main lane.

The 98th percentile speed found to be 87.097 kmph which is used for design speed for the road section. The 85th percentile speed was 71.15 kmph which is upper speed limit for regulation. The median speed that is 50th percentile speed found to be 58.19 kmph which is average speed of vehicle travelling on the road section. The lower speed limit for regulation i.e. 15th percentile speed was 49.81 kmph.

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ABOUT AUTHOR(S)



Sagar Gautam: He has completed his Master's degree in Transportation Engineering and Management from Nepal Engineering College (*nec*-CPS). He has been involved in detailed design and cost estimates of different road projects in Nepal as well as engaged in the teaching profession for the last four years. He is currently working as a lecturer at Acme Engineering College. His research interests are intelligent traffic management and real-time traffic, the use of recycled materials in pavement construction, and the design of multimodal integrated transportation services.



Prof. Dr. Thusitha Chandani Shahi: She has completed her Ph.D. in Transportation Engineering from Moscow State Automobile and Road Construction Institute (Technical University). She has been involved in the teaching profession for the last 16 years and is currently working as a Professor at Nepal Engineering College. Her research interests are traffic management and road safety.

Climate Responsiveness of Traditional Building: A case of Kathmandu Valley

Sharada Poudel^{1,✉}, Sweta Amatya Shrestha², Rujula Tamrakar³, Samjhana Shrestha⁴

Department of Architecture

Nepal Engineering College, Nepal

E-Mail ID: ¹sharadap@nec.edu.np, ²swetaas@nec.edu.np, ³rujulat@nec.edu.np, ⁴samjhanas@nec.edu.np

KEYWORDS

Climatology
Climatic data
Traditional buildings
Climate responsive design
Mahoney Table
Kathmandu Valley

ABSTRACT

Climatology is one of the important parameters in a building design to meet the human comfort. Traditional buildings have always given the essence of comfort within its living in terms of physical and mental well-being of a person. Its comfort level is always a matter of concise implementation of climate responsive design. This study aims to analyse the traditional buildings in terms of climate responsiveness. For the purpose, Mahoney's Table has been used. Mahoney's Table are a set of reference table in architecture which relate design decisions on the basis of prevailing climate of the area. In this study, climatic data from three years 2014, 2016 and 2018 has been considered. In reference to climatic data in Mahoney's Table, climate responsive design outline has been delivered for the respective study areas. Those design outline has been deliberated as a checklist to check climate responsiveness of the traditional buildings at the study areas. Based on the checklist surveyed traditional buildings reflected the climate responsiveness.

INTRODUCTION

Climate of Kathmandu Valley

The Kathmandu Valley is located between 27°36' to 27°50' north latitude and 85°7' to 85°37' east longitude at an altitude of about 1311 meters above sea level. Kathmandu lies in the warm temperate climate. The temperature in summer ranges from high 28°-29° C to a low of about 20° C, while winter sees a high of about 18° C to a low of 2° C. The total rainfall in the country can be about 1400mm.

Traditional buildings

Traditional building architecture of Kathmandu valley is highly influenced by culture, local building materials and climate. The traditional houses are mainly designed to optimize the use of natural resources like the sun and wind [1], [2].

The average traditional houses of Kathmandu valley are rectangular in shape. The depth is generally 6 meters and its length is governed by size and the availability of materials. The houses are generally 2, 3 or 4 storied. The main door is low and narrow with small windows on both sides of the door. The windows are generally medium in size except in the top floor where Sa: Jhya: is placed. Wall is usually constructed of three different vertical layers of masonry, with a total width varying from 45 to 75cm. The outer face is constructed of burnt brick. For the main front of important buildings or temples, a special wedge-

shaped brick is used. The inner face of the wall is made burnt or even unburnt brickwork. In between the inner and outer face is filled with brick rubble. Floor is constructed with closely spaced joists over which terracotta tiles or wooden planks are placed and then a thick layer of mud topping is done. Slope roofs with large overhang are provided which protect the wall from monsoon rains [3], [4].

MAHONEY'S TABLE

Mahoney's Table are a set of reference table in architecture, used as guide to climate appropriate design developed by Carl Mahoney. The table relate design decisions to climatic stress and how to relieve it.

The data needed for Mahoney's Table are monthly mean maximum and monthly mean minimum air temperature, average relative humidity (RH) and average rainfall of each month of the year. From the monthly mean maximum and minimum temperature, mean temperature range of each month is calculated. Secondly the highest and lowest mean temperature of year is recorded and from this AMT (Annual Mean Temperature) and AMR (Annual Mean Range) are calculated.

From the average RH of each month, humidity group is divided: group 1 (below 30%), group 2 (30-50%), group 3 (50-70%) and group 4 (above 70%). Accordingly, humidity group of each month of the year is noted. These humidity groups are then linked with AMT to

define lower and upper thermal comfort limits. There are three levels (AMTs): AMT over 20°C, AMT between 15 and 20°C, and AMT below 15°C. After knowing the comfort limit, thermal stress for both the day and the night of each month of the year is obtained. For this the monthly mean maximum temperature is compared with the day comfort limits while the monthly mean minimum temperature is compared with the night comfort limits. When the temperature is higher than the upper limit there is hot discomfort (H) while there is cold discomfort (C) when the temperature is lower than the lower limit. Temperatures falling between the comfort limits are comfortable (O).

The thermal stress obtained gives an indication of the remedial action the architect can take to achieve comfort. The remedial action determined for how many months of the year, there is need for ventilation, rain protection and thermal storage. This is specified by the humid indicators (H1, H2, H3) and arid indicators (A1, A2, A3). The humid indicators (H1, H2) show whether air movement is essential or only desirable. The need for rain protection depends on the amount of rainfall in the particular month. The arid indicators deal with the thermal aspects of design. The need for thermal storage arises when there are hot days and cold nights. Uncomfortable night temperatures suggest outdoor sleeping while special treatment is required in cold climates. The total number of months when remedial action needs to be taken is then recorded in Table.

Based on the numbers of month of remedial action, design recommendations are made to alleviate thermal distress. Design recommendation are made on orientation, layout, and spacing of building, size, position and protection of openings, wall (external and internal), floor thickness, roof of the building and rain protection and drainage to protect from severe downpour.

OBJECTIVE OF THE STUDY

The main objective of this paper is to check the climate responsiveness of the traditional buildings of Kathmandu Valley by using climatic data of the study area and the design outline given by the Mahoney's Table.

Specific Objectives

- To analyse the climatic data of all three study sites using Mahoney's Table
- To come up with the climate responsive design outline from the Mahoney's Table
- To check the climate responsive design outline on the study site and analyse the data to see whether the traditional buildings are climate responsive or not

METHODOLOGY

This study is based on the literature review, site study and qualitative and quantitative data analysis.

Table 1: Mahoney's Table (Climatic Data Analysis of Kathmandu, 2016)

Location: Kathmandu	Year: 2016	Nos. of Month(s)	Latitude		Longitude		Altitude		Highest DBT = 31.2 Lowest DBT = 4			AMT = 17.6		AMR = 27.2
Months			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Mean Monthly Max			18	23	27	31.2	28.9	29.2	28.1	30	27.9	27	24	20.8
Mean Monthly Min			4	6.3	10.3	14.2	16.2	19.5	20.4	20.1	19.3	16	8.5	5.8
Range			14	17	16.7	17	12.7	9.7	7.7	9.9	8.6	12	15	15
RH (%) average			68	59	54.2	41.1	71.9	78.3	86.6	82.4	82.9	76	70	72.2
Humidity Group			3	3	3	2	4	4	4	4	4	4	4	4
Mean Rainfall (mm)			0.4	25	6.3	11	92.3	370	478	126.8	282	91	0	0
Day Comfort	Min		21	21	21	22	20	20	20	20	20	20	20	20
	Max		26	26	26	30	25	25	25	25	25	25	25	25
Night Comfort	Min		14	14	14	14	14	14	14	14	14	14	14	14
	Max		21	21	21	22	20	20	20	20	20	20	20	20
Thermal Stress	Day		C	O	H	H	H	H	H	H	H	H	O	O
	Night		C	C	C	O	O	O	H	H	O	O	C	C
Air Movement Essential	H1	6												
Air Movement Desirable	H2	2												
Rain Protection	H3	3												
Thermal Storage	A1	4												
Outdoor Sleeping	A2	0												
Cold Season Protection	A3	1												

In the first step, study has been carried out on Mahoney's Table as mentioned above. Mahoney's tables provide results of thermal comfort analysis using primarily temperature and humidity data, and recommendations of predesign guidelines [5].

Secondly, climatic data of three different study sites namely Kathmandu, Bhaktapur and Lalitpur has been collected from their respective weather stations. Climatic data of three years 2014, 2016 and 2018 has been considered and analysed quantitatively using Mahoney's Table as a tool. Mahoney's Table resulted design recommendations in terms of orientation, spacing, layout, openings, position of the openings, protection of openings, roofing, wall and floor typology and external drainage features.

Based on these outlines, survey on the study area has been carried out. Analysis has been done on the basis of their design in order to determine the applied climate-responsive design strategies. For this, collected data has been qualitatively analysed. Qualitatively analysed data when met the 70% of the design criteria were then categorised into climate responsiveness.

In the fourth step, analysed data concluded that the traditional houses are much adapted to the local climate conditions.

STUDY AREA

This study covers three traditional courtyards of Kathmandu, Bhaktapur and Lalitpur. In total 28 different traditional buildings of the courtyards are surveyed and analysed. In Kathmandu, Lalitpur and Bhaktapur study has been carried out on Jana Bahal, Kwalkhu and Kolachhe: respectively.

DATA COLLECTION AND ANALYSIS

Climatic data such as monthly mean temperatures (minimum, maximum), average relative humidity, rainfall of

Kathmandu, Lalitpur and Bhaktapur on three different years 2014, 2016 and 2018 are collected and analysed using Mahoney's Table. One of the analysis on Mahoney's Table has been illustrated in Table 1.

The analysis showed the similar climatic conditions with minimal variations in the study areas. The table below illustrate the same: Analysis figured out that on an average in 12 months' thermal stress condition for days and nights in all the study areas are similar. Out of 12 months, 2 months are cold, 3 months are comfortable and 7 months are hot in day. While, out of 12 months, 7 months are cold, 3 months are comfortable and 2 months are hot in night.

Remedial Actions for Kathmandu Valley

Table 2: Climatic Data and Humidity Group

Location	DBT		Humidity Group
	Highest (°C)	Lowest (°C)	
Kathmandu	30.4	3.7	2,3,4
Lalitpur	29.5	2.7	3,4
Bhaktapur	30.66	1.5	3,4

Table 3: Thermal Stress Outcome

Location	Thermal Stress (Nos of months) Where C: Cold, H: Hot & O: Ok	
	Day	Night
Kathmandu	2C, 3O, 7H	6C, 4O, 2H
Lalitpur	2C, 3O, 7H	7C, 3O, 2H
Bhaktapur	2C, 2O, 8H	7C, 2O, 3H

Based upon the thermal stress of the analysed data, following remedial actions has been figured out for the Kathmandu Valley.

Table 4 explains that following requirements are needed in the building design as per the climate of the Kathmandu Valley:

- For 5 months of a year air movement is essential
- For 1-month air movement is desirable
- Rain protection is essential for 2 months
- Thermal storage is essential in the building for 5 months
- There is no need of outdoor sleeping
- For 2 months' cold season protection is essential.

Table 4: Remedial Action for Kathmandu Valley

Remedial Actions	Indicators	Kathmandu	Bhaktapur	Lalitpur
Air Movement Essential	H1	5	5	5
Air Movement Desirable	H2	1	1	1
Rain Protection	H3	3	2	2
Thermal Storage	A1	5	5	5
Outdoor Sleeping	A2	0	0	0
Cold Season Protection	A3	2	2	2

Climate Responsive Design Recommendations for Kathmandu Valley

Based on the remedial actions, following climate responsive design recommendations for Kathmandu Valley has been figured out:

FINDINGS AND CONCLUSIONS

Climate responsive design recommendations listed in Table 5 are taken as checklist parameters for the survey of traditional building. In surveyed households (Table 6a & Table 6b) it has been found that 63% in Kathmandu, 33% in Lalitpur and 67% in Bhaktapur have E-W longer axis orienting towards North and South. Similarly, 100% of surveyed building have open spacing for breeze penetration with medium (20-40%) opening and heavy floor and massive wall construction for thermal comfort. Whereas none of the building have insulated roof due to change in roofing material to CGI sheets after earthquakes.

Table 5: Climate Responsive Design Recommendations for Kathmandu Valley

Remedial Actions					Design Recommendations as per Mahoney's table
Remedial Actions	Indicators	Kathmandu	Bhaktapur	Lalitpur	
Air Movement Essential	H1	5	5	5	Spacing: Open Spacing for breeze penetration and protection from hot and cold wind
					Air Movement: Rooms single banked, permanent provision for air movement
					Position of Opening: In north and south at body height on windward side
					Roof: Light, well Insulated
Air Movement Desirable	H2	1	1	1	
Rain Protection	H3	3	2	2	Protection of opening: Provide protection from rain
					External Features: Adequate rainwater drainage
					Layout: Orientation north and south (long axis East - West)
Thermal Storage	A1	5	5	5	Openings: Medium openings, 20%-40%
					Walls: Heavy external and internal walls
					Roof: Light, well Insulated
Outdoor Sleeping	A2	0	0	0	Walls and floors: Heavy, over 8 hours' time lag
					Layout: Compact Courtyard Planning
Cold Season Protection	A3	2	2	2	Openings: Medium openings, 20%-40%
					Protection of openings: Exclude direct sunlight

Similarly it has been found that out of 14 different design recommendation parameters minimum 10 recommended design parameters have been met in surveyed traditional buildings. In Kathmandu, out of 9 traditional buildings, 33% met 10 parameters and 66% met 12 parameters. In Bhaktapur, out of 10 traditional buildings, 11% met 10 parameters, 44% met 11 parameters, 33% met 12 parameters and 22% met 13 parameters. In Lalitpur, out of 9 traditional buildings, 66% met 11 parameters, 11% met 12 parameters and 22% met 14 parameters. The data has been illustrated

Table 6a: Recommended Design Parameters found on surveyed households based in Kathmandu, Lalitpur and Bhaktapur

Study Area	Orientat- ion (E-W axis)	Open Spacing (breeze penetrat- ion)	Spacing (Single bay)	Opening (20-40%)
Kathmandu	63%	100%	0%	100%
Lalitpur	33%	100%	100%	100%
Bhaktapur	67%	100%	33%	100%

Table 6b: Recommended Design Parameters found on surveyed households based in Kathmandu, Lalitpur and Bhaktapur

Study Area	Roof (Insulated)	Layout (Compact Courtyard)	Wall and Floor (Heavy)
Kathmandu	0%	100%	100%
Lalitpur	0%	100%	100%
Bhaktapur	0%	78%	100%

in figure no 1.

The conducted survey and analysed data showed that surveyed traditional buildings met 72% to 83% of the climate responsive criteria. Figure 2 below portray the data

Figure 1 and Figure 2 demonstrate that surveyed traditional buildings in Kathmandu met 72% of the responsive criteria and in Lalitpur and Bhaktapur more than 80% of the criteria has been met. Despite of the location building features are common in all with some modification done as per ongoing time. Some common features found in all of them are explained in the paragraph below.

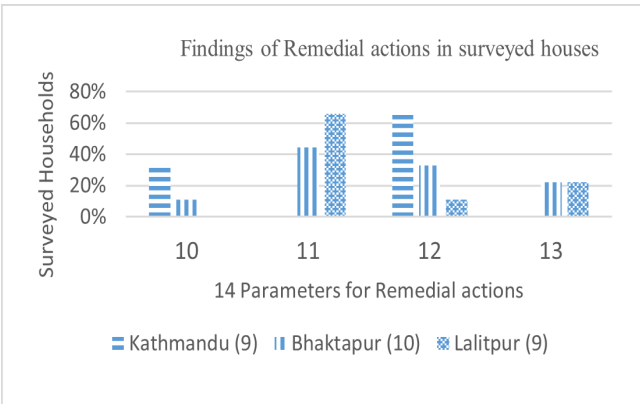


Figure 1: Recommended design parameters found on surveyed households in Kathmandu, Bhaktapur and Lalitpur

The figure 3 shows that the traditional building of Kathmandu valley has been planned with compact

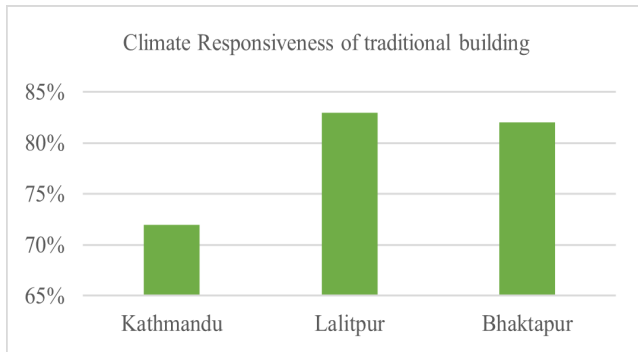


Figure 2: Climate Responsiveness of traditional buildings of study sites

courtyard and ground floor are found with opening for breeze penetration as recommended by Table no 5.

The size and position of opening for air movement and the projection of roof for rain and sun protection as well as massive wall (both external and internal) and heavy floor construction for thermal storage has been found in traditional building as recommended by Table no 5. The figure 4 and 5 shows the detail section.

Henceforth, it can be concluded that traditional buildings are climate responsive and its design elements are wisely designed to respond well with its prevailing local climate.

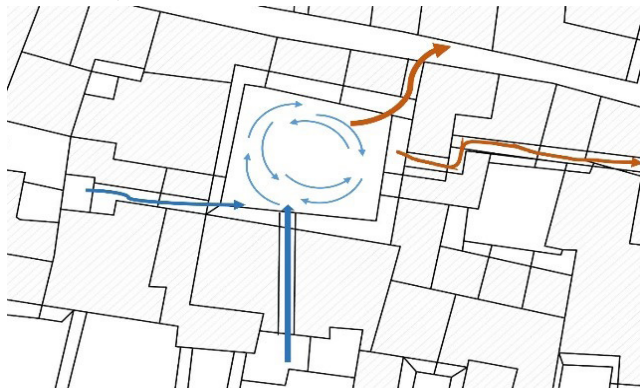


Figure 3: Wind flow inside the courtyard of traditional settlement, Site Location: Bhaktapur

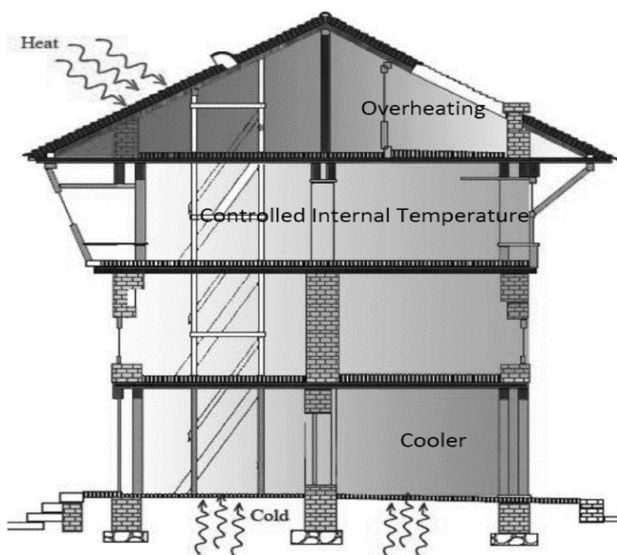


Figure 4: The constructional method of building adding internal temperature control (Source: Singh, A., 2019)

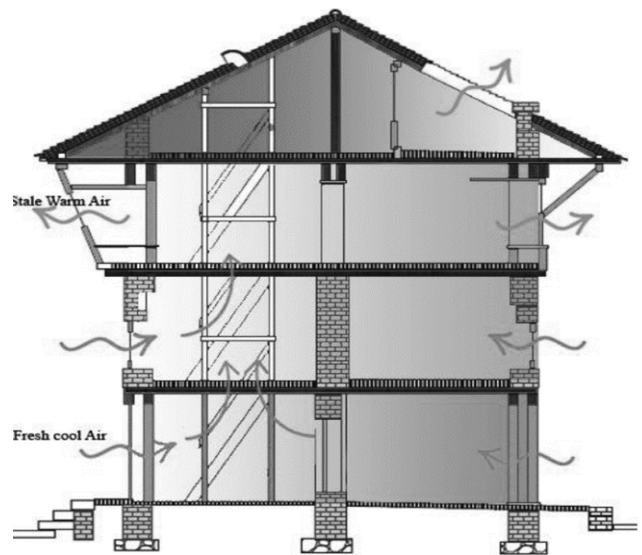


Figure 5: Flow of breeze through the traditional building aiding in cooling the building [6]

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ABOUT AUTHOR(S)



(Sharada Poudel) has received her Master's degree in Urban Planning from Tribhuvan University, IOE, Pulchowk Campus. She has been working as Assistant Professor in Nepal Engineering College since 2015 A.D. Her research interest is in Urban Planning and Sustainable Architecture.



(Sweta Amatya (Shrestha)) has received her M.Sc. in Engineering in Disaster Risk Management from Institute of Engineering, Tribhuvan University. Currently, she is working as an Assistant Professor in Nepal Engineering College. Previously, she had been involved as a Senior Technical Manager and Project Architect in DRR and Architectural field respectively.



(Rujula Tamrakar) has received her Master's degree in Urban Design and Conservation from Purbanchal University, Khowpa Engineering College. She has been involved in teaching profession for last 9 years and currently she is working as Assistant Professor at Nepal Engineering College since 2015 A.D. Her research interest is in Traditional buildings/settlements and its Conservation



(Samjhana Shrestha) has received her M.Sc. in Engineering in Disaster Risk Management from Tribhuvan University, IOE, Pulchowk Campus. She has been working as Assistant Professor in Nepal Engineering College since 2011 A.D. Her research interest is in Sustainable Architecture.

Game-Based Understanding of Pointers

Naresh Prasad Das✉

Department of Computer Science and Engineering

Nepal Engineering College, Bhaktapur, Nepal

Email ID: nareshpd@nec.edu.np

KEYWORDS

Pointers
Game-play
Game-based learning
Learn by example

ABSTRACT

C programming is a mandatory course in computer science and engineering and other allied programs because it familiarizes students with basic programming principles. In C Programming, a pointer is one of the crucial topics because a pointer deals with memory addresses, which are tough for learners to grasp, making it one of the more challenging concepts to understand. Gamification is one of the strategies that has resulted in improved motivation, engagement, and learning outcomes since the introduction of technology in the contemporary period. A game-based knowledge of pointers is developed to assist learners in visualizing memory addresses and their contents. The digital revolution is changing the way students study and access information. This study focuses on visualizing the idea of pointers to fully understand C programming.

INTRODUCTION

Programming is a fundamental skill in the software development sector. Several programming courses are available to students in preparation for future careers. C programming is a well-known and significant truth. A strong conceptual understanding of C programming subjects serves as a solid foundation for learning other programming languages. C programming is included in many universities' curricula; however, it is a tedious process to study theory and then practice developing programs to enhance one's C programming abilities. When today's learners are examined, it is observed that they rarely study on paper and prefer to play computer games. Many of the kids have a general habit of constantly playing games.

In C programming, pointers are an important yet difficult concept to grasp. Because the material is virtual, it is challenging and dull for students. Pointers deal with memory addresses, and it is difficult to imagine a computer's memory address. It is important to encourage and involve pupils to enhance the educational system. Gamification principles can help achieving this.

The goal of this paper is to make pointers enjoyable to understand. Students were given a game-based knowledge of pointers in C programming, and the pointers were designed to be evaluated and taught in a more enjoyable manner. Gamification principles seek to increase user-platform engagement by engaging and motivating people to learn independently. It is also crucial to note that this tool is not intended to replace instructors, but rather to assist them in the learning processes and methodology of their respective fields.

RELATED WORK

Tan and Seng [1], gave a case study on how they used a computer game to help them teach a data structures course. It assisted students in visualizing data structures as well as data access operations on stacks and queues. They also discovered that when it comes to understanding data structures, pupils are highly positive about the use of games.

Costa et al. [2] highlighted the design and construction of DSLEP (Data Structure Learning Platform), an interactive web learning environment used to help students in higher education IT courses. The method combines fundamental ideas taught in this field such as stacks, queues, lists, arrays, and trees, and was designed to accept new ones. The system also includes gamification ideas like points, levels, and leader boards to reward students and drive self-learning.

Yassine et al. [3] demonstrate the creation of serious games for teaching science courses in general, and particularly programming languages. They regarded serious games as an innovative teaching method since they use information and communication technologies as well as gamification to promote learning.

Ramle et al. [4] created, tested, and built game-based learning of stack data structure utilizing question prompts. They use games to help students learn the insert and remove operations of a stack. They used pre-and post-game assessments to compare student performance on the stack.

POINTERS

Pointers are variables in memory that hold the address of another variable. Because pointers have memory addresses as their values, they are said to "point to"

the variable whose reference they hold. Memory addresses are the places in computer memory where program instructions and data are stored. Pointers can be used to retrieve and manipulate data.

Our computer's memory may be viewed as a set of memory cells, each of which is the smallest size that computers can manage. Each cell is typically referred to as a byte and is connected with a number known as the address. Typically, addresses are consecutively numbered beginning with zero. The final address is determined by the memory size. As illustrated in Figure 1, a computer with 64KB of memory will have a final address of 65535.

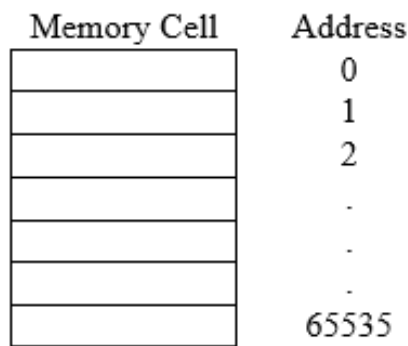


Figure 1: Memory Representation

Declaring variables implies putting them someplace in the computer's memory. A variable is associated with an appropriate and unique address. The variable's value is stored in the one-of-a-kind address location. Take, for example, the following statement:

```
int number = 170;
```

This line directs the system compiler system to locate an integer variable in computer memory, assign that address to a variable number, and store value 170 at that place. Assume the system has selected the address location 7085 for the variable number, which will be shown in Figure 2.

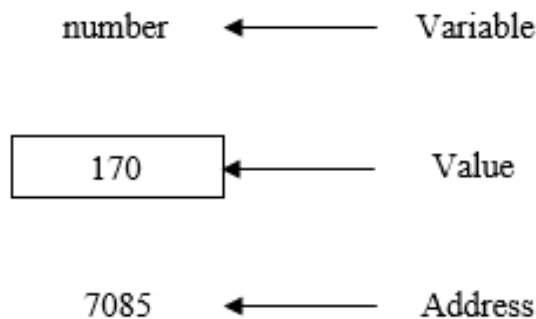


Figure 2: Variable Memory Visualization

During program execution, the computer always associates the variable's name with the allocated memory location. In the preceding example, the name number always corresponds to the address 7085. The variable's value has access to the variable's name or the location where it is placed. For example, the value 170 can be accessed by the name number or the address 7085.

A reference to a variable is the address that locates that variable within a computer memory. This variable reference may be retrieved by preceding the variable's identifier with an ampersand sign (&), also known as the reference operator.

The value stored in the variable can be directly accessed by the use of a pointer. To access the value we have to precede the pointer's identifier with an asterisk (*), known as dereference operator.

A pointer is a variable that is located in any memory address and it contains the address of another location in computer memory where another variable is located. For example, suppose we assign the address of a variable number to a pointer variable ptr.

```
ptr = &number;
```

The mapping of pointer variable ptr and variable number can be visualized in Figure 3.

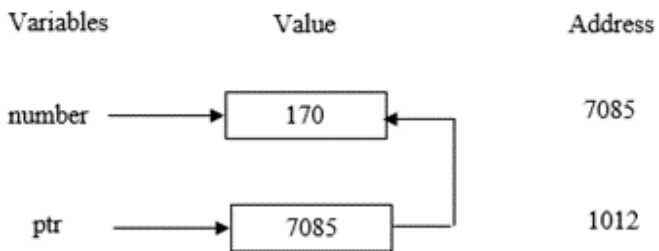


Figure 3: Pointer variable and Normal Variable mapping

GAME-BASED LEARNING METHODOLOGY

This game was created to help students learn the concept of pointers. Because pointers deal with memory addresses in programming, they are virtual for beginners and difficult to visualize. The gaming interface displays the memory address, allowing learners to quickly grasp the fundamentals. This game was created with Python as a programming language, and the required memory assumptions were built in order to offer the learners an interface linked to memory. As seen in Figure 4, the system is separated into two modules: learn by example and games.

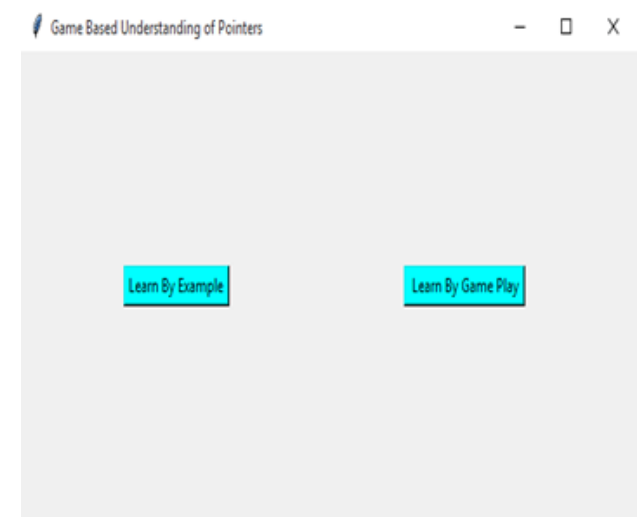


Figure 4: Interface showing two modules

Learn By Example

The Learn by Example module is connected to the basic principle of pointers and shows an example of a pointer and its memory mapping. Two-pointer variables and two normal variables of distinct data types were established at the start of this section. The address of normal variables of the same data type is stored in pointer variables. As illustrated in Figure 5, two buttons were created to demonstrate memory mapping of pointer variables and normal variables.

After clicking the Show Memory mapping button the system will show the memory address and value of related variables as shown in Figure 6.

Game Play

In this module, normal and pointer variables have been randomly placed in matrix form. These variables have been connected with the dotted line. For the player to score the point, one should match the correct pair by selecting the dotted line based on the concept of

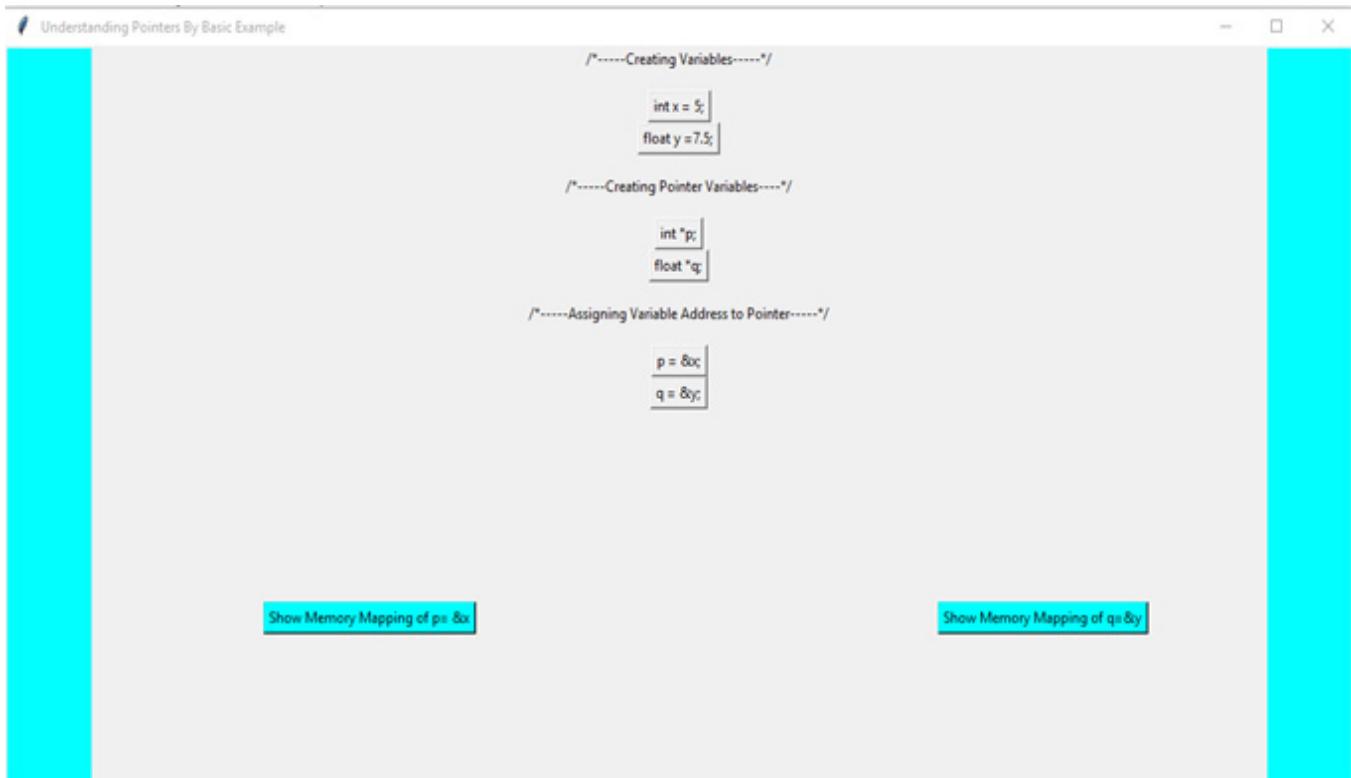


Figure 5: Module Learn by example showing variable creation

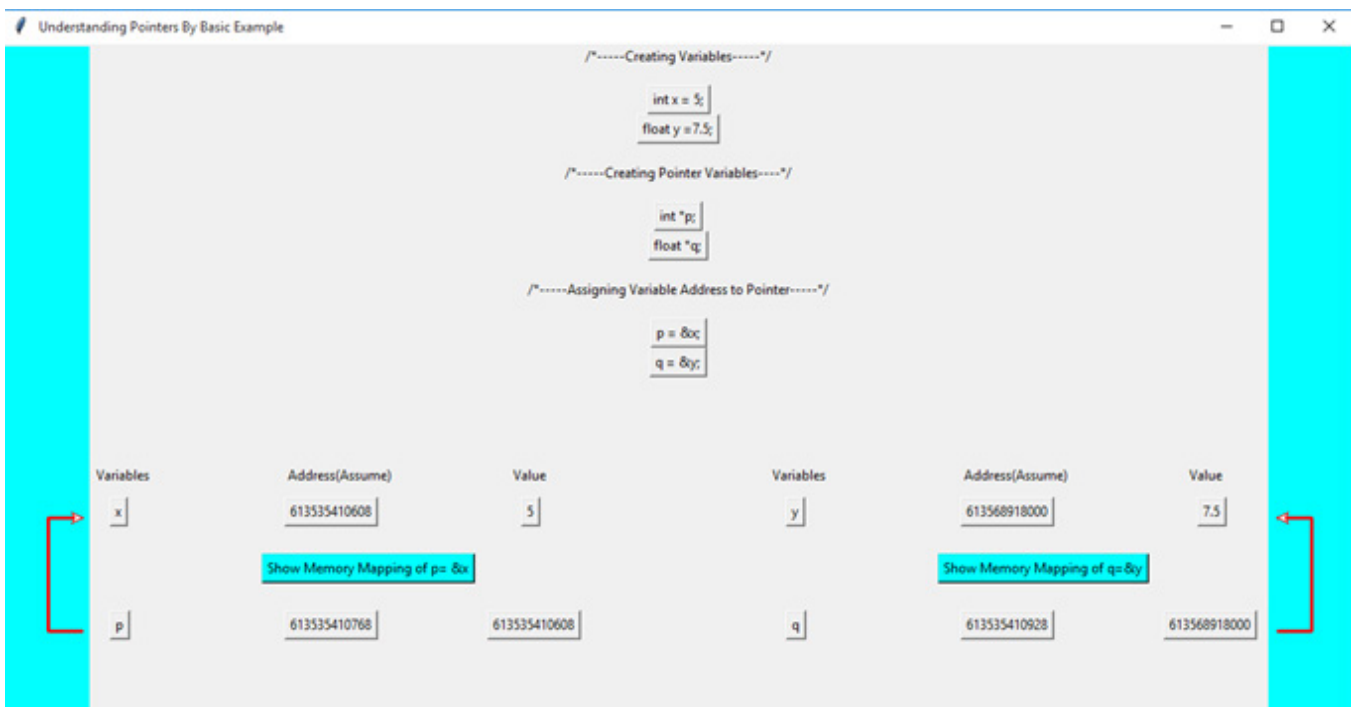


Figure 6: Showing pointer variable and normal variable memory mapping

pointers. The Figure 7 shows the screenshot of this module.

The game is meant for two players, and each player must choose a dotted line. The player receives a point if the selected dotted line is legitimate according to the regulation. Following the selection of one line, the turn is passed to the next player as shown in Figure 8. The following player follows suit as shown in Figure 9. In this manner, the process is repeated until all of the dotted lines were picked as shown in Figure 10. Once all of the dotted lines have been picked, the interface displays the appropriate score depending on the proper match and declares the winner as shown in Figure 11.

CONCLUSIONS

This study offers a game-based knowledge of pointers that allows students to view the memory address of pointer variables and normal variables. Because

it increases awareness by visualizing the ideas connected to pointers, using a game as a learning and assessment method is both pleasant and efficient for the learners. Learners can relate to and see how the pointer mechanism works in computer memory. The goal is to make the learning process more appealing than traditional learning and teaching methods.

LIMITATIONS AND FUTURE WORK

The game has been developed by only considering the basic concept of pointers. This work can be extended in many ways in the future:

- Incorporate multiple pointers and dynamic memory management into the software.
- Conduct further tests to assess the effectiveness of using the software.
- Extend the scope of the system with basic programming concepts.

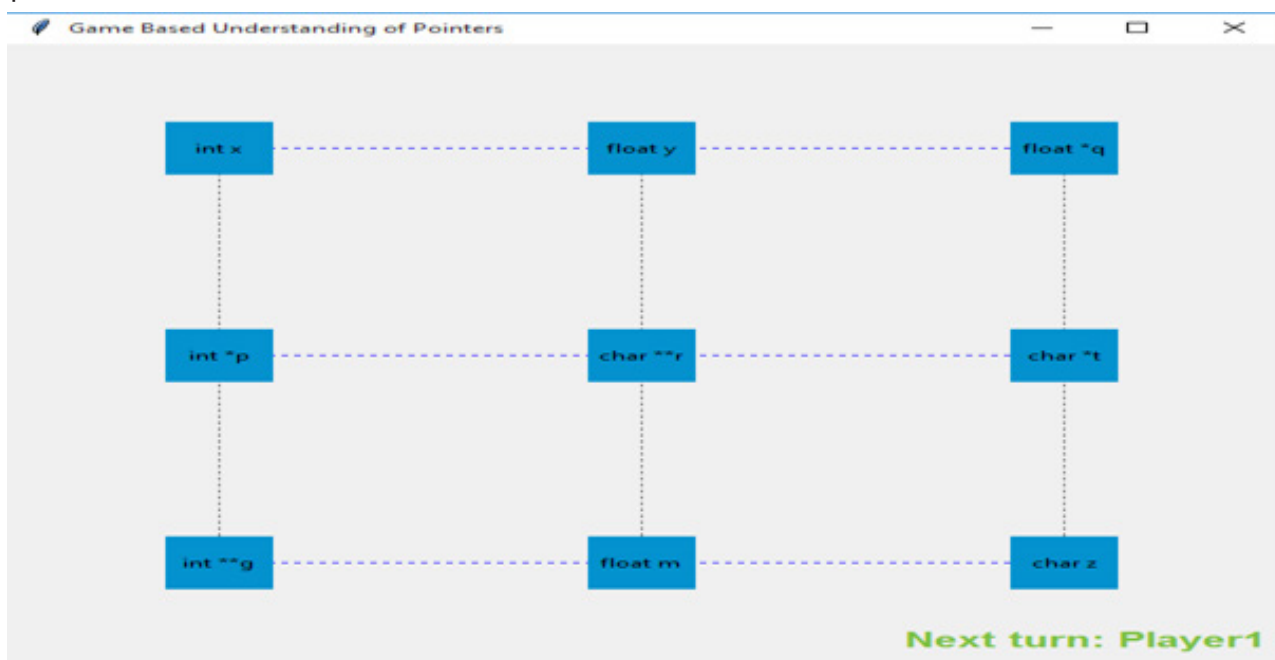


Figure 7: Showing gameplay module

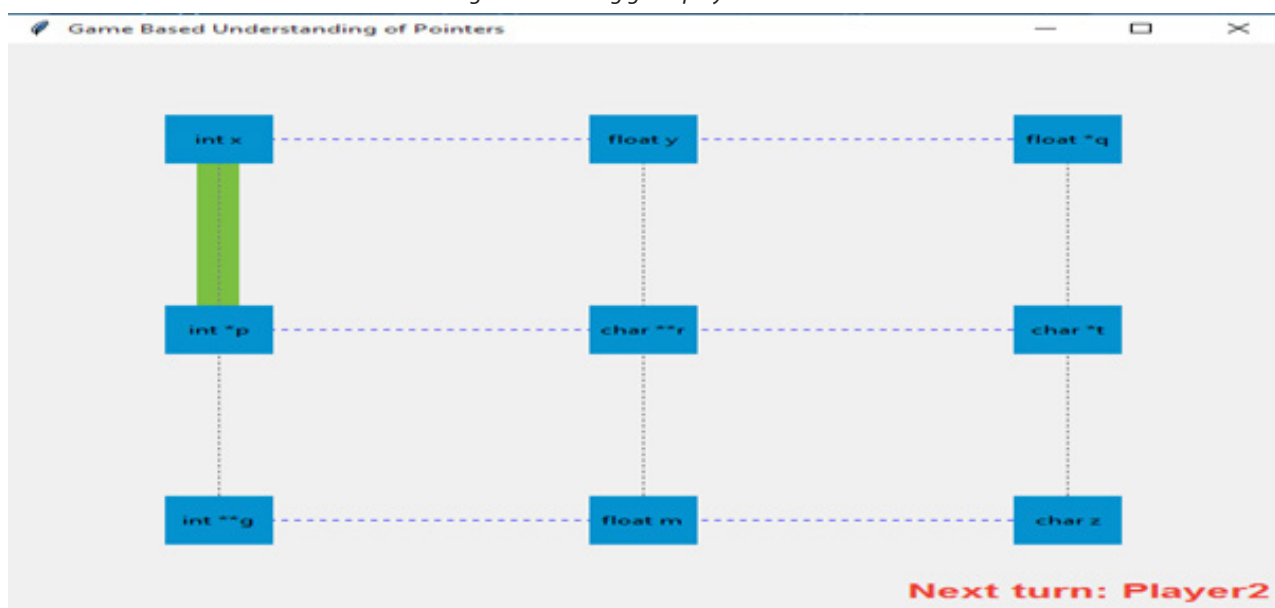


Figure 8: Showing gameplay module

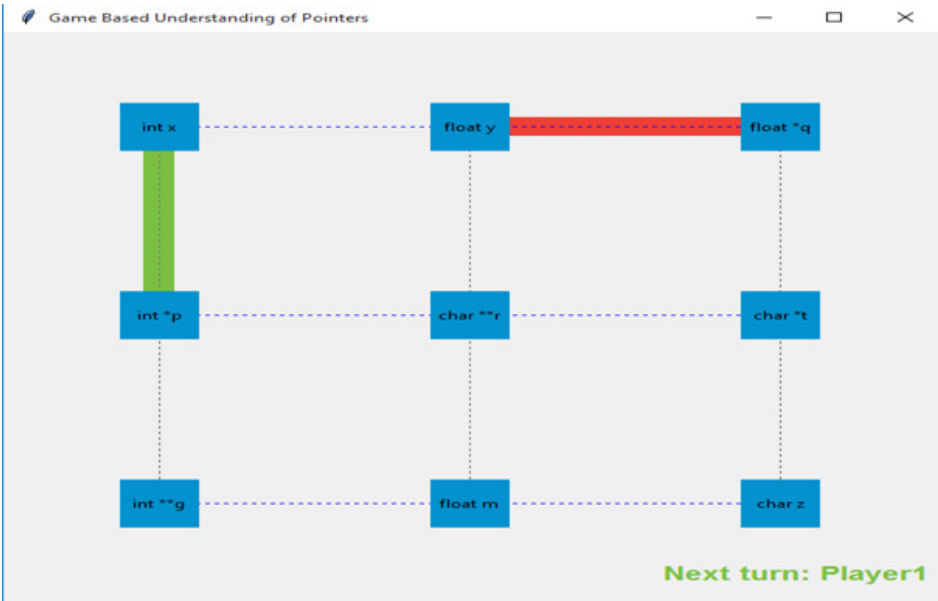


Figure 9: Showing Selected dotted line

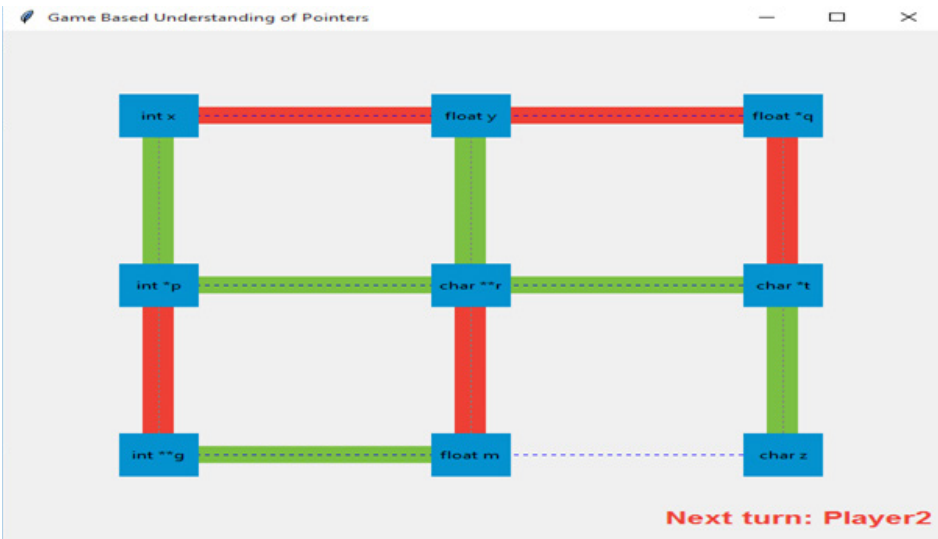


Figure 10: Showing selected dotted line

Winner: Player 1

Scores

Player 1 : 3

Player 2 : 2

Figure 11: Showing Scores of the game

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ABOUT AUTHOR(S)



(Naresh Prasad Das) has completed his M.TECH-Digital Electronics and Communication Systems from Jawaharlal Nehru Technological University Anantapur, Andhra Pradesh, India. He has been involved in the teaching profession for the last 7 years and is currently working as Assistant Professor at Nepal Engineering College. His research interests are Programming and Simulation, Wireless communication, Data structure and Algorithm.

Harmonics reduction in three-phase grid-connected inverter by using the third-order filter

Yam Krishna Poudel ✉

Department of Electrical and Electronics Engineering

Nepal Engineering College, Bhaktapur, Nepal

Email ID: yamkp@nec.edu.np

KEYWORDS

Transfer function
Third-order filter
Grid-connected inverter
Harmonics reduction
LCL filter

ABSTRACT

To ensure the power quality of power electronics interfaced based grid-connected distribution system, the IEEE 1547 has imposed a limit on the magnitude of current harmonics (THD) level around the inverter switching frequency. This limit introduces the necessity of a proper filter in-between the inverter and the electric grid. In this research study, the LCL filter is designed and simulated in a MATLAB environment. Transfer function-based detailed calculation of LCL filter for the three-phase grid-connected inverter is also elaborated. The study shows that the most effective filter for suppressing the current harmonics occurring from the switching frequency injected into the grid is the LCL filter. The proper design of the LCL filter is necessary to achieve the high-quality grid current, otherwise, the adverse scenario is created by resonance. The experimental simulation results show that a high degree of harmonics is decreased if a proper LCL filter is designed and implemented

INTRODUCTION

Nowadays, the green and clean energy concepts are more popular day by day. This concept leads to the integration of renewable energy sources into the existing traditional grid. The output obtained from Renewable Energy Source (RES) like the photovoltaic system has dc out output. In order to feed it into the utility grid, an inverter is needed. In order to ensure the power quality, the system follows certain grid interconnections standards like IEEE 1547. It has imposed the limit on the magnitude of current harmonics at the output of the inverter around its switching frequency. This limit calls for an AC side filter. Filter helps to reduce the harmonic content in grid current so as to inject the purely sinusoidal waveform into the grid [1].

Harmonics generated by power conversion device switching is the primary source of problems for sensitive equipment or connected loads, especially for applications above several kilowatts, where filter cost and total harmonic distortion (THD) are also important factors to consider during the system design phase [1,2].

The design of an LCL filter begins with a consideration of system factors such as inverter output voltage, rated active power, grid frequency, switching frequency, and resonance frequency. The rest of the LCL filter design technique entails mathematical computations. The pulse width modulation PWM method is used to place the output current of the grid-connected inverter.

Ramle R., Rosli D., et al. [4] created, tested, and built game-based learning of stack data structure utilizing question prompts. They use games to help students learn the insert and remove operations of a stack. They used pre-and post-game assessments to compare student performance on the stack.

So, it contains higher-order harmonics. There are various types of filters used in between the inverter and the grid, such as L, LC, LCL, etc. in order to suppress the existing harmonics. However L filter has higher voltage drops, and therefore more advanced LCL filter is introduced. The LCL filter is more effective in reducing the switching harmonics but has a resonance problem. Therefore, an effective design and parameter calculation are necessary for the LCL filter. The design procedure that determines the parameter value for the LCL filter is quite complex as compared to the L filter [3].

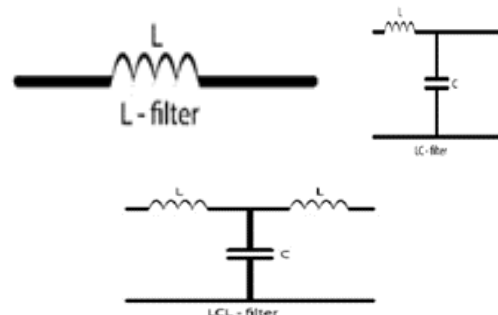


Figure 1: Different types of filters

LCL filter design

In the design consideration, let's assume the ideal filter component, the LCL filter without any external damping resistance is used here.

L1 is the converter side inductor, L2 is the grid side inductor and C is the filter capacitor. This figure represents the three-phase LCL filter.

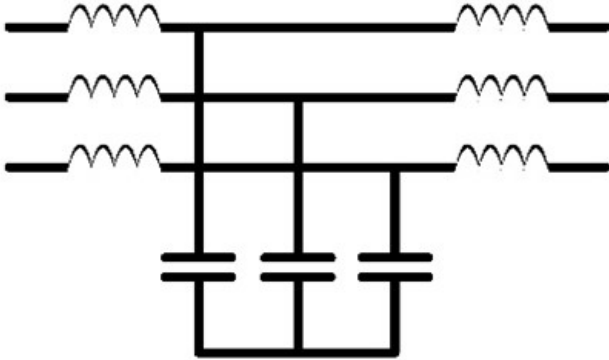


Figure 2: Three-phase LCL filter

METHODOLOGY

In this paper, a third-order (LCL) filter is used. The parameter values are obtained from the transfer function model. Filter design considerations are taken from the IEEE standard. The design considerations are simulated in MATLAB 2018a version and the results are analyzed and presented.

Transfer function:

The transfer function obtained for the given third-order filter is as follows.

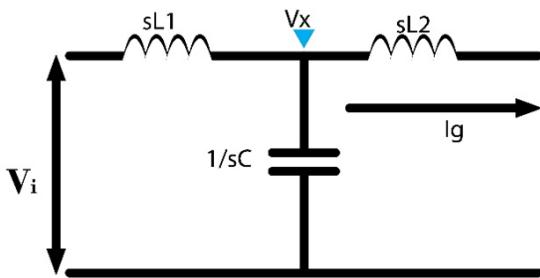


Figure 3: Three-order LCL filter

From KCL

$$\frac{V_i - V_x}{sL_1} = I_g + \frac{V_x}{1/sC} \dots\dots\dots (1)$$

$$V_x = I_g \cdot sL_2 \dots\dots\dots (2)$$

$$\frac{I_g}{V_i} = \frac{1}{s^3 L_1 L_2 C + s(L_1 + L_2)}$$

Let, $L_1 = L_2 = L$ & $L_p = L_1 * L_2 / (L_1 + L_2)$

$$\frac{I_g}{V_i} = \frac{1}{sL(1 + s^2 CL_p)}$$

$$W_{res} = \frac{1}{\sqrt{CL_p}}$$

$$F_{res} = W_{res} / 2 * \pi$$

Filter Design:

Step 1: Selection of switching frequency /resonant frequency

The size of the LCL filter can be decreased significantly using a higher switching frequency to obtain an overall better performance. To avoid the resonance problem for the filter. The switching frequency and grid frequency range is

$$10F_g < F_{res} < 0.5F_{sw}$$

Step: 2 finding the value of capacitance

A filter capacitor is designed based on the reactive power absorbed at the rated conditions. Reactive power 'Q' is absorbed by the capacitor limited to 5% of the rated power(S).

$$Q = \frac{V^2}{1/2\pi.F.C} = 5\% \text{ of } S$$

$$C = \frac{0.05.S}{V^2.2.\pi.F}$$

Step: 3 finding the value of inductance

The value of the inverter side inductor (L1) is selected based on the maximum permissible current ripple. The current ripple should be limited to 20% of the rated current.

$$\frac{I_g}{V_i} = \frac{1}{sL(1 + s^2 CL_p)}$$

Put $s = jw(sw)$

$$\frac{I_g(sw)}{V_i(sw)} = \frac{1}{jw_{sw}.L(1 + \frac{jw_{sw}^2}{w_{res}^2})}$$

$$L = \frac{1}{(1 - \frac{w_{sw}^2}{w_{res}^2})w_{sw} \frac{I_g(sw)}{V_i(sw)}}$$

As per IEEE standard

$$I_g(sw) = 0.3\% \text{ of } I_g$$

$$V_i(sw) = 0.9 * V_g$$

This gives the minimum value of inductance.

Again, $V_i = 20\% \text{ of } V_{grid}$

$$L_{max} = \frac{0.2 * V_{grid}}{2 * \pi * F * I}$$

Control module

In this grid-connected three-phase inverter, synchronous reference frame theory is applied to control the pulse with modulation. PLL is designed to maintain the phase as per grid output by varying the wt. the current controller is used to maintain the required PWM.

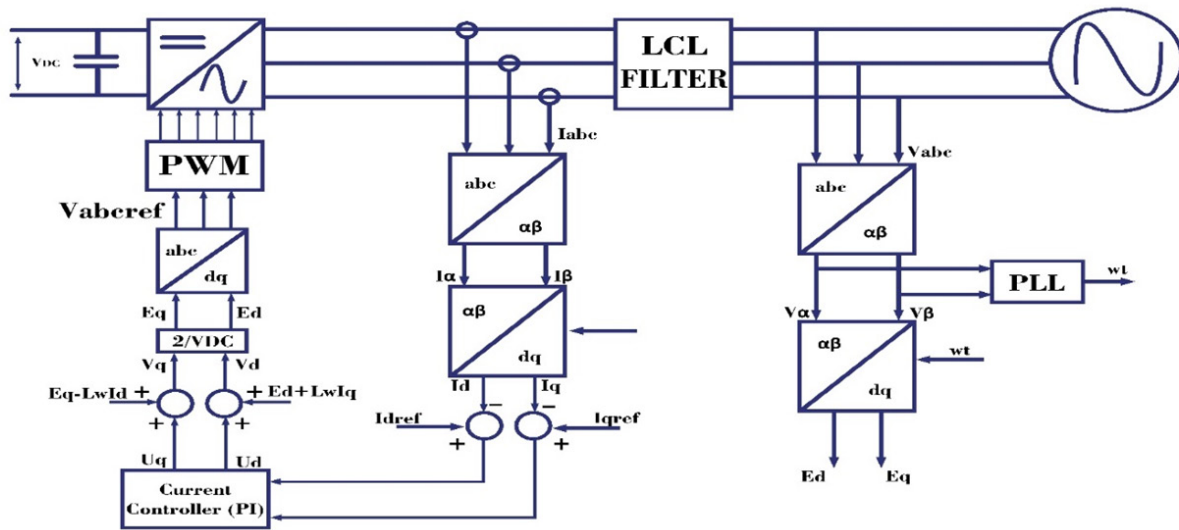


Figure 4: DQ control module for LCL grid-connected inverter

In this experiment, inverter gate signals are controlled by the PWM method. 100KVA, 10KHZ, 415 RMS voltage, and grid-connected inverter is designed. The natural frequency of the grid is 50Hz. The calculated value of inductance for $L_1=500\mu\text{H}$, $C=100.28\mu\text{F}$, $L_2=500\mu\text{H}$. The resistive load power is set to 1000 Watt. The inductive current reference is set to zero.

Various Parameters of Designed LCL filter	
Grid Voltage	415 V (RMS)
KVA rating of Inverter	100 KVA
Grid Frequency	50 Hz
Switching Frequency	10 KHz
Resonant Frequency	1000 Hz
Converter side Inductor	500 μH
Filter Capacitor	100.28 μH
Grid side Inductor	500 μH
DC link Voltage	800 V

Figure 5: Various parameters of grid connected LCL filter

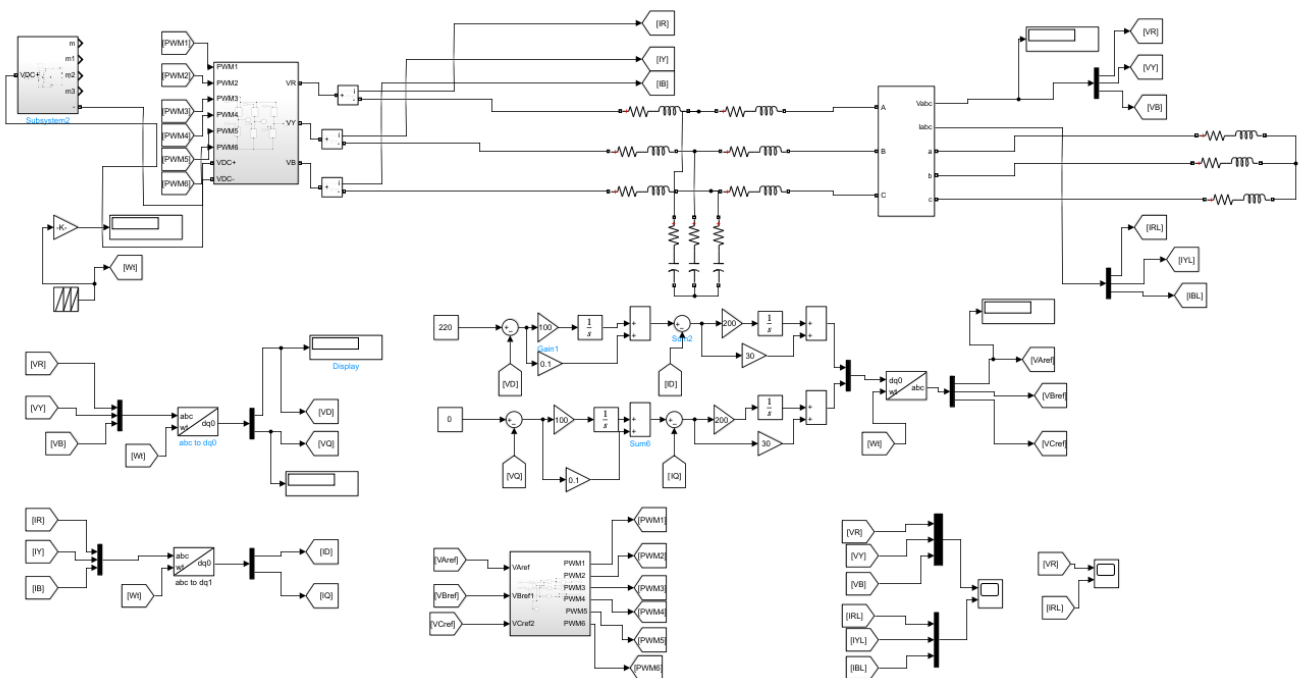


Figure 6: MATLAB simulation model

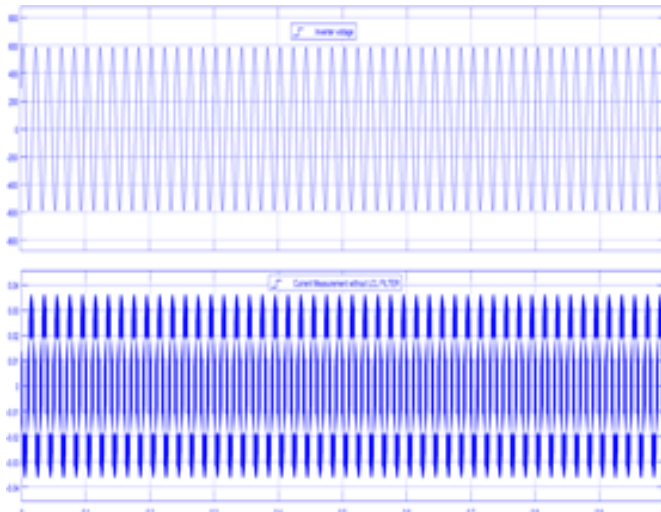


Figure 7a: Output of Inverter voltage and Inverter Current

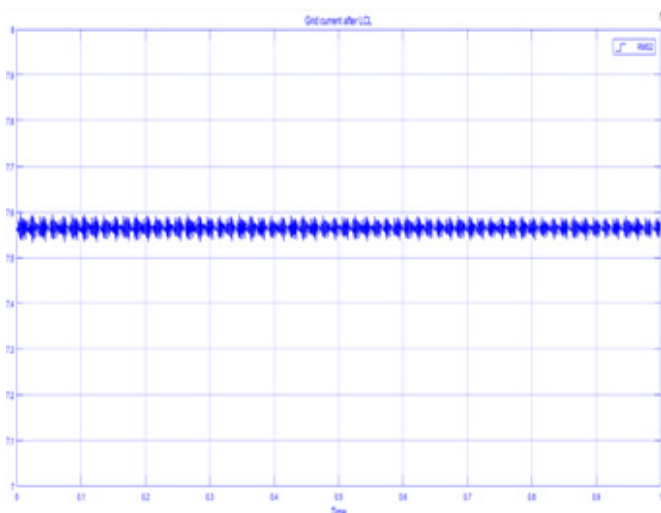


Figure 7b: Microscopic view of grid current waveform

Simulation Results and analysis

In this figure, the inverter voltage and inverter current are shown before the third-order filter (LCL). Here the inverter current has maximum harmonics contents.

The grid current waveform after the LCL filter is given above. The microscopic view is shown here.

In the figure, the total harmonics distortion for the grid current before the LCL filter and after the LCL filter is compared. This shows LCL filter decreases the high degree of harmonics. As per the MATLAB simulation result, the total harmonics distortion is about 0.25. As per the IEEE standard, Total harmonics below 5% is acceptable and below 3% are highly entertained.

To avoid resonance, the standard criterion $10F_g < F_{res} < 0.5F_{sw}$ is fully satisfied here. $50 \times 10 < 1000 < 0.5 \times 10000$

CONCLUSION

From this study, the LCL filter parameters required for a three-phase grid-connected inverter are calculated. Overall design consideration and parameters are successfully operated and analyzed in the MATLAB Simulink environment. Total harmonic distortion (THD) is obtained with and without an LCL filter.

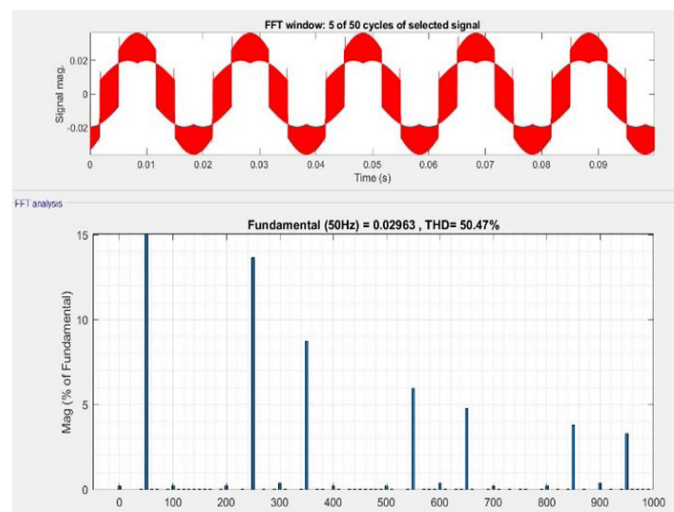


Figure 7c: THD Sampling

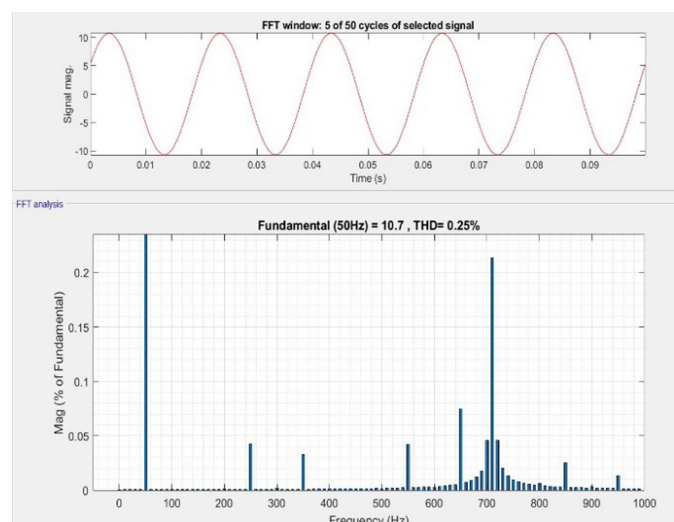


Figure 7d: THD Obtained

The study concludes that an LCL filter suppresses the higher-order switching frequency to ensure the better quality of grid current, and helps prevent overlay of the grid inverter voltage, and current within a short time.

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ABOUT AUTHOR(S)



(Er. Yam Krishna Poudel) is PhD Scholar at RIMT University, India working in the field of smart grid and machine learning algorithm having seven years of experience in academic field. He is the active member of IEEE, Nepal Engineers Association. He also obtained the two prestigious international awards outstanding youth achiever award and outstanding global educator award. Poudel has the 5 national and international publications till date. His research interest areas are Distributed generation, Smart Grid , Machine learning algorithm.

Conserving the conservation trends in the cultural capital, Bhaktapur

Shyam Sunder Kawan ✉

Department of Architecture

Nepal Engineering College, Bhaktapur, Nepal

Email ID: shyamsk@nec.edu.np

KEYWORDS

Heritage Resources
Urban Landscapes
Urban Heritage
Bhaktapur

ABSTRACT

Heritage resources both tangible and intangible carry a sense of belongingness and enrich urban landscapes. They also portray an authentic community formation with its generic identity; enabling cultures to inherit and memories to reverberate in historic cities. Conserving these resources not only transforms historic cities into a cultural centre with a nourished city environment for city dwellers but also secures collectively as fundamental elements of urban heritage. However, historic cities which are sensitive to development are equally complicated to conservation. Apart from the traditional sponsorship from the head of the state or government and international donors, heritage conservation in Bhaktapur and other valley towns is unique because of 'Conserving conservation trends'. Music and Dances, rituals and festivals, feasts and Worships still prevail in Bhaktapur, the cultural capital of Nepal. This study examines how such rituals are still retained by the inhabitants with very less funding from the central government but by their own capacity. It also highlights the significant ways these rituals and community initiatives adopt a traditional mechanism to renovate monuments and heritages in the modern context. In other words, conservation trends in such ways flourished to maintain social order in historic cities even before conservation policies were promulgated globally. This paper generally presents the findings from a study of the socio-cultural context in one of the traditional neighbourhoods located at the edge of Bhaktapur, especially the Guthi system of Newars and the impacts of economic aspiration of the communities in this globalized context.

INTRODUCTION

Both tangible and intangible heritages have since long prevailed in historic cities in Kathmandu valley for which the ethnic group, Newars are credentials to the upkeep of all such urban systems and functions. Despite various changes and inevitable development pressures in all of the historic towns, some have coped well with the extensive indigenous practices till now, one is namely Bhaktapur. These trends and activities are inherited by every inhabitant of the street in the form of their cultural identity and collective memory that they acquire. This study focuses mainly on the socio-cultural activities which have primarily been the factor in the conservation of the entire urban fabric of Bhaktapur, the cultural capital of Nepal. It also highlights the socio-economic impacts that came in the course during the conservation of the cultural heritage in this city.

The historic town, Bhaktapur is located at 27° 36' to 27° 44' North latitude and 85° 21' to 85°31' East longitude and is situated 12 kilometress North-east of the capital city, Kathmandu. The present municipal limit of this

town spreads over an area of 6.88 sq. km. in an altitude of 1,401m from the sea level. The town lies in a small non-cultivable spur stretched between two rivers in the north Kusan khosi and in south Hanumante. This spur is surrounded by agricultural land spread over to different VDCs. As one of the major towns in Kathmandu valley, it also constitutes predominantly the inhabitants called Newars.

Besides agriculture, the inhabitants are involved in various other economic activities like trading, handicrafts, potteries, woodworks and governmental services. Trade though used to prevail in ancient times but now it has been displaced since lots of people who are descendants from this community have migrated and settled in various other parts of the country including Kathmandu, the capital. The social distribution according to the caste system among the Newars is believed to happen in the 14th century which still remains and likewise is their occupancy in the town in different regions [1]. Neighbourhoods are the basic constituents forming the urban built-up core of this town essentially the fabric.

Gutshow and Kolver [2] have pointed out that this town had 24 tols (Newari: tva) which were subdivided into neighbourhoods. While the morphological characteristics of Bhaktapur comprise of the never-ending street networks forming varieties of open spaces endowed with ponds, public monuments and rest houses aligned into the edges of these open spaces.

The study area for this paper is one of the traditional neighborhoods- Taulachhen tol which is situated at the eastern part of municipality. This tol lying in cultural heritage sub-zone comprises ward no. 1, ward no. 2 and ward no. 3 according to current administrative boundaries. There are 567 households in this tol and 5790 populations out of which 2863 males and 2927 females. The total area of this neighborhood is 5.99 ha and the population density of this neighborhood area is calculated as 965.67 persons per ha. The neighborhood is dominated by the caste of Prajapati (potters) and Maharjan (Jyapu) community. The caste of Shrestha, Shakya, Napit and other communities are in minority. This tol, at its western end, is connected to the famous Dattatreya square included in the Protected monument zone whereas to its east runs Pashikhel road, a link road between the two main highways (Araniko highway and highway to nagarkot from Kamal pokhari) along the town.

This study is based on a critical literature review and my personal reconnaissance survey in one of the traditional neighbourhoods of Bhaktapur which is strategically located in between the protected monument zone and the new development area. Along with the random household survey, interviews with various experts, community representatives and stakeholders were also conducted through the unstructured questionnaire survey. The main aim of this study is to understand the historic towns of Kathmandu valley and the indigenous systems of heritage conservation which have so far enabled to upkeep of the socio-cultural phenomena and simultaneously the growing interest in economic development among the stakeholders and local inhabitants. It also aims in presenting the findings from the study area especially the guthi system of the newars in Taulachhen tol and the socio-cultural activities and impacts generated by modern economic development and aspiration among the communities of this neighbourhood.

LITERATURE REVIEW

Historic Towns

Historic towns in Nepal not only exhibit physical attributes like monuments but also are intermingled with socio-cultural practices that have proven significant in the continuity of intangible heritage from different layers of humankind. With the surplus of these indigenous practices, skills and crafts inherited from generations, Kathmandu valley alone is known for being the cradle of art and culture. At present different forms of heritage resources vividly lay into these cultural attenuations according to the contemporary definition of heritage. Cultural heritages

are at first elementary to local cultural identity besides materialistic forms and then subjective to universal recognition of humankind [3]. Inherent through many generations, most often they cope with urban changes (Poete, quoted in Boyer 1994) even before the avail of conservation trends and charters.

Newars, Newar Urbanism and their building culture

"The newars are a community of urban disposition and whether they live in the towns or in the villages; their settlements always reveal an urban character. Most of the valley settlements are built on high grounds or on the flat tops of the hills meaning less useful for agriculture purposes" [4].

These settlements have a long history of more than 15 centuries of sustained development and continued use of the same physical space as a built culture which managed and adapted to the dynamic heterogeneity of living [5]. He further argues that common economic activity, social status or interest tied to a social facility, a sense of homogenous characters are well portrayed in the urban living and spatial pouches formed in Newar towns resembled through tolerance in religions, caste distribution and other public activities. Tiwari [6] explains that the spaces in valley towns/settlements were meant for public life and buildings were designed to create space on the outside and the interiors too have motives of exterior spaces. In addition to, the extremely carved windows, the proportion of the building to enrich the streetscapes meant the same objective of the built culture for which the citizens are the experts and their willingness in supporting these creations is the limelight globally.

"Despite the urban features of the settlement as marked by the skillful architecture, brick houses of many storeys and streets and lanes laid with stones suggests the high material culture in the newar towns" [4].

Heritage Conservation in Nepal

Various interests so confer invaluable heritages; from an individual to different institutions and organizations, national and international. Why they want to conserve it is because they value the heritage with a sole interest. Tiwari highlights the efforts of treatment of stone sculptures since the Lichchhavi period and that also being inscribed into various stone Tablets with specific terminologies mentioned [7]. Similarly, institutions like Chhen-Bhadel existed in the Malla period for city-level conservation activities [8]. Only after the 1950s, Nepal has become outwardly and is prone to changes accordingly with the global exchange and so heritage conservation mattered. Ancient structures then were repaired and maintained through the Nirman Samitis (Construction committees) through Public Works Department [9]. Occasionally, as in ancient times, the repair and maintenance of important cultural heritage were carried out in part by various community groups, with some significant occasions for beautification and renovations by state agencies (Ibid). Department of Archaeology was established in 1952-53 and the Ancient Monuments Preservation Act was disseminated in 1956 "to maintain peace and

order by preserving the ancient monument and by controlling the trade in archaeological objects as well as the excavation of the place of ancient monuments and by acquiring and preserving ancient monument and archaeological, historical or artistic objects” [10].

Every inscription inscribed into parts of the built heritage probably states about the sponsorship, maintenance and continuity in using the resources at every corner of valley towns in different reigns of the rulers in Nepal, probably dating back from the Lichchhavis. Chapagain [9] mentions that such activities of sponsorships with the provision of reserves for maintenance and repair work in order to sustain public and communal buildings for longevity and regular functions were ensured by the ruler class, elites and donors for either personal dignity or attaining 'dharma'. Generally, guthis (groups of trustees i.e. social institutions) were responsible for the upkeep and care-taking of these sponsorships and reserves in various means like materials, money, land and volunteerism for shared purpose. The word guthi is derived from the Sanskrit term “gosthi” and dates back to Lichchhavi period for ‘association’ or an ‘assembly’ of a group of people or members of a clan based on caste, patrilineal grouping or territorial aspects [11]. These guthis are the indigenous system and have helped to conserve the cultural heritage of Kathmandu valley for centuries. During the Malla period, the term guthi was widely used (879-1769 AD). It seems reasonable to assume that many guthis were established during this time period to ensure monument maintenance and festival observance (Ibid). Aside from intergovernmental organizations such as UNESCO and ICOMOS, many individual development agencies are actively engaged in conservation activities. Even if they do not have the same direct influence on cultural heritage policy as UNESCO, their work has been noticed by a wider audience both nationally and internationally, and their working principles have frequently placed Nepal in theoretical and practical experiments on global conservation debates [9].

The current scenario of heritage conservation in Nepal especially in the historic towns is more prone to conflicting situations. Many of the local inhabitants habitual with the traditional rituals have continually kept their ancestral intangibles despite of the threats encountered with the stringent controls and streamlined policy formulation process of bureaucracy [11].

Indigenous systems and administrative approach of Conservation

Munankarmi [12] distinguishes guthi system generally into 2 categories as Rajguthi and Duniyaguthi in terms of managerial prospect. However, he argues that there used to be various other forms of guthis like si-guthi, dapha- guthi, dhalacha guthi, dewali guthi, sorhasradha guthi, dharmasala guthi, hiti guthi, jatra guthi, etc. depending upon various rituals and functions within the newar community. After the land reform in 1951, Guthi Sansthan (GS) was established in order

to nationalize all the guthi, guthi endowments and associated land assets for managing the guthi-related attributes. It is after the nationalization of the guthi systems and the conflicting issues with land reform, that there have been loopholes and trade-offs in concern of guthi assets and their ownerships and their management which directly impacted the cultural activities till now [11], [12]. Guthi endowments are in the form of land, monetary, rentals and voluntarism by the rulers, elites, and locals seeking social prestige and goodwill for the common interests. And unfortunately, there is a significant number of resemblances for privatization of guthi assets associated with public heritages which Guthi Sansthan has no records of.

Apart from the traditional sponsorship from the head of the state or government and international donors, heritage conservation in Bhaktapur and other valley towns is unique because of indigenous approaches to heritage conservation. The only reason for continued cultural activities and existence of heritage resources is because of these indigenous conservation trends. Music and Dances, rituals and festivals, Guthis and Worships still prevail in Bhaktapur from the reserves and yields from guthi endowments which have now become the cultural heritage but originally are the way of life for Newars [12]. The inhabitants keep the ability to make these rituals flourish in the city with very less funding from GC but by their own capacity. Examples are the recent renovation of 55 windows palace, 5 storeyed temple and Bhairabnath temple complex with the use of local expertise, local materials and funding from Bhaktapur Municipality and the donation from local citizens in their own capability. These initiatives from the local affluent families or community groups and local guthis to restore or renovate monuments and heritages enliven other cultural entities, a sort of intangible heritages. Conservation approaches are criticized for being responsive to donor agencies and inter-governmental agencies more and less to inhabitants. These initiatives from local efforts sow buds of intangible heritage which should be identified by the national conservation policies. They are even easy since they are mobile in nature and can be taken to anywhere by the inhabitants themselves. Such trends need encouragement with any means possible by the government. It is therefore to encourage local skills, technology and resource mobilization through active community participation.

DISCUSSIONS

Continued Socio-cultural activities

In the case of Bhaktapur, social and cultural events entailed with past memoirs form an intimate part of heritage for the people even now. Based upon trust and faiths that people collectively share these heritages add on joyous moments and flavour to their place as their pride. These ritual mediations therefore ever remained unconditioned and unquestioned and thus comforted urban conservation. In a true sense, these social and cultural functions are dared not evaluated through standardized norms as they vary according to cultures. What is authentic of these socio-cultural activities is expressed in their continuum through

cultural spaces at present and needs no justification.

1. Guthi and Worships

Guthi system in Taulachhen as one of the major socio-cultural activities of Bhaktapur is still the way of accomplishing a lifestyle. The culture of conserving i.e. renovating, maintaining and utilizing historic buildings also do occur within this self-sustained system with trusts established for communal and religious faith. Most often the principles of authenticity and integrity remain unanimous to these systems, excluded and even conditional to their adopted norms for various performances.

Almost 86% of the households from the survey conducted are associated with guthi systems. Similarly, those who conduct Puja are found to be 72%. On the basis of religious beliefs, these rituals are prolonged being performed in Bhaktapur with the same spirit. Apparently seen as many households being involved in guthis is only because of threats from societal norms being implied to every family member. In fact, the households who really depend upon other sources of the economy have hardly managed time to get involved. Along with individuals' escape from societal norms, they would either be fined heavily or made deprived of rituals during the birth and death of the family members.

Feasts and Festivals

As long as the year is, so are the feasts and festivals for Newars. Every individual house will have feasts at festive moments and life rituals and every individual is emoted to them from birth to death. Chariots and Khats of Gods are circumambulated to most of the streets and courtyards of these neighbourhoods during festivals. Major festivals passing through them according to the respondents are Gai Jatra, Indra Jatra, Nawa Durga Jatra, Bramhayani Jatra. Apart from the festivals related to deities, there are also some festivals sensitive to urban environmental protection and upkeep, like Sithinakha (pre-monsoon preparation of water elements) and Gathamuga (wiping the evils out of the city). Most of the respondents in Taulachhen seem to enjoy their life at these festivals. As guthis, these festivals also happen in a critical condition with local efforts rather than through authorization. Despite, another crucial matter that demands integrity is the pradakshina which bound the city intact physically, socially, culturally and spiritually.

Music and Dances

An author, Jagadish Shumsher Rana argued that music and dances in Bhaktapur were not only taken as instrumental but to cherish livelihoods. It also involved every single individual of the city through inheritance and is generally associated with festivals. Munankarmi [11] considers dapha/bhajans too as a form of guthi system related to religious shrines in most of the neighbourhoods to sing slogans and perform music related to the deity of the shrine. According to locals, dapha/bhajans were not as compulsions as Guthis. Around 62% of the respondents answered that they are still associated with dapha/bhajans. They

include children in the learning phase, youths as main performers and old as tutors. Mostly observed through dapha/bhajans are Bhairab, Nagacha, Jhyaure and Lakhe dances in this tol. But unfortunately, the younger generations hardly manage time out of their academic schedules for achieving this culture unless there is coordination among the institutions and such informal associations. It goes even more serious when they reflect on things from an economic perspective.

Socio-economic determinants

Tourism

Where heritages exist tourism is a matter to think about, no matter either domestic or foreign [8]. Urban conservation should aim to flourish tourism activities throughout the city. Tourism at present plays a significant role in sustaining historic cities but professionalism is where it lacks. In the case of Bhaktapur, such activities seem to concentrate on PMZ only, unlikely to its dispersal throughout the town. Damp and dark alleys in the backyards seem never been walked by tourists though heritages besides tangible, wander here. Likewise, Dattatreya square and some shop owners in the main street of Taulachhen are benefitted from tourism. Only 17% of the respondents were involved in tourism-related businesses. Though BM insists on improved city environment and tax waive for citizens from tourism revenue, less interest in tourism-related activities is the probe of less tourism influence in the economic condition of the impoverished house-keepers of cultural heritage. In fact, there is no evidence of tourism plans and promotions implemented in Bhaktapur to introduce and showcase heritage resources. Urban conservation perhaps doesn't constrict into the concept of monuments show-off and institutional operation but adopt sustainable tourism to solute economic deadlock in the local community as well.

Diminishing neighbourhood values

Neighbourhoods are socio-spatial units constituting class, ethnicity, race, family and housing stock. Gutshow and Kolver [2] also argue that neighbourhoods were an integral part of the city even when they were formed of various social classes. Homogeneity in heterogeneous neighbourhood concepts has long been adopted in the traditional neighbourhood system in Bhaktapur. This trend which has taught many generations in the valley to remain in a cluster and integrated to form such a complicated social structure reflected in spatial patterns of Newar towns is now degrading [13]. Taulachhen, one of the oldest neighbourhoods of this town still contains many joint family structures. Almost 56% of the total households surveyed are found to be living separately as nuclear families though some are still sharing their kitchens. Space deficit and family division are not that severe currently but are a potential threat to the decline of neighbourhood values. Strikingly, emerging trends of enjoying an individual identity seem less aware of shared vision, and common interests Taulachhen.

Agriculture to modern employment seeking

Agriculture has been the major economic source for people in Bhaktapur. However, the trend of sustaining their livelihood has also shifted. The main idea lies here not to demonstrate the overturn of agriculture as an occupation. The majority of people in Taulachhen are intact with agriculture till now but its reliance on people is gradually decreasing. With agriculture, they are involved with side businesses, services and workshops too. In Taulachhen among 64 households surveyed, 20.31% are found to be purely agriculture-dependent, 42.19% are involved in agriculture with side jobs, 29.69% are totally involved in business and 7.81 in craftsmanship. This indicates clearly that modern employment-seeking purposes also led people in cultural heritage areas to move their dwellings to the periphery. With this significant shifting in economic source, building use and spatial occupancy also need to be altered to meet the living standards and demands of the people. It also brings an in-compliant social composition and spatial formation from the historical composition of the community and economic structure though they are inherent from the traditional core with the same economic root.

Development Concerns

As cities are characteristically live and evolutionary, control of change and countervailing through preservation makes no longer the sense to imply or else lead to a frozen moment for urban living [14], [15]. Urban systems are based on human activities in cities to reflect changes and adaptations into city fabrics as community demands change with socio-economic conditions. In fact, development and conservation are mutual supporters rather than antagonistic; coinciding between the management of physical limits, and resources with changing demands and activities as both are the origin of urban evolutions. Thus, conservation activities deserve opportunities from developing urban areas while at the same time development seeks resources for its prosperity. Taking heritage resources and development objectives complementary to each other, urban conservation in an integrated approach has to enable consideration of inescapable development pressures [16] and their respective actors and interests.

Land use zoning and development control

The urban typology of Taulachhen lies in Cultural Heritage Sub-zone according to the present land-use plan of Bhaktapur Municipality. The present land use plan neither could retain the traditional spirit of land use nor could address the change in land use of buildings due to commercialization and functional changes of space. Buildings lining the main streets and some in secondary streets have developed the retail activities and as well parking spaces for two-wheelers as their present demands. The building bye-laws are only controlled measures which insignificantly consider physical control on individual buildings and have very less concern for land uses. Expectation for effective urban conservation with the aid of such impractical regulations is worth vanity. The extent of illegality

and encroachment of public spaces along with street corridors seen in this neighbourhood is a probe of ineffective and inadequate measures of development control in Bhaktapur Municipality. Most illegality cases are found to be breaking height standards, shop overflows, use of plasters, modification of traditional building facades and planning approaches, etc. Many of the reconstructed buildings are found to be built with new construction technology with relatively higher floor heights with brick claddings and odd expressions in the original character of the place. These trends not only deteriorate the heritages but also influence existing heritages to spoil the built environment.

Land development and property division

The survey in Taulachhen shows that space deficit and family division are speeding and prone to transformation, transaction and development of land and property with independent rights. Many of the division cases introduce a complicated scenario that doesn't solve their space deficit problem but piles on the burden to the existing townscape i.e. the intensification; while they insisted not on leaving the place. Vertical division cases that are more frequent in many of traditional residences affect the existing urban fabric and lead to a ruinous state of buildings. These families because of weaker economic conditions are vulnerable being displaced elsewhere but are helpless. In fact, the residents don't have any choice except squeeze themselves into the congestion.

Aspiration for transport ease and motor dependability

The major socio-economic change found in Taulachhen is their aspiration for easy transportation of household goods. The majority of the respondents expressed their difficulty in transporting their goods due to narrow alleys for access or even inaccessibility to their homes and courtyards. They have to carry goods with their own energy. Among total households surveyed, only about 61% have access wide enough for a vehicle. Besides, public vehicles frequently need to pass through these streets for different purposes like light vehicles for waste disposal, water supply tankers, ambulances and school buses, etc. Despite their needs, they are also threatening the existing built structures. However, 55% of the total respondents own vehicles for travelling mostly two-wheelers and found their ground floor passages as parking and some in public places.

CONCLUSIONS AND RECOMMENDATION

In the context of the study area, the socio-cultural essence and value are still the concern of local inhabitants as part of their livelihood. The guthi systems, musical groups and festivals are still significant in maintaining the integrity of the neighbourhood and the entire town. These indigenous systems for retaining the urban morphological characteristics i.e. the structure and function of neighbourhood areas were based upon the societal norms, religious faiths and art of living in the historic towns. Because of

the nationalization, economic values have overruled these city functions which were a kind of guidelines for conserving the urbanism, undoubtedly cultural heritage and historic landscapes at present. The gradual shift of the interests among the local inhabitants on economic perspectives and unsatisfactory managerial demonstration of the government authorities, these indigenous activities in historic towns have turned to be informal. So, with reference to the degrading situation of urban spaces in the historic area and changing socio-economic demands of the people bearing these intangible heritages, such indigenous systems need conservation and encouragement by whatsoever means possible. Newar urbanism presents the cosmic image, so only the physical space and monuments but the livelihood in town become significant with a variety of social groups equally important for urban systems to function sustainably. The sweepers, worshippers, masons, carpenters, artists and farmers all become significant in due course of built culture amongst newars. Their skills and crafts for city building, maintaining rituals and performing arts are essentially the only means of cultural heritage at present according to the definition attained so far in heritage discourse.

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ABOUT AUTHOR(S)



(Shyam Sundar Kanwar) is currently a PhD scholar at Shanghai University. He was a “Daayitwa-Nepal ka Yuwa” fellow in the year 2015 for envisioning a “Cultural Heritage sensitive urban development strategy for Kathmandu valley. He was awarded an Asian Development Bank Scholarship for pursuing

his postgraduate studies in Urban Planning at the University of Hong Kong in 2010. He has participated in numerous national and international forums as an activist and a researcher on cultural heritage issues and ecological aspects of historic cities.

Visual Cryptography based on Shamir's secret sharing (VCSSS) and its comparison with Caesar Cipher Algorithm for Image Encryption

Sachin Maharjan^{a,1}, Nirmal Maharjan^a, Nikhil Maharjan^a, Sujan Raj Tuladhar^a, Krishna Bikram Shah^{a,b,2,✉}

^aAcademia International College, Lalitpur, Affiliated to Tribhuvan University

^bDepartment Computer Science and Engineering,

Nepal Engineering College, Changuarayan, Nepal, Affiliated to Pokhara University

Email ID: ¹sachinmaharjan@acd.edu.np, ²krishnabs@nec.edu.np

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ABSTRACT

This article offers a (k,n) visual cryptography (VCSSS) where a binary secret picture may be divided into n meaningless shares using Shamir's secret sharing, making the produced shares more like noise images and adding randomness to the sharing process. The requirement for minimum threshold shares ultimately leads to the confidentiality of secrets. (k, n) visual secret sharing uses a threshold scheme by using the concept of Lagrange's polynomial interpolation. In this study, we have compared it to the Caesar Cipher encryption with an image and then calculated the efficiency of the encryption in terms of the Number of Pixel Change Rate (NPCR) and Unified Average Change Intensity (UACI). We have a key in Caesar cipher that is used to encrypt and decode picture color pixel values. We took the original pixel value and encrypted it with the key, then subtracted the encrypted pixel values with the key for decryption. The average value of NPCR for Shamir's Secret Share is 99.9993. Also, the average NPCR value of the Caesar cipher algorithm is 100. Similarly, the average value of UACI for Shamir's Secret Share is 65.9841. Also, the average UACI value of the Caesar cipher algorithm is 97.66. Hence based on NPCR and UACI the Caesar cipher seems to be a better algorithm but the key used in the encryption can be guessed easily. Since shares are distributed and threshold shares are necessary to reveal the original image, visual secret sharing is a quite stronger algorithm in image encryption.

INTRODUCTION

Cryptography is a technique of securing information through the use of codes so that only those for whom the information is intended can read and process it. Cryptography has four main objectives. They are confidentiality, integrity, non-repudiation, and authentication. Confidentiality means the information cannot be understood by anyone for whom it was intended. If the information could not be altered in storage or transit between sender and intended receiver then we can say the integrity of information is maintained. Non-repudiation means the creator/sender of the information cannot deny at a later stage his or her intentions in the creation or transmission of the information. Authentication is maintained when the sender and receiver can confirm each other's identity and the origin/destination of the information.

Till now lots of cryptographic techniques and algorithms have been developed such as AES

(Advanced Encryption Standard), RSA (Rivest, Shamir, Adelman), Diffie-Hellman, DES (Data Encryption Standard), BlowFish, MD5, SHA, and many others. But these algorithms depend upon the secret key. Imagine we encrypt our important files with one secret key and if such a key is lost then all the important files will be inaccessible. Keyed cryptographic techniques provide various ways to protect secret information but most of them require highly complex encryption and decryption. Thus, secure and efficient key management mechanisms are required. Instead of providing the secret key for one individual, it is a better idea to distribute the secret key among the multiple intended people so we can prevent damage that can happen if the key is lost or prevent any misuse. A secret sharing scheme is one of them that splits the secret into several parts and distributes them among selected parties. The secret can be recovered once these parties collaborate in some way [1]. Thus, confidentiality can be achieved without complex computation.

Visual cryptography is a cryptographic technique that allows visual information (pictures, images, etc.) to be encrypted in such a way that the decryption can be performed by the human visual system. In this algorithm, the given data is portioned into multiple shares. Then we define the minimum threshold number of shares which when gathered from shared participants can reveal the secret. Suppose the data 'D' is divided into N shares. Then 'D' can be constructed from 'K' shares out of 'N'. Complete knowledge of k-1 shares reveals no information about 'D'. 'K' of 'N' shares is necessary to reveal secret data. Visual cryptography was pioneered by Moni Naor and Adi Shamir in 1994 at Eurocrypt. Visual cryptographic schemes are used to secure visual data based on authentication techniques that contain sensitive data such as military surveillance, satellite images, medical records, etc. The visual cryptographic scheme also provides a secure way to transfer images on the internet [2].

In Caesar cipher, we have a key that is used to encrypt and decrypt the image color pixel values. We add the existing pixel value with the key for encryption and subtract the encrypted pixel values with the key for decryption again.

LITERATURE REVIEW

In a technique for encryption of visual data by generating the share from a binary image into two shares Share1 and Share2 in a perfectly secure way that can be decoded directly by the human visual system. The black and white pixels are expanded with different possibilities of transparency. The original encryption problem can be considered as a 2 out of 2 secret sharing problem. The shares (secret) are printed transparency. The original image is revealed by placing the 2 shares transparency by stacking with each other. The generated shares are random noise transparency i.e., obtained by pixel expansion of white '1' and black '0' each having 2 possibilities for individual shares [2].

A visual cryptography approach for color images has been proposed by [3] M. Quist-Aphetsi Kester. In their approach, each pixel of the color secret image is expanded into a 2x2 block to form two sharing images. Each 2x2 block on the sharing image consists of red, green, blue, and alpha, respectively, and hence no clue about the secret image can be identified from any one of these two shares alone. There would be 4! Possible combinations according to the permutation of the 4 colors. Because human eyes cannot detect the color of a very tiny sub-pixel, the four-pixel colors will be treated as an average color [3].

The visual cryptography schemes to share two secret images in two shares were presented in 1998 by A. Sharma. Two binary secret images are hidden into two random Shares, namely s_1 and s_2 , such that by stacking the two shares the first secret can be visible, denoted by $s_1 \otimes s_2$, and by first rotating s_1 by some angle (θ°) anti-clockwise the second secret can be obtained. They designed the rotation angle θ to be 90° [4].

In another study done by JTamilarasi [5], a cryptographic Image Encryption technique based on the RGB Pixels

shuffling has been proposed in 2013. No pixel's bit has been changed during encryption and decryption because of no pixel expansion. Instead, the numerical values are transposed, reshaped, and concatenated with the RGB values shifted away from their respective positions and the RGB values interchanged to obtain the cipher image. The RGB values are shifted out of their native pixel and interchanged within the image boundaries by the algorithmic process. The shuffling of the image was done by displacing the RGB pixels and also interchanging the RGB pixel values.

Zhi Zhou, Gonzalo R.Arc, and Giovanni D Crescenzo proposed the concept of visual cryptography [6]. In this method, a secret binary pixel is encoded into an array of sub-pixels in each of the n-shares. These sub-pixels are called halftone cells. Visually halftone shares can be obtained by using halftone cells of an appropriate size. The halftone share carries significant visual information to the viewers, such as landscape, buildings, etc. The above method can be applied in several visual secret sharing applications which require high-quality visual images, such as watermarking, electronics cash, etc.

In the progressive visual secret sharing scheme proposed by Jin, W.Q. Yan and M.S. Kankanhalli, when more shares are stacked progressively, the recovery of the secret image will be clearer and clearer [7]. The only sketch will be revealed when a few shares are being staked and more details will be recovered when more shares are being used.

Young-chang Hou developed an additive and subtractive model which is commonly used to describe the structure of colors [8]. Three primary colors red, green, and blue (R, G, B) are used in the additive model. All the desired colors are obtained by making these RGB components. For calculating the intensity of red/green/blue in the compound light can be adjusted. Television is a great example of the additive model. In the subtractive model, color is represented by applying the combinations of colored lights reflected from the surface of an object. This model uses Cyan(c), magenta (m), and yellow(y) color components and produces a wide range of colors. The color printer is an example of a subtraction model. Hou's scheme utilizes the principle of the halftone technique and color decomposition. Halftoning is the process of using patterns of the pixel of varying size and color to give illusions of various shades. The color secret image is decomposed into three separate images that are respectively cyan(c), magenta (m), and yellow(y). The three-color images are translated into halftone images using the halftone technique. A color halftone image is finally generated containing the three halftone images.

A proactive secret sharing scheme that renews the shares of all users forming a group periodically, so that any share compromised by an adversary during one time period, becomes useless from the next. Initially, all the users obtain their secret shares by any traditional threshold secret sharing [9]. To renew a secret share a set of polynomials, having their free coefficients equal to 0 (i.e. $\delta(0) = 0$ where q is the polynomial) is used.

Each such polynomial is sent to any user, by one of the other users. This scheme depends on all users in a group to renew the share of any one user.

METHODOLOGY

Visual cryptography is one of the best cryptographic schemes as it embodies both the idea of perfect secrecy and a very simple mechanism for decrypting the secret without involving complex mathematical computation. The methodology includes implementing Naor Shamir's secret sharing algorithm and Caesar Cipher algorithm for image encryption. The secret and cover images are standard images. To share the secret among 'n' participants we first extract R, G, and B values of the image pixels. Then apply Shamir (k, n) visual secret sharing algorithm.

Adi Shamir's visual secret Sharing

We constructed the n shares using the polynomial equation of degree k-1 where k is a threshold. Similarly, we reconstructed the original image using LaGrange's interpolation equation.

Shamir's approach divides a secret number into n shares, and recovering the secret takes at least k shares. To divide a secret number D into n shares D1, D2,..., Dn, choose a prime number p that is greater than both D and n at random and create the polynomial of degree k - 1 that follows

$$q(x) = (a_0 + a_1x + a_2x^2 + \dots + a_{k-1}x^{k-1}) \mod p$$

in which $a_0 = D$. Each share of D is evaluated by $D_1 = q(1), \dots, D_i = q(i), \dots, \text{and } D_n = q(n)$. The k - 1 coefficient $a_1, a_2, \dots, \text{and } a_{k-1}$ are randomly chosen from a uniform distribution over the integers in $[0, p)$. Given any k pairs of $\{(i, D_i) \mid i = 1 \dots n\}$.

Then for the decryption, Lagrange's Interpolation is applied with the minimum required threshold shares as

$$Y = q(x) = \sum_{i=0}^n y_i l_i \sum_{i=0}^n y_i l_i(x) \mod p$$

$$\text{where } l_i(x) = \prod_{j=0, j \neq i}^n \frac{(x - x_j)}{(x_i - x_j)}$$

In Adi Shamir's algorithm, we first input a secret image in the system. Then we divided the image into 'n' shares, where n is the number of participants.

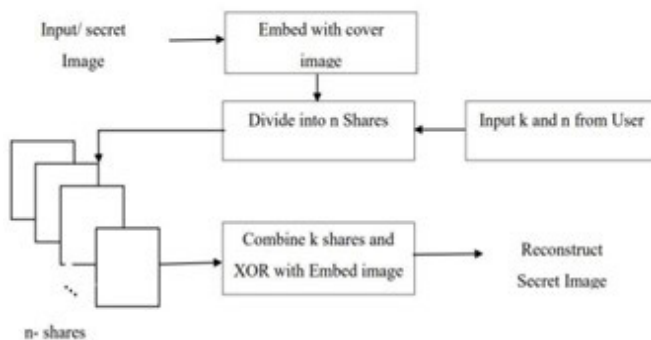


Figure 1: Shamir's Visual Secret Sharing Scheme

Similarly, for decryption (image reconstruction) we input 'k' number of shares in the algorithm to get the original image.

Shamir's Secret Share Scheme for n=4, k=6 is shown below



Figure 2: Original Secret Image



Figure 3A: Share 1



Figure 3B: Share 2



Figure 3C: Share 3



Figure 3D: Share 4

Caesar cipher algorithm for image encryption

We used to add the key to the color pixel value of the original picture in the Caesar cipher technique for encryption.

Mathematically, $I_e = I_o + \text{key}$

Similarly, for decryption, we subtract the key from the color pixel of the encrypted picture.

Mathematically, $I_d = I_e - \text{key}$

The n shares are constructed using the polynomial equation of degree $k-1$, where k is a threshold. Similarly, we use LaGrange's interpolation equation to recreate the original picture.

Generation

Step 1: Take inputs n as total shares and k as the minimum number of required thresholds to recover secret.

Step 2: Generate polynomial equation of degree $(k-1)$ as

in which x = pixel value and $a_0, a_1, \dots, a_{k-1}$ are coefficients $< p$, p is a large prime.

$$q(x) = (a_0 + a_1x + a_2x^2 + \dots + a_{k-1}x^{k-1}) \bmod p$$

Reconstruction

Step 1: Apply Lagrange's Interpolation with the minimum required threshold shares as:

$$Y = q(x) = \sum_{i=0}^n y_i l_i \sum_{i=0}^n y_i l_i(x) \bmod p$$

$$\text{where } l_i(x) = \prod_{j=0, j \neq i}^n \frac{(x - x_j)}{(x_i - x_j)}$$

Encryption using Caesar Cipher for key=5 is shown below



Figure 4 (A): Original Image



Figure 4 (B): Encrypted Image

APPROACHES OF ALGORITHM COMPARISON

Number of Pixel Change Rate (NPCR)

Human eye cannot separate tiny changes on the light intensity of the image pixel. Even though two different images look the same, it does not mean their pixel intensities are also the same. Even a small number of bit changes on the key does not reveal the original secret. So, to distinguish how many pixels are changed from the original image with shared images, the number of pixels change rate (NPCR) is used. It gives the total number of different pixels that are different from the original images' pixels.

Mathematically, NPCR is defined as:

$$NPCR = \sum_{i=1}^M \sum_{j=1}^N \frac{D(i,j)}{T} * 100\%$$

$$\text{where } D(i,j) = \begin{cases} 0, & \text{if } I_o(i,j) = I_{share}(i,j) \\ 1, & \text{if } I_o(i,j) \neq I_{share}(i,j) \end{cases}$$

Here, M = Number of pixels in width and N = Number of pixels in height and $T=M*N$ is the total number of pixels of the image.

The NPCR measures the percentage of different pixel numbers between original images and the shared image. A high NPCR value is interpreted as high resistance to differential attacks.

Unified Average Change Intensity (UACI)

It determines the average intensity of differences between the two images. It is better to have a high UACI value to be considered as having good results.

Mathematically UACI is defined as

$$UACI = \left[\sum_{i=1}^M \sum_{j=1}^N \frac{|I_o(i,j) - I_{share}(i,j)|}{F} \right] * \frac{100\%}{T * C}$$

Where $T=M*N$ is the total number of pixels. F is the largest supported pixel value and C is the total number of a color component of the image.

RESULT AND DISCUSSION

After implementing Adi Shamir's visual secret sharing algorithm and the Caesar cipher algorithm for image encryption, we performed the NPCR and UACI test. The result of NPCR obtained from both algorithms is given in Table I.

The average value of NPCR for Visual Secret Sharing scheme is 99.9993 whereas the NPCR of the same image with Caesar Cipher Algorithm is 100. Both algorithms generate good results. But in the case of NPCR the result of Caesar Cipher is quite better.

The result of UACI obtained from the both algorithm is given in Table II.

secret sharing is 65.9841. For the same image, the UACI of Caesar Cipher is 97.66. Caesar Cipher has good results in the case of the UACI test.

When we produce shares and recover the secret, we

Table I: NPCR Test Results

SN	(Threshold(k), Total Shares(n) and p=257	Shares	NPCR (%)	
			VSS	CC
1	(2,3)	1	100	100
		2	100	
		3	100	
2	(3,5)	1	100	
		2	100	
		3	100	
		4	99.9967	
		5	100	
3	(4,6)	1	100	
		2	99.9943	
		3	100	
		4	100	
		5	99.9943	
		6	100	
4	(7,7)	1	100	
		2	100	
		3	100	
		4	100	
		5	100	
		6	100	
		7	100	
Average			99.9993	100

Table II: UPCI Test Results

SN	(Threshold(k), Total Shares(n) and p=257	Shares	NPCR (%)	
			VSS	CC
1	(2,3)	1	98.4435	97.66
		2	97.2726	
		3	96.1089	
2	(3,5)	1	96.4980	
		2	89.4941	
		3	78.5990	
		4	63.8132	
		5	45.1361	
3	(4,6)	1	93.774	
		2	67.7042	
		3	5.0583	
		4	88.7959	
		5	3.50192	
		6	31.9066	
4	(7,7)	1	77.8210	
		2	11.6731	
		3	81.7120	
		4	88.7959	
		5	88.7959	
		6	50.5836	
		7	30.3501	
Average			65.9841	97.66

evaluate a polynomial and its inverse, respectively. For each $k-1$ secret inner code, n shares are produced in a (k,n) -threshold secret sharing system. The share production is done $s/(k-1)$ times for a secret document with s inner codes. As a result, the polynomial is evaluated $(s/(k-1))*n$ times throughout the secret document. In the worst situation, because evaluating a polynomial of degree $k-1$ takes time $\Theta(k)$, the total share production takes time $O(s.n)$. As stated above, the inverse evaluation of a polynomial of degree $k-1$ requires time $\Theta(k^2)$. As a result, in the worst-case scenario, the overall time complexity for recovering the secret is $O(s.k)$.

CONCLUSION

The study presents the approach to demonstrate how the visual secret can be applied in modern applications and also the comparison of the visual secret sharing with the Caesar Cipher algorithm for image encryption. We found that there are different types of image encryption technology and one of the most popular ones is visual secret sharing. Similarly, the Caesar Cipher algorithm is one of the primitive algorithms for message encryption. Besides, there are many other algorithms for shared generations. We find that many scholars in the different universities have done more research in the field of image encryption techniques. The main goal is to discover an effective

and efficient algorithm for image encryption that can be used to secure digital media such as images especially. Finding a highly secure site which cannot be rebuilt easily by intruders is the ultimate goal of this project.

We have computed the NPCR and UACI of both algorithms. The value of NPCR and UACI lies between 0 to 100. The higher the NPCR and UACI values, higher is the security. In terms of the NPCR and UACI, the Caesar Cipher algorithm for image encryption has the best result. We conclude that NPCR and UACI only define the difference between the original image and the encrypted image. So, by using different techniques it is very difficult to generate the old original image. Also, we have to consider that the Caesar Cipher algorithm uses only one key. So, guessing the key will be easy and if any intruder gets the key, then he/she can easily decrypt the encrypted image and get the original image.

Although the NPCR and UACI value of Visual secret sharing are not so good. It is a strong technique because we need a threshold number of shares to decrypt. So, we conclude this study by recommending the Visual Secret Sharing scheme as a secure algorithm although it is weak in terms of NPCR and UACI.

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ABOUT AUTHOR(S)



(Sachin Maharjan) is Software Developer at Dish Media Network Limited. He has received his Bachelors Degree In Computer Science and Information Technology from Tribhuvan University. He has high degree of interest in real world problem solving through Software and enterprise software designs.



(Nirmal Maharjan) has completed B.Sc. CSIT from Academia International College. Currently he is working as ASP Dot Net Developer in Professional Computer System Pvt. Ltd.



(Nikhil Maharjan) is the Data Science and Analytics enthusiast and has BSC. CSIT degree from Tribhuvan University. He is a aspiring AI researcher. He is currently working as Data Engineer in Cotivity Nepal.



(Sujan Raj Tuladhar) is a python Django Developer and B.Sc CSIT Graduate from Academia International College, Lalitpur. He is Machine Learning aspirant. He is currently working as python Django developer at Outcode Tech Pvt. Ltd.



(Krishna Bikram Shah) is currently works as an assistant professor in the Department of Computer Science and Engineering, Nepal Engineering College, affiliated to Pokhara University. Beside this he is also a visiting faculty at Academia International College, Lalitpur, affiliated to Tribhuvan University. His current research interests include the Artificial Intelligence, RS-GIS, DIP, Bioinformatics, AIoT & SWM.

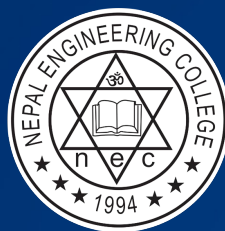
About Chief Editor

Prof. Dr. Hari Krishna Shrestha is a registered Professional Engineer of Nepal and a Chartered Engineer of India, and is associated with the Nepal Engineering College since 1994. After completing his graduate studies and completing a 2-year assignment of a groundwater modelling in the USA, he conducted several research activities and published the outputs in different peer-reviewed professional journals and popular magazines for the general public. He has developed guidelines for the hydrological analysis of bridge design and is currently preparing another guideline for the design of hydrological monitoring system. Dr. Shrestha's recent professional experiences involve international consulting for institutional analysis of the Bangladesh Water Development Board, development of web-based Road Asset Management System for various municipalities in Nepal, another web-based prioritization tool for the selection of sub-watersheds for proper watershed management, and as the Principal Investigator of climate change mitigation measures in Upper Mustang. Dr. Shrestha managed Nepal Engineering College as the Vice Principal in 2007 and Principal from 2009 to 2012. After retreating to regular teaching and research work at the college from 2012 to 2018 he is serving the college as the Principal since May 2018.



About Managing Editor

Assoc. Prof. Sachin Shrestha has been working as Managing Editor of Journal, SCITECH Nepal since 2018. He has published the journal from Volume 13 No 1 onward. During his tenure, the SCITECH Nepal has been listed in the Nepal Journal Online and thus each paper has been receiving the DOI ever since. The journal has also maintained the double-blind peer review system onward. As for the academics, he has completed his Masters in Information and Communication Engineering from IOE, Pulchowk Campus. He has been involved in teaching profession for the last 15 years and is currently working as Associate Professor, Department of Electronics and Communication Engineering at Nepal Engineering College, Changunarayan, Nepal. He is also the Chief of Student Welfare and Extra Curricular Activities Division of Nepal Engineering College since 2021. He has published different international patents as well as published several national and international publications in his field of research. His research field includes ultra-low powered system design, biomedical signal processing, embedded system design, and high-tech system design for neuro-disability. He has also been serving the field of neuro-disability of Nepal, especially with the research and development of high-tech system designs and has been serving as one of the executive board members of the Autism Care Nepal Society.



Nepal Engineering College

Changunarayan - 4, Bhaktapur

Phone: 01-5221006

(DAO Bhaktapur Regd No. 552-2060)

nec.edu.np | info@nec.edu.np