CONVENTION PAPERS

16th NATIONAL CONVENTION OF ENGINEERS

JANUARY 03-04, 2024

Engineering for National Prosperity and Effective Governance

Nepal Engineers' Association

Convention Papers

Technical Committee

Chair-Person
Er. Tapendra Bahadur Khadka

Co-chairs
Er. Narayan Hari Rijal
Er. Subash Neupane
Er. Uday Raj Neupane
Er. Vijay Bhushan Jha

Members
Er. Ujjwal Koirala
Er. Kailash Karki
Er. Abinash Aryal
Er. Iswor Aryal
Er. Dipendra Kharel
Er. Aayush Humagai
Er. Samir Pokhrel
Er. Arvind Kumar Karn
Er. Kamal Marasaini
Er. Manisha Sharma
Er. Bisikha Subedi

Member Secretary
Er. Dinesh Tripathee

Advisors
Er. Dr. Hari Bahadur Darlami
Er. Dr. Narayan Pd. Adhikari
Er. Rabi Bhushan Jha
Er. Tapendra Bahadur Khadka
Er. Umesh Kumar Gupta (Rauniyar)

Editors
Er. Dinesh Tripathee
Er. Suraj Chapagain
Er. Rosy Shrestha

Reviewers
Er. Dr. Ajay Chandra Lal
Er. Dr. Ajay Kumar Jha
Ar. Dr. Bijaya Krishna Shrestha
Er. Dr. Bijaya Thapa
Prof. Dr. Gokarna Bahadur Motra
Er. Dr. Kirti Kusum Joshi
Er. Narayan Hari Rijal
Er. Dr. Rajan Suwal
Ar. Dr. Sanjaya Uprety
Er. Subash Neupane
Er. Dr. Surendra Shrestha
Er. Uday Raj Neupane
Er. Vijay Bhushan Jha

Nepal Engineers' Association
Pulchowk, Lalitpur, G.P.O. Box: 604, Kathmandu, Nepal
Tel.: +977 1 5010251, 5010252, Email: info@neanepal.org.np
www.neanepal.org.np

Nepal Engineers' Association

33rd Central Executive Committee

Er. Dr. Hari Bahadur Darlami
President

Er. Dr. Narayan Pd. Adhikari
Vice-President

Er. Rabi Bhushan Jha
General Secretary

Er. Saroj Dhital
Dy. General Secretary

Er. Dinesh Tripathee
Treasurer

Er. Deepak Adhikari
Joint Treasurer

Executive Member

Er. Manish Mallick

Er. Sagar Bhattarai

Er. Kushalta Nyoupane

Er. Hari Narayan Ray Yadav

Er. Suraj Chapagain

Er. Nishan Nepal

Er. Bidhya Baral

Er. Binod Bahadur Pal

Er. Ishwor Pokharel

Er. Anupam Parajuli

Er. Ashes Niroula

Er. Khum Bahadur Bhandari

Er. Ran Bahadur Bam
(Sudurpaschhim Province)

Er. Roshan Subedi
(Koshi Province)

Er. Binod Pun
(Karnali Province)

Er. Ravindra Lal Mul
(Gandaki Province)

Er. Vishwa Ranjan Mishra
(Lumbini Province)

Er. Subrat Aryal
(Bagmati Province)

Er. Sanjay Kumar Yadav
(Madhesh Province)

NEPAL ENGINEERS' ASSOCIATION

2nd Provincial Executive Committee

Koshi Province	
Er. Jayanath yadav	Chairperson
Er. Suresh kumar Shrestha	Vice Chairperson
Er. Mahesh Dhital	Secretary
Er. Saroj bhattarai	Joint Secretary
Er. Bibhash Kumar Mishra	Treasurer
Er. Subhash Kumar Karn	Member
Er. Dharmen Kumar Chaudhary	Member
Er. Avinash Thakur	Member
Er. Pradeep Parajuli	Member
Er. Subarna Basnet	Member
Er. Sachin Mandal	Member
Er. Manisha Karki	Member
Er. Bheshraj Ghimire	Member
Er. Deepa Gautam	Member
Er. sudhir Yadav	Member

Madhesh Province	
Er. Gauri Pandit	Chairman
Er. Kartikesh Jha	Vice Chairman
Er. Ram Narayan Yadav	Secretary
Er. Ram Ishwar Yadav	Joint-Secretary
Er. Tej Narayan Yadav	Treasurer
Er. Neha Karna	Member
Er. Sitesh Kumar Yadav	Member
Er. Anjali Thakur	Member
E. Pravin Kumar Yadav	Member
Er. Ravi Kumar Sah	Member
Er. Priyansu Gupta (Rauniyar)	Member
Er. Summi Mishra	Member
Er. Rita Kumari Yadav	Member
Er. Deepak Kumar Mandal	Member
Ar. Vinita Yadav	Member

Bagmati Province	
Er. Rohini Paudel	President
Er. Surendra Kaini	V. President
Er. Dinesh Neupane	Secretary
Er. Dr. Bijay Thapa	Joint Secretary
Er. Bipin Bhusal	Treasurer
Er. Oshan Thapa Magar	Member
Er. Pramod Mahat	Member
Er. Prahlad Basnet	Member
Er. Rohit Paudel	Member
Er. Chiranjibi Khatiwoda	Member
Er. Brizesh Singh	Member
Er. Gaurav Paudel	Member
Er. Diraj Thapa	Member
Er. Rakesh Bhattarai	Member
Er. Prabin Chhetri	Member

Gandaki Province	
Er. Brijendra KC	Chairman
Er. Santosh GC	Vice-Chairman
Er. Anjan Thapa	Secretary
Er. Subarna Shrestha	Joint Secretary
Er. Khem Raj Timilsina	Treasurer
Er. Asmita Khanal	Member
Er. Santosh Kaphle	Member
Er. Rajiv Subedi	Member
Er. Rabindra Paudel	Member
Er. Bikash Subedi	Member
Er. Biswash Acharya	Member
Er. Yam Krishna Poudel	Member
Er. Yudip Subedi Chhetri	Member
Er. Hem Prasad Gurung	Member
Er. Sagar Basyal	Member

NEPAL ENGINEERS' ASSOCIATION

2nd Provincial Executive Committee

Lumbini Province	
Er. Shailendra Prasad Shrestha	Chairman
Er. Lekha Bahadur Basnet	Vice-Chairman
Er. Govinda Pangeni	Secretary
Er. Arjun Giri	Joint Secretary
Er. Sandeep Regmi	Treasurer
Er. Bidhya Bhusal	Member
Er. Darshan Tiwari	Member
Er. Arjun Pandey	Member
Er. Tulsiram Wosti	Member
Er. Pravin Mishra	Member
Er. Aarati Devkota	Member
Er. Dipesh Ghimire	Member
Er. Vinay Kumar Gupta	Member
Er. Ishwor G.C.	Member
Er. Shoaib Ahamad Ansari	Member

Karnali Province	
Er. Hari KC	Chairman
Er. Janak Bhattarai	Vice Chairman
Er. Ram Krishna Acharya	Secretary
Er. Shrawan Kumar Mahatara	Joint Secretary
Er. Devendra Bhattarai	Treasurer
Er. Nilam Budha	Member
Er. Bijay Rana	Member
Er. Dhirendra Kumar Shahi	Member
Er. Narendra Bhatta	Member
Er. Dhirendra Jung Shahi	Member
Er. Kiran Kumar KC	Member
Er. Balaram Tiwari	Member
Er. Tara Prakash Karki	Member
Er. Nabin Thapa	Member
Er. Ram Bahadur Karki	Member

Sudurpashchim Province	
Er. Pradeep Kumar Pant	Chairman
Er. Bhaskar Chataut	Vice-Chairman
Er. Padam Bahadur Madai	Secretary
Er. Rajendra Bahadur Saud	Joint Secretary
Er. Bir Bahadur Bhat	Treasurer
Er. Govinda Bhatta	Member
Er. Kapil Dev Bhatta	Member
Er. Khagendra Awasthi	Member
Er. Harendra Bikram Shah	Member
Er. Janaki Badaila	Member
Er. Saroj Shah	Member
Er. Ramesh Bohara	Member
Er. Umesh Singh Kathayat	Member
Er. Deviraj Neupane	Member
Er. Rajendra Nath	Member

Message from the President

Dear Friends,

We are honored to organize the 16th National Convention of Engineers. This gathering of bright minds in our country highlights how pivotal engineers are in shaping our nation's path forward. Engineering drives progress and development. It's the backbone for infrastructure, technology and innovation. In difficult times, our prosperity and effective governance depend deeply on the dedication and creativity of engineers.

In pursuing national prosperity, engineers have consistently led the way in creating sustainable solutions that accelerate economic growth and enhance quality of life for all citizens. Our work spans designing resilient infrastructure to pioneering clean energy technology that combats climate change. Effective governance also relies on judicious use of technology, data-driven decisions and continuous improvement in public services. Engineers play a key role in designing and implementing systems that make governance efficient, transparent and accountable. In the modern era, research and development connect the power of IT, AI, energy and technology transfer to tackle challenges, streamline resource utilization and enhance overall governance.

16th National Convention of Engineers was formerly scheduled by the 32nd Executive Committee of NEA for March 4 - 6, 2020, to be held in Kathmandu with the theme "Smart Infrastructure for National Prosperity". However, it could not be organized due to the unavoidable circumstances created by COVID-19. The 33rd Executive committee has decided to organize the 16th National Convention of Engineers with the theme *"Engineering for National Prosperity and Effective Governance"*.

We express our gratitude to the dedicated engineers and architects whose contributions played a crucial role in ensuring the remarkable success of this convention. A special acknowledgment goes to the Technical Committee as well as the architects and engineers who devoted countless days and nights to overcome challenges and ensure the convention's excellence. Moreover, the continuous effort of NEA Secretariat has played an important role for the success of this convention.

I look forward to the ideas and solutions that will emerge from this convention and I am confident that, with your expertise and commitment, we can build a brighter future for our nation.

Thanking you,

Er. Dr. Hari Bahadur Darlami
President
Nepal Engineers' Association

Message from General Secretary

Dear esteemed engineers, architects, honored guests and distinguished participants,

I am delighted to express my opinion associated with the 16th National Convention of Engineers, centered on the vital theme of *"Engineering for National Prosperity and Effective Governance."* Engineering is the cornerstone of progress, shaping our nation's infrastructure, technology and innovation. In this era of multifaceted challenges, we rely on engineers' innovation to drive our nation's prosperity and enhance governance efficiency. As we pursue national prosperity, engineers lead the way with innovative and sustainable solutions that stimulate economic progress and improve lives. Our work, from resilient infrastructure to clean energy technologies, contributes to a prosperous and sustainable future.

Effective governance pivots on technology, data-driven decisions and service improvements. Engineers play an important role in creating efficient, transparent and accountable systems. E-government, the application of Information and Communication Technology (ICT) within public administration, provides government, the citizen and business with a set of tools that can potentially transform the way in which interactions take place, services are delivered and public administration reform and good governance goals are met. Together, we can address complex societal issues and improve governance for all citizens.

The technical sessions of this convention have been entitled as: Engineering Leadership for Effective Governance, ICT for Innovation and Technology Convergence, Technological Innovation in Construction Industry, Tripling Global Renewable Energy Capacity and Double the Progress in Energy Efficiency by 2030: Who Takes the Stake?, and Nepal's Engineering Dilemma: A Roadmap to Solution. As we explore the theme "Engineering for National Prosperity and Effective Governance," I encourage bold thinking and the embrace of professional responsibilities. Together, we can drive our nation toward a brighter future where governance truly serves all citizens.

I eagerly await the innovative ideas and practical solutions that will emerge from this convention. With your expertise and dedication, we can make significant strides toward a more prosperous and efficiently governed nation.

We are grateful to all the engineers and architects who have contributed for the success of the 16th National Convention of Engineers. Further, we are thankful to all, including staff of NEA secretariat and the volunteers, whose continuous effort has been important for the successful organization of this convention.

Sincerely,

Rabi Bhushan Jha
General Secretary
Nepal Engineers' Association

Message from the Chairperson – Technical Committee

Dear Valued Engineers, Architects and Readers

On behalf of the Technical Committee, I would like to extend a very warm welcome to the readership of souvenir on this especial occasion of 16th National Convention of Engineers. I take this opportunity to thank our authors, reviewers, and editors; all of whom have volunteered to contribute to the success of this journal.

The 16th National Convention of Engineers has adopted the theme *"Engineering for National Prosperity and Effective Governance,"* to emphasize the significant role that engineering plays in shaping a nation's future and facilitating efficient governance. The inputs from the engineers and architects are the most to bring prosperity in the nation. The convention has incorporated five technical sessions each of which incorporate a keynote presentation followed by a panel discussion. This pre-print consists of the papers received from the authors in response to our call for papers under seven different sub-themes.

The technical sessions have been entitled as: Engineering Leadership for Effective Governance, ICT for Innovation and Technology Convergence, Technological Innovation in Construction Industry, Tripling Global Renewable Energy Capacity and Double the Progress in Energy Efficiency by 2030: Who Takes the Stake?, and Nepal's Engineering Dilemma: A Roadmap to Solution. Indeed, the technical sessions are cross-disciplinary which have been expected to serve as a novel platform for technological exchange by capturing knowledge and experience of the presenters and panelists.

We are happy to be part of 16th National Convention of Engineers, a momentous occasion organized by the Nepal Engineers' Association (NEA). It's a celebration of the engineering community and an opportunity to promote and foster the spirit of engineering excellence. This pre-print includes the papers received from engineering professionals from various sectors, including industries, academic institutions, research and development organizations, and government organizations. These papers aim to share experiences, concepts, innovative ideas, research findings and other relevant insights to our readers.

It is my indeed pleasure and great honor working as chairperson of the Technical Committee of NEA. I believe that this publication helps to disseminate the information about the technological innovation and its application. It also helps to the reader to broaden their knowledge in various technical fields.

Finally, I would like to thank the highly experienced advisory team, editorial board and member of various committees who helped a lot to make the convention successful. My sincere thanks to Technical Committee Team as well as all architects and engineers and who have contributed for the success of this convention. At last, but not the least on behalf of the technical committee, I am grateful to NEA's 33rd Executive Committee for providing us the great opportunity.

Thank you!

Er. Tapendra Bahadur Khadka
Chairperson
Technical Committee
Nepal Engineers' Association

Message from the Member Secretary
Technical Committee

Nepal Engineers' Association, an umbrella organization of engineers and architects of Nepal with about 40 thousand members, has a tradition of conducting national convention of engineers in the span of every 2 years. This 16th series of the convention is being organized in quite challenging condition of the country facing inconvenient economic situation. After entering into the federal structure and three tiers of government being setup, the role of engineers for implementation of development policy has been paramount.

In this transforming context, the engineering fraternity is facing new challenges and many issues are to be addressed. Further, Nepal is also suffering weak governance which makes it tough to achieve the development goals set forth to meet the public expectation. In this backdrop, engineering leadership is necessary to advance the development of the country. In line of this concept, the theme *"Engineering for National Prosperity and Effective Governance"* has been chosen for the convention.

Engineers should be involved more on policy level and entrusted for leadership role for prosperity of the nation. In the meantime, they should be capacitated with new approaches continuously updating with the ongoing changes in technology across the globe. This convention is the very right forum where wide range of engineers/architects working at different sectors from local level to the central level; implementation level to planning level; field level to policy level come together to share their experience, review each other's research works and problems faced as well as solutions achieved during their professional practice.

Last but not the least, on behalf of the Technical Committee and on my own, I would like to express my sincere gratitude to the authors of papers and reviewers who significantly contributed for this publication with continuous and dedicated effort. I would also extend my gratitude to NEA Secretariat whose rigorous efforts were instrumental in making this convention possible.

Er. Dinesh Tripathee
Member Secretary
Technical Committee

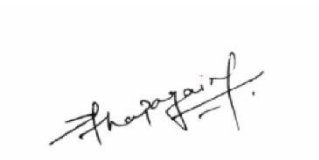
Message from the Member Secretary
Publication & Media Coordination Committee

The National Convention of Engineers is one of the most awaited events for the engineers/architects of Nepal occurring every 2 years. The 16th Convention of Engineers has been organized with the theme *"Engineering for national prosperity and effective governance."* With immense pleasure, I welcome you all engineers/architects from different sector within the country in this convention. I would also like to wish you all Happy New Year 2024.

This publication is the result of relentless effort of not only the 33rd Executive Committee but also painstaking effort of the authors and reviewers. Their commitment has given us tremendous enthusiasm at times and also inspired our team to deliver more efficiently. On behalf of the Publication Committee, I would like to express my sincere gratitude and appreciation to all contributors for their valuable contribution in this publication and the ongoing convention.

We do strongly believe that the papers incorporated in this publication would greatly support the theme of the 16th National Convention of Engineers. Moreover, this publication will support the practicing engineers at implementation level to better understand the technology and provide new approach in dealing with the engineering challenges and issues.

Finally, I would like to express my deep gratitude to the 33rd Executive Committee, on behalf of the Publication Committee for their support and motivation throughout the process of publication. I would also extend my gratitude to the Technical Committee coordinating for paper. I would also thank the NEA Secretariat, printing press for their commendable performance to bring out this publication within stipulated time-frame.



Er. Suraj Chapagain
Member Secretary
Publication & Media Coordination Committee

Content

Compliance of Strength, Core Cutter Test, and Non-Destructive Test

Shrestha J M[1], Shrestha P[2]

*Corresponding email: jagadiswar.personal@gmail.com[1], prajeshstha@gmail.com[2]

Abstract

Concrete is a widely utilized construction material renowned for its strength, durability, fire resistance, and adaptability, allowing for the creation of diverse and innovative structures. In Nepal, concrete grades ranging from M15 and above are commonly employed, with specific attention needed to quality control during the complex concreting processes. The quality assurance of concrete is the prime concern in construction since the inferior quality of concrete causes serious issues concerning the strength of the structures. This paper outlines the required compressive strength of concrete at 28 days along with destructive and non-destructive tests.

The analysis, based on crushing 28-day sample cubes, guides the determination of concrete strength, with 7-day cubes providing tentative indicative values. Non-destructive tests offer an alternative to reduce core cutting, supporting compliance assessment. The compliance criteria involve the number of samples, their average strength, and considerations for standard deviation. Failure to comply necessitates further analysis through core cutting. This paper clarifies the acceptance criteria for concrete. (The common misconception is that e.g. M25 grade concrete with a strength of 25MPa is sufficient at 28 days) whereas as per IS 456:2000, the required strength for compliance is minimum individual sample ≥ fck-3 & av. of group of 4 consecutive sample ≥ fck+3 or fck+1.65 std.dev. whichever greater.

The paper also details the core cutting process, emphasizing the acceptance criteria. Correction factors for core strength include length-to-diameter ratio, diameter, rebar presence, casting direction, and concrete age. These corrections contribute to the determination of the corrected compressive strength.

Keywords: *Specimen, Sample, Compliance of Strength, Non-Destructive Test, Core Cutter Test*

1. Introduction

Concrete stands out as a favored material across various construction applications, owing to its strength, durability, fire resistance, and adaptability. Its ability to take on virtually any shape facilitates the creation of imaginative and innovative structures. Additionally, the readily available local ingredients used in concrete contribute to its widespread usage. These qualities collectively make it a robust and enduring choice for a multitude of residential and commercial settings, establishing concrete as the premier building material for sustainable infrastructure. The utilization of different concrete grades has surged, particularly in the construction of high-rise buildings, longer spans, and expansive infrastructures, necessitating

larger sizes. In Nepal, concrete grades ranging from M25 to M45 are commonly employed, with occasional use even up to M70 in specialized cases, such as corrosive environments. The concrete mixture uses various ingredients and encompasses processes such as batching, mixing, transporting, placing, compacting, and curing. Consequently, the quality control of concreting becomes intricate and demands meticulous attention at each step, preferably handled by experienced professionals. Any lapses in the quality control process could result in the failure to attain the required strength.

Ensuring the quality of concrete is a primary focus in construction, as subpar concrete can lead to significant strength and durability issues over the lifespan of structures. Unlike metals, the immediate assurance of concrete strength is not possible upon delivery from the production line, as it requires a reasonable amount of time to achieve its expected strength. Consequently, trial mixes and slump testing are conducted before accepting concrete to verify that it meets the specified strength requirements.

It's crucial to note that trial mixes are anticipated to demonstrate a higher mean strength compared to the mean strength obtained from in-situ cast cube tests to minimize risks. The failure of a single cube test result at the construction site does not necessarily indicate the failure of the entire batch or a portion of the concrete in the structural element. This is because assessments must be fair to both consumers and producers. Therefore, establishing compliance criteria for concrete holds great importance for consultants.

2. Materials and Methods

Representative sample cubes will be extracted for both 7 and 28 days. The concrete strength will be assessed based on the crushing of the 28-day sample cubes. The seven-day cubes provide provisional indicative values for the 28day strength, and if these values are lower, caution should be exercised in subsequent concrete processes.

Should the targeted 28-day strength not be attained, additional examination becomes necessary, involving the crushing of core cuttings obtained from the concrete. If the cores also fail to meet the required strength, load tests for flexural members must be conducted under the full dead load of the structure plus 1.25 times the imposed load for a 24-hour duration, after which the imposed load should be removed. Recordings of deflection caused by the imposed load alone are then taken. Under these conditions, it is expected that 75 percent of the deflection should be recovered. Failure to achieve this requires a repeat test

after a 72-hour interval, with the expectation of an 80 percent recovery. Otherwise, the result is considered non-compliant. Non-destructive tests also play a role in minimizing the need for core cuttings, provided that they meet the corresponding core cutter strength criteria. The determination of the required strength for the 28-day representative cube sample relies on compliance with strength standards. The analysis is conducted using the available cube samples, and the frequency of cube preparation aligns with the concreting quantities specified in Table 1 (Clause 15.2.2 of IS456:2000)

Table 1 : Frequency of Cube Sample

Quantity (m^3)	No. of Sample
Up to 5	1
5.1 – 15	2
15.1 – 30	3
30.1 – 50	4
> 50	4 + 1 for each 50 m^3 or part thereof

A minimum of 3 specimens each for 7-day and 28-day strength is required, and the average of these 3 specimens constitute one sample. Each 28-day strength specimen should not deviate more than ±15 percent from the average sample value; failure to meet this condition renders the result invalid (Clause 15.4 of IS456:2000). The variation may cause due to non-homogeneity because of improper compaction and not level of specimens during preparation of cubes sample. It could be minimized by simply levelling of cubes and proper vibration on table (see figure 1) during preparation of cubes.

Figure 1: Core cutting, measurement & testing

Additionally, for the first initial sample, the required strength must be ≥ (fck+4) N/mm², where fck represents the concrete grade used. In cases where 2 or 3 samples are available, the minimum average strength required should be ≥ (fck+4) N/mm², and each sample should be ≥ (fck-2) N/mm². For samples ranging from 4 to 30, the minimum average strength of a group of 4 non-overlapping consecutive samples should be ≥ (fck+0.825 Std. Dev.) N/mm² or (fck+3) N/mm2, whichever is greater.

Table 2: Assumed Std. Deviation

Grade (f_{ck})	Std. Dev.
M15	3.5
M20, M25	4.0
M30 to M60	5.0

However, no single sample should fall below (fck-3) N/mm2. The standard deviation in this scenario is determined according to Table 2 (Clause 9.2.4.2 of IS456:2000 Amd.4-2013). If the sample size exceeds 30, average strength of group of 4 non-overlapping consecutive required shall be ≥ (fck+0.825 Std. Dev.) N/mm² or (fck+3)N/mm² , whichever is greater but no one sample shall not less than (fck-3)N/mm². The standard deviation is taken in this condition shall be from the actual calculation. When concrete cube samples fail to meet the above conditions, further analysis is required through core cutting at the actual site, with tests conducted on core cylinders. It's worth noting that in practice, there is often confusion, mistakenly assuming compliance with strength standards based on the concrete grade designation mentioned in Table 2. The above matter is simplified and summarized in table 3.

Table 3: Compliance of Strength of Concrete Cubes as per Table 11, IS 456:2000, Amendment No 4

SN	No. of Sample	Specified Grade	Individual Test Sample	Mean
1	1	M15 and above	≥ (fck+4) N/mm²	
2	2 to 3		≥ (fck-2) N/mm²	≥ (fck+4) N/mm²
3	4 to 30		≥ (fck-3) N/mm²	≥ (fck+3) N/mm² or (fck+0.825 x Std. Dev. from Table 2) N/mm² whichever greater of 4 non-overlapping consecutive groups
4	>30		≥ (fck-3) N/mm²	≥ (fck+3) N/mm² or (fck+0.825 x Established Std. Dev.) N/mm² whichever is greater of 4 non-overlapping consecutive groups

Note:
The test results of the individual sample shall be the average of the strength of 3 specimens. The individual specimen variation shall not be more than ≤ ±15 % of the average. If this criterion does not comply the result is invalid.

At least three cores are required from a site where the representative cube samples do not meet compliance standards. Concrete in the structural member, as indicated by core test results, is deemed acceptable if the average equivalent cube strength of the cores is at least 85 percent of the cube strength specified for the concrete grade at the corresponding age, with no individual core having a strength less than 75 percent of the cube strength. In instances where rebar is unavoidable in the core cutting sample from the site, there is no specific standard size and rebar insertion condition. Extracting a vertical concrete core from beams and shear walls may not be possible; in such cases, a horizontal core is taken. While the standard age for cube samples is 28 days, core cutter samples are performed after disputing the 28-day result due to non-compliance with strength standards, prompting the decision to carry out core cutting. Concrete strength is also influenced by the age factor, necessitating correction for factors such as core cylinder height-to-diameter ratio, diameter, rebar presence, direction of core cutting, and age.

These corrections are briefly outlined below.

The corrected core strength, once converted to a 28-day strength (in MPa), will be provided as follows:

$$f_{cylinder}(28d)=(F_{L/d} \times F_{dia} \times F_{reb} \times F_{dir} \times F_{age}) \times F_{core}(t) \quad \ldots\ldots\ldots\ldots 1$$

$$f_{cube} = 1.25 \times f_{cylinder} \quad \ldots\ldots\ldots\ldots 2$$

Where,

$F_{L/d}$ = Length to diameter ratio strength correction factor

F_{dia} = Diameter strength correction factor

F_{reb} = Rebar correction factor

F_{dir} = Casting direction strength correction factor

F_{age}= Casting age strength correction factor

F_{core} (t) = Core cylinder strength on (t) day

1. Length-to-diameter ratio strength correction factor ($F_{L/d}$)

The length-to-diameter ratio can be adjusted based on site conditions and standards. A ratio of 2 is considered without correction, but for H/D values between 1 and 2, a correction factor must be applied. Cores with an H/D ratio less than 1 produce unreliable results. The correction involves multiplying the result by factors specified in the equation

$F_{L/d}$= 0.893+0.107 (L/D-1), as per clause 5.6.1of IS 516:1959 Reaffirmed 1999,

Where, L/D=Ratio of height to diameter of cylinder.

Figure 2: Core cutting, measurement & testing

2 Diameter Strength Correction factor (F_{dia})

In addition to the H/D ratio, the selection of core size is guided by a general principle that the diameter should be at least 3 times the maximum size of the stone aggregate. Cores with a diameter less than 3 times the size of the aggregate require an increased number of tests. The standard permits the use of six-inch or four-inch cores, and even two-inch cores are allowed. However, it is generally advised against using very small diameter cores, as they exhibit greater variability in results compared to larger diameter cores. The diameter of the core also influences its strength, with the standard considering four inches (100mm) as the standard diameter with no need for correction (i.e., correction factor is 1). Conversely, for diameters of two inches, three inches, and six inches, correction factors of 1.06, 1.03, and 0.98, respectively, are required.

3. Reinforcement Correction Factor (F_{reb})

When obtaining a core sample from a reinforced element, it is uncommon to find a sample without a reinforcement bar. Therefore, it is crucial to minimize the presence of steel bars, and if they are oriented along the core cutting direction, such samples should be rejected. This is achieved by scanning the surface to eliminate the minimum amount of rebar. Rebar correction is necessary based on the number of bars and their distance from the nearer end of the core. The correction factor for the reinforcement bar is determined by the formula:

$$F_{reb}=1.0+1.5\ (\emptyset_r\ h)/(\emptyset_c\ l)$$

Where $\emptyset_r$= bar diameter

$\emptyset_c$ = core diameter

h = distance of bar axis from the nearer end of the core

l = uncapped core length

For cores with multiple bars, the correction factor is calculated as per clause 7.2.2 of BS 1881 Part 120, using the expression:

$$F_{reb}=1.0+1.5\ (\Sigma(\emptyset_r\ h))/((\emptyset_c\ l))$$

4. Strength Correction Factor for Casting Direction (F_{dir})

The casting direction is performed layer by layer from bottom to top. The standard considers the core extracted from top to bottom in the vertical direction. However, in specific cases such as beams and walls, the core may be taken in the horizontal direction. In such instances, a correction factor of 1.04 is applied.

5. Age Correction Factor for Casting Strength (F_{age})

The age of a concrete sample can extend beyond 28 days, with the concrete's strength generally experiencing a noticeable increase up to approximately three months. After this period, any further strength gain tends to be minimal. The relationship for the increment factor from 28 days as per clause 5.2.1 of SP24 -1993 is expressed as

$$F_{age} = (4.7+0.833\ t)/t$$

Where,

F_{age} = age strength correction factor, and

t = concrete age at the time of core testing from casting in days.

The value obtained after multiplying with correction factor is called corrected compressive strength.

If the core test results fail to meet these criteria, or if such tests have not been conducted, load tests may be employed. These tests involve applying the full dead load plus 1.25 times the imposed load for a 24-hour period. Subsequently, the imposed load is removed, and only the deflection due to the imposed load is recorded. If, within 24 hours of removing the imposed load, the structure fails to recover at least 75 percent of the deflection under the superimposed load, the test may be repeated after a 72-hour interval. If the recovery is less than 80 percent, the structure is deemed unacceptable. As the load test is a cumbersome job, strengthening of failed member is carried out. Some of the strengthening of member is performed by jacketing, grouting, wrapping by carbon fiber etc. There will performed again non-destructive test and if the later results are improved with sufficient strength by comparing previous results and may considered as compliance by the Engineer.

Non-destructive Tests:

Non-destructive tests (NDT) are employed to estimate the properties of concrete within structures. Two popular NDT methods are the Rebound Hammer test (Mechanical) and Ultrasonic Pulse Velocity (Electrical) method. The Rebound Hammer test primarily assesses surface hardness, while the UPV method involves the penetration of sound through concrete, potentially relating the voids within the structure. Various factors, including the type of cement, aggregates, moisture content, curing, age of concrete, and the presence of reinforcement bars in the specimen, can impact NDT values.

Results obtained from NDT methods may vary by up to ±25% from actual values. Therefore, these methods are not considered highly accurate and should not be solely relied upon for predicting the concrete strength in a structure or for comparing inferior concrete with known concrete strength members. Both methods provide a relative quality assessment of concrete, ranging from excellent to poor, and are not intended as a sub stitute for compressive strength testing. To enhance the accuracy and confidence in the results, the relationship between NDT tests and compressive strength can be verified through tests on core samples from the structure or standard specimens made with the same concrete materials and mix proportions.

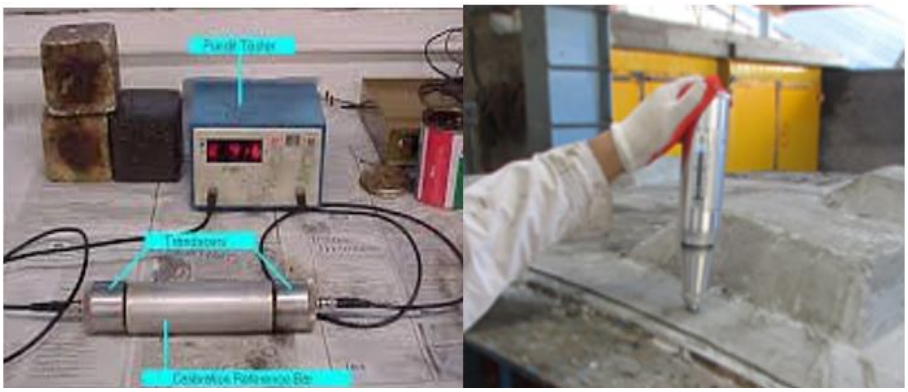


Figure 2: Ultrasonic Pulse Velocity Meter & Schmidt Hammer

Qualitatively, the results provided by NDT methods can be presented as follows:

Table 4: Schmidt Hammer Values Applications and Approx. Impact energy

Impact Energy of Rebound Hammers for Different Applications		
SN	Applications	Approx. Impact Energy (Nm)
1	For testing normal-weight concrete	0.25

2	For light-weight concrete	0.75
3	For testing mass concrete as roads, hydraulic structures, etc.	30.00

Table 5: Velocity Criterion of Concrete Quality Grading for UPV method

Velocity Criterion of Concrete Quality Grading for UPV method		
SN	Velocity (km/sec)	Concrete Quality Grading
1	Above 4.5	Excellent
2	3.5 to 4.5	Good
3	3.0 to 4.5	Medium
4	Below 3.0	Doubtful

To address the limitations of both the Ultrasonic Pulse Velocity (UPV) and Rebound Hammer (RH) tests, a combined approach known as SonReb (**Son**ic + **Reb**ound) method is employed. Various formulas have been developed by different researchers, and a notable contribution to the understanding of the relationship with practical values is found in the study titled 'Accuracy in predicting the compressive strength of concrete using the 'SonReb method' by Di Leo & Pascale, 1994. One of the more effective expressions derived from this study is as follows:

$$f_c = 1.2 \times 10^{-9} \times RN^{1.058} \times UPV^{2.446} \text{ MPa.}$$

Where, RN = Rebound number and UPV = velocity in m/sec

3. Results and Discussions

From the Table 3 of Every structure is designed with a specific strength grade, optimized for practical achievement. However, in construction, it is imperative to attain the expected strength outlined in the design. Addressing the failure to achieve the required strength presents a considerable challenge. Two primary factors contribute to non-compliance with strength standards.

The first factor concerns the consistency of concreting. Even if sufficient strength is achieved, it does not meet compliance if the average of three specimens differs by more than ±15 percent from each individual specimen. To address this issue, careful attention is needed

during the preparation of sample cubes, focusing on factors such as levelness and vibration for compaction, mirroring the conditions in actual construction.

The second factor involves attaining less strength than the specified compliance requirements. This may indicate poor-quality concreting corresponding to the sample, posing a severe condition for construction. Since the cube sample represents only a portion of the concrete quality, analysis is required based on the actual strength of cores obtained from the concrete, utilizing a probabilistic approach. SonReb can also helps to assess the performance more realistic to some extent as it is a combination of outer surface strength by rebound hammer and internal strength by ultrasonic pulse velocity.

If one sample fails to meet compliance, it may be associated with a group of four non-overlapping samples, suggesting that the individual poor strength corresponds with nearby concrete before failure occurs. The required concrete strength is defined as the average of a minimum of three cubes at 85 percent, with no individual core concrete falling below 75 percent of the specified grade. If the desired strength is not achieved through core samples, an actual flexural test must be conducted through deflection analysis, a process that is both costly and labor-intensive.

4. Conclusion

The structural designer bears the responsibility of selecting the concrete grade, especially in the case of high-grade concrete in which achievement of strength is difficult due to high grade. If achieving the required strength becomes challenging or is only attainable with great difficulty using the available materials, consideration should be given to lowering the grade, possibly necessitating a revision of the design. On the other hand, the construction supervision engineer must pay careful attention to the proper selection of construction materials and diligently supervise the concrete process, encompassing batching, mixing, transporting, placing, compacting, and curing.

All engineers involved should possess a comprehensive understanding of the principles and applications related to the compliance of strength in sample tests. Additionally, they should be well-informed about the procedures to follow when the required strength is not achieved

in the field. This proactive approach ensures that undesired conditions do not arise after the concrete has been placed. If compliance of strength is not achieved, satisfactorily remedial measures shall be performed and if not possible, it shall be demolished or if not possible, the design load shall be reduced.

References

1. Concrete Technology –M.S Shetty, S. Chand
2. Reinforced Concrete Structures-Park R & Paulay,T, Wiley-Interscience new York
3. SonReb Method for Evaluation of Compressive Strength of Concrete-Narayan R Chandak, Hemraj R Kumavat
4. Plain and Reinforced Concrete Code of Practice, IS:456-2000 (Fourth revision)
5. Non-destructive testing of concrete- Ultrasonic Pulse velocity (IS 13311- Part 1 1992 (Reaffirmed 2004)
6. Non-destructive testing of concrete- Rebound Hammer (IS 13311- Part 2 1992 (Reaffirmed 1999)
7. Amendment no. 4 of IS456:2000 in May 2013
8. Testing of the strength of hardened concrete Part1/Section 1 2021
9. Explanatory handbook on IS code 456:2000-SP24 1983

Minireview on Environmental Economic Theories and Models for Decision Making on Sustainable Solid Waste Management

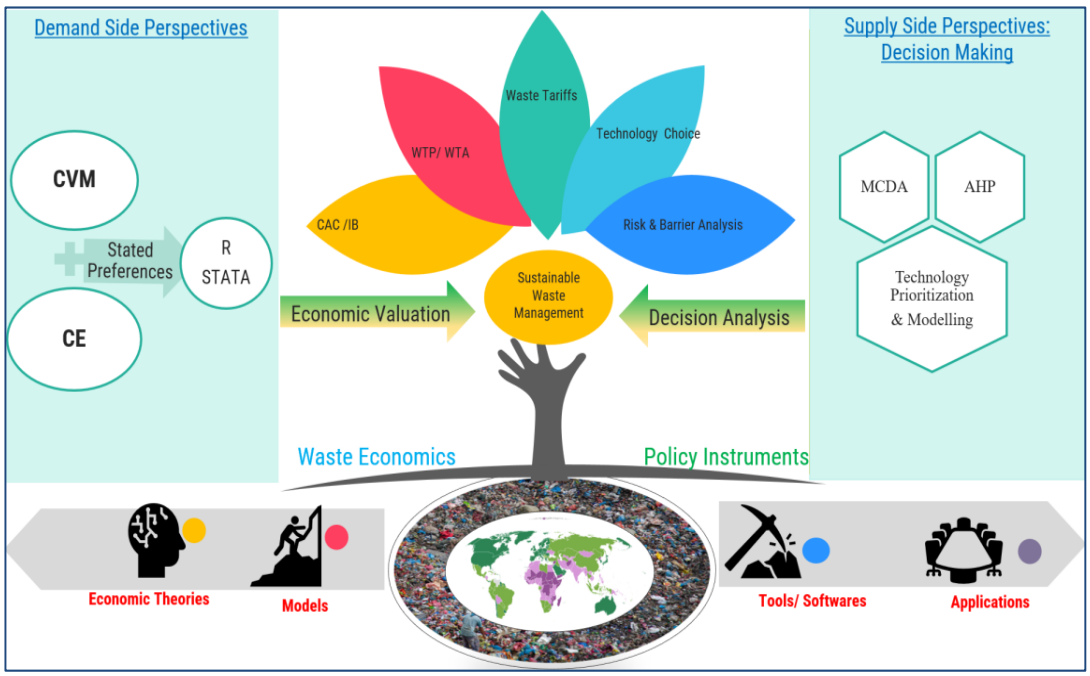
Mukesh Ghimire[1,2], Sudeshana Pandey[1], JongRoul Woo[1*]

[1] *Graduate School of Energy and Environment (KU-KIST Green School), Korea University, Seoul, South Korea,*

[2] *Alternative Energy Promotion Center, Ministry of Energy, Water Resources and Irrigation, Government of Nepal, Kathmandu, Nepal*

**Corresponding email: jrwoo@korea.ac.kr; mukeshghimire.ku@gmail.com*

Graphical Abstract:



(Source: Drawn by authors based on existing literatures review)

Highlights:

- Environmental economic theories: Command and Control (CAC) and Economic Instruments (EI) are briefly discussed.
- Waste management economic models and instruments: Contingent valuation method (CVM) and Choice Experiment (CE) as demand-side instruments and Multi Criteria Decision Analysis (MCDA)- Analytical Hierarchical Process (AHP) as supply-side decision-making instruments are reviewed and analysed.

- Applications of Contingent Valuation Method (CVM), Choice Experiment (CE) and AHP models in waste management along with various software tools are discussed.

Abstract

Waste management is one of the global problems, which is multidisciplinary in nature covering the demand and supply side perspectives, various complex technologies, stakeholders, and their behaviours. Environmental economics attempts to address these multiple problems through various economic theories & policy instruments, models, and tools. This review highlights the fundamentals economic theories for waste management, econometric models and instruments for demand and supply side perspectives of waste management, applications of economic theories and models in developed and developing countries. Even though many developing countries are adopting more CAC tools and instruments for environmental regulations than EI tools. EI instruments are more effective tools for market intervention than the CAC based solutions. Findings revealed that CVM and CE are most widely used models for the waste management especially for determining the non-use economic valuation of environmental goods and services. Devising demand side policy instruments such as waste tariffs, willingness to pay/acceptance (WTP/WTA), siting waste management facilities, identifying significant determinants are commonly done through CVM and CE with the help of statistical software like R and STATA. Complex decision making such as identifying, choosing alternatives, and ranking criteria, barriers, risks, etc can be done with the help of MCDA tools such as AHP, ANP, etc. AHP is most applied MCDA tools for solving waste management supply side perspective issues for policy decision analysis.

Keywords: *Waste Economics Theories, Models, Tools, CVM, CE, AHP*

1. Introduction

Waste management is one of the top global environmental problems (Kim et al., 2022). Global annual waste is expected to grow to 3.40 billion tonnes by 2050 (Kaza et al., 2018). In 2030, the global population of 8.5 billion is expected with the global solid waste production of 2.59 billion tons (Peng et al., 2023). The World Bank report highlights that annually about 2.2 billion tons of waste have been produced globally with the average waste per person 376 kg which is about six times the weight of person (considering 62 kg/person) and the report also estimates that over the next three decades, waste generation from the middle income countries will rise sharply in comparison to the high income and low income countries, the estimates also showed that in comparison to the global population, waste is growing three times the pace with population (Kaza et al., 2018). This demands comprehensive approaches for reducing waste at source and its proper

management through different demand and supply side environment and economic approaches(Ye and Wu, 2022).

Treating through environmental economics approach and tools, waste behaves as a property of common goods and thus the proper management of waste through economic approach requires the knowledge and understanding of environmental and resource economics (Şeren, 2019) . Internalizing the "Externalities" consequences of waste are necessary interventions for the waste management through economic approaches. Most of the environmental problems including waste management have been traditionally dealt with the application of CAC regulations which mainly deals with the regulation of behaviours through prescription of certain specific regulations and legislation and standards through the use of fines and penalties as tools for noncompliance (Perman, 2003), whereas the EI and tools like environmental subsidies and taxes aim to change the behaviour through indirectly, with the change in relative prices (through incentives and taxes mechanisms) which ultimately affect the individual or business entity. Applying these EI instruments in the context of SWM, involve providing incentives for the waste generators (consumers and producers) and to service providers for motivating them to reduce waste generations and seek the alternatives for final disposal of waste to landfill (such as reuse, recycling or recovery). The principle behind is that the polluter bears all the internal and external environmental costs (Hoornweg et al., 2003).

Stated preferences and revealed preferences are the most commonly economic valuation method of the environmental products and services, stated preferences is used for estimation of use and non-use value whereas for the use value estimation, only revealed preference method is commonly used(Yang et al., 2022, Schwarz, 2022). Among these stated preferences, which mainly assume the hypothetical markets, contingent valuation and choice modelling are mostly used techniques for the valuation. Demand side policy instruments such as waste tariffs, WTP/WTA, siting waste management facilities, identifying significant determinants are commonly done through CVM and CE (Pearce and Özdemiroğlu, 2002) with the help of statistical software like R and STATA. On the other hand, supply side and policy decision analysis on waste management involves complex decision making steps and strategies such as identifying, choosing and ranking various criteria, choosing and evaluating various alternatives, issues like peoples' perceptions on barriers, risks, etc. which can be done with the help of MCDA approach which utilizes the fuzzy concepts and tools such as AHP, ANP, etc. (Vlachokostas et al., 2021) ((Abdullah et al., 2021) for

the decision analysis. Most of these waste management economic theories, models and tools are concentrated mainly for developed countries with the limited studies in developing countries(Cárcamo and Peñabaena-Niebles, 2022, Li et al., 2022). Thus, based on the experiences of those issues in developed and other developing countries, this study attempts to explore 1) Environmental |Economic theories: Command and Control (CAC) and Economic Instruments (EI) in general; 2) Waste management economic models and instruments: Contingent Valuation Method (CVM) and Choice Experiment (CE) as demand-side instruments and Multi Criteria Decision Analysis (MCDA)- Analytical Hierarchical Process (AHP) as supply-side decision-making instruments; 3) Applications of Contingent Valuation Method (CVM) & Choice Experiment (CE) and AHP models in waste management in developed and developing countries

2. Environmental Economic Theories: Principles & Applications

2.1 Environment Management Economic Theories & Valuation Techniques

Valuation techniques for marketed and non-marketed products and services are different. Environmental products are non-marketed goods whose real market values are unknown or unestablished, which greatly vary in the specific situation and peoples' perception and behaviour. (Pearce and Özdemiroğlu, 2002) described the valuation techniques for both marketed and non-marketed goods as shown in Figure 1.

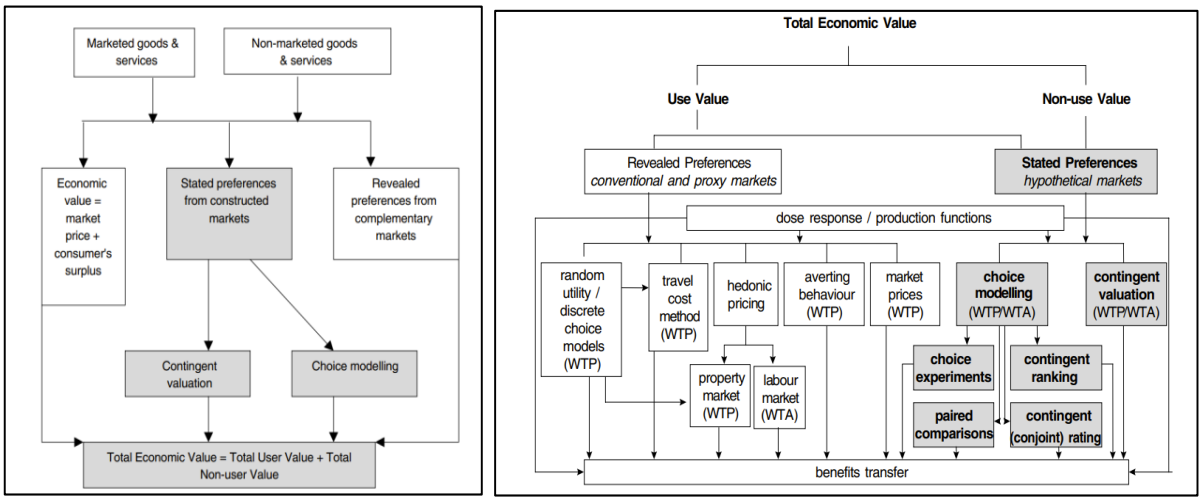


Figure 1: Economic valuation methods and techniques (Pearce and Özdemiroğlu, 2002)

For the economic valuation of the environmental products and services, the most commonly used method is stated preferences which is used for estimation of use and non-use value whereas for

the use value only revealed preference method is commonly used. Among these stated preferences, which mainly assume the hypothetical markets, contingent valuation and choice modelling are mostly used techniques for the valuation. Willingness to Pay (WTP) or Willingness to Acceptance (WTA) are commonly used tools for the economic valuation. In general, country specific policies for waste management such as tariff rates, waste fees, etc. has to be formulated based on the analysis of the WTP which is mainly done in the developed countries (Tassie and Endalew, 2020) whereas in most of the developing countries these policies are not systematically prepared. In comparison to the EI based policies, more CAC types of polices are mostly practiced in developing countries (Tang et al., 2020). Strong relationship exists between the economic instruments and polluter pay principle (Hoornweg et al., 2003). Few examples of EIs which are commonly used in the areas of waste management has been summarized in Table 1, which mainly include product and input taxes, deposit-refund system quantity-based waste collection charges, etc.

2.2 Environmental Management Economic Policy Instruments and their applications

Command and Control (CAC) and market-based solutions or Economic Instruments (EI) or also called Incentive Based (IB) mechanisms are mostly used policy instruments in the field of environmental regulation for the internalization of externalities. Additionally, some CAC type regulations are also categorized as voluntary based. The global environmental management policy instruments, tools and theories applied in the areas of different environmental fields have been described in the Table 1.

Table 1: Environmental Management Policy Instruments

Policy Instruments Types	**Instruments/ Tools**	**Specific Policy**	**Applied field**	**Country**	**Reference**
Command and Control (CAC)	Discharge standard	Pollution discharge standard	Overall environmental management	China	(Ren et al., 2018)
	Restriction on production technologies	Cleaner production standard	Cement industry	China	(Ren et al., 2018)

Economic Instruments (EI)	Environmental tax / Emission charge	Pollution discharge fee, Pollution charge, Taxes and fee	Sewage treatment, solid waste management	China, Central & Eastern Europe, FSU	(Ren et al., 2018) , (Anderson, 2002)
	Emission trading / Tradable permits	Pilot tests for SO2 emission trading, emission permits, effluent, water rights, fisheries access	Environment and energy, pollution and waste	China, Chile, many other countries	(Ren et al., 2018), (Anderson, 2002)
	Input or output charges, Taxes, Fees, Carbon emission permits trading	Environmental Exchange-Maximum open interest, carbon tax, leaded gas tax, fertilizer tax, water user fee, sewer fee, CFC tax	Fossil fuels, wastewater, environment	China, Thailand, Philippines	(Ren et al., 2018) (Anderson, 2002)
	Subsidies for environmentally friendly activities	Subsidies for energy products, subsidies for industrial pollution control, agricultural activity, municipal sewage plants	Energy and environment	China	(Ren et al., 2018) (Anderson, 2002)
	Removal of subsidies for environmentally harmful activities	Fuel subsidies, agricultural subsidies	Energy, environment, agriculture	China, Egypt	(Anderson, 2002)
	Liability	Natural resource damage assessment, FSU	Natural resource management	Russia	(Anderson, 2002)
	Performance bond	Bonds in mining and timber harvesting	Mining, Timber harvesting	Indonesia, Philippines	(Anderson, 2002)
	Deposit Refund	Beverage container, Lead acid battery	Environment, waste management	Korea, Greece	(Anderson, 2002)

Voluntary Environmental Regulations	Environmental labelling	Environmental mark certification	Environment	China	(Ren et al., 2018)
	Environmental certification	ISO-14000	Environmental management	China	(Ren et al., 2018)
	Environmental letters and visits	Measures for environmental letters and visits (2006)	Environmental management	China	(Ren et al., 2018)
	Environmental information disclosure	Bulletin of environmental conditions, Toxic release information, Product characterization	Environment	Mexico, China, India, Korea, Thailand	(Ren et al., 2018), (Anderson, 2002)
	Conservation programs	Energy conservation, water conservation, cleaner production	Energy and environment	India, China, Bangladesh	(Anderson, 2002)

These EIs theories and models have been widely used in the context of developed countries since 1980s and experiences have shown that these theories and models are found to be effective for meeting the environmental objectives to reduce waste or diverting less waste-to-waste disposal facilities provided that the adequate enforcement mechanisms are in place (Nahman and Godfrey, 2010).

3. Waste Management Economics and Decision Analysis: Models, Tools & Applications

3.1 Economic Models and Tools for Waste Management

Modelling is one of the approaches which is mainly used for the systematic identification of solutions to a given problem. Modelling has been used in waste management since the 1970s and the first model was used to optimize the costs with the limited scope of type of waste management system and time (Morrissey and Browne, 2004). The models summary developed during ?-1990s periods are given by (Gottinger, 1988, ML, 2001, Berger et al., 1999, Tanskanen,

2000) and further model developed by (Baetz and Neebe, 1994) incorporates dynamic mixed integer programming model. Multiperiod and multi-regional model were developed by (Everett and Modak, 1996) whereas static non-linear programming model was developed by (Sundberg et al., 1994). Further , (Berger et al., 1999, Tanskanen, 2000) pointed out the first optimization models which dealt with the specific problems such as vehicle routing (Truitt et al., 1969) and transfer station siting (Esmaili, 1972). The major limitations of the earlier models were that they were not suitable for long term planning as they considered for only one time period, only one processing option, recyclables rarely considered, etc. Later these models extended the system boundaries and covered MSWM at system level. Computer programming also helped to deal with more complex problems, they also tried to integrate the social equity issues and peoples' attitudal issues (Motameni and Falcone, 1990). During the periods of 1990s, recycling and other waste management models have been included for the MSWM (Morris, 1991, Chang and Wei, 1999)

The three basic categories of models are existing 1) Models based on cost benefit analysis; 2) Models based on life cycle assessment; 3) Models based on multicriteria decision making(Morrissey and Browne, 2004). The model could be of very simple in nature like optimization of collection routes for vehicle whereas some models could be more complex like evaluation of alternative waste management strategies. The models which are commonly used in the waste management have been presented in Table 2.

Table 2: Basic Models, Theories and Software Packages for Waste Management Analysis

Model's category	**Model economic theories**	**Model**	**Different model versions/ Elicitation Techniques**	**Measurement**	**Analysis Software & Package**	**Reference**
Based on cost benefit analysis	Economic valuation-stated preference: Random Utility Theory	CVM	Bidding game (BG) Open-ended (OE) Single-bounded discrete choice (SBDC) Double-bounded discrete choice (DBDC)	WTP/ WTA Determinants	R (Icens, Dcchoice) STATA	(Pearce and Özdemiroğlu , 2002); (Schuermann and Woo, 2022)

			Multiple-bounded discrete choice (MBDC) Payment card approach (PC)			
		CE (Choice experiment, Contingent ranking, Paired comparison, Contingent (conjoint) rating)	Logit Nested Logit Conditional Logit Probit Mixed Logit Multinominal Logit	WTP/ WTA Determinants	R (mclogit) STATA (LIMDEP)	(Pearce and Özdemiroğlu, 2002); (Huh et al., 2015)
Based on life cycle assessment	Life cycle analysis and assessment, ISO14040	Energy and material flow analysis Cradle-to-Gate Cradle-to-Grave Life cycle costs	LCI analysis LCA assessment Hotspot analysis Social life cycle cost analysis	Life cycle Environmental impacts	SimaPro GaBi Solutions Open LCA Umberto Brightway2 TOTAL Database: ecoinvent, Federal Commons	(Huh et al., 2015); (Morrissey and Browne, 2004)

Based on multicriteria decisions	Multicriteria decision analysis Fuzzy Theory	MCDA	AHP Delphi ANP ANN FMEA DEMATEL WASPSA PROMETHE	Subjective measurements for decision making. Prioritization of projects and problems	EXPERT CHOICE Transparent Choice ELECTRE TRI HiView LOGICAL DECISIONS	(Morrissey and Browne, 2004); (Pathak et al., 2022); (Ilbahar et al., 2022)

3.2 Common Welfare Measurement Methods in Waste Management: CVM and CE

The most applied econometric models for the consumer preferences and welfare measurement in waste management fields are stated preference methods for examples as contingent valuation method (CVM) and choice experiment (CE), which value the non-market benefits by creating a hypothetical markets to elicit people's willingness to pay (WTP) or willingness to acceptance (WTA) for the changes in non-market goods to establish benefits (Jin et al., 2006). Solid waste management (collection and disposal services) activities are generally under-priced or even non-priced, thus is difficult for inferencing benefits from the market price from ordinary markets (Anaman and Jair, 2000). Thus, the stated preferences techniques like CVM and CE are common approaches for welfare measurement in waste economics.

CVM is the most commonly used non-market valuation method for the estimation of environmental benefits of goods and services (Bishop and Romano, 1998, Carson et al., 2001, Mitchell and Carson, 1989), which is very effective in the condition to analyse one attribute. CE is another method for non-market valuation technique which is mainly suitable for the situations where multiple attributes and options are to be considered (Diamond and Hausman, 1994, Stevens et al., 2000). Both methods are based on random utility theory (Hanley et al., 1998a, Hanemann, 1984, Hanley et al., 1998b). There are few research which highlights the differences and comparison of these two approaches fit the similar environmental problem such as ecosystem management (Stevens et al., 2000), water quality (Abou-Ali, 2003), solid waste management (Jin et al., 2006) etc.

3.2.1 Theoretical models for CVM and CE

The utility theory, on which the CVM and CE are based on, compare the utility between the alternatives available and the alternatives which provide highest utility shall be the preferred choice (McFadden, 1973, Louviere et al., 2000, Adamowicz et al., 1998). The utility function of each of the alternatives is expressed as:

$$U_i = V_i + \varepsilon_i \tag{1}$$

Where, U_i is overall utility, V_i is indirect utility; specified as a function of the characteristics of that of an environmental goods or services, ε_i is unobserved attributes which affects the choices.

Probability of individual n choosing alternative i is given by.

$$\begin{aligned} P_n(i) &= P_r\left(U_{in} \geq U_{jn};\ \forall_j \in C, i \neq j\right) \\ &= P_r\left(V_{in} + \varepsilon_{in} \geq V_{jn};\ \forall_j \in C, i \neq j\right) \end{aligned} \tag{2}$$

After assumption of the error term are as type I extreme values as distributed (McFadden, 1973) , the choosing alternative i probability is given by

$$P_n(i) = \frac{\exp^{\mu V_{in}}}{\sum_{j \in C_n} \exp^{\mu V_{jn}}} \tag{3}$$

Where α_{in} is a scale parameter, which is usually assumed to be equal to 1 (Hanley et al., 1998b).

Assuming the utility function is linear and additively separable (Louviere et al., 2000) , the indirect utility function of alternative i for respondent n can be expressed as:

$$V_{in} = \alpha_{in} + \beta X_i + \gamma Z_n + \delta(Y_n - C_i) \tag{4}$$

Where α_{in} is a constant term that captures intrinsic preferences of respondent n for alternatives i; β, γ, δ are coefficients terms and X represents the alternative i characteristics; whereas C represents bid offered in CVM or cost in CE; Y represents income; Z represents socioeconomic characteristics of that respondent n.

3.3 Multicriteria Decision Analysis (MCDA) for Policy Decision

Multi criteria decision analysis (MCDA) is an extensively used approach for effective decision making and policy analysis. MCDA is a popular framework which is employed in previous

studies on municipal solid waste management that can help multiple stakeholders for the evaluation of often-conflicting criteria, identifying and communicating their preferences, rank or prioritize various kinds of MSWM strategies and also to finally agree on the strategies and also to make an applicable and appropriate decision (Pavan and Todeschini, 2009). The MCDA process has been illustrated in Figure 2.

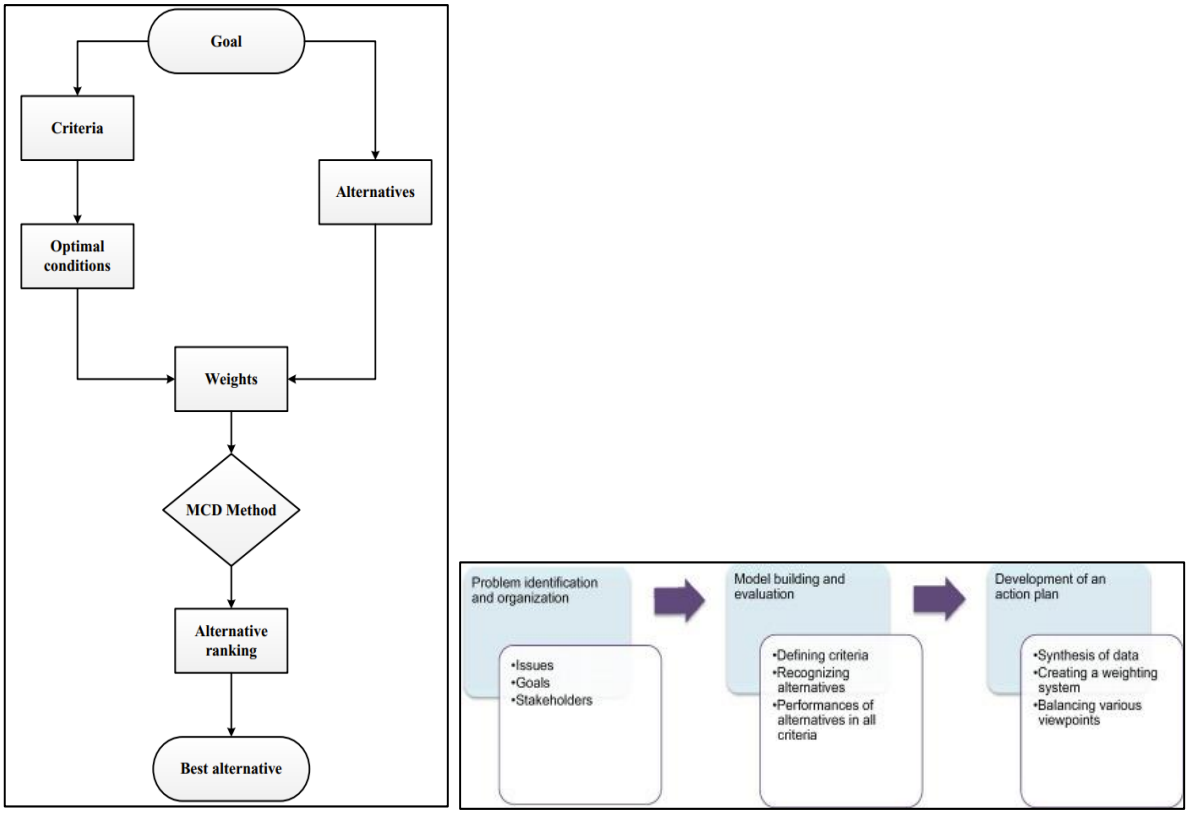


Figure 2: a) Multicriteria Decision Process (Pavan and Todeschini, 2009) (Khan and Kabir, 2020); b) General Process of MCDA Technique (Belton and Stewart, 2002)

The different techniques under the MCDA depend upon their underlying philosophy, assumptions, information for inputs, etc. (Vlachokostas et al., 2021). Common MCDA methods are : 1) Analytical Hierarchical Process (AHP) / Analytical Network Process (ANP), 2) ELimination Et Choix Traduisant la Realite (ELECTRE), 3) Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE), 4) Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), 5) Multi-objective programming (MOP), 6) Simple Additive Models (SAM), and 7) Other newer or less popular techniques (Vlachokostas et al., 2021). Among these different methods AHP is most popular and commonly used method for MCDA analysis(Abdullah et al., 2021).

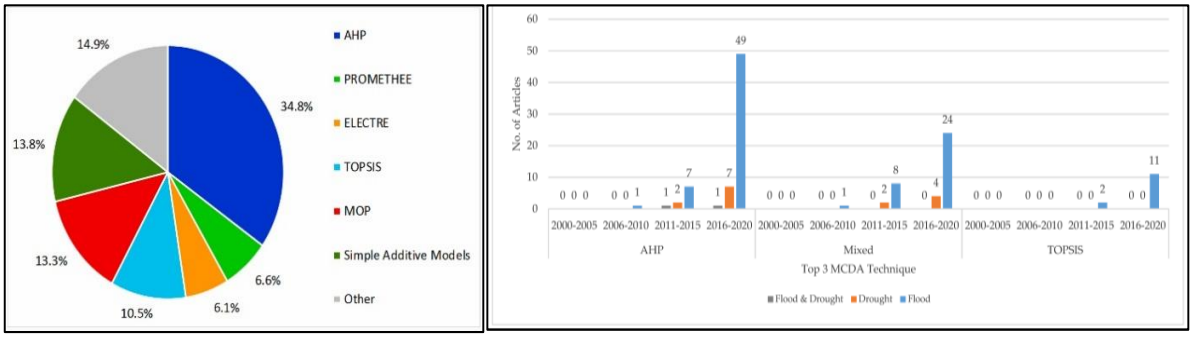


Figure 3: Distribution of AHP and other MCDA models a) In waste management (Vlachokostas et al., 2021) ;b)In water related drought events (Abdullah et al., 2021)

AHP is one of the basic theories and a widely used tool for the subjective measurement of the decision making and prioritizing the projects and problems. It is based on the fuzzy theory of mathematics, AHP involves following methodological steps for solving multicriteria decision analysis problems. AHP model was first developed in the 1970s by Thomas L. Saaty (Saaty, 2004) and is being continuously being used for the MCDA. Recent comprehensive review of MCDA techniques by (Vlachokostas et al., 2021) and (Abdullah et al., 2021) highlighted in one of the review of 163 case studies and 153 scientific articles revealed that AHP is mostly used technique.

4. Conclusion

This study conducted minireview and analysis of environmental economic theories, models and decision-making tools on sustainable solid waste management. The key contribution of this review research are in following three fonts: 1) Understanding of the environmental economic theories: Command and Control (CAC) and Economic Instruments (EI) and their applications in different environmental problems; 2) In-depth analysis of waste management economic models and instruments: Contingent Valuation Method (CVM) and Choice Experiment (CE) as demand-side instruments and Multi Criteria Decision Analysis (MCDA)- Analytical Hierarchical Process (AHP) as supply-side decision-making instruments; 3) Applications of CVM, CE and AHP models in waste management in case of developed and developing countries along with introduction of various software tools together;

Waste economic instruments and tools like CVM and CE are widely used stated preference techniques for determining the economic valuation of environmental goods and services. These tools are widely used in developed countries for determining waste tariffs, WTP/WTA, siting waste management facilities, identifying significant determinants. Software like R and STATA

are commonly used software for statistical analysis. MCDA tools are very useful for solving complex decision-making problems such as identifying, choosing & ranking criteria, choosing alternatives, identifying & ranking barriers, risks, etc. AHP is mostly applied tool for studying and analysing MCDA problems in waste management sector for decision analysis.

Acknowledgments

The authors hereby kindly acknowledge the support from KU-KIST Green School and GETPPP program.

References

1. ABDULLAH, M. F., SIRAJ, S. & HODGETT, R. E. 2021. An Overview of Multi-Criteria Decision Analysis (MCDA) Application in Managing Water-Related Disaster Events: Analyzing 20 Years of Literature for Flood and Drought Events. *Water*, 13**,** 1358.
2. ABOU-ALI, H. 2003. Using stated preference methods to evaluate the impact of water on health: the case of metropolitan Cairo. *rapport nr.: Working Papers in Economics*.
3. ADAMOWICZ, W., BOXALL, P., WILLIAMS, M. & LOUVIERE, J. 1998. Stated preference approaches for measuring passive use values: choice experiments and contingent valuation. *American journal of agricultural economics*, 80**,** 64-75.
4. ANAMAN, K. A. & JAIR, R. M. 2000. Contingent valuation of solid waste collection services for rural households in Brunei Darussalam. *Singapore Economic Review*, 45**,** 223-240.
5. ANDERSON, R. C. 2002. Incentive-based policies for environmental management in developing countries.
6. BAETZ, B. W. & NEEBE, A. W. 1994. A planning model for the development of waste material recycling programmes. *Journal of the Operational Research Society*, 45**,** 1374-1384.
7. BELTON, V. & STEWART, T. 2002. *Multiple criteria decision analysis: an integrated approach*, Springer Science & Business Media.

8. BERGER, C., SAVARD, G. & WIZERE, A. 1999. EUGENE: an optimisation model for integrated regional solid waste management planning. *International Journal of Environment and Pollution*, 12**,** 280-307.
9. BISHOP, R. C. & ROMANO, D. 1998. *Environmental resource valuation: applications of the contingent valuation method in Italy*, Springer Science & Business Media.
10. CÁRCAMO, E. A. B. & PEÑABAENA-NIEBLES, R. 2022. Opportunities and challenges for the waste management in emerging and frontier countries through industrial symbiosis. *Journal of Cleaner Production*, 363**,** 132607.
11. CARSON, R. T., FLORES, N. E. & MEADE, N. F. 2001. Contingent valuation: controversies and evidence. *Environmental and resource economics*, 19**,** 173-210.
12. CHANG, N.-B. & WEI, Y. 1999. Strategic planning of recycling drop-off stations and collection network by multiobjective programming. *Environmental management*, 24**,** 247-263.
13. DIAMOND, P. A. & HAUSMAN, J. A. 1994. Contingent valuation: is some number better than no number? *Journal of economic perspectives*, 8**,** 45-64.
14. ESMAILI, H. 1972. Facility selection and haul optimization model. *Journal of the Sanitary Engineering Division*, 98**,** 1005-1020.
15. EVERETT, J. W. & MODAK, A. R. 1996. Optimal regional scheduling of solid waste systems. I: Model development. *Journal of Environmental Engineering*, 122**,** 785-792.
16. GOTTINGER, H. W. 1988. A computational model for solid waste management with application. *European Journal of Operational Research*, 35**,** 350-364.
17. HANEMANN, W. M. 1984. Discrete/continuous models of consumer demand. *Econometrica: Journal of the Econometric Society***,** 541-561.
18. HANLEY, N., MACMILLAN, D., WRIGHT, R. E., BULLOCK, C., SIMPSON, I., PARSISSON, D. & CRABTREE, B. 1998a. Contingent valuation versus choice experiments: estimating the benefits of environmentally sensitive areas in Scotland. *Journal of agricultural economics*, 49**,** 1-15.
19. HANLEY, N., WRIGHT, R. E. & ADAMOWICZ, V. 1998b. Using choice experiments to value the environment. *Environmental and resource economics*, 11**,** 413-428.
20. HOORNWEG, D., THOMAS, L. & OTTEN, L. 2003. Economic instruments for solid waste management: Global review and applications for Latin American and the Caribbean. *Environmental network regional policy dialogue study series.*

21. HUH, S.-Y., WOO, J., LIM, S., LEE, Y.-G. & KIM, C. S. 2015. What do customers want from improved residential electricity services? Evidence from a choice experiment. *Energy Policy*, 85**,** 410-420.
22. ILBAHAR, E., KAHRAMAN, C. & CEBI, S. 2022. Risk assessment of renewable energy investments: A modified failure mode and effect analysis based on prospect theory and intuitionistic fuzzy AHP. *Energy*, 239**,** 121907.
23. JIN, J., WANG, Z. & RAN, S. 2006. Comparison of contingent valuation and choice experiment in solid waste management programs in Macao. *Ecological Economics*, 57**,** 430-441.
24. KAZA, S., YAO, L., BHADA-TATA, P. & VAN WOERDEN, F. 2018. *What a waste 2.0: a global snapshot of solid waste management to 2050*, World Bank Publications.
25. KHAN, I. & KABIR, Z. 2020. Waste-to-energy generation technologies and the developing economies: A multi-criteria analysis for sustainability assessment. *Renewable Energy*, 150**,** 320-333.
26. KIM, S., BYUN, J., PARK, H., LEE, N., HAN, J. & LEE, J. 2022. Energy-efficient thermal waste treatment process with no CO2 emission: A case study of waste tea bag. *Energy*, 241**,** 122876.
27. LI, Y., LI, M. & SANG, P. 2022. A bibliometric review of studies on construction and demolition waste management by using CiteSpace. *Energy and Buildings*, 258**,** 111822.
28. LOUVIERE, J. J., HENSHER, D. A. & SWAIT, J. D. 2000. *Stated choice methods: analysis and applications*, Cambridge university press.
29. MCFADDEN, D. 1973. Conditional logit analysis of qualitative choice behavior.
30. MITCHELL, R. C. & CARSON, R. T. 1989. *Using surveys to value public goods: the contingent valuation method*, Resources for the Future.
31. ML, M. 2001. Solid waste management models: a state of the art review. *J Solid Waste Technol Manag*, 23**,** 73-83.
32. MORRIS, J. 1991. Source separation vs. centralized processing: An avoided-cost optimization model provides some intriguing answers. *J. Resour. Manage. Technol.*, 19**,** 37-46.
33. MORRISSEY, A. J. & BROWNE, J. 2004. Waste management models and their application to sustainable waste management. *Waste management*, 24**,** 297-308.

34. MOTAMENI, R. & FALCONE, T. 1990. The application of Martin Fishbein's theory of reasoned action in solid waste management and recycling. *Journal of Resource Management and Technology*, 18**,** 144-150.
35. NAHMAN, A. & GODFREY, L. 2010. Economic instruments for solid waste management in South Africa: Opportunities and constraints. *Resources, Conservation and Recycling*, 54**,** 521-531.
36. PATHAK, S. K., SHARMA, V., CHOUGULE, S. S. & GOEL, V. 2022. Prioritization of barriers to the development of renewable energy technologies in India using integrated Modified Delphi and AHP method. *Sustainable Energy Technologies and Assessments*, 50**,** 101818.
37. PAVAN, M. & TODESCHINI, R. 2009. 1.19 - Multicriteria Decision-Making Methods. *In:* BROWN, S. D., TAULER, R. & WALCZAK, B. (eds.) *Comprehensive Chemometrics*. Oxford: Elsevier.
38. PEARCE, D. & ÖZDEMIROĞLU, E. 2002. *Economic valuation with stated preference techniques: Summary guide*, Department for Transport, Local Government and the Regions.
39. PENG, X., JIANG, Y., CHEN, Z., OSMAN, A. I., FARGHALI, M., ROONEY, D. W. & YAP, P.-S. 2023. Recycling municipal, agricultural and industrial waste into energy, fertilizers, food and construction materials, and economic feasibility: a review. *Environmental Chemistry Letters*, 21**,** 765-801.
40. PERMAN, R. 2003. *Natural resource and environmental economics*, Pearson Education.
41. REN, S., LI, X., YUAN, B., LI, D. & CHEN, X. 2018. The effects of three types of environmental regulation on eco-efficiency: A cross-region analysis in China. *Journal of Cleaner Production*, 173**,** 245-255.
42. SAATY, T. L. 2004. Decision making—the analytic hierarchy and network processes (AHP/ANP). *Journal of systems science and systems engineering*, 13**,** 1-35.
43. SCHUERMANN, H. & WOO, J. 2022. Estimating consumers' willingness to pay for reusable food containers when ordering delivery food: a contingent valuation approach. *Journal of Cleaner Production*, 366**,** 133012.
44. SCHWARZ, P. M. 2022. *Energy economics*, Taylor & Francis.
45. ŞEREN, G. Y. 2019. Solid Waste Management in the Context of Public Policies and Private Sector Participation: Thoughts on the Need of a Comprehensive Approach. *Ethical and Sustainable Supply Chain Management in a Global Context*. IGI Global.

46. STEVENS, T. H., BELKNER, R., DENNIS, D., KITTREDGE, D. & WILLIS, C. 2000. Comparison of contingent valuation and conjoint analysis in ecosystem management. *Ecological economics*, 32**,** 63-74.
47. SUNDBERG, J., GIPPERTH, P. & WENE, C.-O. 1994. A systems approach to municipal solid waste management: A pilot study of Göteborg. *Waste management & research*, 12**,** 73-91.
48. TANG, K., QIU, Y. & ZHOU, D. 2020. Does command-and-control regulation promote green innovation performance? Evidence from China's industrial enterprises. *Science of the Total Environment*, 712**,** 136362.
49. TANSKANEN, J.-H. 2000. Strategic planning of municipal solid waste management. *Resources, conservation and recycling*, 30**,** 111-133.
50. TASSIE, K. & ENDALEW, B. 2020. Willingness to pay for improved solid waste management services and associated factors among urban households: One and one half bounded contingent valuation study in Bahir Dar city, Ethiopia. *Cogent Environmental Science*, 6**,** 1807275.
51. TRUITT, M. M., LIEBMAN, J. C. & KRUSE, C. W. 1969. Simulation model of urban refuse collection. *Journal of the Sanitary Engineering Division*, 95**,** 289-298.
52. VLACHOKOSTAS, C., MICHAILIDOU, A. V. & ACHILLAS, C. 2021. Multi-Criteria Decision Analysis towards promoting Waste-to-Energy Management Strategies: A critical review. *Renewable and Sustainable Energy Reviews*, 138**,** 110563.
53. YANG, M., CHEN, H., LONG, R., SUN, Q. & YANG, J. 2022. How does government regulation promote green product diffusion in complex network? An evolutionary analysis considering supply side and demand side. *Journal of Environmental Management*, 318**,** 115642.
54. YE, C. & WU, L. 2022. Research on the policy synergy of supply-side and demand-side environmental policies: An analysis based on green value chain of manufacturing enterprises. *Environmental Science and Pollution Research*, 29**,** 46929-46952.

Damage Study of Buildings in Jajarkot Earthquake 2080

Rajan Suwal[1], Gokarna Bahadur Motra[2], Rupendra Bar Dhoj Thapa[3]

[1] *President, Structural Engineers Association Nepal*

[2] *Professor, Pulchowk Campus, Institute of Engineering, TU*

[3] *Executive Member, Structural Engineers Association Nepal*

Corresponding email: rajan_suwal@ioe.edu.np

Abstract

Jajarkot Earthquake 2080 occurred in Jajarkot district on 3rd November. Epicenter of earthquake is in Ramidada of Barekot Rural Municipality. This Earthquake killed 153 person and injured 364. It is reported 26,557 houses have been complete damaged. Jajarkot, West Rukum, Salyan districts were mainly affected with this earthquake. Main objective of this research is to find out the conditions and possible solutions of earthquake affected buildings. In the methodology of works site visit of earthquake affected area was done. Typology of buildings were studied. Damage pattern of buildings was found out. Building materials and building technology which were used in building were studied. Observed real condition of affected buildings. It was taken photograph of damaged buildings. Most of the buildings were constructed with round river stone with mud mortar and few were constructed with quarry stone with mud mortar. It was studied the ages of damaged buildings. The buildings which were constructed with river round stone with mud mortar were damaged. In reinforced concrete building, it was observed minor cracks. It was found out caused of building failure and given recommendation for retrofitting and rebuilding of these type of buildings.

Key words: Jajarkot Earthquake, Stone Masonry, Mud Mortar, Damages, Buildings

1. Introduction

Jajarkot earthquake occurred on 3rd November 2023 at 23.47 in epicenter of Ramidada, Barekot Rural Municipality, Jajarkot district, Nepal. Magnitude of this earthquake is 6.4 and located in western part of country. Series of earthquake occurred after the main shocks. This earthquake killed 153 people and injured 364 people.

According to the records maintained by the Nepal Emergency Operation Centre under the Ministry of Home Affairs, the latest quake damaged over 26,500 houses fully and over 35,000 partially in Jajarkot, Rukum West, Rukum East, Salyan, Rolpa, Nawalparasi East, Dailekh, Baitadi, Jumla, Kalikot and Pyuthan districts.

After earthquake site observation, it is found mainly stone masonry in mud mortars and few of RC types of buildings. More than 80% buildings were constructed in stone in mud mortars. Only

few buildings were constructed in RC frame structures. From the field study it observed that most of the stone masonry buildings in mud mortars were collapsed and damaged.

The main objective of this paper is to find out the causes of failures, failure pattern of buildings and give possible solutions for improvement in further construction.

2. Materials and Methods

Following methodology is considered in this research:

1. For detail study of work, site visit is done in damaged building areas.
2. Materials and construction technology used are studied.
3. Material qualities are studied.
4. It is taken photographs of damaged buildings for detail studies.
5. Possible causes of failure of building are discussed.
6. Possible solutions are discussed.
7. It is given recommendations for future construction of this type of buildings.

3. Results and Discussions

3.1. Weak construction materials

From the field observation it is seen that stone masonry with mud mortars are weak materials. Most of the stones are river round stones and thick layer of mud. Bond between round stone and mud mortar seems very weak. Quality of construction seems poor so most of the stone in mud mortar walls fail. Most of the building age are old and survived number of small earthquakes so might be micro crack between stone and mortars. Few pictures of this situation can be seen in the following pictures.

Figure 1: Weak construction materials

3.2. No through stone in thickness of wall

Most of the buildings have separate layer of stones inside and outside of wall. In between the wall layer it is not seen through stone block because of its wall fails separately outside, and inside which is seen in figure 2.

Figure 2: No through stone block in wall thickness

3.3. Out of plane failure

Certain buildings of stone masonry with mud mortar fail in out of plane failure. There is no proper connection of main wall with transeverse walls. No bands connection is seen in the walls. This type of failure is shown in figure 3.

Figure 3: Out of plane failure

3.4. Diagonal cracks

Diagonal cracks in the buildings are observed where there are no horizontal bands in buildings. Length of transverse direction wall with respect to longer is comparatively very less so it seems very less seismic resistance capacity in transverse direction. Because of it, it can be seen diagonal cracks in transverse walls. This type of failure can be seen in figure 4. Horizontal timber bands and increased the thickness of transverse wall help to prevent the diagonal cracks.

Figure 4: Diagonal cracks

3.5. Corner failure

If corner bands (L type) are not provided in masonry walls, corner of wall fails. This type of failure can be seen in following figure (figure 5). It can be restrained by providing corner and horizontal bands in different levels. By adding corner connection stone and corner timber band, corner failure can be resisted.

Figure 5: Corner failure

3.6. Failure due to heavy roof

It is found that the roofs with heavy weight fail the buildings. In roof construction it is found that roof with timber, mud layer and above that stone slate which produces heavy weight. The connection of roof and wall is also poor. Because of it these types of buildings collapsed. Typical

type of this roofs is shown in figure 6. This type of failure can be prevented by reducing weight of roof that means using thin stone slates or GI sheets.

Figure 6: Building with heavy roof weight.

3.7. Vertical crack in opening

When deep opening is provided in buildings and between the windows there is inadequate vertical height of masonry, vertical crack might occur. It might be occurred in the case of absent of horizontal band also. Failure of these is shown in figure 7. Failure of these type can be prevented strengthen the wall between openings vertically or reducing height of openings. Strong horizontal bands can also reduce these types of cracks.

Figure 7: Vertical crack in opening

4. Overall Observation

- Most of the buildings are made of stone masonry with mud mortar, timber and stone slates.

- Floors are mainly timber with mud
- Age of buildings are old (age effect)
- It is seen poor quality of building materials.
- Horizontal timber bands are not provided in walls.
- Through stone in thickness of wall are not provided.
- Portion of mud in stone masonry wall in very high.
- Most of the stones are round type in stone with mud mortar wall.
- Damages of buildings in hill area are more means it is seen topographic effect of earthquake in Khalanga, Jajarkot district.
- Less damage in epicenter of earthquake due to use of quarry stones and horizontal timber band
- Most of the buildings are made of regular stones with timber band in walls do not damage.
- RC buildings comparatively new and seen minor cracks in infill walls.
- Building bylaws and building design codes in Municipalities and Rural Municipalities are not being used effectively.
- Building bylaws and building design codes in Municipalities and Rural Municipalities are not being used.

5. Conclusion

- The quality of construction material should be good.
- It is required to use quarry stones and horizontal and corner timber band in walls rather than river round stones in masonry walls.
- Through stones are needed to provide to make tie between outside and inside wall layer.
- Must use seismic resistance construction technology to build this type of stone masonry in mud mortar.
- Weight of roof should be reduced to make buildings less damaged in earthquake.
- It must be used horizontal timber bands in walls and need to provide gable bands to resist failure of gable and other walls out of plane failure.

- Must use seismic resistance construction technology to build this type of stone masonry in mud mortar.
- Must follow bylaws and building design codes in Municipalities and Rural Municipalities.

References

1. https://kathmandupost.com/national/2023/11/09/jajarkot-earthquake-raises-concerns-about-poorly-built-houses
2. Nepal Emergency Operation Centre under the Ministry of Home Affairs
3. https://www.ucl.ac.uk/epicentre/news/2023/nov/jajarkot-nepal-ml64-earthquake
4. https://myrepublica.nagariknetwork.com/news/experts-recommend-relocation-of-jajarkot-settlements/

A COMPREHENSIVE FRAMEWORK FOR STRUCTURAL DESIGN COMPLIANCE IN NEPAL'S BUILDING CONSTRUCTION

Seiichiro Fukushima[1], Milan Karki [2*], Masato Kawai[2], Kiyotaka Owada[2], Sachin Sapkota[2]

[1] *RKK Consulting Co., Ltd.*

[2] *Oriental Consultants Global Co.,Ltd.*

**Corresponding email: [2]memilan.karki@gmail.com*

Abstract

The seismic vulnerability of buildings in Nepal, particularly in smaller residential constructions, has been a pressing concern due to a lack of adherence to quality construction practices. Addressing this, the "Project for Promotion of Nepal National Building Code Compliance for Safer Building Construction" introduces the "Building Construction Working Procedure" to fortify the building permit system. A crucial aspect of this procedure is the incorporation of detailed structural checklists based on the revised Nepal Building Code 105 to ensure structural design compliance. The checklists, designed for both reinforced concrete and steel structures, addresses the complexities from the five distinct design methods outlined in NBC 105. They offer a dual-step examination process, covering linear and non-linear properties of materials. Emphasizing design check uniformity, the checklists are made for designers and design checkers to check compliance. This study emphasizes the innovative features of the checklists, focusing not only on the Equivalent Static Method and Modal Response Spectrum Method but also on Elastic Time History Analysis, Non-linear Static Analysis, and Non-linear Time History Analysis. Thorough investigations into building features, modeling adequacy, actions on the buildings, analysis results, member design, and performance checks ensure a comprehensive approach to seismic resilience. The proposed framework, embedded in the BCWP, aims to make buildings in Nepal stronger during earthquakes by promoting commitment to the national building code. The checklists function as tools for municipalities and third-party experts, facilitating compliance verification and contributing to safer building constructions nationwide.

Keywords: *Structural checklists, Nepal Building Code 105, Compliance verification, Building Construction Working Procedure (BCWP), Building permit system*

1. Introduction

In the domain of seismic resilience, nations have systematically dedicated resources to fortify building construction, advance building codes, and elevate earthquake awareness. Developed nations, firm in their commitment to stringent building codes, consistently exhibit lower casualties in the aftermath of seismic events.

Navigating compliance issues is more pronounced in developing nations, where guidelines for design often lack clarity, and the roles of stakeholders involved in construction are ambiguous.

Despite the establishment of Nepal Building Code (NBC) in 1994, challenges persist, especially in the residential sector where adherence remains elusive. In countries like Nepal, where a comprehensive building code framework is conspicuously absent, informal construction practices prevail. Owners and builders frequently engage in construction without explicit adherence to any specific code, thereby exacerbating risks, particularly in regions prone to seismic activity. (Dixit, A. M., 2004)

There is a lack of standard working procedures and guidelines to carry out design works as per prevailing building bylaws and building code. The role and responsibilities of the major stakeholders of building constructions are not clearly defined. Even though some municipalities conduct checks at the plinth level and upon completion, these measures prove to be less effective. Moreover, the informal stakeholders of building sectors lack training, proper equipment, and awareness regarding building norms, criteria, quality control, and detailing to safeguard the building stocks from potential natural disasters, particularly earthquakes. Realizing these adverse situations on building sector, Department of Urban Development and Building Construction (DUDBC) has taken initiation to revise Building Construction Working Procedure (BCWP) based on Building Act 1999 to support municipalities to enforce building regulations following building bylaws and building code of Nepal. BCWP serves as a practical guide to ensure buildings are designed and constructed with due consideration for seismic resilience, highlighting their crucial role in addressing vulnerabilities. The main purpose of the revised building construction working procedure is to officially stipulate the building approval process under the compliance of NBC and bylaws in accordance with the building act. Accompanying the BCWP, practical guidelines and manuals were crafted, detailing the roles of stakeholders - municipalities, building owner, designer, supervision consultant, contractor and mason in the building approval process illustrated in Fig. 1. The NBC 105 has undergone revision, but the design check supporting

checklist hasn't been updated. Hence, there's a requirement to formulate structural checklists based on material types and various analysis methods.

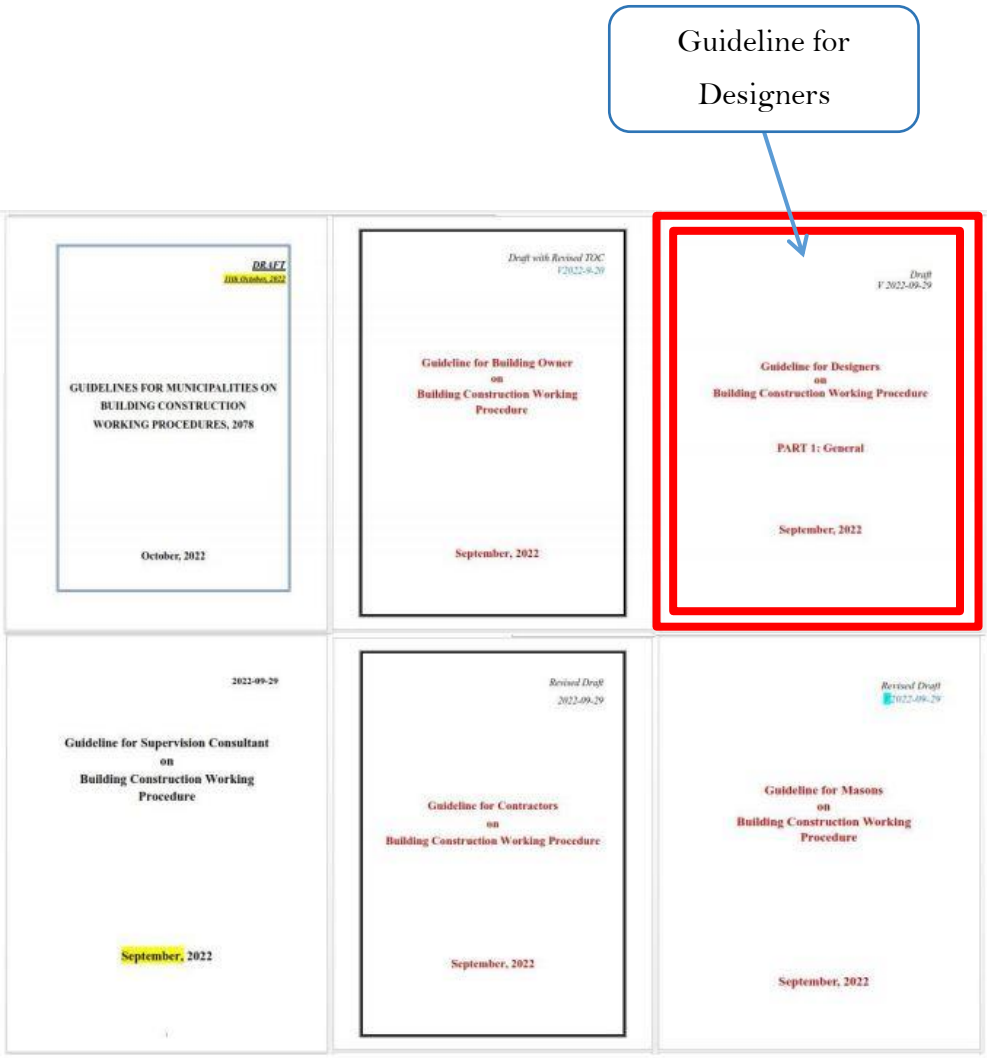


Figure 1: Guidelines supporting BCWP

The "Guideline for Designers" is part of BCWP, helping with checklist completion and verification. As seen in Fig. 2, the Guideline for designers has three sections: 1) General, 2) Checklist Instructions, and 3) Annexes.

The "General" part aids designers in following building laws, ensuring quality designs for earthquake resilience.

The second part checks if designers understand code requirements and apply them to the building's design. It explains checklist parameters briefly.

The "Annexes" contain checklists which serve as a means of verification by municipalities or third-party experts.

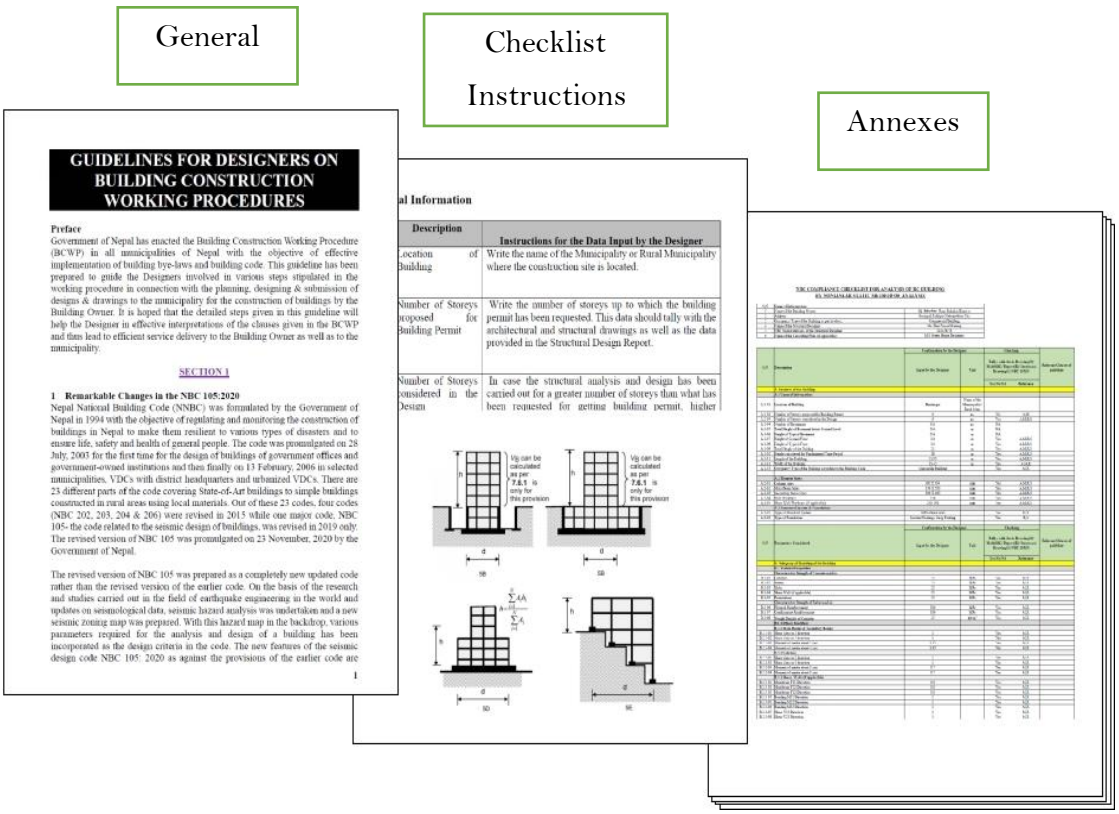


Figure 2: Three volumes of the "Guideline for Designers"

Additionally, the introduction of structural checklists serves as a practical tool to ensure that buildings are designed and constructed with due consideration for seismic resilience. This research sheds light on the many aspects to code compliance, especially in the context of residential construction. The main aim is to encourage using BCWP and structural checklists more to make buildings safer. This, in turn, contributes to the mitigation of seismic risks and the creation of safer structures in regions prone to seismic vulnerabilities.

2. Research Methodology

As depicted in Fig. 3, the research methodology unfolds through a series of fundamental steps. These important stages guide the progression of our study and include:

1. Literature review: The selection of parameters for this checklist was primarily based on a thorough review of building codes, encompassing both national and international building codes.
2. Identify Gaps: The gaps related to design checks were identified along with finding the need for the research.
3. Develop preliminary parameters: An initial list of parameters and a sample checklist were developed, followed by consultations with professionals and experts associated with NBC.
4. Meetings + Group Discussions: Collaboration with government organizations and experts was actively pursued, and their input during meetings significantly influenced the selection of parameters. Subsequently, additional parameters were incorporated based on insights gained from these consultations, leading to the creation of other necessary checklists.
5. Final checklists: This collaborative process culminated in the formulation of the final checklists, enriched by valuable comments and feedback from the involved stakeholders.

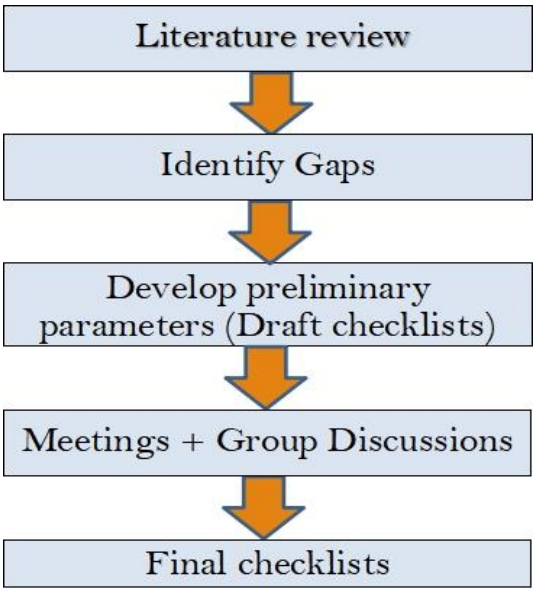


Figure 3: Flowchart of the research methodology

3. Types and components of structural checklist

In section 3.1 of NBC 105:2020, a range of methods for analyzing a building's structure is presented. Section 3.2 outlines where each method is most suitable, and this information is well presented in the table 1.

Table 1: Applicability of different analysis methods

Analysis Methods	For Structural design	For Performance Check
Equivalent Static Method (ESM)	✓	✓
Modal Response Spectrum Method (MRSM)	✓	✓
Elastic Time History Analysis (ETHA)	✓	✓
Non-linear Static Analysis (NLSA)	×	✓
Non-linear Time History Analysis (NLTHA)	×	✓

A total of 10 separate checklists has been developed based on two different criteria: analysis methods (Equivalent Static Method (ESM), Modal Response Spectrum Method (MRSM), Elastic Time History Analysis (ETHA), Non-linear Static Analysis (NLSA) and Non-linear Time History Analysis (NLTHA)) and construction materials (Reinforced Concrete (RC) and Steel). The checklists have been prepared to verify that the Designer has correctly interpreted the requirements of the design codes, applied in the preparation of analytical model of the building and then undertaken the design and detailing of various structural elements. While the prime responsibility of applying the codal provisions to produce safe building structure satisfying the functional requirements of the Building Owner lies with the Designer himself/herself, the objective of the checklist is not only to document the basic parameters as design basis but also to provide a means of verification of them by Municipality or other third-party experts when needed. In the following section, brief explanations on the various parameters included in the checklist have been given. In case of ambiguity, the Designer shall refer to the relevant clauses of NBC 105:2020 as well as other codes. The components of the checklists are divided into 6 parts similar to that of the design process given in Fig. 4.

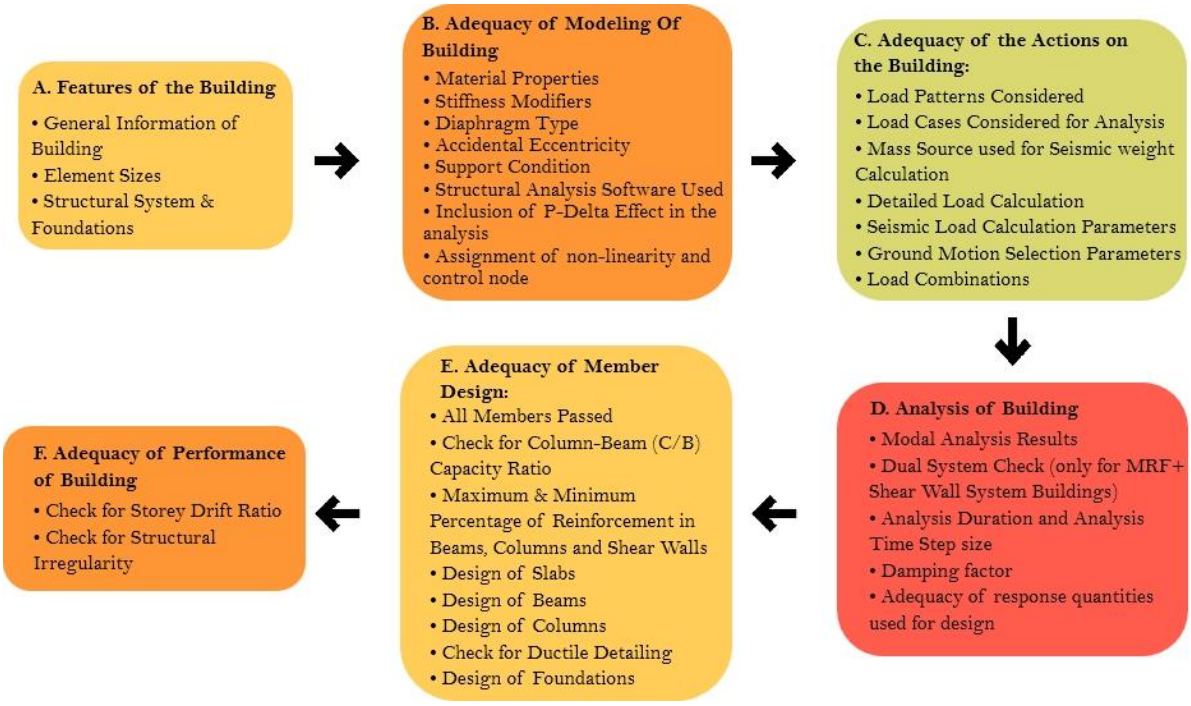
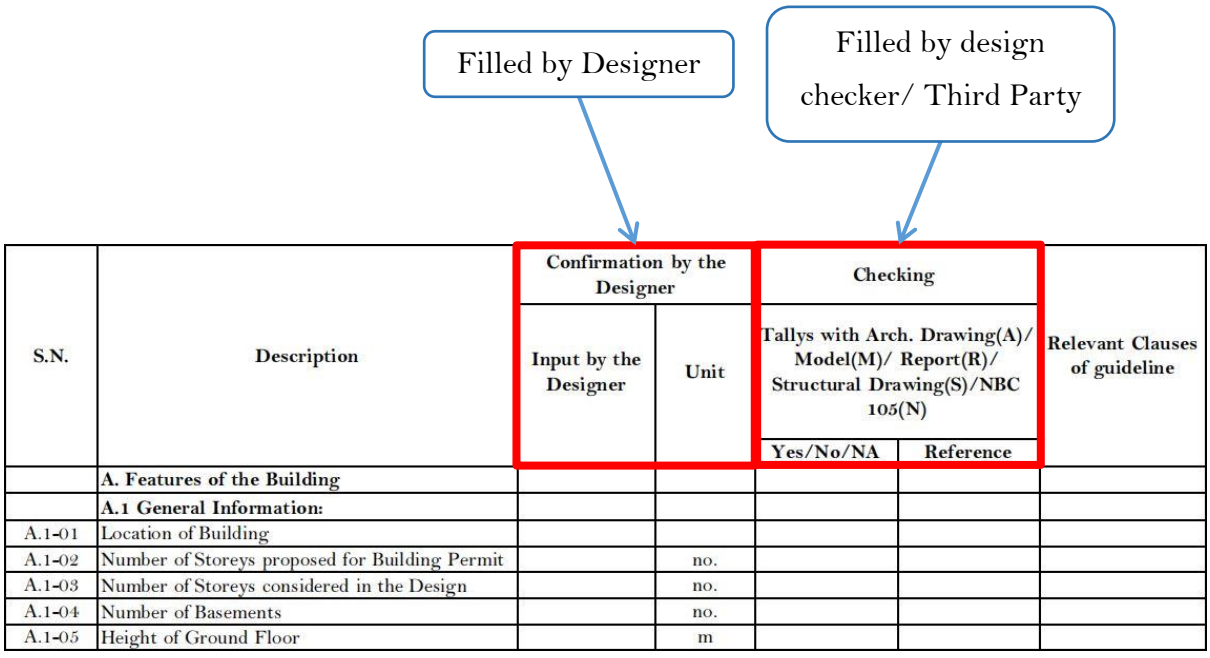


Figure 4: Components of checklist

The checklist is a two-step checklist in which the items filled by the designers can be verified by a third party which can be municipality or other design checkers. Fig. 5 shows the features of the checklist. If the designer or the design checker gets confused regarding what needs to be checked, they can refer to the relevant clauses of the designer's guideline.



S.N.	Description	Confirmation by the Designer		Checking		Relevant Clauses of guideline
		Input by the Designer	Unit	Tallys with Arch. Drawing(A)/ Model(M)/ Report(R)/ Structural Drawing(S)/NBC 105(N)		
				Yes/No/NA	Reference	
	A. Features of the Building					
	A.1 General Information:					
A.1-01	Location of Building					
A.1-02	Number of Storeys proposed for Building Permit		no.			
A.1-03	Number of Storeys considered in the Design		no.			
A.1-04	Number of Basements		no.			
A.1-05	Height of Ground Floor		m			

Figure 5: Features of the checklist

3.1 Features of the Building:

In this part of the checklist, various parameters describing the configuration of the building, element sizes, foundation types and types of structural system adopted are described. In the evaluation of the building's features, careful consideration is required for the following items:

- *General Information of Building*
- *Element Sizes*
- *Structural System & Foundations*

3.2 Adequacy of Modeling of Building:

In this part of the check list, various parameters required for the preparation of analytical model of the building, such as material properties, section properties, section modifiers, types of diaphragms, accidental eccentricity, boundary condition at the support, etc. are to be given.

The data provided in the checklist shall match with those in the analytical model file as well as with data described in the structural design report. In case of any discrepancy between them, municipality will notify the Designer to correct them. In the process of modeling the building, it is imperative to thoroughly examine and verify the following list of items:

- *Material Properties*
- *Stiffness Modifiers*
- *Diaphragm Type*
- *Accidental Eccentricity*
- *Support Condition*
- *Structural Analysis Software Used*
- *Inclusion of P-Delta Effect in the analysis*
- *Assignment of non-linearity and control node*

While the first six items are relatively straightforward, items regarding P-delta effect, the assignment of non-linearity and control node require further elaboration due to their complexity in structural analysis. The details are as follows:

3.2.1 Inclusion of P-Delta Effect in the analysis

P-Delta Effect is a second order geometric non-linearity, which accounts for the effect in laterally displacing structures under gravity load. P-delta effect is prevalent in tall multi-storeyed buildings having gravity loads and lateral displacement due to seismic or wind effect. A simple cantilever column has been used in Fig. 6 to illustrate P-Delta Effect.

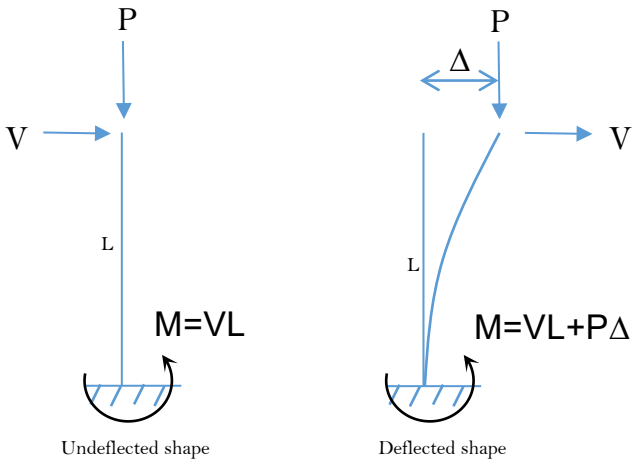


Figure 6: P-Delta Effect

3.2.2 Assignment of non-linearity and control node

For the non-linear analysis (Nonlinear static and nonlinear dynamic), non-linearity is induced in the structure at material level. In non-linear time history analysis, the behavioral characteristics of members such as pinching, stiffness degradation, and strength degradation depending on the reversed motion can have a significant influence on the response of the structure. In particular, a moment resisting frame is more flexible than shear walls or braced frame structures, and the behavior of the whole structure is dominated by the hysteresis characteristics of these frame members as it needs to resist seismic forces through the frame action of columns and beams. Therefore, a suitable hysteresis model with actual behavior of the frame members should be applied when performing non-linear time history analysis. Fig. 7 shows some examples of hysteresis model.

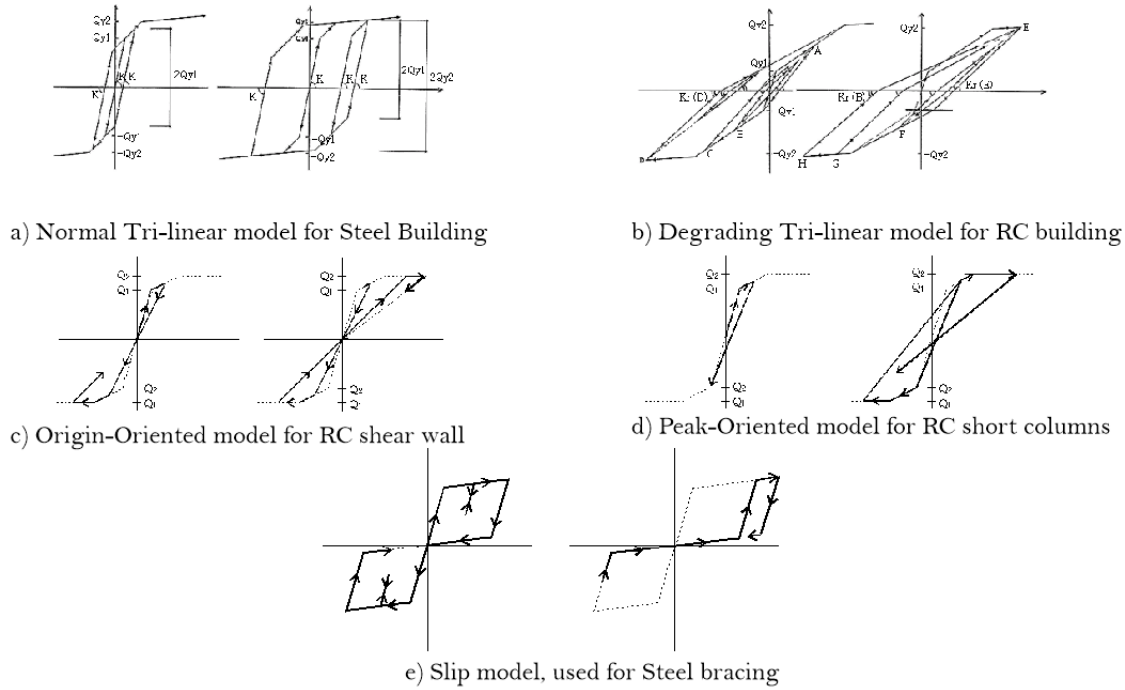


Figure 7: Hysteresis models

For the normal tri-linear model, it is noted that degradation in stiffness does not occur. However, for the degrading tri-linear model, stiffness decreases based on the maximum displacement up to the point.

3.3 Adequacy of the Actions on the Building:

In this part of the checklist, various parameters required for the application of loads or actions on the analytical model of the building, such as load patterns, load combinations, mass source for seismic weight calculations, load cases for non-linear modeling, etc. are defined. The following parameters contribute to a comprehensive understanding of the applied loads and actions:

- *Load Patterns Considered*
- *Load Cases Considered for Analysis*
- *Mass Source used for Seismic weight Calculation*
- *Detailed Load Calculation*
- *Seismic Load Calculation Parameters*
- *Ground Motion Selection Parameters*
- *Load Combinations*

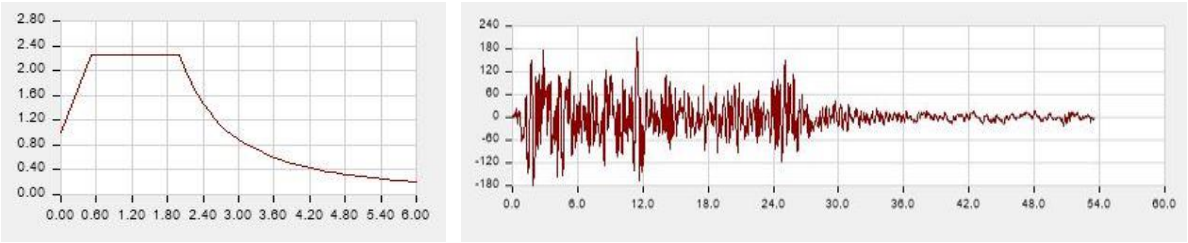
While many of these parameters are well understood by engineers in Nepal and are relatively straightforward, it's crucial to highlight the unique nature of 'Ground Motion Selection Parameters.' This particular aspect is a new topic in the NBC 105:2020, and its explanation has been given due to its unfamiliarity in the local context.

3.3.1 Ground Motion Selection Parameters

In case of dynamic analysis, proper set of ground motions with magnitude, fault distance, site-conditions etc. should be checked as it greatly affects the analysis. If simulated ground motions are used, fitting criteria should be checked. Being a complex problem by itself, proper ground motion selection governs the reliability of the seismic design.

Characteristics of ground motion are determined by the amplitude characteristics and time characteristics. In the engineering field, the amplitude characteristics are often given by the response spectrum, that is an indirect expression of amplitude characteristics of input ground motion. It is noted that the response spectrum is also given as the product of amplitude and spectral shape. For understanding, a sample of target response spectrum and a time history ground motion can be seen in Fig. 8. In many seismic design codes, the amplitude is determined from seismic hazard map, and spectral shape is determined based on the soil condition. ESM and MRSM employ the response spectrum as a design target spectrum to obtain the response of the structure under seismic action. Therefore, it can be said that the amplitude characteristics are essential to determine the design seismic force.

On the other hand, the time characteristics are necessary in case of conducting the dynamic analysis, since the response of the structure may differ per ground motions though the amplitude characteristics are identical. The time characteristics are often divided in to two parts; duration time and envelop function. There are several ways to determine them.



(a) Response Spectrum for Soil Type D

(b) Time History of Ground motion (El centro EW)

Figure 8: Response Spectrum and Time History Ground Motion sample

One of the practical ways is to employ the earthquake records observed in the past earthquakes. As well as the amplitude characteristics, the time characteristics depends on the seismic magnitude, focal distance, site ground condition and so on. It is noted that amplitude characteristics of the earthquake records are not maintained by the adjustment of amplitude to the target spectrum, however time characteristics remains.

Followings are the points to select ground motions from the records:

1. Location of Observation Station: It is preferable to select the ground motion record observed at the station close to the building site since the effect of path and site condition will be automatically included.
2. Intensity of Ground Motion: It is preferable to select the ground motion record that have an adequate ground motion intensity so that the scaling factor remains in the range stated by Building Code.
3. Earthquake Type: It is preferable to select the ground motion records considering the earthquakes surrounding site. It is noted the number of the selected earthquakes need not to be unity.
4. Magnitude: It is preferable to select the ground motion record caused by the earthquakes with large magnitude. The magnitude may preferably be 5 or greater.
5. Duration Time: It is preferable to select the ground motion record with large duration time so that the building oscillation reaches to the steady state. This is important for the building with the long natural period and small damping, such as steel high-rise building.

Figure 9 illustrates the Ground Motion Selection Parameters for pre-recorded earthquakes outlined in the checklist, providing a visual overview of crucial considerations for seismic design.

S.N.	Parameters Considered	Confirmation by the Designer		Checking		Relevant Clauses of guideline
		Input by the Designer	Unit	Tallys with Arch. Drawing(A)/ Model(M)/ Report(R)/ Structural Drawing(S)/NBC 105(N)		
				Yes/No/NA	Reference	
	C.5.3 Base Shear from Linear Time History Method of Analysis:					
	C.5.3.1 Seismic Load Calculation Parameters					
C.5.3	Selection of ground motion parameters					
C.5.3-01	Total No. of ground motions selected					
C.5.3-02	Ground motion taken from					
C.5.3-03	Type of ground motion selected (Pre recorded earthquakes/ Simulated)					
	Checking of ground motion parameters for pre recorded earthquakes					
C.5.3-04	Ground motions with appropriate magnitude considered?	[ ] Yes [ ] No				
C.5.3-05	Ground motions with appropriate fault type considered?	[ ] Yes [ ] No				
C.5.3-06	Ground motions with appropriate fault depth and focal distance considered?	[ ] Yes [ ] No				
C.5.3-07	Ground motions with appropriate maximum acceleration taken?	[ ] Yes [ ] No				
C.5.3-08	Ground motion with appropriate duration considered?	[ ] Yes [ ] No				
C.5.3-09	Method used for spectral matching	[ ] Time domain [ ] Frequency domain				

Figure 9: Ground motion parameter checks for pre-recorded earthquakes

For the selection of ground motion parameters for simulated ground motions, target spectrum compatible to design location based on NBC 105:2020 should be used. Fitting period range shall be consistent with NBC105. The number of fitting point used in general practice for Japan is 200 to 300. General criteria for the condition of fitting in Japan has been used as an example:

Fig. 10 illustrates the concept of ground motion generation by spectrum fitting.

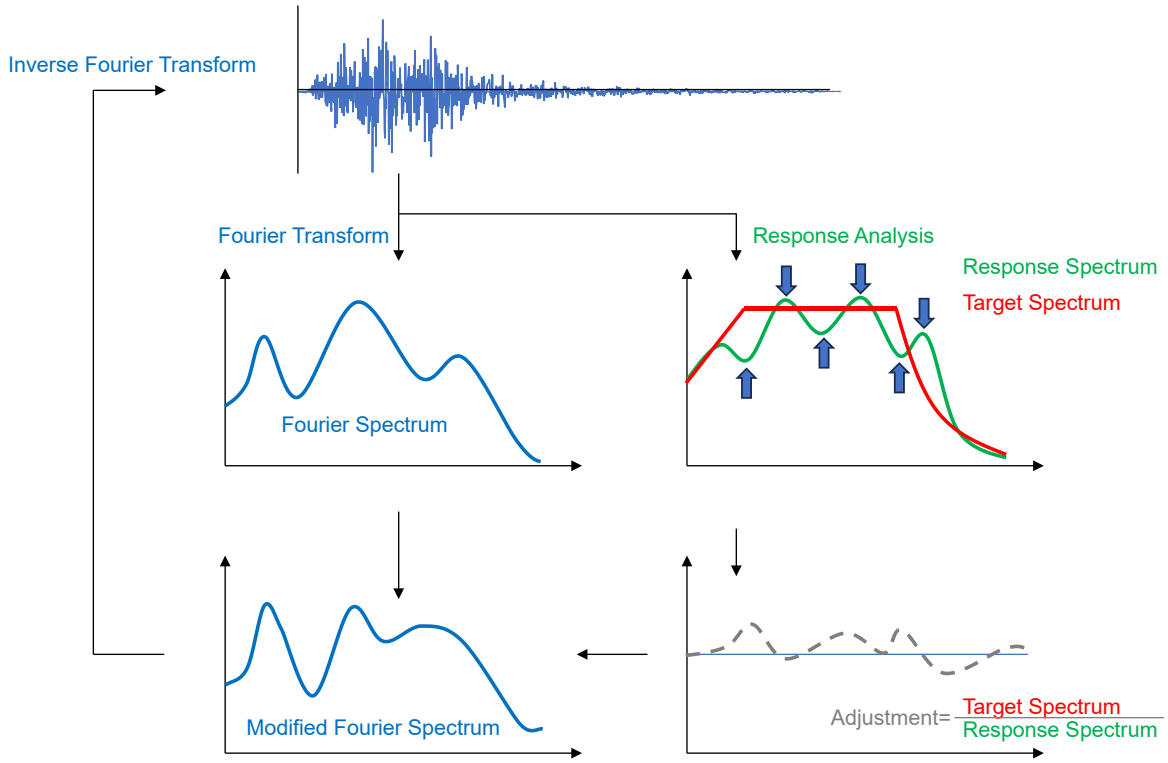


Figure 10: Ground motion generation from spectrum fitting

After the generation of the ground motion by spectrum fitting, some criteria such as minimum spectral ratio, maximum spectral ratio and coefficient of variance needs to be verified. The maximum spectral ratio should be less than or equal to 1.4. The minimum spectral ratio needs to be greater than or equal to 0.85. Coefficient of variance should be lesser than or equal to 0.05.

$$\text{Maximum spectral ratio: } \left[\frac{Sa(T_i)}{DSa(T_i)}\right]_{max} \leq 1.4 \quad (1)$$

$$\text{Minimum spectral ratio: } \left[\frac{Sa(T_i)}{DSa(T_i)}\right]_{min} \geq 0.85 \quad (2)$$

$$\text{Coefficient of variance, } v = \sqrt{\frac{\sum(\varepsilon_i - 1.0)^2}{N}} \leq 0.05 \text{ where } \varepsilon_i = \frac{Sa(T_i)}{DSa(T_i)} \quad (3)$$

The minimum and maximum spectral ratio has been depicted in the Fig. 11.

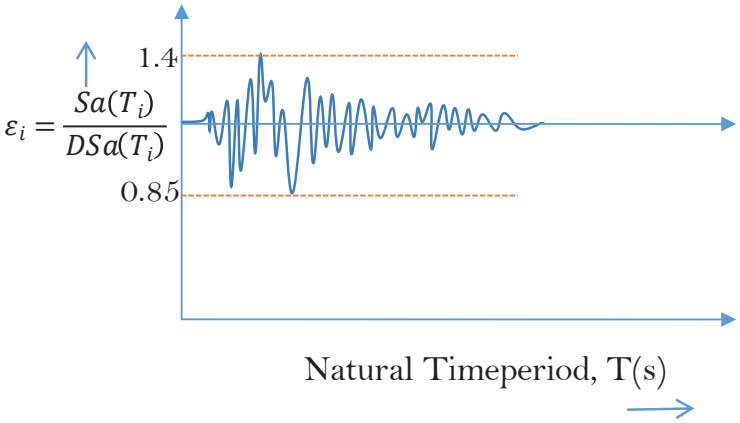


Figure 11: Maximum and minimum spectral ratio

In case that the above criteria do not match the thresholds, ground motion shall be re-adjusted as illustrated in Fig. 10.

Fig. 12 illustrates key considerations for seismic design, showcasing Ground Motion Selection Parameters outlined in the checklist and emphasizing simulated earthquakes.

S.N.	Parameters Considered	Confirmation by the Designer		Checking		Relevant Clauses of guideline
		Input by the Designer	Unit	Tallys with Arch. Drawing(A)/ Model(M)/ Report(R)/ Structural Drawing(S)/NBC 105(N)		
				Yes/No/NA	Reference	
	Checking of ground motion parameters for simulated ground motions					
C.5.3-10	Target response spectrum is adequately set?	[ ] Yes [ ] No				
C.5.3-11	Ground motions to be scaled are adequately selected?	[ ] Yes [ ] No				
C.5.3-12a	Simulated ground motions have enough duration time for the building of concern?	[ ] Yes [ ] No				
C.5.3-12b	How long are the duration times?					
C.5.3-13a	Fitting has been done correctly?	[ ] Yes [ ] No				
C.5.3-13b	Range of period for fitting and number of fitting point					
C.5.3-13c	Maximum spectral ratio: $[Sa(Ti) / DSa(Ti)]_{max} \leq 1.4$					
C.5.3-13d	Minimum spectral ratio: $[Sa(T) / DSa(T)]_{min} \geq 0.85$					
C.5.3-13e	Coefficient of Variance: $(\Sigma(\varepsilon i-1)^2/N)^{0.5} <= 0.05$, $\varepsilon i = Sa(Ti) / Dsa(Ti)$					
C.5.3-13f	Overlying Sa and Dsa shows good agreement (Visual check)	[ ] Yes [ ] No				

Figure 12: Ground motion parameter checks for simulated earthquakes

3.4 Analysis of Building:

In this part of the check list, the modal behavior of the building is checked. The modal shapes give us an insight of the dynamic characteristics of the building. Any warning messages along with modal stability check may also be considered post analysis.

- *Modal Analysis Results*
- *Dual System Check (only for Moment Resisting Frame+ Shear Wall System Buildings)*
- *Analysis Duration and Analysis Time Step size*
- *Damping factor*
- *Adequacy of response quantities used for design*

The check items for the analysis of buildings have been explained below in detail:

3.4.1 Modal Analysis Results

In this part of the checklist, number of modes, modal mass participation ratio and modal combination methods are to be mentioned.

While carrying out dynamic analysis, it is required that sufficient number of modes are to be included in the analysis so that the majority of seismic masses are participating in the building vibration within the number of modes included in the analysis. Clause 7.3 of NBC 105:2020 requires that the number of modes included shall be such that at least 90% of the total seismic mass are participating in a direction under consideration.

The Designer also has to mention the modal combination method used for combining the modal effects such as storey shear, bending moments, storey drifts, displacements, etc. NBC 105:2020 clause 7.5 permits the use of SRSS, CQC or any other generally accepted methods for the modal combination rules. However, it is to be noted that that SRSS method for modal combination shall be used only when the modes are not closely spaced. Modes are said to be closely spaced if the difference in frequencies of any two consecutive modes is less than or equal to 15% as per the clause 7.4(b) of the code.

3.4.2 Dual System Check (only for Moment Resisting Frame+ Shear Wall System Buildings)

A dual system is a structural system consisting of a combination of moment resisting frame and shear walls. Codal provisions require that the moment resisting frame shall be designed to resist at least 25% of the design base shear.

3.4.3 Analysis Duration and Analysis Time Step size

In the time domain analysis, it is required that the oscillation of buildings reaches to the steady state. For this, duration time of input ground motion need to be long enough as stated in "Selection of Ground Motion Parameters". Therefore, the duration time of analysis shall be long as the duration time of ground motion at the shortest. In reality, the identical duration time of analysis is used regardless of the duration time of input ground motions which may be different to one another to make the analysis simple. In case that the duration time of input ground motion is shorter than analysis duration time, the building shows the free vibration.

From the viewpoint of accuracy of analysis, the analysis time step needs to be as short as possible. However, the extremely short time step may bring the excessive calculation time by which the analysis is not realistic.

The time step of 0.01s is often adopted for linear (elastic) time history analysis in Japan as a practice. However, shorter time step such as 0.005s is adopted for nonlinear time history analysis to reduce the error caused by the changes in stiffness and in restoring force in each time step. Though some analytical techniques exist to reduce the error, it is noted that adopting shorter time step is still effective.

3.4.4 Damping factor

Damping factor based on the material of the structure should be chosen. Not using a compatible damping factor may have influence in the peak response levels. Table 2 shows the damping factor used in Japanese practice for RC and steel buildings.

Table 2: Damping factors for RC and Steel buildings

Analysis Methods	Reinforced Concrete	Steel
Linear analysis	5%	3%
Non-linear analysis	3%	1%-2%

3.4.5 Adequacy of response quantities used for design

If less than 7 numbers of ground motion records are used, maximum values of the response quantities from these ground motions shall be used. If the number of ground motions used are equal to or more than 7, then the average values of the considered number of ground

motions shall be used for the response quantities. Refer to Fig. 13 for a visual representation of the checklist items related to analysis check parameters for LTHA.

S.N.	Parameters Considered	Confirmation by the Designer		Checking		Relevant Clauses of guideline
		Input by the Designer	Unit	Tallys with Arch. Drawing(A)/ Model(M)/ Report(R)/ Structural Drawing(S)/NBC 105(N)		
				Yes/No/NA	Reference	
	D. Analysis of Building					
	D.3 Analysis Duration and analysis time step					
D.3-01	Analysis duration of dynamic analysis		sec			
D.3-02	Time step of dynamic analysis		sec			
	D.4 Damping check					
D.4-01	Is the damping factor compatible to the structural type?	[ ] Yes [ ] No				
	D.5 Check for adequacy of response quantities used for design					
D.5-01	Is the maximum value of response quantities used for the design if less than 7 Ground Motions are being used? If the number of ground motion is more than 7, are the average values of the response quantity used for design?	[ ] Yes [ ] No				

Figure 13: Analysis check parameters for LTHA

3.5 Adequacy of Member Design:

In this part of the check list, various outputs obtained from the software such as deflection of beams, column-beam capacity ratios, maximum and minimum percentage of reinforcements in beams & columns, indication of whether all members have passed in the design or not, etc. are verified. If all of these parameters are found to be OK, it shows that the member design carried out by the software is acceptable. If any one or more parameters are not found OK, redesign after modifying the section properties or material properties may be required.

- *All Members Passed*
- *Check for Column-Beam (C/B) Capacity Ratio*
- *Maximum & Minimum Percentage of Reinforcement in Beams, Columns and Shear Walls*
- *Design of Slabs*
- *Design of Beams*
- *Design of Columns*

- *Check for Ductile Detailing*
- *Design of Foundations*

Among the comprehensive list of considerations in the member design check, only certain key items have been explained below:

3.5.1 Check for Column-Beam (C/B) Capacity Ratio

For assuring compliance with the strong column-weak beam criteria in a RC framed structure, the Clause 4.4.4 of the Annex-A of NBC 105:2020 requires that at every beam-column junction in a frame, the summation of the moment capacities of the column end sections shall be greater than 1.2 times the summation of the beam end moment capacities.

3.5.2 Design of Slabs

There will be a number of slab panels at a floor level of a RC building. The Designer has to include the detailed design of the critical panel of the slab in the structural design report.

3.5.3 Design of Beams

This check is carried out for the deflection check of beams in case of simply supported or continuous beams in a steel and RCC framed buildings. This is the simplified version of the check. For cantilever beams with span more than one meter, it is suggested to carry out deflection check for all span lengths through detailed calculation for deflection check.

For long span beams with span greater than or equal to 6 m, long term deflection check is also required. For such beams, deflection check by L/d approach may not be sufficient and hence detailed calculation using the procedure given in the code IS 456: 2000 under Clauses 22.3.2, 23.2.1, 42.1 and Annex C is to be adopted. The designer shall submit such detailed calculation for long span beams in the structural design report.

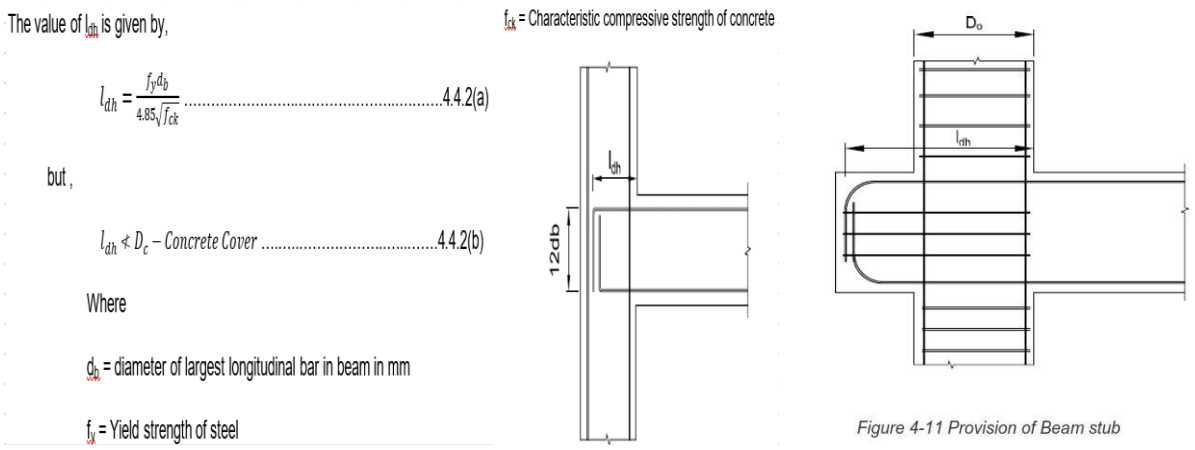
3.5.4 Design of Columns

This check is carried out whether the RC columns in the RCC framed buildings are slender or not and if slender, whether this effect has been considered in the design or not.

3.5.5 Check for Ductile Detailing

This part of the check list pertains to the verification of detailing shown and presented in the structural drawings of a RC or steel framed building against the provisions indicated in the Annex-A of the code for ductile detailing compliance of a RC or steel building.

As shown in Fig. 14, anchorage of beam longitudinal reinforcement in exterior beam-column joint is also to be checked as proper reinforcement anchorage is essential to enhance the performance of joints. If the provided horizontal anchorage length does not satisfy the requirements, exterior stubs should be provided.


The value of l_{dh} is given by,

$$l_{dh} = \frac{f_y d_b}{4.85\sqrt{f_{ck}}} \quad \text{.....4.4.2(a)}$$

but ,

$$l_{dh} \nless D_c - \text{Concrete Cover} \quad \text{.....4.4.2(b)}$$

Where

d_b = diameter of largest longitudinal bar in beam in mm

f_y = Yield strength of steel

f_{ck} = Characteristic compressive strength of concrete

Figure 14: Anchorage of beam longitudinal bars (NBC 105:2020, Annex A)

For steel structures, the connection between members is necessary to be checked. Bolts and welds shall not be designed to share force in a joint. The connections shall be designed so as to limit localization of plastic strains, high residual stresses and prevent fabrication defects. Connections fabricated by means of full penetration butt weld satisfies the overstrength criterion. Adding stiffness to the beams is an approach to the reduction in vibration in the structures. While designing, proper size of beam and girder should be chosen and checked against the vibration criteria. Other methods of controlling the vibrations are providing multiple bays, splitting floors and adding tuned mass dampers.

Adding stiffness to the beams is an approach to the reduction in vibration in the structures. While designing, proper size of beam and girder should be chosen and checked against the vibration criteria. Other methods of controlling the vibrations are providing multiple bays, splitting floors and adding tuned mass dampers. The checklist in Fig. 15 serves as a reference for these detailing checks, encompassing a range of considerations for steel structure design.

S.N.	Parameters Considered	Confirmation by the Designer		Checking		Relevant Clauses of guideline
		Input by the Designer	Unit	Tallys with Arch. Drawing(A)/ Model(M)/ Report(R)/ Structural Drawing(S)/NBC 105(N)		
				Yes/ No/NA	Reference	
	E.7 Check for Ductile Detailing					
	E.7.3 Connections between members					
	Welding and Bolting connection					
E.7.3-01	Check if the number of bolts is adequate or in case of welding check the adequacy of the welding	[ ] Yes [ ] No				
E.7.3-02	Is the bolt-to bolt distance and bolt-to-edge distance checked?	[ ] Yes [ ] No				
E.7.3-03	Is full penetration welding done in case normal stress is acting?	[ ] Yes [ ] No				
	Column Splices and gusset plate					
E.7.3-04	Does the splice plate and gusset plate have enough capacity to transfer member forces?	[ ] Yes [ ] No				
E.7.3-05	Are column splices provided away from the beam column flange connection and provided on both sides of the web?	[ ] Yes [ ] No				
	Beam-column connection					
E.7.3-06	Is rigid beam column connection provided in case of moment resisting frames?	[ ] Yes [ ] No				
	E.7.4 Buckling prevention					
E.7.4-01	Are the structural steel sections taken either plastic or compact?	[ ] Yes [ ] No				
E.7.4-02	Is global and local buckling avoided ?	[ ] Yes [ ] No				
	E.7.5 Fatigue					
E.7.5-01	Is excessive vibration avoided?	[ ] Yes [ ] No				

Figure 15: Detailing checks for steel structure

3.6 Adequacy of Performance of Building:

Besides the structural design, NBC 105 requires the check of building performance for 2 limit states: Serviceability Limit State (SLS) and Ultimate Limit State (ULS). For verification of performance, check for storey drift ratio and irregularities are performed in a structure.

- *Check for Storey Drift Ratio*
- *Check for Structural Irregularity*

3.6.1 Check for Storey Drift Ratio

NBC 105:2020 requires the checking of inter-storey drift ratio for the ultimate limit state as well as for serviceability limit state. Clause 5.6.3 of the code states that for the ultimate limit state, the ratio of inter-storey deflection to the corresponding storey height, which is also known as inter-storey drift ratio, shall not exceed 0.025. For the serviceability limit state, the ratio of inter-storey deflection to the corresponding storey height shall not exceed 0.006.

Table 3: Inter-Storey Drift Limit for ULS and SLS

Limit State Type	Inter-Storey Drift Limit
ULS	0.025
SLS	0.006

3.6.2 Check for Structural Irregularity

In this part of the checklist, the Designer has to state whether the checks for the torsional irregularity, soft storey, in-plane discontinuities of vertical LFRS, mass irregularity, re-entrant corner irregularity, diaphragm discontinuity irregularity, out-of-plane offset irregularity, etc have been carried out or not. These irregularities from NBC 105 can be seen in Fig. 16.

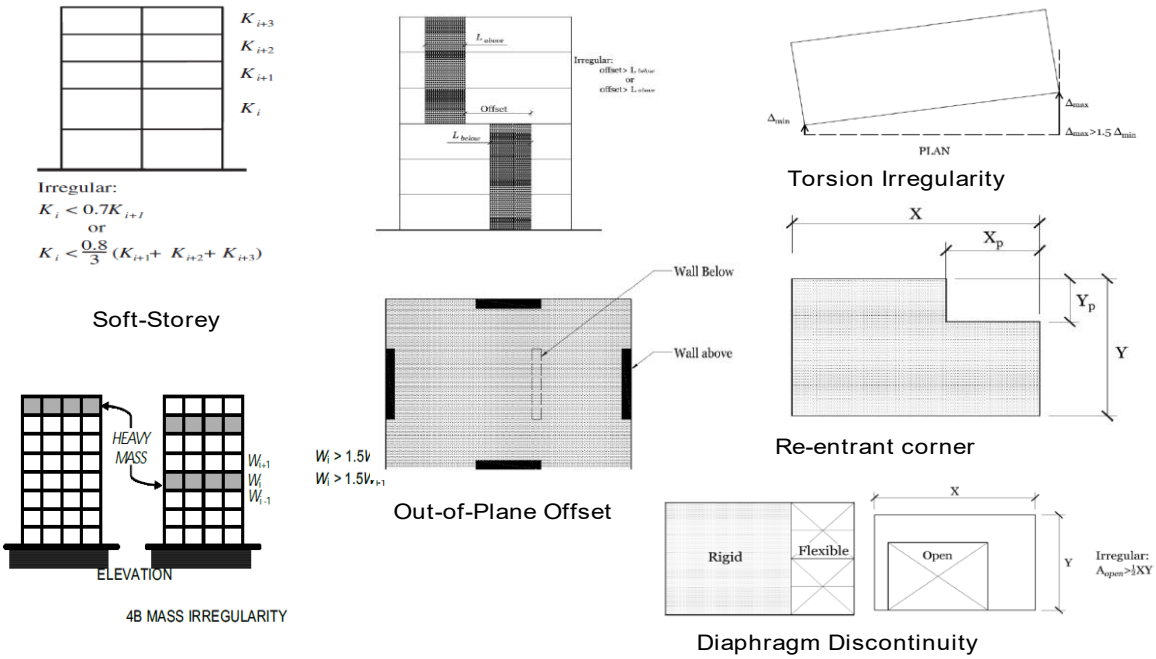


Figure 16: Structural Irregularity (NBC 105:2020, Clause 5.5)

4. Results and Discussion

Several training and workshops were conducted to distribute and explain the checklist. Engineers were equipped with essential architectural and structural documents, including drawings, reports and models, to facilitate checklist completion and verification. As a result, engineers were able to fill the checklists. The training and workshops also served as a platform for valuable suggestions and feedback, which were later considered to enhance and refine the checklist for improved effectiveness.

5. Conclusions

This paper introduces the structural checklists and the parameters that can be used for different analysis method and material types. The checklists developed encompasses a thorough examination of various parameters crucial for ensuring the safety, efficiency and reliability of building's structural design. The emphasis on consistency across architectural and structural drawings, structural reports and structural model tends to increase the reliability in the structural design. The inclusion of specific checks for seismic considerations, such as ground motion parameters and modal analysis results, highlights the importance of addressing dynamic forces in the design process. The structured organization of parameters covering various aspects such as general information, checking modeling adequacy, load considerations, analysis and member design provides a firm framework for assessing and verifying the key elements in the structural design process.

Acknowledgement

The authors would like to specially thank the Department of Urban Development and Building Construction (DUDBC), Earthquake Resistant Technology Consultancy Pvt. Ltd. (ERTech Consultancy) for helping prepare the checklists and providing their valuable time and suggestions for the discussion and improvement of the guidelines and checklists.

References

Seismic Design of Buildings in Nepal, NBC 105: 2020. Department of Urban Development and Building Construction, Kathmandu, Nepal, 2020.

CSI America. (2016). CSI Analysis Reference Manual.

Dixit, A. M. (2004, August). Promoting safer building construction in Nepal. In 13th World Conference on Earthquake Engineering.

IS 1893 (Part1):2016. Indian standard criteria for earthquake resistant design of structures, 5th revision. Bureau of Indian Standards, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi; 2016.

I.S. 456:2000, "Code of Practice for Plain and Reinforced Concrete". Bureau of Indian Standards. New Delhi, India.

Addressing Earthquake Risk of the Kathmandu Valley

Yogesh P. Shrestha[1], Bijaya K. Shrestha [2] Shraddha Dotel [3],

[*]*Nest Pvt. Ltd.*

Corresponding email: nest.geocom.paragon@gmail.com, bkshrestha2014@gmail.com, dotelshraddha@gmail.com

Abstract

The Kathmandu valley, the capital region of Nepal, comprises of diverse social fabrics in terms of land characters, population density, land use and housing typology and above all socio-economic condition of residents. As a result, making valley earthquake resilient has become a challenging task. The objectives of this study are four folds: (i) identifying the natural hazards and ranking them in terms of damages in the past, (ii)analyzing the vulnerability, (iii) capacity and linking the causes of intensification of vulnerability, and (iv) proposing some key recommendations. The study methodology combines the critical review of numerous documents and consultation with experts and stakeholders engaged in disaster risk reduction and management. Based on the damages caused by the past disaster (1971-2023), the earthquake has been found the most devastating one. Urban growth in the absence of risk sensitive land use plan and without basic infrastructure provision, change in building use on ad-hoc basis, dominance of owner-built houses, vertical division of traditional houses, increase in building floor area ratio without increasing capacity of road network all have intensified earthquake risk in the valley. These issues are not being addressed through the existing legal and institutional framework. Formulation of risk sensitive land use plan, development of planning regulations and urban design guidelines and linking them to the incentive mechanism can reverse the present trend of development. Site specific programs with incentive packages is suggested to make the existing settlements safer and community resilient.

Key words: *Earthquake risk, vulnerability and capacity, disaster resilient, Kathmandu valley.*

1. Introduction

The Kathmandu valley comprising 18 municipalities and some wards of additional two rural municipalities cover an area of 721 sq. km is the national capital region of Nepal (Fig. 1). Vulnerable to multiple hazards such as earthquakes, flood and landslides, the valley has sensitive geology and vulnerable ecology due to its soft floor and bowl-shaped geography surrounded by weak mountain. It comprises of diverse urban (and social) fabrics: planned vs. unplanned and new vs. old settlements (Shrestha and Vaidya, 1978; Shrestha, 2011). These segments are

characterized by diverse infrastructure quality and inhabitants with different socio-economic capability, reflecting the prevailing regulations of different political periods. Urban system made up of a historic core area surrounded by peri-urban areas and further satellite towns are becoming a single spatial unit due to integration of their economic and human flow (Muzzini and Aparicio, 2013). However, they have been administered and their urban growth is being regulated by twenty different local governments, after restructuring of municipalities in 2017.

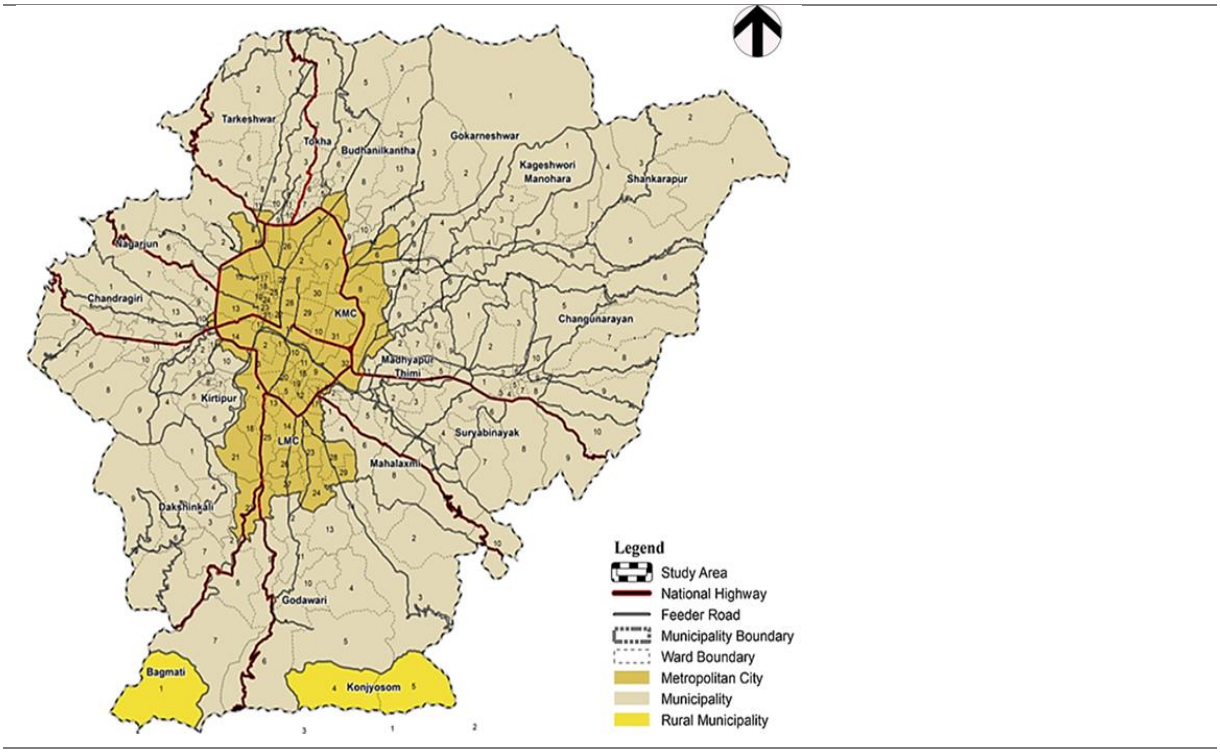


Figure 1 Kathmandu valley: 18 different municipalities and few wards of additional two rural municipalities

Poverty, occurrence of natural disasters, poor education and health facilities in the rural regions, on one hand, and adaptation of centralized policies thereby concentrating socio-economic investments in the limited urban centres, on the other hand, have encouraged huge population migration into the valley thereby causing rapid urbanization with haphazard urban growth and transformation in the buildings in the urban centres.

Except the planned areas (land pooled area and private sector-built housing estates), many peripheral urban growths occurred on an ad-hoc basis are often characterised by building structures built by inappropriate and informal methods, road layout of inadequate width and insufficient space, lack of open spaces and other social amenities (Bhattarai and Conway 2010;

Shrestha 2010). It is believed that the valley alone contributes around 30% to national gross domestic product (GDP), which was increased from 23.4% one decade before (MOUD, 2015).

Against such a backdrop, this paper aims to assess the earthquake risk of the valley with four-fold objectives. First, it demonstrates various natural hazards of the valley and then rank them in terms of loss of lives and property damaged by the past disasters. Second, it analyses the key activities responsible for increasing vulnerability and then assesses the capacity of the valley for emergency situation. Third, it relates those weaknesses to the existing legal and institutional framework of the municipality and valley level agencies to check their effectiveness. Fourth and last, it draws a conclusion and proposes some key recommendations.

2. Materials and Methods

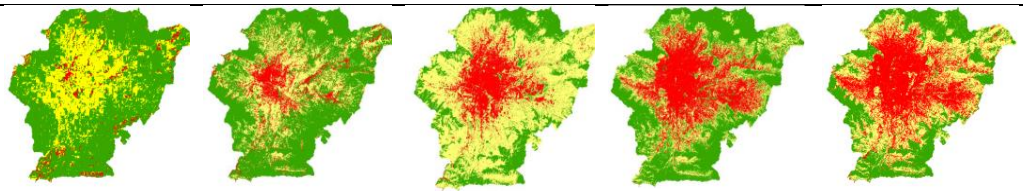
This study combines both qualitative and quantitative research techniques. Numerous documents associated with urban development and disaster risk reduction and management were critically reviewed. Literature related to hazards, vulnerability and capacity in the form of plans, programs, legislation, regulation and Acts including municipal annual investment were focused. Various fragmented hazard maps were updated. Municipalities of the valley and Kathmandu Valley Development Authority (KVDA) staffs were also interviewed, besides consulting with private real estate companies, service providing agencies and non-government organizations working on disaster mitigation.

Vulnerability is both a product and a process that results from physical, social, economic and political factors within a given society and culture. The human factor through 'structural process' plays a decisive role than natural phenomenon itself in increasing vulnerability on community (Hamza et al., 1998). Risk can be expressed as R = H (hazard) × V (vulnerability) / C (capacity). 'Capacities' refers to people reacting suitably during and in the immediate aftermath of disasters. However, this equation can be better rewritten in the form of R = H × V × LC, where LC represents lack of capacity to respond to disasters. Such separation of vulnerability and capacity is desirable for identifying the causes of vulnerability and their solutions (Davis et al., 2004). Improvement in any component of either physical vulnerability or socio-economic vulnerability reduces the level of risk (Aysan, 1990); however, it does not guarantee community's safety unless other precaution measure is carried out. Individual self-protection through good income and better housing will have little meaning unless one's surroundings including the working and

entertainment places are safe and other emergency services are available at that particular place at the time of emergency.

Analysis of urban growth trend of five different periods in the valley reveals that there has been growth of settlements in all directions (Table 1). Significant spatial growth can be observed between 2000 and 2010, which was mostly contributed due to Maoist's insurgency in the country. Agriculture land has been reduced from 409.86 sq. km to 181.08 sq. km in the same period. There has been significant reduction of forest land (planted area, which might be of private ownership too) between 1990 to 2000.

Table 1: Urban growth in Kathmandu valley (trend from 1983-2020)

Land use	*Land coverage (sq. km)*				
	1983	*1990*	*2000*	*2010*	*2020*
Built up	29.01	84.01	125.27	202.84	242.99
Forest	493.49	444.21	186.76	337.97	233.47
Agriculture	200.62	193.67	409.86	181.08	245.34
					

Note: information derived from GIS map and satellite images of various years

The general trend shows that with increase in valley's population, the agriculture land is decreasing. With increase in population, there has also been increase in vehicular registration number and accordingly, the pollution is also rising (Fig. 2).

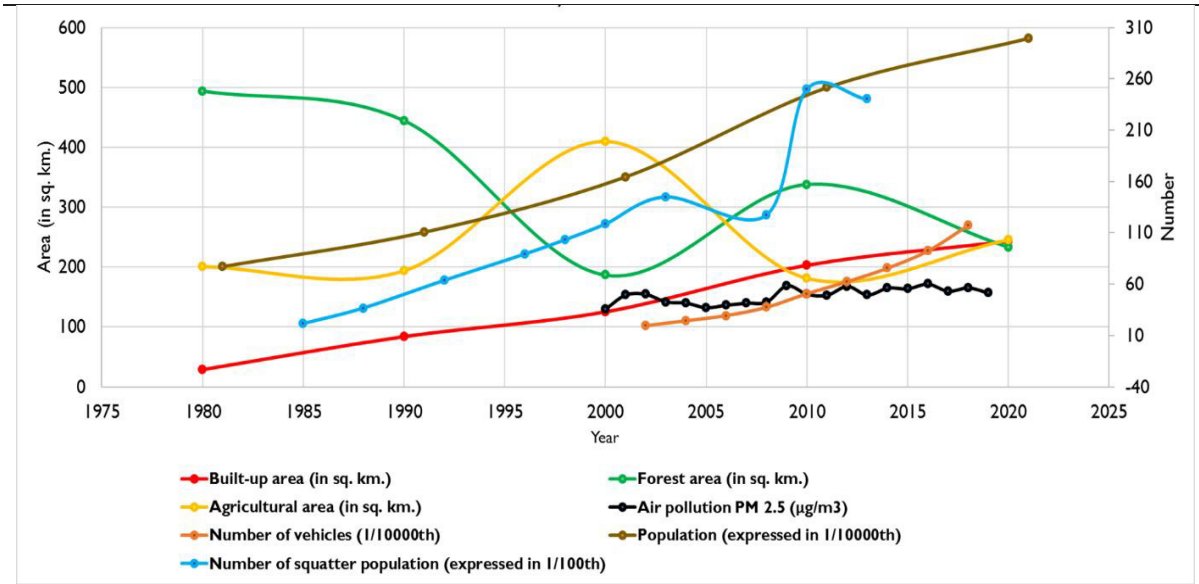


Figure 2 Development activities against different factors

3. Results and Discussion

3.1 Hazard ranking

While reviewing the impacts of past disasters in the Kathmandu valley from 1971 to 2023, it has been revealed that major disasters of the valley include landslides, flood, earthquake, fire and heavy rain. Each disaster severely impacted all three districts: Kathmandu, Lalitpur and Bhaktapur. In the past more than fifty years, landslides alone occurred more than six dozen times, causing death of 79 persons, injuring 44 persons and affecting 218 people in Kathmandu district alone (UNDRR Disinventar Sendai (no date); Ministry of Home Affairs, GON (no date)). The incidents also destroyed 78 no of houses and additional 48 no of houses were damaged. In the case of flood, human casualties have been found large number in Lalitpur district but Bhaktapur district has more affected people. Similarly, earthquake and fire has impacted both human and property loss in all three districts.

Among major disaster events in the past, the earthquake ranks first in terms of human casualties (death and injury) and buildings collapsed and destroyed (Table 2). The economic loss inflicted by the earthquake is likewise enormous and will persist for many years. Floods come in first place when simply the number of persons affected is considered, as they have affected a large number of people. The fire disaster ranks second in all areas, including the number of events. This calamity alone killed 809 people, injured 809 people, and affected 6,832 people, while also demolishing 1,038 completed houses and injuring an additional 1,312 buildings. In terms of

human casualties, landslides have become the valley's third deadliest hazard. However, floods have destroyed more structures in the valley than landslides in the past (1971-2023).

Table 2: Hazard ranking based on the past disaster impacts in the Kathmandu valley

Hazard ranking	No.of disaster events	Casualties of people (no)			Building impacts (no)		Economic loss (NRs in million)
		Death	Injured	Affected	House destroyed	House damaged	
First	Earthquake (23)	Earthquake (1766)	Earthquake (13,294)	Flood (14,118)	Earthquake (103,759)	Earthquake (74,689)	Earthquake (huge, exact information no available)
Second	Fire (2971)	Fire (254)	Fire (809)	Fire (6832)	Fire (1038)	Fire (1312)	4646.299115 (fire)
Third	Landslides (160)	Landslides (131)	Landslides (96)	Heavy rain (2337)	Flood (256)	Flood (804)	201.27573 (flood)
Fourth	Flood (152)	Flood (100)	Flood (33)	Landslides (1001)	Landslides (227)	Heavy rain (231)	47.429025 (landslides)
Fifth	Heavy rain (104)	Heavy rain (11)	Heavy rain (32)	Earthquake (538)	Heavy rain (72)	Landslides (56)	23.8707 (heavy rain)

Note: Though Kathmandu valley covers around half of Lalitpur district, the data shown belongs to whole district

Source: Compiled from UNDRR DesInventar Sendai (no date) in https://www.desinventar.net/DesInventar/profiletab.jsp and NDRRP (Nepal Disaster Risk Reduction Portal),
Ministry of Home Affairs, GON (no date) in http://drrportal.gov.np/

3.2 Earthquake hazard of the Kathmandu valley

Earthquake hazard of the Kathmandu valley is due to four major geophysical processes. First, the valley (and Nepal) lies in an active earthquake belt between Tibetan and Indian plates that is constantly pushing each other thereby developing stresses in the main central active fault, Mahabharat thrust and main boundary active fault. The recent study by installing GPS points in the Himalayas of Nepal indicates that India is moving North-East (NE) at the rate of 58 mm/year and the Southern Tibet is shifting towards North East (NE) at the rate of 36 mm/year resulting shortening of Nepal by 2cm per year (Bilham, 1999). Formed by a collision between the Indian plate and southern Tibet some 50 million years ago, the Himalaya was under great earthquakes

in the past. Four 300 km long ruptures slipped each by more than 5 m in the past century and the areas between those ruptures are the most probable sites the next great earthquake that hits in the Himalaya (ibid.). Second, many active fault lines have criss-crossed the Kathmandu valley particularly on the western and southern parts and movement of any of them can cause a great disaster. Third, the whole Valley is located on the bed of a drained lake, making the land unstable and flood prone. It is believed that the Valley's geological development took place around one million years ago in three phases - (i) 200 m thick sediment on the rock bed during the five hundred thousand year (ii) about 200m to 300m thick special type of clay deposit during the following five hundred thousand year and (iii) about 20m thick mixture of clay and sand deposit during the next fifty thousand year (Pandey, 1999). This type of soil can easily be compacted by the ground vibrations induced by the earthquake, resulting in the development of excess hydrostatic pore water pressures of sufficient magnitude to cause liquefaction of the soil. Moreover, soft soil contributes amplification of seismic waves resulting in strong ground shaking. River banks of the valley are highly prone to subsidence, erosion and flooding as well as to liquefaction. Finally, there is a great chance of reoccurring earthquake event in the area that has been hit by past earthquakes after certain year of interval depending on the magnitude of earthquake. In the last century alone, great earthquakes ranging from five to eight Richter scale had hit Nepal and the surrounding regions seventy-one times.

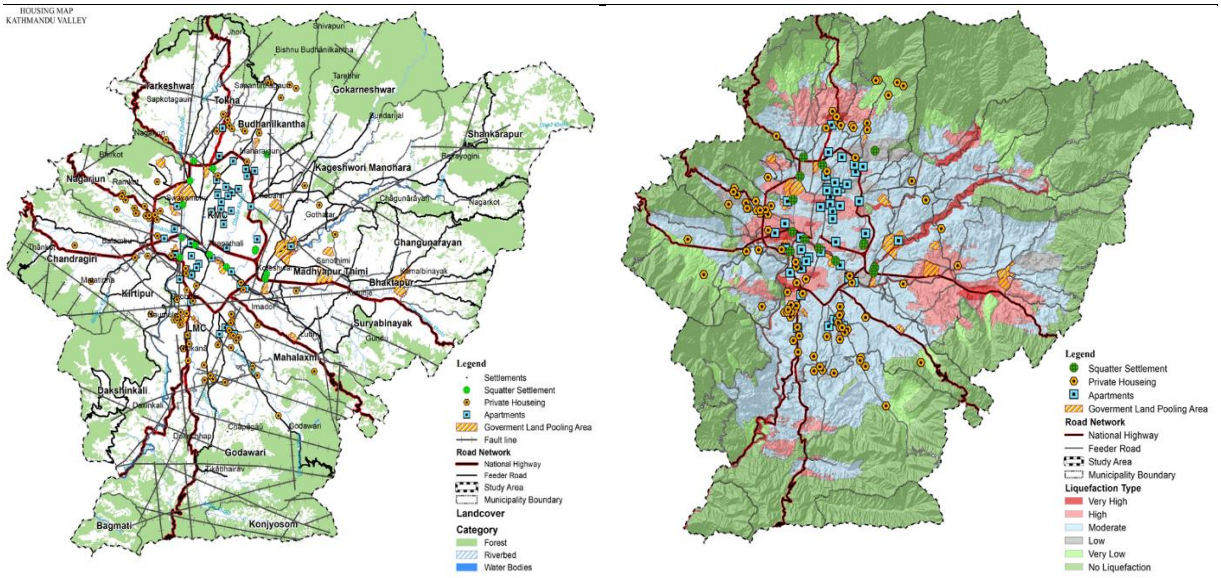
3.3 Urban activities increasing vulnerability

3.3.1 Haphazard urban growth in hazardous areas

Significant percentage of the existing settlements in the municipalities lie in earthquake hazardous zone. Spatially looking at the map of earthquake hazard of the valley, the major settlements of the three principal cities namely KMC, LMC and Bhaktapur municipalities lie in very high hazardous areas. The southern part of the valley, Godawari, Mahalaxmi, Kirtipur and Chandragiri municipalities have also part having 'very high' hazardous area. In terms of absolute area, LMC, KMC and Godawari municipality become the first three with larger area lying to 'very high' hazardous zone.

Private sector and government agencies are gaining momentum in developing valleys, with private housing concentrated in north, south, west, and east directions, and high-rise apartments in existing ring road areas and its peripheral areas. Even planned development areas are located in vulnerable sites (Figure 3a and b). The risk sensitive land use plan (RSLUP) of Kathmandu

valley prepared by KVDA with support from UNDP was not officially approved. The existing and even proposed some of housing estates, land pooled areas are located in hazardous sites, closed to fault lines and around liquefaction site. Land assembly in the sloped areas and along the riverbanks is comparatively easy and hence many private sector-led housing developments are located in such areas.



(a) Planned development near the fault line (b) Planned development near high liquefaction areas

Figure 3: Housing and apartments built by real estate company vs hazardous sites

3.3.2 Increasing slums and squatter settlements in the valley

The squatter settlements in the valley started in the early 1950s when rural migrants moved into cities for employment (Toffin, 2010). There were only 17 squatter settlements in the valley in 1985. By 2000, there were 61 squatter settlements with 2031 households and 11,851 people which increased to 64 by 2003, increasing the squatter households to 2134 and population to 14,500 (Table 3) (Lumanti, 2003). In 2008, Lumanti identified 45 informal settlements, of which 40 recognized themselves as squatters. These 40 squatter settlements included 12,726 people (6612 male and 6114 female) living in 2735 households (Lumanti, 2008). An additional 40% of squatters were estimated to be occupying public lands making the total squatter population up to nearly 20,000. Toffin (2010) reports 75 squatter settlements have been identified in the valley, out of which 65 are located in Kathmandu metropolitan city. Another study confirmed the 24,021 settlers were living in 46 informal settlements in Kathmandu in 2013. In the span of 25 years, the squatter population increased from 2134 in 1985 to 25,000 in 2010, almost 11.71 times with

annual growth of 42.8%. The number of settlements and their population has further increased. However, there is no updated documentation of their origin, number, location, population, and overall situation and those existing are incomplete and even conflicting. Accurate documentation is challenging due to internal and external migration.

Table 3: Demographic status of squatter settlements in the Kathmandu valley

Year	*Status/no of squatter settlement*	*Population*	*No of households*
Early 1950s	Squatter settlement emerged	na	Na
1985	17	2134	
1988	24	3665	348
1992	33	6355	1271
1996	47	8927	1783
1998	49	10,323	2021
2000	61	11851	2031
2003	64	14,500	22,134
2008	40	12726	2735
2010	71	25,000	Na
2013	46	24021	

Source: compiled from Lumanti, 2003; 2008; Tanaka, 2009; Toffin, 2010; DUDBC, 2010; Dangol and Ay, 2017

The majority of squatter settlements in the valley are located along the riverbanks or in public lands with limited or no access to basic services. Encroachment of dilapidated religious buildings and structures is also rampant, particularly in the valley. Squatting in private land is very rare. Urban poor living along the river banks, sloped lands and in the old buildings in the historic core of Kathmandu and Lalitpur are vulnerable not only because of their building structure and location of housing but also due to their low affordability level, poor education and lack of funds. Emergency, rescue and relief work would be difficult in such locations.

Weak public policies and institutions allowed the expansion of informal settlements and poorly regulated development in such areas exposed to hazards. Being illegal settlements and occupied by squatters, the planning regulations are difficult to implement. They are not entitled to receive formal assistance to improve housing and infrastructure. Without external supports, they are

unable to improve their housing and infrastructure of the habitat. These people mostly depending on daily wages are living in slums and squatter settlements are highly vulnerable to seismic hazard not only due to the location of their housing along the riverbanks and sloped areas but also because of their inability to afford basics, poor education (or illiteracy) and lack of funds to assist in their recovery (Shrestha, 2013).

3.3.3 Decreasing public open spaces

Public safety is enhanced with improved access for emergency vehicles, whilst the earthquake hazard from falling buildings is reduced through wider streets and increased open space for evacuation. Open space and recreational area essential for disaster relief and rescue work in case of an earthquake should be about 5% of total municipal area (MOUD, 2013). However, in Kathmandu and Lalitpur 0.48% and 0.06% of municipal area can be categorized as open space (MOUD, 2015). World Health Organisation (WHO) and Food and Agriculture Organisation (FAO) suggest a minimum availability of 9 sq. m. per person of green open spaces for the city dwellers. KMC has only 0.25 sq. m. per person as per its periodic plan. Destruction of community spaces, provision of only 2.5-5% of open space in the planned residential neighbourhoods and existence of only 6% open space (compared to 10-12% in other metropolitan cities of the world) with per capita organised open space of less than 1.0 sq. m. in Kathmandu (Pradhan, 2003) all demonstrate that the value and meaning of public spaces are yet to be understood.

3.3.4 Vulnerable individual buildings (old and new)

When parental properties are equally divided among sons, it has become the norm to divide traditional building stocks vertically and then create new openings randomly on the load-bearing front walls, provide restrooms and staircases in the divided portion by demolishing the portion of the existing structure, and add habitable rooms by either converting the ground floor into a room or by adding new floors frequently of different materials, floor heights, and construction techniques on the top of the existing buildings. These kinds of operations are frequently done without consulting licensed engineers and without obtaining permission from the relevant local governments. The entire rebuilding process has made the old homes in the historic core less resistant to seismic activity. This includes the formation of soft storeys, discontinuities in the load transferring system, lateral stiffness and strengths that cause a torsional effect, the creation of a 'pounding effect' due to differences in the floor and building heights, and the materials and construction techniques used in the neighboring buildings. The valley's traditional homes are

particularly vulnerable because of their weak foundation, lack of a damp-proof course, uneven size and lack of tie at the corner walls, heavy roof tiles set in mud mortar, loose joints between facing and inner brickwork, and weak building materials. The combined effect of these actions was evident in the 2015 Gorkha earthquake, which destroyed many old houses in the historic core of old cities of the valley.

Individual owner built new buildings on the peripheral areas are also not safe against earthquake. They often comprise of many building structures built by inappropriate and informal methods, road layout of inadequate width and insufficient space for vehicle turning place thus making the entry of fire fighters and ambulance impossible during emergency situation, and lack of open spaces and other social amenities, needed for rescue and relief operation. Though modern materials such as cement, concrete, iron, etc. are used in new buildings, the construction trend - generally five and half storey height with soft storey on the ground, three-foot projections from the second floor onwards, and often characterised by 'weak columns and strong beams' and 'short column'– produces vulnerable structures. Lack of quality control on construction work and building materials, wrong detailing of bars in slabs and columns and absence of supervision on the site have further weakened those new buildings. Exposing reinforced bars of columns and slabs for many years aiming at future expansion is also dangerous as it diminishes the strength of the structures due to rusting of the bars.

Penetration of new economic activities resulting from the commercialization of space has not only caused the conversion of ground floors of buildings, even located inside courtyards without vehicular access, into shops but has also accelerated the replacement of small open spaces available in the form of building setbacks, kitchen gardens or storage shed by new high-rise structures thereby converting the narrow pedestrian lanes, street squares and courtyards into parking lot, garbage dumping site, and above all into 'death traps.'

3.3.5 Prevailing building use change

Numerous private schools, colleges and private nursing homes are running their activities in ordinary residential buildings, built by informal process (owner built without hiring professional contractor and supervision by qualified technicians). Lack of vehicular access to the building, absence of playground and open spaces and other safety measures such as fire extinguishers are common in such 'mass gathering' facilities. These buildings should generally act as 'evacuation shelters' as well as 'mass treatment center' during emergency are the first to be hit by earthquake.

3.4 Capacity to deal with disaster emergency

As there is no proportionately increase in emergency facilities compared to growth of population, the level of preparedness at individual and city levels is not satisfactory in the valley. Most of the government hospitals and private nursing homes are located in the urban centres will find difficult to provide effective services during emergency situation due to the limited number of beds, medical staffs and the medicine stocks needed for mass treatment. Moreover, immediate rescue and first aid treatment will be hampered due to blockage of streets and pedestrian lanes from the debris of the collapsed surrounding buildings during the earthquake emergency. Though hospital buildings might be safe and medicine stockpiling might be available, but during emergency period, in many cases, there would be difficult to bring the earthquake victims (as well as together hospital staffs) in the hospitals due to blockage of road network. Those medical staffs would not be able to give services if there is no electricity, no water supply despite safety storage of equipment. Rescue and relief operation would be very difficult and challenging in the historic core area with compact and dense settlements served by narrow lanes and paths, as seen during the earthquake of 2015. The available fire brigade number, its capacity is simply inadequate to provide services to huge population and larger areas that also comprise of high-rise apartments, many petrol pumps within the city centres and urban sprawl in the peripheral agricultural lands. Recently, free ambulance service is being operated in the valley under the joint program of Kathmandu metropolitan city and Nepal ambulance service. Such services cannot be expected to be effective in the emergency situation when mass injuries need to transfer from different disaster sites to the hospitals through the valley's narrow congested streets.

Five fire engines are stationed in the New Road fire station, three in the Lalitpur metropolitan city, and two in the Bhaktapur municipality in the valley (Maharjan, 2022). Only three are operating at KMC. It has the capacity to control fires up to 10 storied buildings only. At present, 10 fire bikes are in operation for narrow places. Underground water pipe line is completed in Ason (ward 24) and is underway on other wards especially on the narrow and inland road that cannot reach the fire station. Chemical foam is also used for fire control. The city is trying to procure three sophisticated fire equipment including a 60 m high ladder and a 6,000 liter capacity water tank (ibid). Kathmandu city has three fire stations: Basantapur, Bauddha Ramhiti and Balaju and two more stations – Maharajgung and Balkhu - will be established in coming years.

4 Existing legal and institutional framework

Many improvements have been carried out in legal and institutional framework associated with disaster risk reduction and management. The National disaster risk reduction policies and strategic action plan (2018-2030) based on Sendai framework of DRR has clearly set out targets as well as activities to be carried out. Similarly, National Disaster Risk Reduction and Management Authority has been established. Many emergencies operating units have been formed at district level as well in KMC. Each municipality has localized National Disaster Management Act and also formed disaster management committee in the municipal organization.

Despite all these legal and institutional improvement, the earthquake risk in the valley is not decreasing. The reasons are numerous. First, urban development activities are not linked with disaster mitigation components and techniques as environed in the Acts and policies. The KMC has increased the floor area ratio (FAR) for building construction even in the dense urban area without considering the emergency rescue plan. Disaster fund allocated in each municipality is generally used for construction of gable walls along the riverbanks and tree plantation only. In some cases, as the case of Kirtipur municipality, such fund has been transferred into other activities. Second, significant percentage of the existing settlements with critical facilities are located in hazardous areas but hardly any municipality has plan to mitigate them. The building bye-laws and National Building Code would be activated only for new construction. In many cases, the renovation and reconstruction work including addition of floors are carried out without taking permission from the concerned municipalities.

Third, there is a lack of coordination among municipalities of the valley to deal with emergency situation. Around 82 different open spaces have been identified for evacuation purpose but such open space does not serve the purpose during rainy season and extreme cold weather. Lack of toilet, drinking water facility and electricity would further complicate the situation. The Kathmandu valley development authority does not have any section to deal with disaster risk reduction and management of the whole valley integrating all twenty local governments.

5. Conclusion and recommendations

Despite improvement in legal and institutional framework of disaster risk reduction and management, the earthquake risk of the valley is yet to be effectively address. Numerous urban activities associated with urban growth and individual building construction lack integration of disaster mitigation components and techniques. To reverse the present trend, the following two

key recommendations are suggested.

(a) Prepare risk sensitive land use plan (RSLUP) of the whole valley as well as of individual municipality. According prepare municipal development plan. Make mandatory that municipal annual plan is based on the RSLUP.

(b) Bring special program (plans with budget provision) to make existing settlements (infrastructure and buildings) safer against earthquake by formulating flexible urban design guidelines and linking them to the incentive mechanism. Such program might be site specific as well as time bound.

References

Aysan, Y. (1990). Social and Cultural Aspects of Community Vulnerability and Risk Communication,' In John Handmer and Edmund Penning-Rowsell (Ed), Hazards and the Communication of Risk, (pp. 319-336). Vermont, U.S.A.: Gower Publishing Co.

Bilham R (1999) Himalayan Earthquake (available on http://www.cires.colorado.edu~bihlam/indexHimEq.html)

Dangol, N., & Day, J. (2017). Flood adaptation by informal settlers in Kathmandu and their fear of eviction.

Davis, I., Haghebaert, B. & Peppiatt, D (2004) Social vulnerability and capacity analysis, ProVention project: tools for community risk assessment & action planning, ProVention Consortium, Geneva.

De Bono, A. (2013). Global exposure database for GAR 2013. *Geneva, Switzerland: UNISDR*, *39*.

LSGS (Lumanti Support Group for Shelter) (2003) A Situational Analysis of Urban Poor Communities in Kathmandu and Lalitpur, Kathmandu: Lumanti (unpublished paper).

Maharjan, S. (2022). Poor access to tackle fire in capital. The Rising Nepal. https://risingnepaldaily.com/news/10621

MoUD (2013). Planning norms and standards. Department of Urban Development and Building Construction. Available at: https://dudbc.gov.np/uploads/default/files/11fc96caa8c2194ab728796d5e9144cd.pdf

MOUD (Ministry of Urban Development) (2015). National Urban Development Strategy 2015. Ministry of Urban Development. Government of Nepal

Muzzini, E., & Aparicio, G. (2013). *Urban growth and spatial transition in Nepal: An initial assessment.* World Bank Publications.

Pandey (1999), Kathmandu Valley's Earthquake Vulnerability. Kantipur, Kantipur Publications, Kathmandu, 4 May (in Nepali).

Pelling, M. (2003a). Viewpoint: Disaster risk and development planning: the case for integration. *International Development Planning Review.* 25(4). pp. i–ix.

Pelling, M. (2003b). *The vulnerability of cities: natural disaster and social resilience.* Earthscan, London.

Pradhan, M. G. (2003). Urban Open Spaces in Kathmandu – Problems and Prospects. Vaastu, 5, 45-46.

Shrestha, B. K. (2010). Housing provision in the Kathmandu Valley: Public agency and private sector initiation, Urbani izziv, Vo. 21, No. 2, pp. 85-95.

Shrestha, B. K. (2011). 'Planned Housing Development in the Kathmandu Valley: From Land Pooling Projects to Private Housing Schemes,' Administration and Management Review, a Journal of the Nepal Administrative Staff College, January, Vol. 23, No.1, pp. 51-79.

Toffin, G. (2010). Urban fringes: Squatter and slum settlements in the Kathmandu Valley (Nepal). *Contributions to Nepalese studies*, 37(2), 151-168.

Identification of major problems associated with the performance of contractor with special focus on Belaiya-Butwal road sector of Rupandehi, Nepal.

Er. Darshan Tiwari [1*], Dr. Khet Raj Dahal[2] and Subik Shresstha[3]

[1] *Himali Danfe C. And Associate, Rupandehi, Nepal*

[2] *LIAST- Lalitpur Kathmandu, Nepal*

[3] *Water Resources and Irrigation Development Division Office, Doti*

[3] *Urban Development and Building Office, Doti*

[3] *Technical University of Munich, Germany*

**Corresponding email: erdarshan16@gmail.com*

Abstract

The construction business is alongside with resource scarcity, institutional weakness and general inability to deal with external issues like COVID-19 pandemic. Time, cost and quality control are important factors in construction systems. Character, increase in development and profit measure the establishment's success. The construction sector seems alone because it's running with liberal government guidelines. There's also evidence that the problems have extended and inflexibility in recent times, affecting and reducing the service production of contractor. The purpose of this study was to find out the causes contributing to the performance of contractor in road projects. This was conducted from April to September 2021. Documents reviews regarding Butwal- Belahiya road of Rupandehi district. ID and KI interview were carried out in this study. Total 72 repliers having experience of road construction were tracked. The achieved result suggested the contributing causes and effect of poor performance of a contractor and strategies to optimize the performance and output. Major causes contributing to the weak performance are payment interruption, absence of a competent project management team, ineffective planning of contractor, inadequate time and cost estimates, resource shortages, change in government regulations and traditional technology. Important strategies to optimize the performance were selection of a competent team to handle project management, review of a low bid awarding system and strict reward and punishment rule. Studies concluded ways of optimizing performance. Recommendations for this study are; timely payment; retention release; selecting a capable team, motivating management regularly; use of technology for project planning and controlling mechanism.

Keywords: *contractor's problems, project delay, performance, and strategies*

1. Introduction

Nepalese Construction business is fast growing industry inside the country which contributes around 10 to 11 percentages to GDP. Around 35 percent of government budget is procured with national contractors (Baral, 2009). In developing country construction industry is significant job creation and infrastructure. The inadequate progress of construction projects hampers development in many developing economies and can be linked to the insufficient implementation of project management best practices, project performance metrics, and critical success factors. These elements collectively form a complex set of variables that impact construction projects. Furthermore, this issue extends to a lack of understanding regarding the correlation of these variables, which may not be immediately apparent. Moreover, (Chen, 2012)emphasized the interconnection of these variables, highlighting their mutual influence. Understanding the dynamics of these relationships becomes crucial for effective management, resource allocation, and control. This research aims to explore the relationbetween project performance measures and project management practices from the perspective of a developing country. The outcome will be the formulation of a model that elucidates the mechanisms governing their relationships in the management of construction projects.

A study related to Nepalease contractors (Adhikari, 2013) highlights the challenges of industry as the primary challenges faced by contractors involve the completion of projects within stipulated timeframes while maintaining quality, a task often deemed challenging. This difficulty may arise from the inadequate availability of full-time technical personnel, equipment, or financial resources owned by the concerned firms. Reputed and well-established contractors encounter harassment from various political parties and hooligans, demanding substantial sums of money. This situation has instilled a sense of insecurity among these contractors. Inconsistent and ineffective government price escalation techniques, unfavorable contract terms for contractors, and intense and unhealthy competition during tendering, driven by existing policies, rules, and guidelines, contribute to demoralization within the contracting profession. Approval of the Lowest Bid; Taxation System; price change; brain drain; unavailability of construction material; user group as major problems of the industry (Baral, 2009). Federation of Contractor's Association of Nepal (FCAN) representative said "The government has not made the full payment of the remaining amount of the previous fiscal year. Around Rs. 4 billion as per the billing, is yet to be disbursed. The money of different suppliers involved in different projects is still due, therefore, suppliers are not being able to supply materials and give payments to their workers. How to work like this? The government needs to reduce projects which cannot see their completion." (Dahal, 2023).

Performance measurement, in construction business, are done as a systematic way of judging project performance by assessing the inputs, outputs and the final project outcomes (Roshana

Takim, 2002). Contractor performance is considered based on their (i) capacity to use resources efficiently, (ii) concern on being reasonable during contract modifications, (iii) ability to structure and work with teams, (iv) ability to continuously improve their internal employee capabilities through training, (v) complete project on time, and (vi) use of high quality materials and quality output (Tumutegyereize, 2013). The performance are also measured in terms of cost, time and quality. Nowadays sustainable development has been included into consideration to evaluate performance of contractor (Cooke-Davies, 2002). The same study identified ten possible indicators for effectiveness measures and are reviewed (client satisfaction on service, user satisfaction with product, project effectiveness, project functionality, free from defects, value for money, profitability, absence of any legal claims and proceedings, learning and exploitation and generate positive reputation). As per the other study, the contractor's financial stability, the contractor's past number and size of jobs completed in terms of quality and management capabilities, the contractor's failure records, and the contractor's capacity measures the overall performance of the contractor (Hosney, 2013).

A good construction practice of any construction project refers that it is free from defects, right things at right time and the continuous improvement of the project. It is measured with the time, cost, quality, and safety of the project which correlates with the finding of chiluwal and mishra (Chiluwal K, 2018).

The use of IT tools and software help Control and disseminate information, making it readily available and useful to project teams. (Bindu Aryal, 2023). As a result, the construction industry can benefit from increased productivity, cost savings, and improved project outcomes. Lack of sufficient digital expertise and the slow adoption of technology within the construction industry have been associated with cost inefficiencies, project delays, poor quality performance, uninformed decision-making, and overall poor outcomes in terms of productivity, health, and safety (A. Nikas, 2007). A study recommended measures for performance involve improved planning and monitoring, resolving technical issues, ensuring sufficient construction resources, realistic contract durations, effective team coordination, addressing political and climate concerns, proper budgeting, managing contracts, enhancing project management, and fostering better communication among construction project stakeholders (Bhatterai, 2023).

This study aimed to determine the major problems associated with performance of contractors in project execution like causes, effects and the probable strategies for solving them. This study was conducted on the TRIP Belhiya-Butwal area. The research has been concluded based on qualitative data which might be biased and limited respondents were consulted.

2. Materials and Methods

This research had attempted to access problems associated with the contractor working on road projects of Rupandehi District. Both explanatory as well descriptive research designs were employed in this research with the use of both primary and secondary data for analysis. Quantitative and qualitative method was being applied. Focus group discussion (FGD), in-depth interview (IDI), questionnaire survey, field observation of case study and review of official publication and certificates issued were implemented for this study.

Data collected from primary sources were coded and entered in excel sheet. Data were analyzed using excel. Major nine problems influencing performance were carried out through secondary and primary data collection methods respectively and also validated through statistical methods. These problems are; project related, design related , Client related , consultant related , contractor related problems, material related , labor related & equipment related , and external factors influencing performance. The RII of each cause contributing for weak performance were found out in these nine separate groups based on the views of the three types of respondents. Subsequently, based on RII value so obtained, ranking of all the attributes was done under each related group separately, based on the views of each respondent group. Nine groups are sub-divided into total 50 problems, top ten most significant problems affecting for performance of contractor were identified based on combined view of the respondents. Similarly six effects of lower performance are ranked and finally 10 top ranked strategies are suggested.

The RII is used to evaluate the ratings of the respondents. In this research, Likert 5-point scale has been used to determine relative importance index (RII) for the factors indicating status of problems, causes and effects of problems, solutions for the construction problems of settling basin construction. The value of RII is in the range of 0 to 1 (0 not inclusive). The higher the value of RII, the more important the attributes/variables of respected topic and ranked at top.

Table 1: Likert 5-point scale

Item	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Scale	1	2	3	4	5
Item	Very poor	Poor	Good	Very Good	Excellent
Scale	1	2	3	4	5

The formula for deriving RII for each factor is given (Duratul Ain, 2021)as follows: -

$$RII = \frac{\sum W}{AN} = \frac{5n5 + 4n4 + 3n3 + 2n2 + 1n1}{5N}$$

where W the load given to each factor by the respondent, ranging from 1 to 5; n5 number of respondents selecting total strongly agree or always; n4 number of respondents selecting agree or often; n3 number of respondents selecting neutral or sometimes; n2 number of respondents selecting disagree or rarely; n1 number of respondents selecting total strongly disagree or never;

and N the total number of respondents.

Related desk review, Field observation, in-depth interview, focus group discussion, and questionnaire are the major tools used during field investigation of this study. The study was conducted during the period of April to September 2021.

Table 2: List of case study road construction projects with major works asphalt paving drain and footpath construction work

S.N.	Name and Id of Road Projects	Contractor	Chainage in KM	Budget of Contract, Below Bid Percentage And Progress Status		
				Estimate Amount in	Below bid %	Status %
1.	TRIP/3372124/BB/073/074-001	Biruwa-Construction	0+000-0+750	228850396	17	70
2.	TRIP/3373124/BB/071/072-002 Achalpur-Lakhanchowk	Biruwa/-Shrestha/Apex J.V	6+200-9+000	635005548	23	100
3.	TRIP/337312/BB/071/72-05 Shakhuwani-Crimson Hospital	Tele -Comunication India Ltd.(TCIL)	15+000-18+000	684916196	18	100
4.	TRIP/337312/BB/071/72-03 Lakahnchowk -Kotihawa	Tele -Comunication India Ltd.(TCIL	9+000-12+000	675455478	0.9	100
5.	TRIP/337312/BB/071/72-04 Kothihawa -shakhuwani	Kalika/-Raymahji J.V	12+000-15+000	676516704	0.2	100
6.	CQMP/TRIP/BB-01-070/71 Dhandapul -Achalapur	Kalika/-Tamanag/Pacific J.v	0+750-2+200& 5+000-6+200	459821459	0.1	100
7.	TRIP/3373124/BB/073/074-003 Chauraha -Chidiyakhola	The -kanchanjunga-Biruwa JV kathmandu	24+500-27+500	534390226	18.9	65

3. Results and Discussion

Classification of respondents based on Profession

Out of a target of 100 respondents for the questionnaire survey, 72 valid responses were collected. The respondents included a maximum of government engineers (22%) related to road projects in Rupandehi and a minimum of consultants (12%) working in the design and study of road projects.

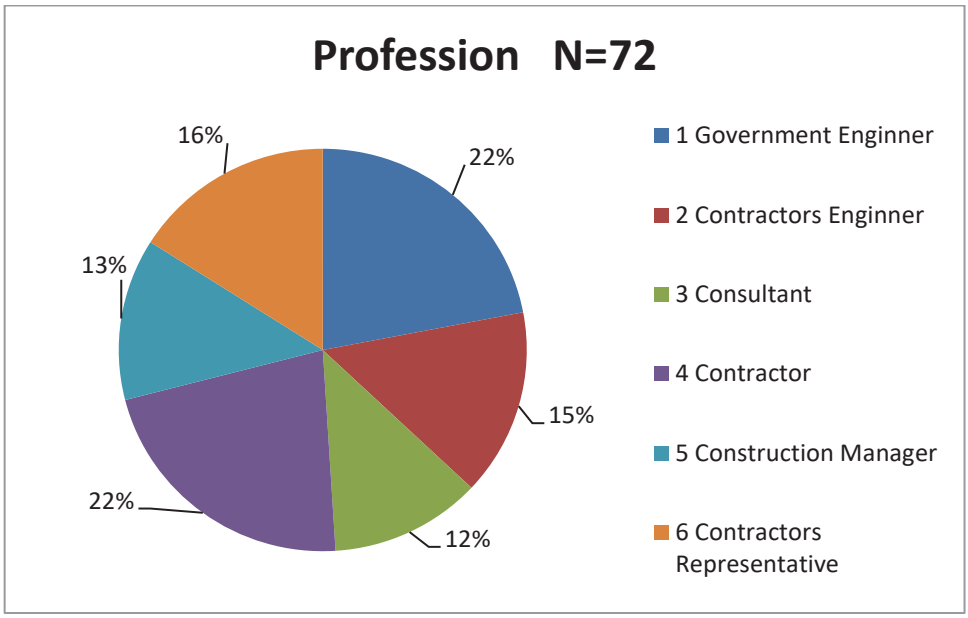


Figure 1: Classification based on profession (Field survey, 2021).

Problems in Performance of Contractors

Based on field observation and focus group discussion, 6 effects are assessed. The relative importance index (RII) is calculated using 5-point likert scale based on questionnaire survey. The survey results that common are time and cost overruns.

Table 3: Construction Problems

SN	Construction problems	RII
1	Payment interruption	0.881
2	Absence of competent management team in project management	0.864
3	Improper Coordination with project stakeholders	0.856
4	Inadequate time and cost estimates of client	0.839
5	Labor and construction material shortages	0.839
6	Ineffective planning and scheduling of project by contractor	0.836
7	Fails to manage of special equipment like Asphalt plant, paver, distributors etc.	0.822
8	External related problems like severe weather, pandemic, earthquake, strike etc.	0.822
9	Slow production rate due to heavy traffic and pedestrian	0.819
10	Change in government rules and regulations	0.819

Problems in Performance of Contractors (Case Study)

Table 4: Problems in Performance of Contractors (Case Study)

S.N.	Name Road Sections	Major factors influencing performance
1.	Belahiya-Bypass	✓ Interruption of Payment due to Election, Earthquake ✓ National Festivals, ✓ Unavailability of Material ✓ Heavy traffic ✓ Change of contractor personnel
2.	Achalpur-Lakhanchowk	✓ Several Payment delay ✓ Unavailability and Price Inflation of Material
3.	Shakhuwani-Crimson Hospital	✓ Partial Payment ✓ Election ✓ unavailability of construction materials ✓ Disputes with users ✓ Loss of life safety issues ✓ material scarcity, strikes
4.	Lakahn chowk -Kotihawa	✓ Improper coordination ✓ Payment delay due to election, ✓ Local festivals and Whether
5.	Kothihawa -shakhuwani	✓ Cause of Rainfall ✓ Payment delay due to election, strike
6.	Dhandapul -Achalapur	✓ Many payment interruption ✓ Three elections ✓ Inflammation in bitumen ✓ Change of project managers
7.	Chauraha - Chidiyakhola	✓ Stay Order from High court Tulsipur Dated 25th April 2018, 7th August 2019 ✓ Hold of contractor payment ✓ Price inflation ✓ Fail to manage heavy equipment

Effect of Problems in construction projects

A total of six effects that can arise from the cause of above problems in project are denoted by

"P" were identified and respondents' views were collected in 5-point scale. Relative importance of the impact of delays was found out by using RII methods.

Table 5: Major Causes of Construction Problems

SN	Effects in performance due to problems	RII
1	Time and cost overruns	0.836
2	Low quality output	0.814
3	Disputes among Projects stakeholders	0.808
4	Loss of reputation of client and contractor	0.783
5	Loss in revenue generation of country and	0.783
6	Poor management of projects	0.728

A number of variation orders are experienced in all contracts; hence, the estimates are not adequate, and all projects experience time and cost overruns. Time overruns are illustrated in Figure (3).

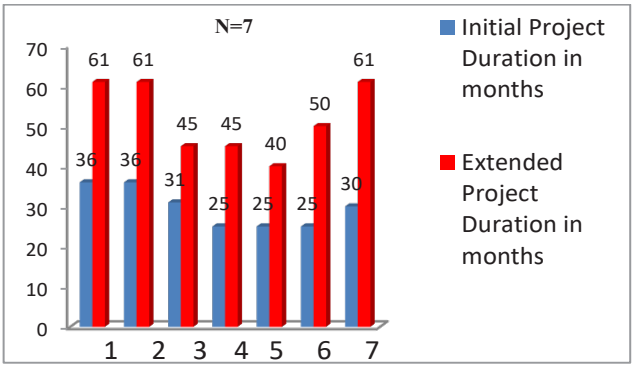


Figure 2: Time over runs of above listed projects

Strategies for optimizing contractor performance

Based on field observation and focus group discussion, a total of thirty factors for optimizing contractor performance relevant to this study were identified through review of previous studies. Relative importance of the strategy causes was found out by using RII methods. The ranking of the strategies for optimizing the performance of construction is presented in Table 4 in decreasing order of relative importance index.

Table 6: Strategies to optimize contractor performance

SN	Strategies to optimize performance	RII
1	Quick payment mode to contractor	0.867
2	Selection of competent management team	0.864
3	Coordination of project stakeholders in control and monitoring	0.858
4	Subsidy to contractor from government to buy equipment and up gradation of	0.853

SN	Strategies to optimize performance	RII
	industry	
5	Review of low bid evaluation system and polices to motivate contractor	0.853
6	Training to contractor for project management skills and techniques	0.850
7	Real time cost and time estimates	0.847
8	Series of meeting should be held within projects stakeholders	0.847
9	Political stability and rigid guidelines with proper reward and punishment system	0.836
10	Use of new technology for planning and monitoring like BIM, PMIS, Drones etc.	0.830

In IDI and FGD the factors influencing the performance of contractor in TRIP-project were discussed. The expert and seniors of industry Standouts payment system of government offices as lengthy process, absent of technical manpower to handle project, improper coordination as key problems. They quote time and cost overrun as effects and they suggest for quick payment mode of client and selection of competent project management team of contractor and client with establishment of proper communication.

4. Conclusions

The study concludes that delay makes cost overruns to employee and employer. Important factors reducing performance of contractor are payment related problems (RII=0.88) as same from case studies is the major problems for project execution of contractor. Change of government rules and regulations (RII=0.81) is a minor problem. In case studies also there is no any change in performance of contractor while many rules regarding procurement amendment. Absence of Competent management team (RII= 0.86) is next severe problem in managing day to day progress of contractor. These problems lead to cost, time overruns in project (RII=0.83) which is undesirable in projects as a result poor management of project (RII=0.72) is traced. To overcome this contractor has to pay timely (RII=.86) and Selection of competent management team (RII=0.86) are major strategies suggested optimizing contractor performance. To overcome from financial difficulties retention money can be paid to contractor after receiving bank guarantee. Nepalese construction industry needs capable managers to cope with changeable environment. Lastly industry is in need of collaboration with new technology (RII=0.83).

Acknowledgements

I am very much thankful to Er. Krishna Prasad Parajuli, Er.Sushil Bhusal(MoI) and Er. Subexya Sharu (DOR) and Project family of TRIP Project Rupandehi for their valuable suggestions and encouragement.

This research would not have been possible without the collective efforts of these individuals and institutions. Thank you for your invaluable contribution.

References

A. Nikas, A. P. (2007). Investigating antecedents and drivers affecting the adoption of collaboration technologies in the construction industry. *Automation in Construction*, 632-641.

Adhikari, S. (2013). Status of Class A Construction Entrepreneurs in Nepal . *GRIN Verlag*, 0-91.

Amend. (2012). *Foundation Preparation,*. United States Department of Agriculture.

Baral, S. (2009). Nepalese Construction Industry: Challenges and Opportunities. *Magazine*.

Bhatterai, M. (2023). Causes of Delay in Construction Projects in Nepal. *Saudi Journal of Engineering and Technology*, 109-114.

Bindu Aryal, D. C. (2023). Application of Information Technology in Construction : A Case From Nepal. *Apex Journal of Business and Management*, 91-102.

Biswas, A. K. (1989, December). Irrigation in Nepal: Opportunities and Constraints. *researchget.net*.

Boushehri, S. (2010, February). Design of Settling Basins in Irrigation Network Using Simulation and Mathematical Programming. *136*(2).

Calin, N. &. (2017, January). Dewatering system of a deep of excavation in urban area – Bucharest case study. Procedia Engineering.

Chen, Y. Q. (2012). Interrelationships among critical success factors of construction projects based on the structural equation model. *Journal of management in engineering 28.3* , 243-251.

Chiluwal K, M. A. (2018). Factors Affecting Performance of Small Hydropower ConstructionProjects in Nepal. *Journal of Emerging Techonologies and Innovative Research*, 262-271.

Cooke-Davies, T. (2002). The "real" success factors on projects. *International Journal of Project Management*, 185-190.

Dahal, R. (2023). Present Problems of Contractors. *FCAN* (p. 1). Kathmandu: FCAN.

Duratul Ain, M. N. (2021). Relative Importance Index (RII) in Ranking the Factors of Employer Satisfaction Towards Industrial Training Students. INTERNATIONAL JOURNAL OF ASIAN EDUCATION.

Hosney, K. N. (2013). Fuzzy clustering validity for contractor performance evaluation: Application to UAE contractors. *Automation in Construction*, 158-168.

Madan Kumar Shah, P. B. (2017). Factors affecting the failures of construction project in Nepal. *International Journal of current Research*, 1-4.

Mohamed, C. L. (2000). An exploratory study into recurring construction problems. *International journal of project management*, *18*, 267-273.

Murali Sambasivan, Y. W. (2007). Causes and effects of delays in Malaysian construction industry. *International Journal of Project Management*, *25*, 517-526.

Neupane, A. (2018). Contractual Issues for Hydropower Construction in Nepal. *Hydro Nepal: Journal of Water, Energy and Environment*, *23*, 56.

Nwachukwu, C. C. (2010). Quality Factor Indexes: A Measure to Project Success Constraints in A Developing Economy. *Interdisciplinary journal of contemporary Research in Business 2.2* , 1-8.

obeydele, S. O. (2021). Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges. *Journal of Building Engineering*.

Rateb J. Sweis, S. M. (2014). Factors Affecting Contractor Performance on Public Construction Projects. *Life Science Journal*, 28-39.

Roshana Takim, A. A. (2002). PERFORMANCE MEASUREMENT SYSTEMS IN CONSTRUCTION. *Research Gate*, 423-32.

Shah, R. K. (2016). An Exploration of Causes for Delay and Cost Overruns In Construction Projects: Case Study of Australia, Malaysia & Ghana. *Journal of Advanced College of Engineering and Management, Vol. 2*, 9-10.
shrestha, s. a. (2019). constrction delay in developing countries ; indian context. *research gate*, 1-8.
sign, R. (2019, july). *FCAN*. Retrieved from FCAN: www.fcan.org.com.np
Soil Cut Design. (2013, october). WSDOT Geotechnical Design Mannual, M-16.
Tumutegyereize, B. C. (2013). Measuring the performance of contractors in developing countries: ugandas context. *African Journal of Environmental Economics and Management* , 106-1112.
Yadav, S. A. (2016). *Analysis of Time Overrun and Cost Overrun Of Public health Buildings in Nepal.* Pokhara University: MSC, Nepal Engineering College Center of Post Grdaduate Studies.

Gender Issues In The Technical Field: A Path Towards Equity

Deepa Poudel[1], Pitamber Subedi[1*], Sushila Shrestha[1], Balaram Bhujel[2]

1. Institute of Engineering, Thapathali Campus, Tribhuvan University

2. Institute of Science and Technology, Trichandra Multiple Campus, Tribhuvan University

**Corresponding email:* pitamber.752416@thc.tu.edu.np

Abstract

This paper aims to examine gender dynamics within the technical field, with a specific focus on engineering education and the workforce. Acknowledging the complex interplay between gender identities, the research explores the nuances of social norms that sustain inequality in STEM fields (Science, Technology, Engineering, and Mathematics). The persistent gender gap in STEM is highlighted by global statistics, which has prompted a thorough investigation of the difficulties faced by women in technical field. Using a mixed-methods approach, the study combines information from the Nepal Engineering Council (NEC) and survey data, interviews, and insights from the Population Census of Nepal 2078 BS. The findings demonstrate intricate patterns of gender disparity in STEM education, with variations between urban and rural environments and between various ecological belts. In particular, during educational experiences and field visits, the paper emphasizes the impact of societal beliefs and biases that lead to unequal opportunities and biased treatment. Workplace issues like leadership discrepancies, wage discrimination, and political influence highlight the ongoing gender gap. The research provides detailed insights into the gender gap in engineering by analysing data from NEC. To effectively address gender disparities in engineering, the paper concludes with recommendations for targeted interventions at the workplace, educational institutions, and policy levels. Thos policies that support women in technical fields, inclusive workplace cultures and equal opportunities should be encouraged. This research serves as a crucial tool for understanding and dismantling deeply ingrained biases, contributing to the ongoing discourse on gender equity within the context of engineering in Nepal.

Keywords: *Gender Disparities; STEM Inclusion; Workplace Diversity; Technological Equity; Education Challenges*

1 Introduction

Gender, a complex interplay of identities, disparities, equity, and efficiency, profoundly influences human society, including the workplace. Traditionally categorized as male or female for simplicity, gender is now acknowledged as multidimensional, encompassing roles, attractions, and more.

This nuanced perspective leads to gender dynamics causing imbalances, culminating in pervasive gender inequality across life aspects, intricately woven into areas like marriage, families, work, the economy, politics, religions, arts, culture, and language. While recognizing a broader spectrum of gender identities, a binary classification is pragmatically used for analytical ease.

This perspective maintains the strength of the original paragraph, understanding gender as multidimensional. These dynamics contribute to the multifaceted issue of gender inequality woven into various aspects of life, including marriage, families, work, the economy, politics, religions, arts, cultural productions, and language.

The gender gap in science and technology becomes apparent as male and female approaches diverge, influencing life trajectories. Women show a greater interest in roles involving people, while men are drawn to positions featuring physical objects and abstract concepts, contributing to barriers and biases, notably in STEM fields.

Global statistics from UNESCO (2009) reveal that women constitute 29 percent of researchers globally, with regional variations. While Latin America achieves gender parity, Asia lags with only 18 percent female researchers. In Africa, women make up approximately 33 percent of researchers, with female participation exceeding 50 percent in biological sciences but remaining below 30 percent in physics, computer sciences, and engineering globally. The field of STEM, which is praised for its innovative and dynamic nature, still reflects a troubling scarcity of gender equality. Women remain disproportionately underrepresented in these important fields despite global advances in education and societal advancement, which raises serious issues with equity, diversity, and growth. Gender stereotypes give rise to the pitiful notion that women are less gifted and are thus less inclined toward the fields of science and technology. Although there are different formulations of the problem, the general issue is that females less often study mathematics, physical sciences, engineering, computer studies, and allied fields at every level of education from elementary school to graduate school (Robertson, 1988; Statistics Canada, 1990).. Sociological research on the gender gap explores shared beliefs influencing various facets, including housework, childrearing, math and science ability, occupational selection, and career trajectories.

On the other hand, attitudes toward gender and society have changed with time. Some sex differences in performance on mathematics tests, which once prompted complex bio-psychological theories of innate cognitive differences between males and females, have all but disappeared over time (Chipman & Thomas, 1987; Linn & Hyde, 1989; Sadker et al., 1991). However, outdated ideas continue to cast doubt on female representation in important disciplines that prioritize creativity and reason.

This study explores gender issues in technology, uncovering disparities' roots. Surveys and literature review unveil factors contributing to gender gaps in the Technological sector. Emphasizing industry perspectives, the research aims for a more inclusive Technological environment, recognizing gender disparity's broader impact on innovation and societal progress.

Additionally, the research addresses gender differences in engineering, examining a national sample of male and female engineers(Chipman & Thomas, 1987, p. 398) Beyond diagnosis, it explores strategies for gender equity, emphasizing male involvement, proactive measures, and advocating equitable opportunities. These efforts align with broader initiatives to reduce the gender gap in STEM fields.

2 Methods and Methodology

2.1 Data Collection

2.1.1 Questionnaire Survey

Google Forms was used in the study's survey-based methodology to gather primary data. The purpose of the survey, which consists of a few questions, was to investigate various viewpoints on gender issues in the technical profession. Internet platforms that catered to those who were either directly or indirectly active in STEM were used to reach the participants. The participants submitted their own opinions in response to the Google Forms. Ethical principles were closely adhered to during the data collection process in order to guarantee confidentiality.

2.1.2 Physical interview

Interviews were conducted with students, entry-level, mid-level, and professional individuals working in the technical sector using this data gathering strategy. When addressing gender-related issues, comparatively inconsistent outcomes were seen. The researcher's own experiences, which are a crucial component of this work, were also taken into account.

2.1.3 Secondary Data Collection via Census of Nepal

We obtained secondary data by doing a thorough review of the literature. Previous research studies from various sources were compiled and included in this investigation. During this process, webinars and video interviews with a number of well-known people were also assembled. Desk study of data from Nepal Engineering Council (NEC), Nepal Engineers' Association (NEA) and Census of Nepal was done to support our objective.

2.2 Data Clean-up and Validation

The data collected from various source is subjected to different amounts of venerability. The primary data should be cross checked before using and the sample Space should be selected in such a way that the sample data model the population. Selection of sample space is a tricky concept but very important for projecting the result for the population. The data thus collected from primary sources and secondary sources should be validated before using it. The data Processing was done to retrieve the necessary data only. The data was then subjected to different hierarchical data structures the primary goal of data pre-processing is to reorganize the necessary data and look whether the data given is valid or not. The hierarchical data structures is like the table where primarily the data is divided into 2 superclass (STEM and NON-STEM). The STEM class was primarily made up of fields: (Science and Technology, Health and Medical Science, Engineering, Agriculture, Animal science and Fishery, Forestry, Computing and Information Technology) and rest from Non-STEM. The STEM data is then further classified into Engineering and other faculty as the research primarily focuses on gender disparity in engineering field. Each division is further classified or categorized in two ways; one based on the development (Urban and Rural) and another based on the ecological belts (Mountain, Hill and Terai).

The Structure, Representation and hierarchy of data can be represented as follows

Table 1: Classification of Students Based on Choice of Field

	STEM	NON-STEM
Male	88173	1706066
Female	15892	1596229

Source : National Population and Housing Census 2021

Table 2: Classification of STEM Students

	Engineering	Other

Male	88173	1706066
Female	15892	1596229

Source : National Population and Housing Census 2021

Table 3: Classification of Engineering Students Based on Origin of Development

	Urban	Rural
Male	88173	14719
Female	15892	1849

Source : National Population and Housing Census 2021

Table 4: Classification of Engineering Students Based on Ecological Belts

	Mountain	Hill	Terai
Male	4013	53880	44999
Female	644	11279	5818

Source: National Population and Housing Census 2021

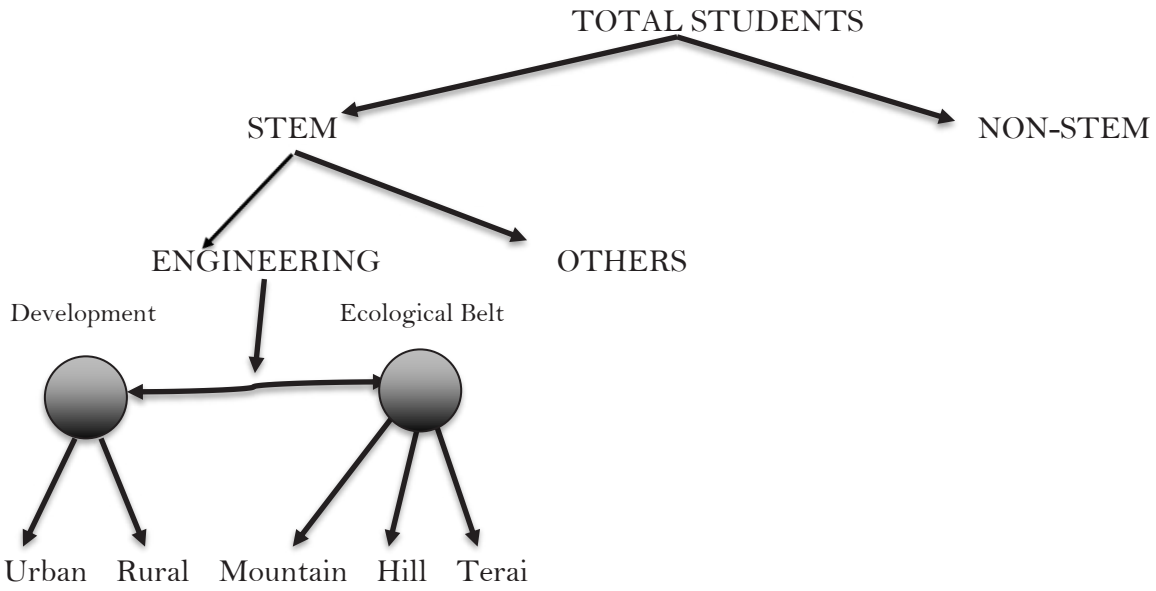


Figure 1: Hierarchical representation of data

2.3 Data Visualisation and Analysis

The data typically provides more than mere numerical values; it unveils underlying patterns, and the probability of occurrence signifies much more than a standalone figure. It offers an opportunity to extract specific data from a randomly selected pool, revealing the distribution of data across the population and illustrating the dynamics within. The hierarchical structure of the data, as depicted in Figure 1, signifies more than just a probability; it embodies conditional probability. This implies that the occurrence of an event is not isolated; instead, it is contingent on the selection of a preceding event. This concept delves into conditional probability and explores the implications of Bayes' theorem in the realm of probabilistic data analysis.

The graph in Figure 2 presents a substantial urban population (357,095 males and 214,544 females) as compared to the rural population (67,198 males and 31,532 females). Gender imbalances are apparent, with urban areas showing a larger male population. In contrast, the rural areas exhibit a more even distribution between males and females. The graph highlights a potential urban-centric gender disparity, highlighting the need for a deeper investigation into the factors contributing to this imbalance. Urbanization appears to influence gender dynamics, warranting attention to policies that address the unique challenges faced by males and females in both urban and rural settings.

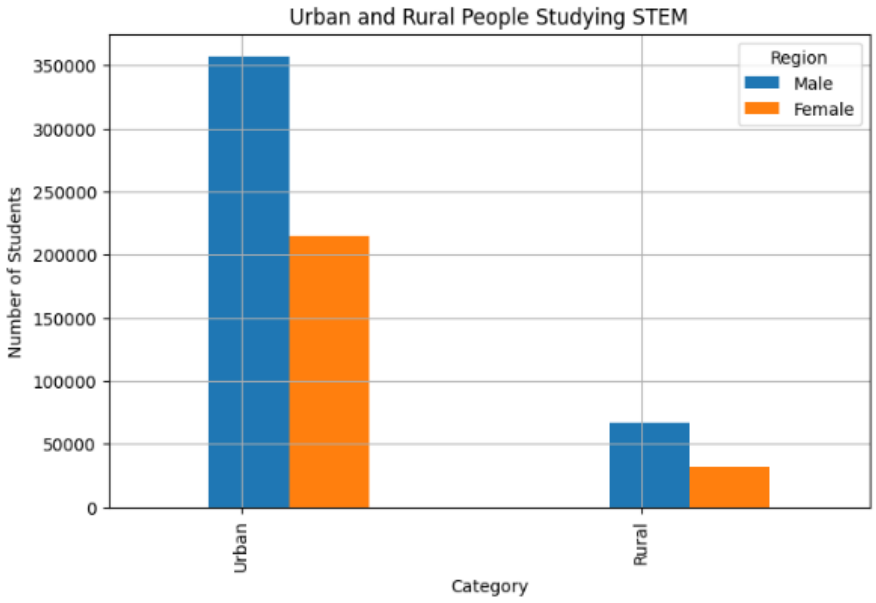


Figure 2: Urban and Rural people studying STEM

The graph in Figure 3 illustrates a substantial gender disparity in engineering studies, with a significantly higher number of males (88173) compared to females (15892). This gap persists in both urban and rural areas, emphasizing the need for targeted efforts to address gender

inequality in STEM education. The data underscores a broader issue and calls for initiatives to encourage and support female participation in engineering across diverse settings.

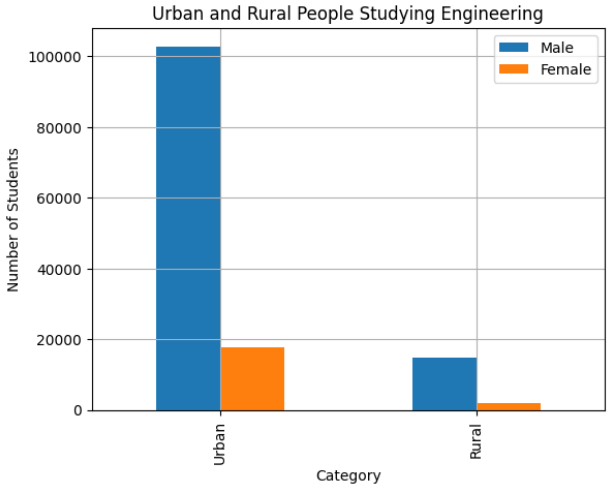


Figure 3: Urban and Rural people studying engineering

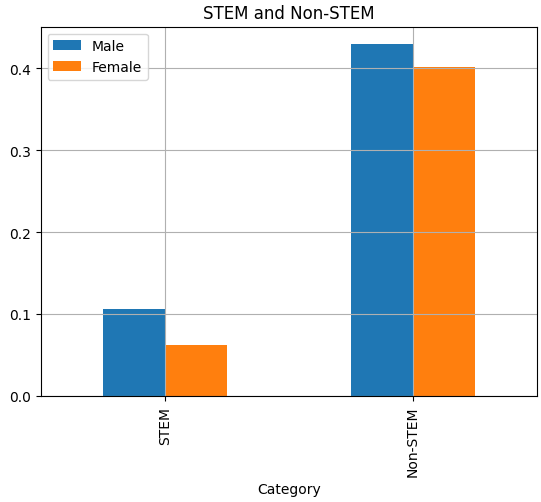


Figure 4: STEM and Non STEM

The graph in Figure 4 illustrates a stark gender disparity, revealing significantly higher representation of males in STEM fields compared to females. In contrast, non-STEM fields show a less pronounced gender gap. These findings underscore the ongoing challenge of gender inequality in STEM disciplines.

The graph in Figure 5 illustrates significant gender disparities in STEM education across ecological belts, with a notably higher number of males pursuing STEM in mountain and terai regions compared to females. In contrast, the hill region displays a more balanced distribution, indicating a potential area of progress in addressing gender inequality in STEM education. The findings underscore the need for targeted interventions to promote female participation in STEM fields, particularly in mountain and terai communities.

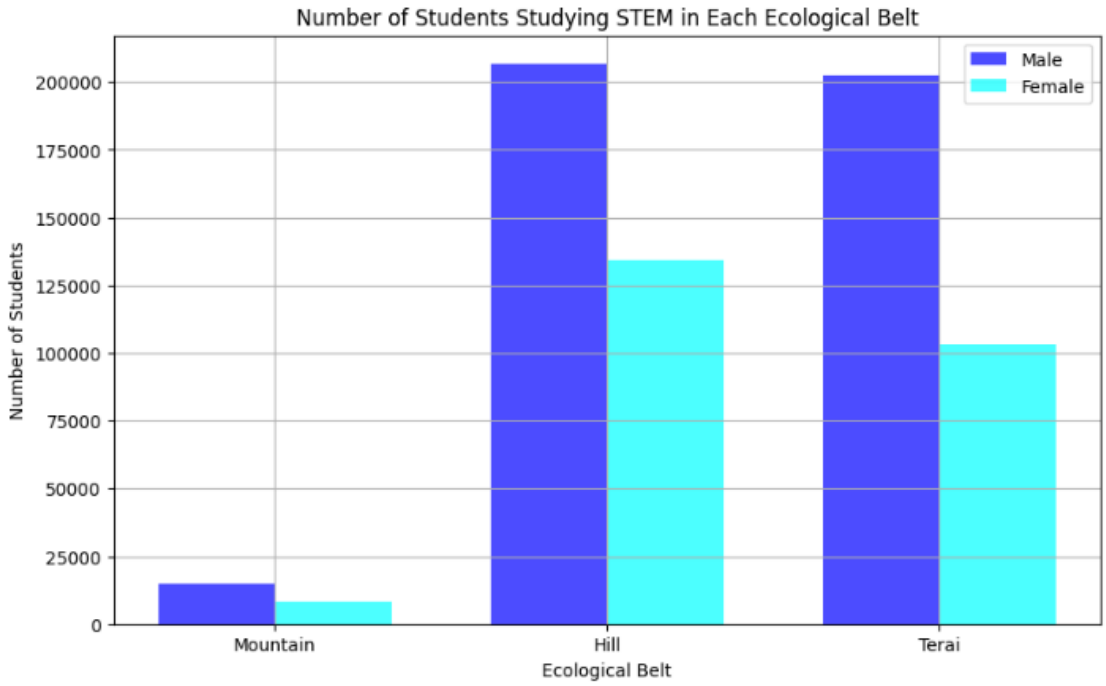


Figure 5: No. of students studying STEM in different ecological belts

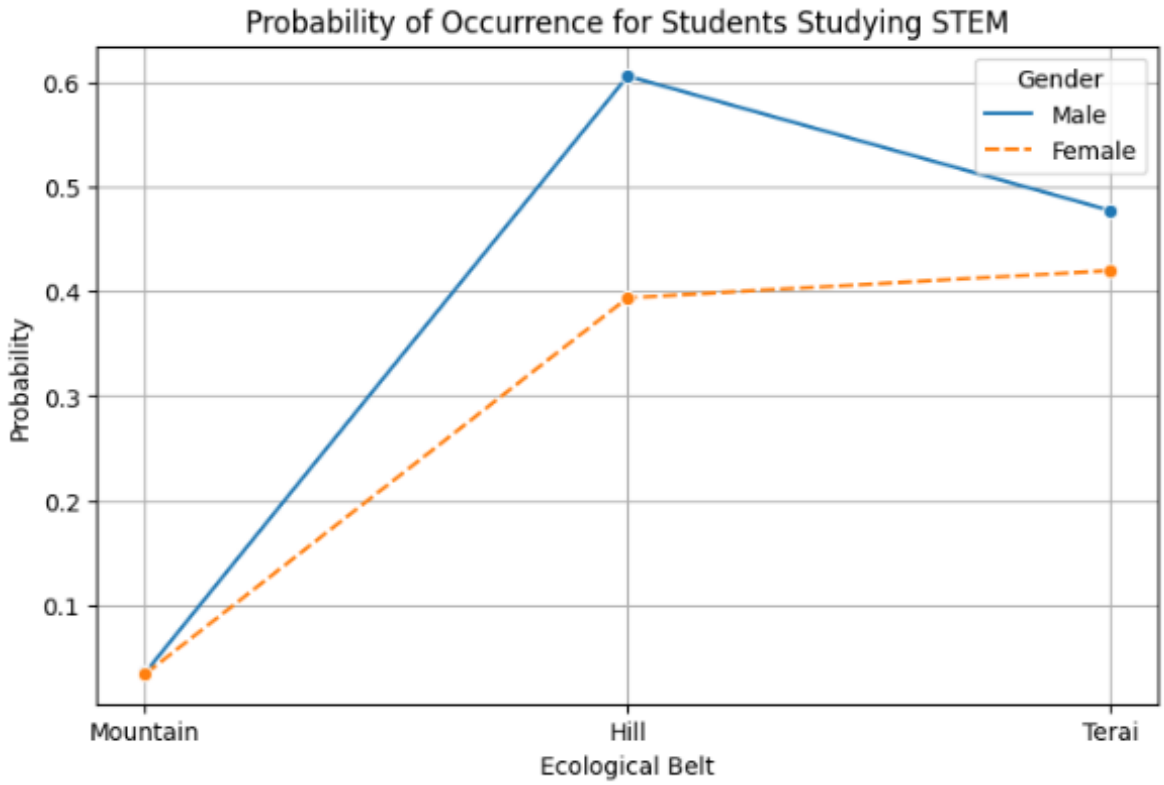


Figure 6: Probability of occurrence for students studying STEM

The graph in Figure 6 illustrates that the probability of male students pursuing STEM is highest in the hill region at 0.62, while female students show a slightly lower probability of 0.39 in the same region. Overall, the data highlights a gender disparity in STEM enrollment, with males having a higher likelihood of choosing STEM, particularly in the hill region.
The graph in Figure 7 illustrates a notable gender disparity in STEM education, with urban areas showing a higher probability of students choosing STEM (0.063) compared to rural areas (0.033). This discrepancy highlights a potential urban-rural divide in opportunities or preferences for pursuing STEM fields, emphasizing the need for targeted interventions to address gender inequality in STEM education across diverse settings.

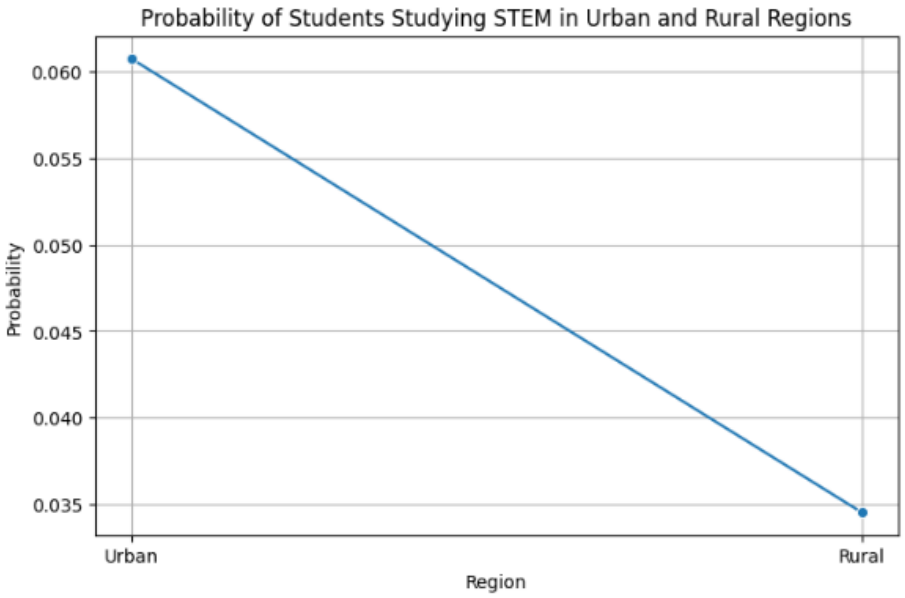


Figure 7: Probability of students studying STEM in urban and rural areas

2.4 Limitations

Convenience sampling's inherent bias potential is one of the study's primary shortcomings. The reliance on online platforms for participant enlistment may have resulted in biases among the sample population, hence affecting the findings' generalizability.

3 Results and Discussions

The online survey comprised 53% female respondents and 47% male. Among them, 74% were from Engineering, 11% from Architecture and 15% from other faculties (Geology, Information Technology, Agriculture, Management and Health sector). Domestic

respondents from within the country were 90% and the remaining 10% were from other countries. 47 % of the total respondents were students, 25% job holders, 10% both and 18% were unemployed.69 % participants were found to be below 25 years of age and 31% were above 25 years of age. Experience-28%mid-level (1-2 years of experience), 12% professional (2-7 years of experience), 60 % technical field students and entry level (less than 1 years of experience).

3.1 Educational Section

32% of the respondents complained of having witnessed biased treatments during lab and field works while the remaining 68% assured of neutral treatments. Lack or insufficiency of female instructors, and issues that affect women such as inadequate facilities for women in academic labs and classrooms (lack of sanitary supplies, private toilets, etc.) were found to not be given as much emphasis. Channeled patriarchal norms was found to be widely prevalent. Women have expressed dissatisfaction about not having had the opportunity to fully explore lab labour and investigations. Unfair treatment in lab tests, internal evaluations, viva, and other situations have been reported.

3.2 Entry Level

79% of the respondents agreed to the influence of politics in various organizations and 21% disagreed.

Table 5: Insights based on Category

Category	Insights
Demographics	• Gender Distribution: Despite a seemingly balanced overall gender distribution (53.2% male, 46.8% female), the analysis reveals underlying gender disparities in educational and professional spheres. • Related Field: The dominance of males in engineering (74.7%) and the minimal representation of females in architecture (11.4%) points to deeply ingrained gender norms dictating career choices. • Study Country: The overwhelming concentration of respondents in Nepal (89.9%) underscores the need to address gender inequality within the local context. • Status: The prevalence of students (46.8%) and the distribution of job holders (25.3%) and unemployed individuals (17.7%) reflect the broader socioeconomic landscape where gender disparities persist.
Lab Experiences	• The identification of gender-based inequality (67.1%) within lab experiences highlights the need for systemic changes to eradicate biased treatment, unequal opportunities, and biased instructor attention. • The alarming revelation that 62% of respondents have observed unequal distribution of internal marks signals a serious issue affecting academic progression.
Field Visits	• Gender-related disparities during field visits (16.5%) expose safety concerns, lack of recognition, and resistance to female leadership, pointing to deeply rooted societal norms impacting professional environments.
Academic Opportunities	• While 72.2% believe in equal academic opportunities, the existence of a significant 15.2% who are unsure suggests a lack of clarity and possibly latent gender biases influencing educational opportunities.

Field of Engineering Participation	• The perception of moderate female participation (44.3%) coupled with the acknowledgment of low participation (43%) underscores the challenges faced by women in pursuing careers in engineering.
Job Opportunities	• The observation that gender influences job opportunities (17.7%) and potential salary discrimination (29.1%) highlights structural issues within the professional landscape that perpetuate gender inequality.
Workplace Environment	• While 58.2% see a fair distribution of leadership roles, the acknowledgment by 41.8% of respondents who observe patterns where females lag behind underscores the persistent gender gap in workplace leadership.
Gender Inclusivity Initiatives	• The limited participation in gender inclusivity training (27.8%) coupled with the perception that recruitment and promotion processes are gender-neutral (49.4%) raises questions about the efficacy of current initiatives.
Legal Awareness	• While 43% feel well-aware of legal rights, the fact that 55.7% actively seek updates on relevant laws suggests a continuous struggle for gender justice, revealing gaps in legal protection and awareness.
Reporting Mechanisms	• The ambivalence towards reporting mechanisms, with 44.3% considering them ineffective, highlights a critical area for improvement in addressing gender-based issues and fostering a supportive and responsive environment.
Mentorship Programs	• The perception that mentorship programs support both genders (48.1%) and the significant neutral stance (29.1%) underscore the need for targeted efforts to enhance mentorship opportunities for women in engineering.
Recruitment and Promotion Processes	• While 49.4% perceive these processes as well-designed for gender neutrality, the substantial neutral stance (29.1%) indicates room for improvement in making recruitment and promotion more transparent and equitable.

Comfort with Job Conditions	• The varying levels of comfort with job conditions (44.3% comfortable, 27.8% neutral, 20.3% very comfortable) reveal the nuanced experiences of individuals, emphasizing the need for tailored interventions to ensure a supportive workplace.
Task Assignment Impact on Confidence	• The belief that the assignment of tasks based on gender reduces confidence (39.2%) brings attention to the psychological impact of gendered task assignments, urging a reconsideration of practices affecting professional self-esteem
Transportation Support for Overnight	• The lack of transportation support for 40.5% of respondents and uncertainty (34.2%) about its availability shed light on practical challenges faced by women in engineering, exposing gaps in support systems.
Communication on Job Conditions	• The agreement (45.6%) on the need for better communication during interviews about conditions that might impact comfort, especially for females, underscores the importance of transparency in recruitment processes.

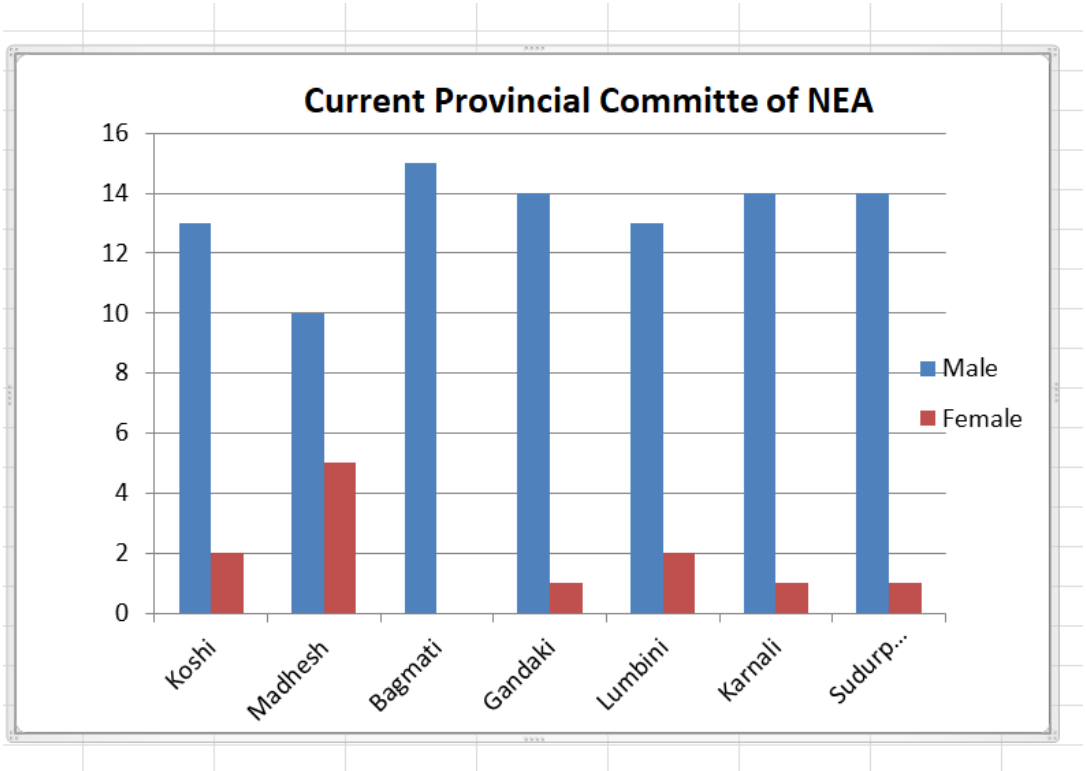


Figure 8: Current Provincial Committee of NEA

The chart in Figure 8 starkly reveals gender inequality in the Nepal Engineers' Association (NEA) provincial committees, as the female participation across provinces is uneven, with several provinces having minimal or no female representation. Additionally, the historical absence of a female president in NEA committee underscores the fact that females have a lower interest towards leadership positions which might be a result of an unsupportive environment and low-morale. The lack of female participation in the Nepal Engineer's Association might be attributed to the passive nature of female involvement in politics and leadership roles within the organization. This phenomenon underscores the need for targeted efforts to overcome barriers and encourage more active participation and leadership from women in engineering and related professional associations.

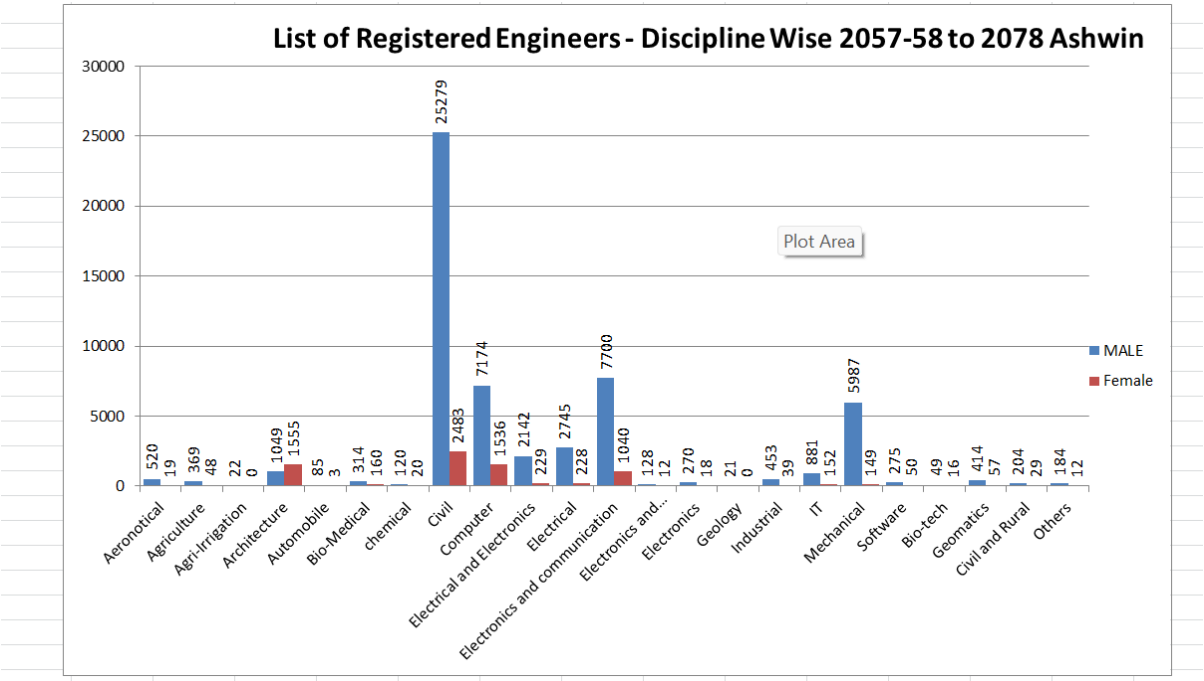


Figure 9: List of registered engineers in NEC? (2057 BS to 2078 BS)

The chart in Figure 9 portraying the distribution of registered engineers across various disciplines from 2057-58 to 2078 Ashwin reveals a glaring gender inequality in the field of engineering. The stark contrast in the numbers of male and female engineers within each specialty highlights a systemic issue that transcends individual disciplines. This gender gap can be attributed to a complex interplay of societal, educational, and workplace factors. Societal norms and stereotypes often discourage young women from pursuing careers in engineering, contributing to a lack of early interest and encouragement. Moreover, workplace environments within the engineering profession might not be conducive to gender diversity, potentially discouraging women from entering or staying in the field.

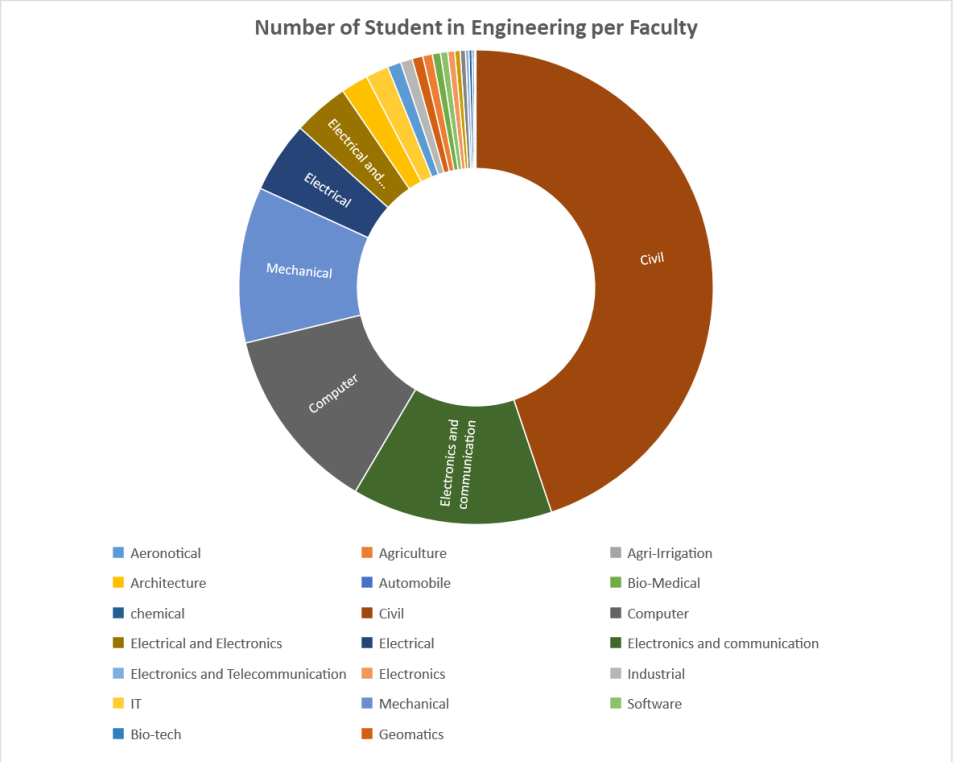


Figure 10: No. of students in different Engineering Faculties

The donut chart, derived from Nepal Engineering Council data, illuminates the popularity of civil engineering as the preferred discipline, likely influenced by historical demand and perceived job prospects. However, a concerning trend of gender inequality pervades all engineering fields, with consistently lower female participation. Notably, architecture bucks this trend, attracting more female students, suggesting potential insights for fostering gender diversity. To unravel why females may avoid engineering, societal expectations and stereotypes need addressing, emphasizing the urgency of targeted interventions such as empowering and encouraging female students from higher secondary levels to create inclusive environments and encourage women to pursue engineering careers.

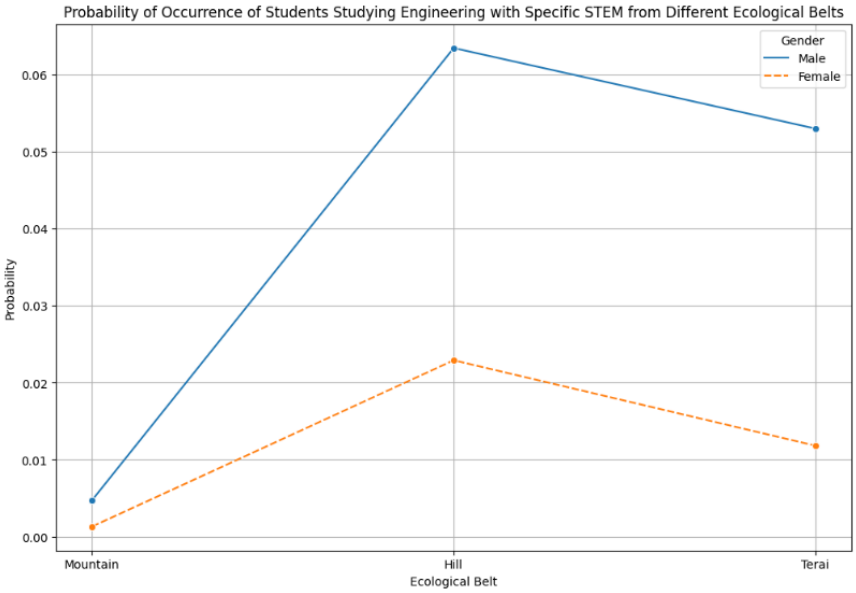


Figure 11: Probability of occurrence of students studying engineering with specific STEM from different ecological belts

The graph depicting the probability of individuals pursuing engineering within specific STEM fields across ecological regions reveals notable patterns. In terms of gender distribution, the probability of female students in the mountain region choosing engineering within STEM is 0.002, while for males, it is 0.005. Similarly, in the hill region, female and male probabilities are 0.023 and 0.0065, and in the terai region, they are 0.012 and 0.053, respectively. These probabilities reflect the likelihood of randomly selecting a student from each region pursuing engineering within STEM, indicating distinct trends in gender representation. Notably, the hilly region exhibits the highest probabilities for both genders, emphasizing the need for further examination of factors contributing to these disparities in the pursuit of STEM education, particularly in engineering, across different ecological belts.

4 Conclusions

In conclusion, the survey data presents a multifaceted view of gender dynamics in the Engineering landscape of Nepal. It reveals the challenges and insights into gender inequality in the field of STEM as a whole. Distinctive experiences faced by women highlights the gender disparities in the field. The survey also revealed unequal opportunities and biased treatment, especially during lab experiences and field visits. Instances of gender-based inequality, such as prioritizing male students in physically demanding tasks and prevalent stereotypes about female capabilities, surfaced as significant issues.

Educational inequalities were exposed through experiences of few female students in certain departments, leading to limited opportunities to fully explore their potential. The revelation that 67.1% of respondents noticed gender-based inequality in college lab experiences in itself presents a systemic problem that demands immediate concern. The conclusion that women are often underestimated, assigned to certain roles, and face biased treatment in various aspects of their career life, further highlights the need for comprehensive reforms.

Within educational institutions, the hidden layers of gender bias can be observed in the disparity in the distribution of internal marks based on gender (62% affirming this) and the belief that not all students have equal access to lab resources (47.1% confirming this issue). These findings not only highlight the prevalence of biased treatment but also emphasize the need for a systematic reform to ensure fairness in academic evaluation and resource allocation.

Moving into the professional realm, the survey delves into gender-related challenges in the workplace. A notable 60.8% of respondents acknowledged the influence of political connections in job opportunities. Salary discrimination (26.6%) averaging both in Academia and Industrial sector and the distribution of leadership roles (41.8%) were also recognized issues, suggesting a gender-based glass ceiling under which women's professional growth impedes. Although, it seems that the leadership is individual characterization ; which is true if viewed for a person , but when it comes for the population characterization, the selection of certain path, thinking pattern are resultant of their upbringing whether it is in school, workplace and thus development of the harsh mentality resulting the avoidance of path by most of them,

Similarly, analysis of data from secondary source also adds on the facts that women are lagging behind in the STEM field in general as the probability of occurrence from the Figure 6 and Figure 7 suggests. The probability of finding women studying from rural area is even low as in Figure 6 to around 3% only. This data gives us the enormous hit on fact of the lack of STEM education in general in Mountain region of country, but in the sophisticated ecological region as hill, there seems more skewness in gender biasness from 60% for male to 40% for female. The no. of women studying engineering is even low around 0.5% which is negligible as shown in Figure 11. The graph is furthermore supported by the surveys where it become clear for gender related biasness.

The workplace environment further came under scrutiny, with concerns about safety during overnight shifts, accessibility of support systems for gender-related grievances, and the notable finding that females were more commonly assigned tasks like making tea, indicating the persistence of traditional gender roles.

From our perspective, this survey serves as a powerful tool for exposing the intricate web of gender inequalities ingrained in both educational and professional spheres in Nepal. The data highlights not only the existence of these challenges but also the urgent need for targeted interventions, policy changes, and cultural shifts to dismantle the deeply rooted biases and create environments that foster true gender equality. The inclusion of qualitative responses adds a rich layer to the quantitative findings, providing a nuanced understanding of the daily struggles faced by women in engineering. This paper, therefore, contributes significantly to the ongoing discourse on gender issues, urging stakeholders to take concrete steps for a more equitable future.

5 Recommendations:

5.1 In the Workplace:

a) Equal Opportunities:

- Provide equal opportunities for employment, promotions, and career growth regardless of gender.
- Establish and implement laws prohibiting gender discrimination.

b) Flexible Work Policies:

- Promote remote work choices and flexible work hours.
- Provide men and women with family-friendly policies, such as parental leave.
- Promote and practise menstrual leave.

c) Inclusive Workplace Culture:

- Promote a varied and inclusive work environment where every individual is valued.
- Provide diversity and inclusion training to all staff members.

d) Leadership Development:

- Encourage women in technical roles to participate in leadership development programs.
- Support and guide women in leadership roles.

e) Networking Possibilities:

- Arrange forums and networking events where women in technical roles can interact, exchange experiences, and lend mutual support.

f) Address Implicit prejudice:

- Hold training sessions to increase knowledge of implicit prejudice and its effects.
- Put procedures in place to reduce bias in hiring and performance reviews.

g) Accountability and Transparency:

- Report and evaluate gender diversity metrics inside the company on a regular basis.
- Make the leadership responsible for creating an inclusive atmosphere.

h) Employee Education Support:

- Give women in the STEM field access to continual training and educational opportunities to help them stay up to date and updated.

5.2 Educational Institutions:

- Promote gender inclusivity in academic projects and extracurricular activities.
- Provide leadership opportunities for female students and encourage their active participation in labs and field visits.
- Offer scholarships to female students, especially those from remote areas in fields like engineering.
- Enhance gender-friendly facilities, such as separate toilets and access to sanitary products, to ensure the well-being of female students.
- Conduct awareness programs on gender discrimination and biases within educational institutions.
- Establish a GEDSI (Gender Equality, Diversity, and Social Inclusion) consultant in educational institutions.
- Encourage female students to pursue STEM education and create programs that break stereotypes and foster inclusivity.
- Ensure equal distribution of resources and opportunities for male and female students in labs and other academic spaces.

5.3 Policy Level

- Reservations for women in each hierarchy in institutes and offices to ensure women leadership in technical field (NEA, NEC, college administration, etc).
- Institutions like NEA and NEC should organize events targeting female population during their higher secondary education to encourage their involvement in technical field.
- Hard implementation of existing policies targeting women empowerment and involvement.
-

Acknowledgement

The Nepal Engineering Council, Minbhawan, Kathmandu; Nepal Engineers' Association, Pulchowk, Lalitpur; and the Nepal Statistics Office, Thapathali, Kathmandu are sincerely acknowledged for their invaluable contributions in providing Census data and various secondary data essential to this research.

Appreciation is extended to all volunteers who, directly and indirectly, dedicated their time and efforts to the survey, data analysis, and the formulation of policy-level recommendations. Their unwavering commitment significantly contributed to the success of this research.

Recognition is also given to Er. Shree Ram Pokharel, Er. Deepak Poudel and all other individuals and organizations that played a pivotal role, offering guidance, resources, and encouragement throughout the research process. Their collective efforts have been instrumental in bringing this research to fruition.

References

[1]. Beura, D. (2017, June 30). Gender gap in science and technology. *Granthalaya, 5*(June 2017), 324-330. Gender gap in science and technology

[2]. Beutel, A. M., & Marini, M. M. (1995). Gender and values. American sociological review, 436–448.

[3]. Charles, M., & Bradley, K. (2002). Equal but separate? A cross-national study of sex segregation in higher education. American sociological review, 573–599.

[4]. Gaskell, J., & McLaren, A. (1991). Women as mothers, women as teachers. Women and Education, 20–32.

[5]. Gaskell, J., McLaren, A., & Novogrodsky, M. (1989). Claiming an education: Feminism and Canadian schools (Vol. 7). James Lorimer & Company.

[6]. Megarry, J. (1984). Introduction: sex, gender and education. Acker, Megarry, Nisbet and Hoyle (eds), World Yearbook of Education, Kogan Page, New York.

[7]. Sadker, M., Sadker, D., & Klein, S. (1991). Chapter 7: The issue of gender in elementary and secondary education. Review of research in education, 17, 269–334.

[8]. Johnson, R. W., Sambamoorthi, U., & Crystal, S. (2002). Gender differences in pension wealth and their impact on late-life inequality. Annual Review of Gerontology and Geriatrics, 22, 116–137.

[9]. Konrad, A. M., Ritchie Jr, J. E., Lieb, P., & Corrigall, E. (2000). Sex differences and similarities in job attribute preferences: a meta-analysis. Psychological bulletin, 126, 593.

[10]. .Chipman, S. F., & Thomas, V. G. (1987). Chapter 9: The Participation of Women and Minorities in Mathematical, Scientific, and Technical Fields. Review of research in education, 14(1), 387-430

Empowering engineering innovation through ICT: a multidisciplinary approach to technology convergence

Suprima Shrestha-[1], Nilima Sangachchhe-[2],

[1] *College of Biomedical Engineering and Applied Sciences*

[2] *College of Biomedical Engineering and Applied Sciences*

**Corresponding email: suprimashrestha11@gmail.com[1], niligrace1@gmail.com[2]*

Abstract

Information and Communication Technology (ICT) has accompanied a new line of innovation, aiming to transform various engineering disciplines through its incorporation. This paper presents the ample role of ICT in facilitating the convergence of technologies, particularly emphasizing its potential impact in biomedical engineering. We explore pioneering advancements in the medical field in diagnosis and how the synergy of machine learning (ML), data analytics and advanced communication technologies leads to the creation of smarter and more efficient systems in medical field. This has been done by extensively examining pertinent literature indexed in databases like PubMed/Medline, Science Direct, SpringerLink, Scopus and EMBASE.

Here, we delve into practical applications of ICT, including machine learning driven cancer detection, MRI-based brain tumor identification and the reduction of high-dose X-ray radiations through deep learning image reconstruction (DLIR) techniques. This study further discusses ICT's contributions toward enhancing sustainability safety and resilience in bioengineering practices.

The research demonstrates the incorporation of ICT into healthcare, presents a significant opportunity to enhance disease diagnosis, and treatment selection and reduce radiation dose by 65-68 % with DLIR without compromising quality. Extensive datasets and ICT tools have been utilized to detect patters in medical data beyond human capability to keep track of intense data, improving various healthcare facets such as patient outcomes and preventive care, with greater accuracy, time efficiency and fewer human errors. Moreover, currently the highest accuracy for many ML diagnosis algorithms like skin cancer is at 87 %, which could be further enhanced by data manipulation techniques and comprehensive research.

Keywords: *Machine learning; MRI; image reconstruction technique; deep learning; image reconstruction algorithm; data manipulation technique*

1. Introduction

The dawn of the Information and Communication Technology (ICT) era has ushered in a transformative wave across various sectors, it is currently reshaping the engineering Field . This paradigm shift is most notable in the field of biomedical engineering. In this realm of engineering, the boundaries are being reshaped with the fusion of ICT. It is creating new hopes in biomedical engineering.

The healthcare industry is forever considered to be having challenges. As we move forward, the world demands better accuracy, efficiency and less invasive medical procedures. This requires a re-evaluation of traditional methodologies with the integration of ICT. As it can

handle large datasets, process complex information, and facilitate rapid communication, it is indispensable in current medical industry progress .

The current research activities in the world underscore the integration of ICT in revolutionizing healthcare facilities. With ICT, new diagnostic tools could be developed which are accurate, efficient and less invasive . ICT in medical field includes various techniques such as Artificial Intelligence which further consist of Machine learning (ML) and deep learning (DL). DL model can recognize complex patterns in pictures, text, sounds and other data to produce predictions or accurate outputs. In medical field, DL in exclusively used in biomedical images or sounds due to its abilities in extracting deep information.

This capability has led to significant contributions in areas like early cancer detection and brain tumor identification. For instance, the areas having data could be processed by the machine learning algorithm for its accurate detection of diseases. Furthermore, ICT plays a crucial role in mitigating the side effects of existing technologies. For instance, advancements in machine learning algorithms have allowed for generation of higher quality medical imaging at lower X-ray doses (McCollough et al., 2009).

Moreover, ICT is helping equally in remote health service access with various technologies such as telemedicine or telehealth which have capabilities of tracking remote monitoring such as high blood pressure, diabetes, heart conditions, asthma and so on. With the prompt response of the technology to the patients suffering from diseases, it has been trying to balance the available resources to the needful. Whereas the development has helped human being in medical aspects, the aim of ICT is not replacing medical professionals but making a revolution in traditional aspects of treatment .

However, integrating ICT in biomedical engineering is not without its challenges. Issues surrounding data security, patient privacy and the ethical implications of automated healthcare decisions are subjects of ongoing debate. The technical and infrastructural demands, especially in resource-limited settings, also pose significant challenges .

This paper aims to explore the medical industry's various areas and analyze specific ICT applications in biomedical engineering, focusing on machine learning for cancer and brain tumor detection. The paper further aims to provide a comprehensive analysis of ICT's role and its broader impacts on sustainability, safety and resilience in biomedical practices. Ultimately, this paper underscores the indispensability of ICT in the evolution of healthcare

technologies and its potential to enhance safety, sustainability, and resilience in the bioengineering community.

2. Materials and Methods

Strategy for literature search and criteria for selection

The research involved systematic exploration of recognized databases, including PubMed/Medline, Science Direct, SpringerLink, Scopus and EMBASE. This work was conducted without any time constraints but was confined to publications in English language.

Protocol for databases and key technologies used.

In analysis focusing on ICT's role in healthcare environment, we employed a thorough keyword search strategy. This strategy included various terms such as 'ICT in healthcare', 'ML in healthcare', 'DL in healthcare', 'AI in personalized medicine', 'AI in patient monitoring', 'AI and ethical considerations in healthcare', 'predictive analytics in healthcare', 'AI in medical diagnostic processes' and 'AI applications in healthcare sectors'.

Process of data collection

The selection of relevant publications was carried out through a detailed evaluation of their titles and abstracts or body paragraph. And, those studies that aligned with the predefined inclusion criteria were considered for further analysis.

3. ICT in biomedical engineering: a paradigm shift

Biomedical engineering stands at the forefront of healthcare innovation and ICT is currently serving at the edge of its innovative transformation. Accuracy, efficiency, and non-invasive procedures in the medical industry are not just ideal now, but with the help of ICT, they are achievable realities(Pantanowiz et al., 2020).

3.1 Advanced diagnostic tools

With ICT, many diagnostic tools can be developed. Convolutional Neural Networks (CNNs) have been trained to classify and segment brain tumors in MRI scans. For example, the BraTS (Brain Tumor Segmentation) challenge has produced numerous deep learning-

based approaches that are capable of distinguishing between different types of brain tumors with high accuracy .

Another case study is application of machine learning in dermatology. Algorithms have been trained on vast datasets of skin lesion images, aiding images in the early detection of skin cancers. This is a demonstration of how ICT can amplify the capabilities of medical practitioners and extend their research beyond the constraints of human limitations. As human beings are unable to keep records of large datasets and process them manually, ICT comes into play with big storage space .

ICT integration can slowly eliminate the traditional medical practice of biopsy and autopsy which requires rigorous medical expertise, consumes time and is cosmetically dangerous. ICT can be shown to reach what ideal non-invasive procedures in medical industry are aimed.

3.2 Enhancing treatment efficacy

Robotic surgery is one of the most prominent advances in medical procedures, whose accuracy comes from its integration with ICT. These surgeries are performed with robotic systems with ICT and controlled by surgeons. The key aspects are such as first of all, the robotic arms are capable of producing minute movements which can reduce human errors during rigorous surgeries. Second, robotic surgeries use sensors with high precision and controls allowing for quick action by the medical surgeons. Third, many robotic surgeries are performed using minimally invasive techniques, requiring only small incisions. This is beneficial for patients as it typically leads to less postoperative pain, lower risk of infection, shorter hospital stays and faster recoveries .

Additionally, prosthetics and implants have sensors that can respond to neural commands which helps it mimic and give users the satisfaction of natural limb movement. This is an ICT contribution to enhance the quality of life for amputees.

3.3 Deep learning in medical image processing

Medical Imaging in radiology is a field of medicine in which medical professionals recreate various images of parts of the body for diagnostic or treatment purposes. Medical imaging procedures include X-rays, Magnetic resonance imaging (MRI), Ultrasounds, CT scans and others. In these places, precise image analysis plays an important role in decision-making, in the patient care process, including detection, characterization, staging, and treatment

response assessment as well as guiding interventional procedures, surgeries, and radiation therapy. The large amount of data makes it difficult for radiologists and physicians to maintain efficient and accurate patient care.

Deep learning's capacity for pattern recognition has redefined medical image analysis. It is because early studies of deep learning applied to lesion detection or classification have reported superior performance compared to those traditional techniques or even better than radiologists in some tasks. This section will delve into a few algorithms and their applications, providing a detailed examination of the current state of Medical Image Processing (Arguello & , Kali S. Thomas, 2017).

3.3.1 Early detection of skin cancer

The occurrence of skin cancer has been on the rise in recent years (Thomasian et al., 2022). There are various types of skin cancer and some are lethal because they are widely spread through the body's lymphatic vessels and blood vessels. Thus, early detection/classification of skin cancer is very demanding .

However, classifying different types of skin cancer is difficult because of the subtle differences in how various categories look. The current landscape of skin cancer encompasses several well-known types including Actinic Keratosis, Basal Cell Carcinoma, Benign Keratosis, Dermatofibroma, Melanoma, Melanocytic Nevi and Vascular Moreover, very few dermatologists can properly diagnose skin cancer accurately with the highest accuracy of the best dermatologist accuracy being 80%. In this case, biopsy for proper identification comes into play carrying with itself huge challenges such as invasiveness which leads to scarring and other difficulties (Kadampur & Al Riyaee, 2020).

So, detecting the features with the help of a machine learning algorithms like VGG-16, Resnet, U-net and others is the current focus and area being well researched. In the realm of early detection and classification of types of cancers, the emphasis is on identifying algorithms that offer high accuracy and reliability .

There is no specific rule for parameter setting for models, but its selection plays a critical role in accurate classification . The algorithm selection can vary from various factors such as data types, quantified data and the number of classes to be identified and so on.

Recent algorithmic Approaches and performance matrix have been seen working well on the ISIC 2016 dataset using DenseNet for four classes of skin cancer with 98% classification

accuracy (Rajarajeswari et al., 2022). With the EfficientNet model for seven classes of cancer, the best accuracy has been 87.91 % as explained below.

Outcome with EfficientNet AlgorithmIn 2022, the HAM10000 dataset was trained on EfficientNets B0-B7, having 10015 images with 7 classes with 87.91% accuracy in the B4 variant. The accuracy could be increased by various approaches such as resolution scaling, data enhancement, noise removal and fine-tuning the CNN model. For the reliability of the model, various things are to be looked after such as metrics, accuracy and sensitivity.

In conclusion, the accuracy of the model could be increased by feeding qualitative data; data has a significant role in transferring the invasive detection of cancer to non-invasive detection of cancer/disease. The integration of these deep learning algorithms in medical imaging tools can significantly advance the early detection of cancer, ultimately leading to better patient outcomes and treatment strategies .

3.3.2 Brain tumor identification

Brain tumor identification is an arduous task for medical personnel and it becomes more difficult when it comes to classifying their types as there are various kinds of brain tumors such as meningioma, pituitary tumor and Gliomas. Noticing nuance details makes it very hard for human beings to classify tumors. Whereas the machine learning algorithms using their deep learning features can classify the tumors correctly, allowing for the needful treatment in a particular technique .

As brain tumor detection is one of the tedious processes in the health care areas, its data mining, classification and early diagnosis of diseases are more challenging steps to be followed. Deciphering every concealed detail within the brain images is an exceedingly challenging task. So, manually identifying various alterations across different regions proves to be an arduous endeavor. Moreover, while analyzing the images manually, it is time consuming, vulnerable to error and not efficient. Due to this, for early diagnosis and on-time treatment of brain tumors to increase the survival rate of patients, algorithms of machine learning involving various image enhancement techniques can provide effective ways for diagnosis of brain tumors.

Different multimodal features like morphology, texture, etc. can be extracted from the MR images along with the use of certain robust machine learning techniques that includes support vector machine, Decision Tree, Logistic regression classifier and so on. These

techniques can then decide the tumor in the brain after applying to the available data sets of brain images. Also, the main objective being performed these days is to identify which particular techniques would cater the highest accuracy that ultimately lead to the better identification of brain tumors. Therefore, computer aided diagnosis has been built up to increase the efficiency to distinguish particular brain tumors for radiologists .

As brain tumor has been a deadly cancer across the world, identifying the abnormal one itself is a challenging task whilst to point out such on the basis of size, grade, shape and area would be more difficult. For classifying these variations, machine learning and deep learning can take a giant leap with the inclusion of techniques for extraction, segmentation and classification purposes .

For instance, Glioma, being one of the common brain tumors, specific model has been developed with the utilization of image processing and artificial neural network. This developed model is an automated glioma detection procedure where Histogram Equalization, for improving the contrast of an image and Gray level co-occurrence matrix, for feature extraction are processed. After the performance accuracy is trained and tested by Probalistic neural network classifier, tumor location can be perceived. In fact, the use of this classifier has been proven to be 90.9% accurate. This accuracy rate can be increased using other efficient optimization techniques such as Particle swarm optimization .

This shows that there are different options available to increase the accuracy, sensitivity and specificity. Realizing this, it tends to be a difficult task for manual handling and identification of brain tumors. Thus, this depicts how the use of neural network classifier provide us the efficient way to view the brain tumor in an automated way. Not only incorporation of medical imaging and deep learning architecture can evolve but can change the manual analysis of any brain images into fully automated platform. In the same way, to eradicate the vulnerability to error, evolutionary algorithms and reinforcement learning through transfer learning can be deployed so as to illustrate multi-classification of brain tumors. Here, the automated classifier has been developed by the utilization of different CNN Models in which the best one with higher accuracy accounted for NASnet . This presents how the computer aided diagnosis with high precision can fulfill the void in the current scenario of brain tumor identification and classification.

These researches are just some instances that machine learning algorithms significantly aid in identifying and analyzing brain tumors by swiftly processing vast amounts of brain

images, enabling accurate predictions and informing healthcare professionals about insights into diagnosis, prognosis and treatment options.

3.4 Reducing risks with innovative imaging

The risks associated with medical imaging, particularly radiation exposure, are significant. This section will focus on innovative methods that ICT has developed to mitigate these risks.

3.4.1 Image reconstruction techniques

Prolonged, high-dose radiation exposure during a CT scan can cause adverse health effects, such as skin erythema (reddening), skin tissue injury, and birth defects following in-utero exposure. There is also a small probability of mutation in offspring and cancer due to the high radiation dose . ICT has played a good role in reducing such risk by maintaining the quality of imaging with low-dose.

The decrease in dose is possible with the help of techniques such as deep learning image reconstruction (DLIR) techniques. Along with that there are various ways for image reconstruction techniques such as Filtered Back Projection (FBP), Model-Based Iterative reconstruction (MBIR) and other. Starting from 5 minutes per scan to a few seconds now technology has played a major role (Koetzier et al., 2023). In research conducted in 2021, the radiation dose was reduced by 65-68 % on comparable quality images, one with DLIR and one normal. In 2023 this technology further advanced reducing dose by 75 % keeping SNR high and less noise in the image quality for chest X-ray . Amongst all image reconstruction techniques, DLRT has good performance because it depends on the quality of the trained data, the more qualitative the training data, the output is more noise free. This method is proven to have fewer artifacts and noises than the other methods.

Using deep learning techniques/ algorithms such as U-net can create a high-quality image in a short time with shorter projections. Various ML models such as U-net can reduce the patient exposure to X-rays which is a significant contribution of ICT in radiation therapy.

ICT has great impact in the field of radiology with the help of cutting-edge techniques, enabling significant reductions in radiation exposure during scans, improving the speed and efficiency of imaging processes and enhancing the overall quality of diagnostic images. This evolution marks a critical stride in balancing patient safety along with increasing the technological efficacy of radiation therapy.

3.5 Broader Impacts of ICT in Biomedical Engineering

One of the impactful contributions of ICT in BME is Telehealth, which is a combination of computer science, medical technologies and informatics. For example, patients can get rid of their chronic diabetes with sensors connected to them and medical professionals can keep track of them which helps prevent the situation get worse. More than 1.6 billion people have anemia which exists among underprivileged children and women due to iron deficiency. Due to the contribution of ICT, a smartphone/smart watch can analyze the anemia with a drop of blood which can be accessed remotely by medical personnel. These innovations with the help of ML algorithms also get rid of waiting weeks to get an appointment. Cardiovascular diseases take 17.9 million lives each year. So, scientists are developing wearable devices that can detect early sign of Atrial fibrillation (AF) and congestive heart failure (HF) which can help patient cure in future.

These technologies have transformed the healthcare system, changing from a need for physical presence to remote monitoring with technologies such as the Internet of Things (IoT), cloud, blockchain and techniques such as reinforcement learning which can help in the early detection of diseases.

This increasing need for AI in the medical field in both diagnosis and preventive care has suggested the demand for the ICT-Medical field in the future .

3.5.1 Sustainability in healthcare technology

Healthcare, especially clinical labs, is significantly known to contribute more carbon emissions and waste to the environment whereas digital transformation aims to enhance healthcare service effectiveness and reduce waste. The following points justify ICT for sustainability in healthcare .

3.5.2 Balancing systems for sustainable healthcare

Telehealth has the potential to reduce carbon emissions due to the reduced daily commute of health professionals, although research is limited. Recently, economic models have changed from the linear "take-make-dispose" to circular models based on recycling and upcycling that have the goal of keeping products, components, and materials at their highest utility and value. The previous linear models threaten human health and well-being and harm natural ecosystems .

Digital transformation promotes resource efficiency within healthcare organizations which is sustainable within the organization.

3.5.3 Smart waste management and ehealth initiatives

Digital transformation can improve smart waste management, reducing the cost of services. Examples include national e-prescription systems and widespread use of ICT for e-health applications, leading to decreased paper use and waste generation.
There is growing interest in sustainable development throughout the worms which is further depicted by software-as-a-service(SaaS) solutions for environmental and social protection (Sciarretta et al., 2022).

3.6 Ethical and Privacy Considerations

In the era of data-driven healthcare, protecting patient privacy has become important. With machine learning (ML) and deep learning systems increasingly used for predictive analytics using sensitive user data, there's a growing concern such as bias, quality data, privacy, data protection, medical consultation, sympathy and empathy.

3.6.1 Data privacy and security

With the increasing digitization of health records, ensuring the confidentiality of patient data becomes very important. However, there's a risk of unauthorized access, data breaches, and misuse of sensitive information . The problems associated with it are like unauthorized use of personal data, the use of big data in healthcare raises moral questions, especially when it comes to unauthorized use of personal data in predictive analytics. This not only poses a threat to patient trust but also risks exposing sensitive information like genetic sequences and medical histories. Also, AI technologies profoundly affect HIM practices. Automated medical coding, data management and governance are all areas where AI's influence is evident. However, these advancements come with concerns about patient confidentiality and data privacy.

Solutions for privacy preservation:

First of all, patients should be fully informed about how their data is used and must consent to it, especially for purposes beyond direct healthcare, like research . Along with that, collecting only the data that is necessary for the intended purpose respects patient privacy. After doing so, implementing robust security protocols, encryption and access controls is

essential to protect data from cyber threats . Adhering to regulations like HIPAA in the U.S., GDPR in Europe and other local data protection laws is crucial . Furthermore, instilling Homomorphic Encryption (HE) allows for computations on encrypted data, maintaining privacy and enabling secure processing without decryption Finally, using secure Multiparty Computation (SMPC) enables collaborative computation of sensitive data without exposing individual data sets, achieved through methods like garbled circuits and secret sharing .

As healthcare continues to integrate more deeply with technology, finding a balance between leveraging big data for medical advancements and protecting patient privacy remains a critical challenge. Implementing robust security measures and adhering to ethical guidelines is not just a technological necessity but a moral imperative in preserving the trust and safety of patients in the digital healthcare era .

3.6.2 Data biases

AI algorithms in healthcare are influenced by biases present in healthcare data. This includes both explicit and implicit biases, which can arise from various factors such as clinical trial eligibility, real-world treatment decisions and demographic variables like sex and ethnicity .

These biases can lead to healthcare inequities, affecting clinical decision-making and the effectiveness of AI in healthcare. This is particularly evident in the poor implementation rates of healthcare services and AI tools in specific demographics, including rural areas, racial and ethnic minority groups, uninsured or underinsured individuals and those with lower education and income.

Addressing these inequalities requires a comprehensive approach, but it's challenged by the need for diverse data, transparent algorithm development and a diverse research team. Additionally, the adoption of AI in healthcare is hindered by the lack of adequate infrastructure, especially in low-income and middle-income countries (LMICs) .

Solutions includes Public Health Approach by Khoury et al, this approach suggests targeted interventions, policy development and establishing efficient delivery systems as key strategies.

First, it involves community engaging with communities to understand and address their specific healthcare needs. Second, focusing on diverse data collection: gathering data from

varied demographics to reduce biases in AI algorithms. At last, ethical algorithm development by developing AI algorithms transparently and ethically to ensure that they do not perpetuate existing biases.

3.6.3 Data quality in AI applications in healthcare

The integration of Convolutional Neural Networks (CNNs) into healthcare, especially for processing non-imaging data such as genetics, clinical data and imaging, faces significant challenges, primarily due to the need for large datasets and the current limitations in data availability. CNNs require substantial and diverse datasets to train effectively and make accurate predictions.

However, in healthcare, there's often a scarcity of such large-scale, high-quality data, partly due to privacy concerns, logistical challenges in data collection and the need for data that is not only extensive but also highly accurate and representative of various patient demographics. This scarcity and the resulting data quality issues can severely impact the performance and reliability of CNN models in healthcare applications. Additionally, the complexity of transforming different types of healthcare data into a format suitable for CNN processing adds another layer of difficulty, further emphasizing the need for robust and comprehensive data collection and pre-processing methods in the healthcare sector .

To effectively address the challenges faced by Convolutional Neural Networks (CNNs) in healthcare, particularly around the need for large and high-quality datasets, a multi-faceted approach is necessary. Firstly, enhancing data collection and sharing is crucial. This involves establishing more robust mechanisms for data collection across healthcare institutions and encouraging data sharing, while carefully respecting privacy and ethical considerations. This approach would significantly increase both the volume and diversity of available data .

Additionally, implementing advanced data augmentation techniques can artificially expand existing datasets, creating a broader training base for CNNs. Ensuring data quality is also paramount which can be achieved through meticulous pre-processing, cleaning and validation processes. Another promising solution is leveraging federated learning, allowing for the training of CNN models on decentralized data, thereby addressing privacy concerns effectively. Specialized techniques to transform non-imaging healthcare data into a format suitable for CNN processing are also essential, ensuring the integrity and significance of the

original data are maintained. Furthermore, fostering public-private partnerships can provide access to more extensive datasets and advanced AI technologies .

Finally, supportive regulatory frameworks and incentives for data sharing can motivate more institutions to participate in collaborative data pooling efforts. Together, these strategies can help overcome data limitations and quality issues, enhancing the performance and reliability of CNNs in healthcare applications.

4. Conclusion

In "Empowering Engineering Innovation through ICT: A Multidisciplinary Approach To Technology Convergence", the potential of ICT in healthcare, especially in biomedical engineering, is immense. This convergence has shown promising results in areas like early cancer detection, brain tumor identification and the reduction of high-dose X-ray radiations through deep learning image reconstruction techniques. However, there remains a significant need for further research to enhance the accuracy of these technologies. Our studies based on recognized databases, including PubMed/Medline, Science Direct, SpringerLink, Scopus and EMBASE have demonstrated the possibility of reducing radiation dose by 65-68% without compromising quality and achieving up to 87% accuracy in skin cancer diagnosis using machine learning algorithms. These advancements, while impressive, underscore the need for continuous innovation and meticulous research, particularly in refining data quality, addressing privacy concerns, and improving the precision of diagnostic tools. The integration of ICT in healthcare promises not only to revolutionize patient care and outcomes but also to lead us towards a future where healthcare is more accessible, efficient, and patient-centric, provided we commit to overcoming the current limitations and exploring new frontiers in technology and medical science.

It is important to address limitations such as data privacy and security, bias and lack of quality data to ensure equitable and effective use of AI. Several measures must be taken to ensure responsible and effective implementation of AI in healthcare.

Firstly, comprehensive cybersecurity strategies and robust security measures should be developed and implemented to protect patient data and critical healthcare operations. Collaboration between healthcare organizations, AI researchers, and regulatory bodies is crucial to establishing guidelines and standards for AI algorithms and their use in clinical

decision-making. Investment in research and development is also necessary to advance AI technologies tailored to address healthcare challenges.

AI algorithms can continuously examine factors such as population demographics, disease prevalence and geographical distribution. This can identify patients at a higher risk of certain conditions, aiding in prevention or treatment. Edge analytics can also detect irregularities and predict potential healthcare events, ensuring that resources like vaccines are available where most needed.

Public perception of AI in healthcare varies with individuals expressing willingness to use AI for health purposes while still preferring human practitioners in complex issues. Trust-building and patient education are crucial for the successful integration of AI in healthcare practice. Overcoming challenges like data quality, privacy, bias and the need for human expertise is essential for responsible and effective AI integration.

Collaboration among stakeholders is vital for robust AI systems, ethical guidelines and patient and provider trust. Continued research, innovation, and interdisciplinary collaboration are important to unlock the full potential of AI in healthcare. With successful integration, AI is anticipated to revolutionize healthcare, leading to improved patient outcomes, enhanced efficiency and better access to personalized treatment and quality care.

References

1. Abdelminaam, D. S., Madbouly, M. M., Farag, M. S., Gomaa, I. A., Abd-Elghany Zeid, M., & Abualigah, L. (2023). ML_BrainDetection: An Intelligent Model for Brain Tumor Identification Using Machine Learning. *3rd International Mobile, Intelligent, and Ubiquitous Computing Conference, MIUCC 2023*, 429–435. https://doi.org/10.1109/MIUCC58832.2023.10278309
2. Abedalla, A., Abdullah, M., Al-Ayyoub, M., & Benkhelifa, E. (2021). Chest X-ray pneumothorax segmentation using U-Net with EfficientNet and ResNet architectures. *PeerJ Computer Science*, *7*, 1–36. https://doi.org/10.7717/PEERJ-CS.607/SUPP-1
3. Ali, K., Shaikh, Z. A., Khan, A. A., & Laghari, A. A. (2022). Multiclass skin cancer classification using EfficientNets – a first step towards preventing skin cancer. *Neuroscience Informatics*, *2*(4), 100034. https://doi.org/10.1016/j.neuri.2021.100034
4. Alowais, S. A., Alghamdi, S. S., Alsuhebany, N., Alqahtani, T., Alshaya, A. I., Almohareb, S. N., Aldairem, A., Alrashed, M., Bin Saleh, K., Badreldin, H. A., Al Yami, M. S., Al Harbi, S., & Albekairy, A. M. (2023). Revolutionizing healthcare: the role of artificial intelligence in clinical practice. *BMC Medical Education*, *23*(1), 1–15. https://doi.org/10.1186/s12909-023-04698-z
5. Amann, J., Blasimme, A., Vayena, E., Frey, D., & Madai, V. I. (2020). Explainability for artificial intelligence in healthcare: a multidisciplinary perspective. *BMC Medical Informatics and Decision Making*, *20*(1), 1–9. https://doi.org/10.1186/s12911-020-01332-6
6. Arguello, D., & , Kali S. Thomas, P. D. H. B. L. M. M. G. E.-L. M. (2017). 乳鼠心肌提取 HHS Public Access. *Physiology & Behavior*, *176*(1), 139–148. https://doi.org/10.1007/978-3-030-33128-3
7. Asiri, A. A., Shaf, A., Ali, T., Aamir, M., Irfan, M., Alqahtani, S., Mehdar, K. M., Halawani, H. T., Alghamdi, A. H., Alshamrani, A. F. A., & Alqhtani, S. M. (2023). Brain Tumor Detection and Classification Using Fine-Tuned CNN with ResNet50 and U-Net Model: A Study on TCGA-LGG and TCIA Dataset for MRI Applications. *Life*, *13*(7). https://doi.org/10.3390/life13071449
8. Bleher, H., & Braun, M. (2022). Diffused responsibility: attributions of responsibility in the use of AI-driven clinical decision support systems. *AI and Ethics*, *2*(4), 747–761. https://doi.org/10.1007/s43681-022-00135-x
9. Boulemtafes, A., Derhab, A., & Challal, Y. (2020). A review of privacy-preserving techniques for deep learning. *Neurocomputing*, *384*, 21–45. https://doi.org/10.1016/j.neucom.2019.11.041
10. Fragão-Marques, M., & Ozben, T. (2023). Digital transformation and sustainability in healthcare and clinical laboratories. *Clinical Chemistry and Laboratory Medicine*, *61*(4), 627–633. https://doi.org/10.1515/cclm-2022-1092
11. Gezahegn, Y. G., Medhin, Y. H. G., Etsub, E. A., & Tekele, G. N. G. (2018). Malaria Detection and Classification Using Machine Learning Algorithms. *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST*, *244*, 24–33. https://doi.org/10.1007/978-3-319-95153-9_3
12. Hagos, D. H., & Rawat, D. B. (2022). Recent Advances in Artificial Intelligence and Tactical Autonomy: Current Status, Challenges, and Perspectives. *Sensors*, *22*(24). https://doi.org/10.3390/s22249916
13. Hashimoto, D. A., Witkowski, E., Gao, L., Meireles, O., & Rosman, G. (2020). Artificial intelligence in anesthesiology: Current techniques, clinical applications,

and limitations. *Anesthesiology*, *2*, 379–394. https://doi.org/10.1097/ALN.0000000000002960
14. Jo, G. D., Ahn, C., Hong, J. H., Kim, D. S., Park, J., Kim, H., Kim, J. H., Goo, J. M., & Nam, J. G. (2023). 75% radiation dose reduction using deep learning reconstruction on low-dose chest CT. *BMC Medical Imaging*, *23*(1), 1–10. https://doi.org/10.1186/s12880-023-01081-8
15. Kadampur, M. A., & Al Riyaee, S. (2020). Skin cancer detection: Applying a deep learning based model driven architecture in the cloud for classifying dermal cell images. *Informatics in Medicine Unlocked*, *18*(December 2019), 100282. https://doi.org/10.1016/j.imu.2019.100282
16. Koetzier, L. R., Mastrodicasa, D., Szczykutowicz, T. P., van der Werf, N. R., Wang, A. S., Sandfort, V., van der Molen, A. J., Fleischmann, D., & Willemink, M. J. (2023). Deep Learning Image Reconstruction for CT: Technical Principles and Clinical Prospects. *Radiology*, *306*(3). https://doi.org/10.1148/radiol.221257
17. Lee, J. E., Choi, S. Y., Hwang, J. A., Lim, S., Lee, M. H., Yi, B. H., Cha, J. G., & Park, H. (2021). The potential for reduced radiation dose from deep learning-based CT image reconstruction: A comparison with filtered back projection and hybrid iterative reconstruction using a phantom. *Medicine (United States)*, *100*(19), E25814. https://doi.org/10.1097/MD.0000000000025814
18. Miller, J. L. (2013). Iron deficiency anemia: A common and curable disease. *Cold Spring Harbor Perspectives in Medicine*, *3*(7), 1–13. https://doi.org/10.1101/cshperspect.a011866
19. Mizusawa, S., Sei, Y., Orihara, R., & Ohsuga, A. (2021). Computed tomography image reconstruction using stacked U-Net. *Computerized Medical Imaging and Graphics*, *90*(April 2020), 101920. https://doi.org/10.1016/j.compmedimag.2021.101920
20. Obasa, A. E., & Palk, A. C. (2023). Responsible application of artificial intelligence in health care. *South African Journal of Science*, *119*(5), 5–7. https://doi.org/10.17159/sajs.2023/14889
21. Pantanowitz, L., Hartman, D., Qi, Y., Cho, E. Y., Suh, B., Paeng, K., Dhir, R., Michelow, P., Hazelhurst, S., Song, S. Y., & Cho, S. Y. (2020). Accuracy and efficiency of an artificial intelligence tool when counting breast mitoses. *Diagnostic Pathology*, *15*(1), 1–10. https://doi.org/10.1186/s13000-020-00995-z
22. Price, W. N., & Cohen, I. G. (2019). Privacy in the age of medical big data. *Nature Medicine*, *25*(1), 37–43. https://doi.org/10.1038/s41591-018-0272-7
23. Rajarajeswari, S., Prassanna, J., Abdul Quadir, M., Christy Jackson, J., Sharma, S., & Rajesh, B. (2022). Skin Cancer Detection using Deep Learning. *Research Journal of Pharmacy and Technology*, *15*(10), 4519–4525. https://doi.org/10.52711/0974-360X.2022.00758
24. Ryan, M. (2020). In AI We Trust: Ethics, Artificial Intelligence, and Reliability. *Science and Engineering Ethics*, *26*(5), 2749–2767. https://doi.org/10.1007/s11948-020-00228-y
25. S M, J., P, M., Aravindan, C., & Appavu, R. (2023). Classification of skin cancer from dermoscopic images using deep neural network architectures. *Multimedia Tools and Applications*, *82*(10), 15763–15778. https://doi.org/10.1007/s11042-022-13847-3
26. Sabry, F., Eltaras, T., Labda, W., Alzoubi, K., & Malluhi, Q. (2022). Machine Learning for Healthcare Wearable Devices: The Big Picture. *Journal of Healthcare Engineering*, *2022*. https://doi.org/10.1155/2022/4653923
27. Sciarretta, E., Mancini, R., & Greco, E. (2022). Artificial Intelligence for Healthcare and Social Services: Optimizing Resources and Promoting Sustainability. *Sustainability (Switzerland)*, *14*(24). https://doi.org/10.3390/su142416464

28. Spinczyk, D., & Krasoń, A. (2018). Automatic liver segmentation in computed tomography using general-purpose shape modeling methods. *BioMedical Engineering Online*, *17*(1), 1–13. https://doi.org/10.1186/s12938-018-0504-6
29. Sravya, V., & Malathi, S. (2021). Survey on brain tumor detection using machine learning and deep learning. *2021 International Conference on Computer Communication and Informatics, ICCCI 2021*, *2021-Janua*, 1–3. https://doi.org/10.1109/ICCCI50826.2021.9457019
30. Stokel-Walker, C. (2023). ChatGPT listed as author on research papers: many scientists disapprove. *Nature*, *613*(7945), 620–621. https://doi.org/10.1038/d41586-023-00107-z
31. Thanuj, M., Teja, P. R., Stun, P. J. D. L., Kranthi Kumar, K., & Sudha Kishore, R. (2023). Brain Tumour Detection Using Deep Learning Techniques. *Proceedings of the 5th International Conference on Inventive Research in Computing Applications, ICIRCA 2023*, *5*(2), 487–492. https://doi.org/10.1109/ICIRCA57980.2023.10220809
32. Thomasian, N. M., Kamel, I. R., & Bai, H. X. (2022). Machine intelligence in non-invasive endocrine cancer diagnostics. *Nature Reviews Endocrinology*, *18*(2), 81–95. https://doi.org/10.1038/s41574-021-00543-9
33. Van Wynsberghe, A. (2021). Sustainable AI: AI for sustainability and the sustainability of AI. *AI and Ethics*, *1*(3), 213–218. https://doi.org/10.1007/s43681-021-00043-6
34. Venugopal, V., Raj, N. I., Nath, M. K., & Stephen, N. (2023). A deep neural network using modified EfficientNet for skin cancer detection in dermoscopic images. *Decision Analytics Journal*, *8*(December 2022), 100278. https://doi.org/10.1016/j.dajour.2023.100278
35. Wen, Z., & Huang, H. (2022). The potential for artificial intelligence in healthcare. *Journal of Commercial Biotechnology*, *27*(4), 217–224. https://doi.org/10.5912/jcb1327
36. Willemink, M. J., & Noël, P. B. (2019). The evolution of image reconstruction for CT—from filtered back projection to artificial intelligence. *European Radiology*, *29*(5), 2185–2195. https://doi.org/10.1007/s00330-018-5810-7
37. Yang, C., Wang, W., Cui, D., Zhang, J., Liu, L., Wang, Y., & Li, W. (2023). Deep learning image reconstruction algorithms in low-dose radiation abdominal computed tomography: assessment of image quality and lesion diagnostic confidence. *Quantitative Imaging in Medicine and Surgery*, *13*(5), 3161–3173. https://doi.org/10.21037/qims-22-1227

Entrepreneurship ecosystem and a case study on problems faced by innovation driven enterprises in Nepal

Santosh Sharma[1]

[1] *Ministry of Education, Science and Technology, Nepal*

**Corresponding email: santosh.moest@gmail.com*

Abstract

Objective: The main objective of this research is to investigate the problem faced by Innovation Driven Enterprises (IDEs) in Nepal under the conceptual framework of Entrepreneur Ecosystem (EE) Model.

Methods: Field surveys and literature study of existing information to gather our findings.

Results: The study illuminated the pivotal role of innovation in amplifying business efficacy and refining product and service quality. Key challenges faced by IDEs encompassed limited institutional support, hesitancy in scaling operations, and apprehensions regarding economic uncertainties. A conspicuous gap in accessing risk capital tools further curtailed their growth trajectories. Notably, universities were identified as vital agents in addressing societal imperatives through research. The need for immediate establishment of incubation hubs for both students and researchers was emphasized to cultivate a culture of innovation. Additionally, the research underscored the significance of fostering partnerships between academia and businesses. Moreover, the sluggish pace of technology diffusion, particularly by large corporations, emerged as a deterrent to innovation.

Conclusion: Government should prioritize ease of risk capital and incubators to start making a conductive environment for IDEs. Businesses should also focus on key areas like farming, information technology, white goods products, tourism product in context to Nepal.

Keywords: *Innovation and entrepreneurial systems, innovation driven enterprises, university & research institutes, incubators, venture capitalist, SMEs*

1. Introduction

Small and Medium Enterprises (SMEs) play a major role in most economies, particularly in developing countries. SMEs account for the majority of businesses worldwide and are important contributors to job creation and global economic development. They represent about 90% of businesses and more than 50% of employment worldwide. Formal SMEs contribute up to 40% of national income (GDP) in emerging economies (The World Bank, 2023).

The distinctions between Innovation Driven Enterprises (IDEs) and SMEs are important for all. For governments looking to create jobs by promoting entrepreneurship, clarity on different types of entrepreneurship is necessary but often lacking, not least because government fundamentally are not entrepreneurial organizations, and often are staffed by people who lack entrepreneurial experience of either the IDE or SME type. As a result, policies frequently lump both sorts of entrepreneurs together, even though their needs are substantially different policies (Aulet & Murray, 2013). The table 1 below tries to make some differentiation between these two types of entrepreneurship.

Table 1. Difference between SME and IDE adapted from (Aulet & Murray, 2013)

SME Entrepreneurship	IDE Entrepreneurship
Focus on addressing local and regional markets only.	Focus on global markets.
Innovation is not necessary to SME establishment and growth, nor is competitive advantage.	The company is based on some sort of innovation (tech, process, business model) and potential competitive advantage.
"Non-tradable jobs"—jobs generally performed locally, e.g. restaurants, dry cleaners, service industry.	"Tradable jobs"—jobs that do not have to be performed locally.
Most often family businesses or businesses with very little external capital.	More diverse ownership base including wide array of external capital providers.
The company typically grows at a linear rate. When you put money into the company, the system (revenue, cash flow, jobs, etc.) will respond quickly in a positive manner.	The company starts by losing money, but if successful will have exponential growth. Requires investment. When you put money into the company, the revenue/cash flow/jobs numbers do not respond quickly.

The government have implemented various measures such as several technical assistance schemes, programs aimed at promoting enterprise and small business development, and inclusion of entrepreneurship education in academic syllabus. Diverse private organizations like Nepal Entrepreneur Hub; Nepalese Young Entrepreneur Forum; Entrepreneurs for Nepal; Nepal Entrepreneurship Forum; Next Growth Conclave; Udhyami Innovation; One to Watch; Nepal Startup Investment Company; Antrapreana; STARTUPS Nepal; Dolma Impact Fund; True North Associates, are working to promote entrepreneurship development through

providing training, education and investment. Yunus Social Business Center at King's College, Kathmandu University BIC, Microsoft Innovation Center Nepal, NSB, I-cube Business Incubation Program, Idea Studio, etc., are some incubation centers that are promoting the entrepreneurship-related curriculum and program. Despite significant investments by government and non-government organizations to develop and promote entrepreneurship in Nepal, country has not seen expected increase in dynamic entrepreneurs, industries, and employment opportunities, with industrial statistics showing slight change (Prajapati & Khanal, 2023).

Many firms die during the transition between a new scientific or engineering discovery and its successful transformation into a commercial application. In US it is seen that the government has played a leading role not only in the early stage research, but also in commercial viability stage. Venture capital funds tend to be concentrated in areas of high potential growth, low technological complexity and low capital intensity, since the latter raises the cost significantly (Mazzucato, 2013).

Based on the scenario presented SMEs in global economies, particularly in developing nations have a major role in contributing to job creation and economic development. It is necessary to distinguishing between SMEs and IDEs for effective policymaking, noting the challenges arising from the conflation of their distinct entrepreneurial characteristics. The key differences between SME and IDE entrepreneurship are but not limited to, market focus, innovation, ownership, and growth dynamics. Despite governmental and private initiatives to foster entrepreneurship in Nepal, the anticipated increase in dynamic entrepreneurs, industries, and employment opportunities has not materialized. The role of government and venture capital is crucial in supporting the various stages of innovation development, underscoring the need for a strategic approach to address challenges in transitioning scientific discoveries to commercial applications. There are limited literatures available in Nepalese context to study the problems faced by the IDEs in Nepal. Accordingly, following research objectives are set for our study:

1. Explore the key elements comprising the Entrepreneurship Ecosystem (EE) for growth of IDEs at national level.
2. Investigate the challenges encountered by Nepalese IDEs.

We address the research objectives above through a literature and empirical study. In the literature section we discuss stakeholders of EE. In the empirical part of the paper, we have explored the IDEs' perspective about the EE and the challenges faced by them during their start and in operation. After the analysis, conclusion are made.

2. Materials and Methods

Descriptive and exploitative research design using structured questionnaire and literature reviews is undertaken to understand the problems faced by IDEs in Nepal. The data collection in both cases involved field research, using online resources, participating in events, following local media, and meeting personnel from local IDEs.

2.1 Research design and data collection

Utilizing a descriptive and exploitative research design, this study employs a structured questionnaire and literature reviews to comprehend the challenges faced by IDEs in Nepal. Data collection involves field research, online resources, event participation, and interactions with local IDE personnel. The research follows a dual approach, first understanding the global EE and then generating primary data from recognized IDEs in Nepal.

2.2 Questionnaire development and conceptual framework

Drawing on literature findings, a conceptual framework is created to guide the development of structured and semi-structured questionnaires. These instruments aim to extract insights from IDE leaders, exploring historical, economic, and sociological factors hindering IDEs. Interviews delve into the social origins of entrepreneurs and their experiences in transforming ideas into businesses.

2.3 Sampling and data analysis

Qualitative research focuses on exploring opinions rather than numerical counts. Entrepreneurs incubated in Idea Studio Nepal are chosen for interviews. Seventy-five innovators are randomly selected via snowball sampling, with survey questionnaires sent and follow-up conducted by phone. Quantitative analysis involves disaggregating, categorizing, and presenting data based on frequency and percentage using Microsoft Excel. The study acknowledges limitations, such as the exclusion of provincial and local government initiatives, reliance on secondary government data and sometimes the biasness of the entrepreneurs as success rate of entrepreneurship is quite less.

3. Results and Discussion

The results and discussion is presented in two sub headings. The first section is about the literature research to reach a conceptual framework for identifying the components of EE for IDEs and then designing a questionnaire based on the components. The second section is about the data presentation based on responses via filled-up questionnaire.

3.1 Entrepreneurial Ecosystem (EE)

Entrepreneurial innovation involves the disruption of existing industries and creation of new ones. Integrating the National Innovation Systems (NIS) literatures, which has been focused upon structures and institutions, and the entrepreneurship literature that has been mostly about the individual or the firm, through understanding the context within which entrepreneurial innovation occurs is important. Different type of contexts influencing entrepreneurial innovation are: industry and technological, organizational, institutional and policy, social, temporal and spatial contexts which are strongly interrelated (Autio, Kenney, Mustar, Siegel, & Wright, 2014).

The NIS is often discussed in two perspectives. NIS in a narrow perspective, in tune with the earlier analyses of national science systems and national technology policy aimed at mapping indicators of national specialization and performance with respect to innovation, research and development efforts, and science and technology organizations. In contrast, the broader approach to NIS takes into account social institutions, macroeconomic regulations, financial systems, education and communication infrastructures and market conditions as far as these have impact on the learning and the competence-building process (Lundvall, Josepth, Chaminade, & Vang, 2009).

Entrepreneurial ecosystems are frameworks that explain entrepreneurial activities within regions and industrial sectors (Cantner, Cunningham, Lehmann, & Menter, 2021). These ecosystems aim to nurture economic development by promoting entrepreneurship, small business growth, and innovation. They provide a contextual environment for entrepreneurship and contribute to policy debates on regional economic development (Meshram & Rawani, 2019). EEs is a relatively new concept that has piqued the curiosity of legislators, researchers and professionals. Research on entrepreneurial ecosystems is growing, but the literature is fragmented. Emergence of EEs is poorly understood, with conceptual research dominating in recent years. Cooperation, knowledge exchange and innovation at the higher levels are more likely to produce favorable entrepreneurship environments (Wadichar, Manusmare, & Burghate, 2022). The sustainable development of entrepreneurship is a priority in the emerging field of entrepreneurial ecosystems (Kang, Li, Cheng, & Kraus, 2021).

The most commonly co-occurring keywords in context to EE are innovation, entrepreneurship, performance, knowledge, and entrepreneurial ecosystem. The three key themes are: innovation (linked to performance, technology, university, and industry), entrepreneurship (with a focus on ecosystem, management, and business), and knowledge (with an emphasis on growth, policy, and networks). There is intensified multi-disciplinary interest in entrepreneurial ecosystem research, underlining the diverse international

attention that it has amassed over the last quarter-century (Robertson, Ferreira, Pitt, & Pitt, 2022).

EE is essential for maintaining a successful interaction among different components such as human capital, technology, resources, talent, knowledge and others. Entrepreneurial ecosystem is all about improvement of entrepreneurs or start-up companies which leads to the development of society economically and environmentally (Monir, 2023). Table 2 is to illustrate the phases through which new innovations are developed keeping in mind the EE system.

Table 2. EE system with stages adapted from (Majava, Kinnunen, Foit, & Kess, 2017)

Phase	Description	Stakeholders
1. Idea generation and technology development	Basic Research, Applied Research	Universities, Research Institutes, Large Companies, SMEs, R&D Funding Bodies
2. Early stage work to support commercialization	Intellectual Property (IP) protection, Exploring potential application	Innovation Service Offices, Incubators, Pre-accelerators
3. Start-up establishment	Business model development and firm establishment, Acquisition of pre-revenue (pre-seed) funding	Business angels, Incubators, Pre-accelerators, Business service providers
4. Seed/early stage funding	Acquisition of the seed and early stage (1st stage and 2nd stage funding	Business angels, VC Firms, Funding agencies, Business service providers, Accelerators
5. Growth phase / later stage funding	Commercial success, later stage funding rounds (3rd stage / pre-IPO), more people are recruited	Funding agencies, Investors, Local talent pool, Trade associations and services organizations
6. IPO, acquisition or merger	Initial public offering, sale of the company or merger with another entity	Large investors and financial institutions, legal service, large companies

The work of (Mason & Brown, 2014) believes EE concept, rooted in diverse intellectual inquiries, offers a novel perspective on economic clustering and firm growth. It introduces a metaphorical device, emphasizing the external environment's role in firm growth over internal characteristics. The ecosystem perspective shifts the focus from individual firms to the entire

context, recognizing the dynamic and evolutionary nature of ecosystems. Contrary to the emphasis on firm size, it views size as a temporary state, acknowledging that high-growth firms contribute significantly to economic growth. The policy implication is to foster ecosystems supportive of ambitious entrepreneurs. The work suggests a shift from conventional transactional incentives to newer, customized policies.

The work of (Schwarzkopf, 2015) through his book based on his research have proposed four circles of entrepreneur to interact which are both internal and external. His comprehensive framework considers the entrepreneur at the center, acknowledging the influence of personal, social, education, and public/business factors on entrepreneurial success. It provides multifaceted approach to analyzing and fostering entrepreneurship within a specific country. The characteristics and elements of each circle can be understood better from table 3.

Table 3. Circles of Entrepreneurs adapted and edited from (Schwarzkopf, 2015).

Circles	Characteristics and Elements
1. Personal Circle (Entrepreneur)	• Personal characteristics of the entrepreneur • Entrepreneurial mindset and vision • Entrepreneurial skills and competencies • Risk-taking propensity • Motivation and passion
2. Social Circle (Family and Friends)	• Supportive family and friends • Role modeling and mentorship • Financial support and encouragement • Social entrepreneurship values
3. Educational Circle	• Accessible Entrepreneurship Education • Quality training and skill development • Academic support and innovation • Research and development opportunities
4. Public and Business Circle	• Government support and policies • Media influence and recognition • Public perception and awareness • Corporate engagement and collaboration • Market opportunities and competition • Internationalization and global presence

- Financial infrastructure and risk financing
- Business network and collaboration
- Public and investor trust
- Regulatory Environment

3.1.1 Innovative Entrepreneurs Ecosystem Framework

In contrast to most small and medium-sized enterprises, nowadays IDEs are proving themselves as efficient investments. These IDE start-ups are formed with the explicit intent to build competitive advantage based on new innovations (that can have their origins in scientific insights, technical change, new business models, supply chains, etc.), to grow quickly and scale well beyond local markets, and aspire to significant growth. With general entrepreneurship being so globally widespread, it is clear that the subset of innovation-driven entrepreneurs derives particular benefit from being in resource rich innovation ecosystems (Budden & Murray, 2019). So IDEs can be regarded as entrepreneurships where knowledge is the major asset.

As discussed earlier the core element of the framework are Entrepreneurs which needs a major and both ways support from National Innovation Systems. The innovative entrepreneurs are start-ups aiming for competitive advantages based on innovations, often emerging from knowledge-rich background. NIS are structures and institutions supporting innovation and entrepreneurial activities, major of which are knowledge creating and managing institutions. All components of NIS are moreover covered by the EE, adding and stressing on new components like incubators, accelerators, business service providers, market, etc. EE advocates on adding multiple source of equity capital including Angel Investors, Crowd Funding, etc. A conceptual framework drawn by the author based on the literature review is presented in figure 1.

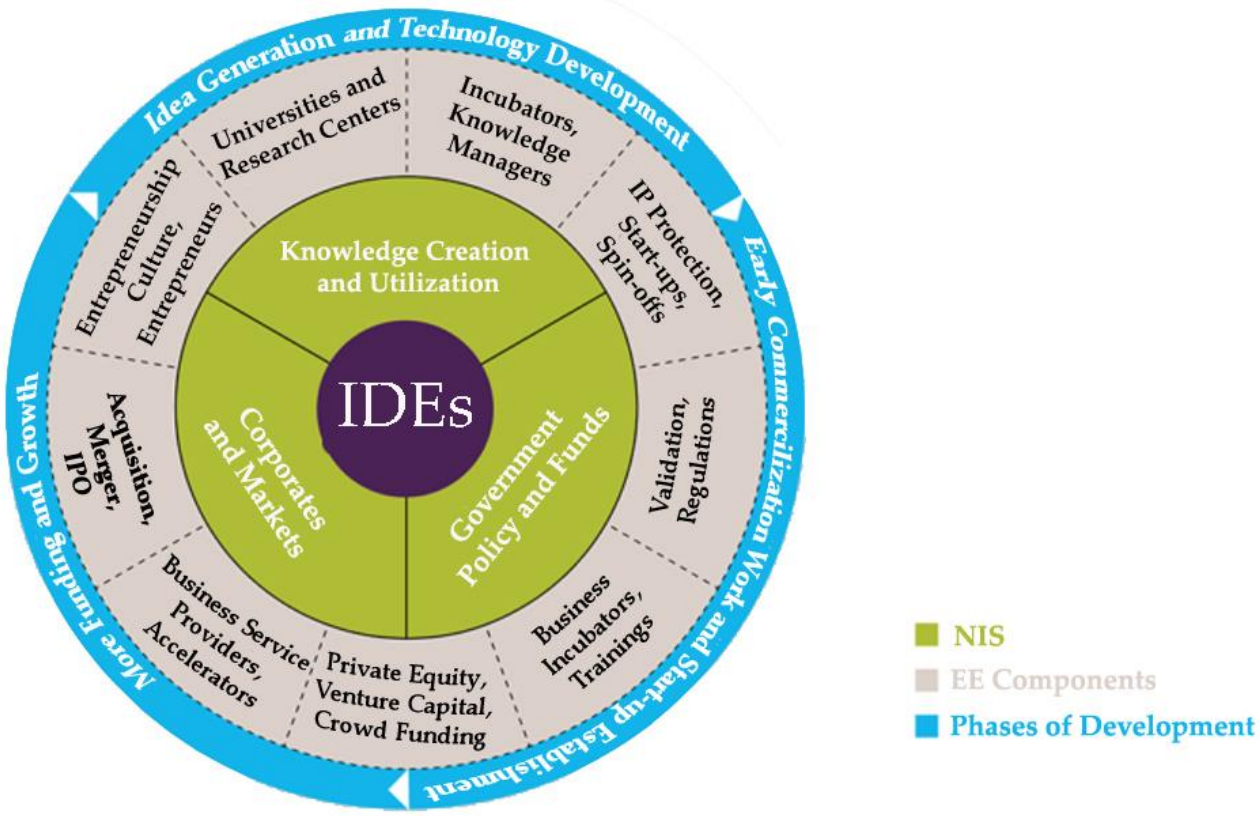


Figure 1. EE Conceptual Framework for IDEs developed by Author

Entrepreneurial culture has a significant impact on entrepreneurship. Founders and managers of private cultural enterprises recognize the importance of entrepreneurial behavior and competences for success (Konrad & Vecco, 2022). The direct and total effects of culture on entrepreneurship vary across countries, with dimensions such as future orientation, gender egalitarianism, assertiveness, and institutional collectivism having positive effects, while uncertainty avoidance has a negative effect (Mornah & MacDermott, 2023). Entrepreneurial culture plays a crucial role in the success of small and medium-sized enterprises (SMEs) in developing countries, as it encourages exploration of new opportunities, innovation, and proactive market actions (Gjorevska, 2023). Overall, national culture influences entrepreneurial activity, with different dimensions of culture having varying effects.

University and research centers play a crucial role in the development of entrepreneurship. They provide students with the necessary learning opportunities and motivation to think and act entrepreneurially (Ayunni, Daud, & Mohd, 2023). Entrepreneurship centers within universities are particularly important in fostering entrepreneurial mindset and competencies among students (Ndou, Secundo, Schiuma, & Passiante, 2018). Universities conducting research have a responsibility to implement the results of their scientific research into practice in an entrepreneurial business environment (Suryanto, 2019). However, there are still areas where the roles of universities and research centers can be further optimized, such as curriculum application and collaboration with external institutions.

Business incubators play a vital role in entrepreneurship development by providing resources, support, and an enabling environment for entrepreneurs (Vaz, Teixeira, & Carvalho, 2022). These incubators contribute to the growth and success of startups by offering services such as physical infrastructure, networking, financial support, and business assistance (Siddiqui & Ahmad, 2022). Additionally, incubators create value by focusing on intangible resources, social and relational aspects, and providing mentorship and collaborative environments (Burton, Zakaria, & Wang, 2023). Overall, incubators are valuable tools for supporting entrepreneurship and driving innovation in various contexts.

Startups and spin-offs play a crucial role in entrepreneurship, particularly in the transfer of scientific knowledge and technology into practical applications in society (Lima, Camara, Ficher, & Magalhaes, 2022). These ventures have been found to have different outcomes and impacts over time, with factors such as origin, technology, financing, and performance measures influencing their development (Auerswald & Branscomb, 2003). However, starting a company involves inherent risks, and not all startups are successful in bringing a product to market (Acs & Amoros, 2008). Entrepreneurship, including startups and spin-offs, is recognized as a vital mechanism for economic development through employment, innovation, and welfare effects.

The government plays a crucial role in fostering the growth and development of entrepreneurship. Government policies, such as entrepreneurship policy interventions and monetary policy, have a positive impact on entrepreneurship growth and development (Salami & Ekakite, 2023). Governments can support entrepreneurship through initiatives that provide funding, such as grants, debt financing, and venture capital programs. Additionally, governments can contribute to the development of entrepreneurial ecosystems by providing financial support for entrepreneurship education and research, enacting favorable laws and regulations, and fighting corruption and red tape (Casanova, Cornelius, & Dutta, 2018). Despite the good intentions, government efforts to promote entrepreneurship through financing have faced challenges and structural issues, making sustained successful efforts difficult.

Equity funding is important in the growth, development, and survival of entrepreneurial ventures. It is a form of financing that allows entrepreneurs to access capital directly from a large number of investors through online platforms (Kazem & Volkmann, 2020). Different types of equity financing, such as venture capital, angel investment, and crowd-funding, have been examined, with crowd-funding gaining significant interest (Wald, Holmesland, & Efrat, 2019). Factors influencing individual investment decisions in equity crowd-funding include the allocation mechanism used by the platform and the information provided by the entrepreneur and other investors (Hornuf & Schwienbacher, 2017). Equity funding is thus an important aspect of entrepreneurship that continues to be explored and understood by

researchers.

Multinational corporations (MNCs) play a significant role in entrepreneurship by driving globalization through the transfer of innovation and cultural values (Ratten, 2022). Corporate entrepreneurship plays a crucial role in driving growth and innovation within organizations. It involves creating an environment that supports and encourages innovation, value creation, and continued growth (Kim & Park, 2022). Globalization has forced businesses to re-evaluate their strategic approaches and embrace corporate-level entrepreneurship to improve productivity and promote economic growth (Westhuizen & Ransburg, 2022). Countries need strategies to utilize big corporates and MNCs for innovation and entrepreneurship.

Summarizing the components of conceptual framework, we are convinced that IDEs stand out among SMEs due to their focus on leveraging new innovations for competitive advantages and significant growth. They thrive within knowledge-rich innovation ecosystems, benefiting from support systems like NIS and EE. Cultural factors significantly influence entrepreneurial success, with varying dimensions like future orientation positively impacting entrepreneurship. Universities and research centers play pivotal roles in fostering entrepreneurial mindsets and translating research into practical applications. Business incubators further bolster startups by offering essential resources and mentorship. While startups and spin-offs facilitate the transfer of scientific knowledge, government interventions are vital but face challenges in promoting entrepreneurship effectively. Equity funding, especially through platforms like crowd-funding, venture capital, emerges as a critical aspect for entrepreneurial ventures, and multinational corporations drive global innovation and economic growth through corporate entrepreneurship.

3.2 Problems faced by IDEs in Nepal

Idea Studio is an oldest platform to turn promising ideas into solutions and ultimately ignite social change by enabling youth potentials in favor of entrepreneurship through innovation in Nepal (Idea Studio Nepal, 2023). This research has tried to study seventy-five of the owners/managers of startups whose ideas were preached in Idea Studio Nepal through the survey questionnaire. The survey was carried in early 2023. Forty-one such entrepreneurs responded. The questionnaire were divided into seven distinct section, which are entrepreneurs individual and firm's demographic information; innovation and entrepreneurship aspect of firm; access to risk capital and funding; roles of university and research centers; corporates' role in entrepreneurship; role of government and inputs from IDEs. The semi structured questionnaire also contained essay type questions. The summary of responses are presented in the seventh section. The calculations in percentage from the responses is round-off to nearest whole number.

3.2.1 *Demographic and other characteristics of entrepreneurship*

The general demographic information captured included the gender, age, level of education, role and duration being involved in the innovative firm, etc. The socio-demographic characteristic of respondents can be better understood from table 4.

Table 4. Socio-demographic characteristic of respondents

Characteristics	Range/Type	Frequency	Percentage (%)
Gender	Male	34	84
	Female	7	16
Age	20-34	22	53
	35-44	19	48
	45 and above	0	0
Education	High-school or below	2	5
	Bachelors	26	63
	Masters and above	13	31
Engagement in Entrepreneurship	One to two years	5	12
	Two to three years	13	32
	Three to five years	7	17
	More than five years	16	39
Role in Entrepreneurship	Owner/MD	28	68
	Manager Director	5	11
	Others	8	21

Out of the responses on the type of industry, here top three field of entrepreneurships is identified. Twenty-seven percentage were from education, training and consultancy business; twenty-two percentage of respondents were engaged in information and communication technology business; twelve percentage respondents were from construction, architecture and interior business. More insights on other aspects of entrepreneurship is presented in table 5.

Table 5. Characteristics of Enterprise

Characteristics	Choice	Frequency	Percentage (%)
Concept of Business	Original and unique	9	21
	Existing concept from foreign countries	17	42
	Existing concept from Nepal	15	37
Legal Status	Sole proprietorship	11	26
	Partnership	15	37
	Others	15	37
Enterprise Establishment	Less than two years	4	10
	Two to five years	20	49
	Above five years	17	41
Market	Kathmandu valley	10	25
	All Nepal	16	40
	Nepal and abroad	15	35

3.2.2 *Innovation and entrepreneurship aspect of firms*

This section of questionnaire was focused on collecting data on entrepreneurs understanding

of IDEs, on how idea was generated, current economic status of firms, engagement in accelerators or incubators, innovative risk taking capabilities, etc. Top three responses on the their understanding of innovation twenty-seven percentage replied added value to customer; twenty-two percent of respondent think innovation to be new business model; seventeen percentage think it is new product development and the other seventeen percentage think quality improvement of current product or service. More insights in this topic can be better understood from table 6.

Table 6. Innovation and Entrepreneurship Aspect of Firm

Questions	Choice	Frequency	Percentage (%)
How your business idea was created?	A copy of similar business abroad.	23	56
	Self-learned	9	22
	Taught in current education system	9	22
	Proactively (distributing to shareholders)	2	5
Is your business in profit?	Running on breakeven	23	56
	Loss	16	39
Have you been incubated or accelerated?	None	23	56
	Business incubation	12	30
	Supported by accelerator program	6	15
Entrepreneurs' risk taking abilities	High	17	42
	Moderate	12	29
	Conservative	12	29
Understanding of Nepali Market	Lot of opportunities	12	29
	Dominated by few players	10	24
	Less transparent	7	17
	Unknown (lack of market research)	12	29
Firms barriers to innovation	Economic risk and inflation	7	17
	Supplies problem (technical delay, price fluctuation)	5	12
	Legislation and regulations policies	4	10
	Market (competition and access)	4	10
	No government support on scaling up	4	10
	others	17	41

3.2.3 *Access to capital by IDEs*

For IDEs availability of capital for starting and growing business, moreover risk capital which are generally banks, venture capital, crowd-funding, etc. were accessed by the survey questionnaire. The responses on financial assistance from traditional financial and new non-financial institutions, key investors, etc. is presented in the table 7.

Table 7. Access to Capital by IDEs

Questions	Choice	Frequency	Percentage (%)
Support from traditional financial institutes like banks	From holdings, bank, finance, banks, etc.	4	10
	Mixed (certain from innovator and certain from tradition financial institutes)	4	10

	None	33	80
Support from non-financial institutes like equity funding, VC, crowd funding, etc.	Government challenge funding	4	10
	Equity funding (VC, accelerators)	4	10
	Crowd funding	4	10
	None	29	70
Current investors	Family/Friends/Relatives	26	63
	Crowd funding	3	7
	Traditional banks, corporative, etc.	7	17
	Private equity or VC	2	5
	Others	3	8

3.2.4 Inputs from Universities and Research Centers in Innovation

Questionnaire developed to take the entrepreneurs views on input from universities and research centers during their entrepreneurship cycle till the day was taken. The questions in this section was more focused on contributors from knowledge centers (universities and research centers), overview about university education system in Nepal, most innovative university, etc. The results are presented in table 8.

Table 8. University and Research Centers inputs for IDEs

Questions	Choice	Frequency	Percentage (%)
How can universities and research centers contribute in innovation	Supplying competent human resources	15	36
	Taking the burden of research	8	21
	Collaboration in innovation	17	41
	None	1	2
University education system in Nepal	No research and innovation oriented	18	44
	Its improving in last couple of years	15	36
	Its degrading	5	12
	None	3	8
Problems in University to support innovation and entrepreneurship	Industry-University Collaboration not happening	11	27
	No incubators in university	10	24
	No enough funding in university research by government	10	24
	University bureaucracy	6	15
	others	4	10

3.2.5 Roles of corporates for IDEs

Questionnaire was developed to get the respondent view about the role of corporates and multinational companies in promoting innovation and entrepreneurship in Nepal. The results are presented in table 9.

Table 9. Role of Corporates for Innovation

Questions	Choice	Frequency	Percentage (%)
How corporates have contributed in	Setting examples for business processes	11	27

innovation and entrepreneurship	Setting standards for quality	11	27
	Creating new vendors	7	17
	Inspiration for innovators	4	10
	They haven't contributed in Nepal	8	19
	Corporates (less than 250 staffs)	15	37
The leaders of business sector in innovation	Large enterprises (more than 250 staffs)	5	12
	Multinationals	9	22
	New enterprises and start-ups	12	29
Should multinationals be subsidized to promote innovation	Yes	24	58
	No	17	42

3.2.6 Roles of government for IDEs

Government is one of the strong pillar in NIS or EE. The survey questionnaire contained questions on government role to promote innovation and enterprises. Questionnaire was focused on funding and regulations aspect. The respondents were also asked which sector to prioritize for sustained innovation. The results are presented in table 10.

Table 10. Role of Government in promotion of EE

Questions	Choice	Frequency	Percentage (%)
Where should government invest to promote IDEs?	Research	10	24
	Ease of doing business (removing administrative hurdles)	9	22
	Education and training	8	20
	Accelerators and incubators	7	17
	Others (not specific)	7	17
Which ministry should lead innovation and enterprise development?	Ministry of Finance	2	5
	Ministry of Industry Commerce and Supplies	13	32
	Ministry of Education, Science and Technology	26	63
Who should invest in research?	Government and industry together	20	49
	All components of ecosystem	17	41
	Others	4	10
Which sector should government prioritize for research and innovation	Agriculture, forestry and fishing	10	24
	Product manufacturing	7	17
	Information and communication technology	9	22
	Education training and consulting	4	10
	Tourism and hospitality	5	12
	Others	6	15

3.2.7 Recommendations from IDEs

From our essay type questions, we were able to get valuable inputs from our respondents on the most difficulty faced by them during their business and how to flourish EE. As the questions was subjective, so most stressed points are taken for each question. The responses

are presented in table 11.

Table 11. Essay type questionnaire inputs

Questions	Views and recommendation
Challenges faced by startups in Nepal	Registration and operations hurdles Human resources out-flows Lack of management skills (business incubation) Lack of support from financial system Lack of incubation facilities (technology incubation) Unclear industry and enterprises policy and acts
Entrepreneurs' barriers in promoting innovation practices.	Research funding Use of knowledge centers Availability of competent human resources Open and very impressive return
Primary strength of Nepali market	Youth population Competition
Views on how to strength national innovation and entrepreneurial capacity	Basic services should be maintained first (like better customs services, education, water, electricity and connectivity). The foremost environment for innovation. Sustained and increased research and innovation fund Academia-Industry-Government collaboration in research Risk sharing by the government / financial enterprise / venture capitalists

The questionnaire survey lead us to get some overview of the entrepreneurship challenges in Nepal and also it helped us to gain insights of the EE from the entrepreneurs' point of view. It is seen that IDEs in Nepal are male dominants. 84% of snowball sampling respondents were male. The age-group who are engaged in IDEs are 20-34 and most of them have completed Bachelor's level as their education achievement. The majority of respondents were CEOs of the IDEs. It is seen that most of the IDEs in Nepal are a copy of startups in foreign countries, which is because they seem to understand less of Nepali market and have no innovation inputs from their higher education institutes. Most of IDEs respondents had an existence of 2-5 years which is the toughest part of the entrepreneurship cycle, so quite few were actually making profit. Many responded that they are in the breakeven point and it would take about a couple of additional years to make some money. So, this means they feel that there is little chance of scaling up and getting merger or IPOs from other big companies. More than fifty percent of IDEs were not incubated. They themselves feel because of different market and capital constants, their risk taking ability is not as that as expected. Eighty percent of enterprises or entrepreneurs were not supported by any means of financial sources and sixty three percent of firms are still owned by family and friends. Knowledge system from university and research centers and also from corporates have little input to the entrepreneur ecosystem as their major role is generating innovative entrepreneurs.

The summary from the questionnaire survey is that Nepal has potential human resources which needs to be nourished to make them innovate. Government funding are not sufficient

in the research phase, in the incubation phase and also government policy and acts are not revisited urgently to make them venture capital friendly. The roles of academia is still not that satisfactory. Foreign direct investments and the multinationals have contributed in technology transfer slowly but they have not contributed in innovation culture establishment and thus small local innovation driven enterprises are not benefited. The respondents advocated an urgent need of sustained support to entrepreneurship ecosystem to make our country a knowledge based innovative economy.

4. Conclusions

A conceptual framework is drawn integrating three distinct systems. The National Innovation Systems, the entrepreneurial ecosystem and cycle of start-ups which are mostly innovation driven. Generating new IDEs are influenced by the entrepreneurial culture of a region or country backed by the knowledge creating and utilizing institutes like university and research centers, incubators, training institutes, innovation promoting agencies, etc. Innovation promotion through incubators is the heart of the framework backed by non-financial and easy access to capital of any form during the start-up or spin-off phase. Government presence is mandatory for introducing innovation through research funding, providing validating services, risk sharing in equity funding, technology transfer via multinationals, protecting the intellectual property rights and also prioritizing innovation based on social and economic need. Private sectors are actual drivers of innovation and entrepreneurships.

The problems faced by the innovation driven enterprises can be summarized as availability of skill and semi-skilled manpower, traditional industrial act and policies, lack of research funding and unavailability of start-up friendly research institute, administrative hurdles to open and run a business, limited access to non-traditional capital market, etc.

Acknowledgements

I would like to acknowledge all staffs from Science and Technology Division of Ministry of Education, Science and Technology Nepal for their motivation for conducting this research and publish this paper.

References

Acs, Z. J., & Amoros, J. E. (2008). Introduction: The Startup Process. *Estudios De Economia*, 121-132.

Auerswald, P. E., & Branscomb, L. M. (2003). The Emergence of Entrepreneurship Policy: Start-ups and Spin-offs: Collective Entrepreneurship Between Invention and Innovation. *Social Science Research Network*, 61-91.

Aulet, B., & Murray, F. (2013). *The Tale of Two Entrepreneurs: Understanding Differences in the Types of Entrepreneurship in Economy*. Ewing Marion Kauffman Foundation.

Autio, E., Kenney, M., Mustar, P., Siegel, D., & Wright, M. (2014). Entrepreneurial innovation: The importance of context. *Research Policy*, 1097 - 1108.

Ayunni, N. A., Daud, N. I., & Mohd, F. (2023). The Contribution of University in Developing Entrepreneurial Students Towards New Venture Creation. *Journal of Entrepreneurship and Business*, 111-122.

Budden, P., & Murray, F. (2019). *MIT's Stakeholders Framework for Building and Accelerating Innovaiton Ecosystem*. MIT's Laboratory for Innovation Science and Policy.

Burton, K., Zakaria, R., & Wang, Y. (2023). Using redundancy analysis to explain intentions to participate in incubators: a gender perspective. *Journal of Developmental Entrepreneurship*.

Cantner, U., Cunningham, J., Lehmann, E., & Menter, M. (2021). Entrepreneurial ecosystems: a dynamic lifecycle model. *Small Business Economics*, 407-423.

Casanova, L., Cornelius, P. K., & Dutta, S. (2018). The Role of Government. In L. Casanova, P. K. Cornelius, & S. Dutta, *Financing Entrepreneurship and Innovation in Emerging Markets* (pp. 263-294). Academic Press.

Gjorevska, E. (2023). Entrepreneurial Culture as Threat to SMEs' Entrepreneurial Orientation-Success Relationship in Developing Countries – The Case of Private Healthcare Sector in Macedonia. *Journal of economics and public finance*, 39.

Hornuf, L., & Schwienbacher, A. (2017). Market mechanisms and funding dynamics in equity crowdfunding. *Journal of Corporate Finance (North-Holland)*, 556-574.

Idea Studio Nepal. (2023, 12 18). *About Us*. Retrieved from Idea Studio: https://ideastudio.org.np/about-us

Kang, Q., Li, H., Cheng, Y., & Kraus, S. (2021). Entrepreneurial ecosystems: analysing the status quo. *Knowledge Management Research & Practice* , 8-20.

Kazem, M., & Volkmann, C. (2020). Equity Crowdfunding: A Systematic Review of the Literature. *Small Business Economics (Springer US)*, 75-118.

Kharel, S., KC, A., Devkota, N., & Paudel, U. R. (2022). Entrepreneurs' Level of Awareness on Knowledge Management for Promoting Tourism in Nepal. *Journal of Information &*

Knowledge Management, 2250023:1-2250023:19.

Kim, J., & Park, M. J. (2022). Influence of Entrepreneurship Manifestation Factor on Organisational Innovation: The Role of Corporate Entrepreneurship and Imperative Innovation Culture. *Journal of Entrepreneurship*, 514-545.

Konrad, E. D., & Vecco, M. (2022). Entrepreneurship in Culture: Concepts, Perspectives, Success Factors. In Y. Jung, N. Vakharia, & M. Vecco, *The Oxford Handbook of Arts and Cultural Management*. Oxford University Press.

Lima, B. B., Camara, S. F., Ficher, B. B., & Magalhaes, R. C. (2022). Performance of spin-offs and Brazilian startups: A study on technological evolution based on entrepreneurship and networks. *Revista de Empreendedorismo e Gestão de Pequenas Empresas*.

Lundvall, B.-A., Josepth, K., Chaminade, C., & Vang, J. (2009). *Handbook of Innovation Systems and Developing Countries*. Edward Elgar Publishing Limited.

Majava, J., Kinnunen, T., Foit, D., & Kess, P. (2017). Analysing innovation-driven entrprises' stakeholders in two spatical ICT eco-systems. *International Journal of Management and Enterprise Development*, 207-220.

Mason, C., & Brown, R. (2014). ENTREPRENEURIAL ECOSYSTEMS AND GROWTH ORIENTED ENTREPRENEURSHIP. *OCED LEED Programme*. OCED.

Mazzucato, M. (2013). *The Entrepreneurial State*. London: Anthem Press.

Meshram, S., & Rawani, A. (2019). Understanding Entrepreneurial Ecosystem. *International Journal of Social Ecology and Sustainable Development*, 103-115.

Monir, M. M. (2023). Social Entrepreneurship and Social Innovation in the Entrepreneurial Ecosystem. *International Conference on Business Excellence* (pp. 822-838). Romania: De Gruyter Open.

Mornah, D., & MacDermott, R. (2023). Institutions, culture, and entrepreneurship: direct, total, and compliance burden effects. *Global Economy Journal*.

Ndou, V., Secundo, G., Schiuma, G., & Passiante, G. (2018). Insights for Shaping Entrepreneurship Education: Evidence from the European Entrepreneurship Centers. *Sustainability* .

Prajapati, B., & Khanal, K. (2023). EMPOWERING ENTREPRENEURS: EXPLORING THE ROLE OF ECOSYSTEM FACTORS IN DRIVING GROWTH INTENTIONS IN NEPAL. *Gomal University Journal of Research*.

Quintas, S., Gonzalez, N., Diaz, C., Crego, M., & Facal, D. (2023). TRAINING FOR INNOVATION DRIVEN RESEARCH: THE SENIOR INNOVATION LAB APPROACH. *INTED2023 Proceedings* (pp. 3022 - 3027). Spain: IATED.

Ratten, V. (2022). Corporate Entrepreneurship. In V. Ratten, *Analyse, Ideate and Grow* (pp. 15-27). Springer Link.

Robertson, J., Ferreira, C., Pitt, L., & Pitt, C. (2022). Entrepreneurial Ecosystems: A 25-Year Bibliographic Overview: An Abstract. *From Micro to Macro: Dealing with Uncertainties in the Global Marketplace* (pp. 347-348). Springer.

Salami, C. G., & Ekakite, S. E. (2023). Impact of government policy on entrepreneurship growth and development of small-scale business. *Journal of Global Social Sciences*, 73-102.

Schwarzkopf, C. (2015). *Fostering Innovation and Entrepreneurship*. Karlsruhe: Springer Gabler.

Siddiqui, D., & Ahmad, N. (2022). Study of Support and Services Provided by Business Incubators in Entrepreneurship. *AMC Indian Journal of Entrepreneurship*, 19.

Suryanto. (2019). Analysis of Entrepreneurship Ecosystem at University. *Journal of Entrepreneurship Education*.

The World Bank. (2023, 12 18). *Small and Medium Entriprise Finance*. Retrieved from The World Bank: https://www.worldbank.org/en/topic/smefinance

Vaz, R., Teixeira, S., & Carvalho, J. V. (2022). Comfortable but Not Brilliant: Exploring the Incubation Experience of Founders of Technology-Based Startups. *Sustainability*, 15864.

Wadichar, R. K., Manusmare, P., & Burghate, M. (2022). Entrepreneurial Ecosystem: A Systematic Literature Review. *Vision: The Journal of Business Perspective*.

Wald, A., Holmesland, M., & Efrat, K. (2019). It Is Not All About Money: Obtaining Additional Benefits Through Equity Crowdfunding. *Journal of Entrepreneurship (SAGE Publications)*, 270-294.

Westhuizen, J. V., & Ransburg, C. V. (2022). Human Resource Management Practices and Business Performance: The Mediating Effect of Corporate Entrepreneurship. *African journal of inter-multidisciplinary studies*, 394-405.

Assessment of Roles of Engineers for Disaster Management in the Context of Nepal

Pankaj Adhikari[1*]
[1]*Department of Civil Engineering, Institute of Engineering, Tribhuvan University*
**Corresponding email: appathik@gmail.com*

Abstract:

Nepal has been repeatedly affected by different disasters. The engineers are considered to be one of the significant stakeholders for disaster risk reduction by the United Nations Sendai Framework of Disaster Risk Reduction (2015-2030). However, the roles of engineers and challenges faced by them in implementing disaster risk management is understudied in the context of Nepal. Therefore, this research is carried out with an overall objective to analyse the role of engineering leadership for DRR. The specific objectives are: (i) To explore the roles of engineers in reducing the disaster risks (ii) To identify the prevailing challenges in the engineering sector. For the purpose, a mixed method was applied. The relevant literature regarding the engineering leadership were fetched from online sources and critically reviewed. Secondly, Key Informant Interview was conducted with engineers and policy makers (n=16) to fathom the challenges observed in the field. The result reveals that engineers belonging to different disciplines have been contributing through various capacities for disaster management in Nepal. Likewise, the major challenges noticed are lopsided capacity development programmes, communication gap with public and insufficient focus to DRR knowledge in undergraduate level of engineering curriculum. It is recommended that for the effective implementation of disaster management, the stakeholders ought to prioritize the capacity development of engineers such as training for risk assessment, Remote Sensing analysis and Machine Learning models. Moreover, the communication gap between engineers, public and DRR institutions should be narrowed down through regular interaction and effective coordination.

Keywords: *Engineers; Disaster Management; DRR; Nepal*

1. Introduction

The huge damages and suffering ensued by disasters throughout the globe are the issue of growing importance for the international community (Crosweller, 2022). Entire South Asia is frequently exposed to severe climate-related disasters, a situation that has been further complicated by unprecedented population growth (Mall et al., 2019). Therefore, in recent decades a dramatic rise in global cooperation on Disaster Risk Reduction (DRR) has been taking place (Enia, 2020). The emergence of Sendai Framework for Disaster Risk Reduction

(2015-2030) (UNISDR, 2015) is one of the significant steps in the initiative of reducing the impacts of disasters. This framework highlights the fact that the state has the primary role to reduce disaster risk but that responsibility ought to be shared with local government, the private sector and other stakeholders. One of the pivotal and contributing stakeholders are the engineers.

Nepal has been repeatedly affected by different disasters. The engineers are considered to be one of the significant stakeholders for disaster risk reduction by the United Nations Sendai Framework of Disaster Risk Reduction (2015-2030). However, the roles of engineers and challenges faced by them in implementing disaster risk management is understudied in the context of Nepal . Therefore, this research is carried out with an overall objective to analyse the role of engineering leadership for DRR. The specific objectives are: (i) To explore the roles of engineers in reducing the disaster risks (ii) To identify the prevailing challenges in the engineering sector. For the purpose, a mixed method was applied. The relevant literature regarding the engineering leadrship were fetched from online sources and critically reviewed. Secondly, Key Informant Interview was conducted with engineers and policy makers (n=16) to fathom the challenges observed in the field.

Engineering is a collaborative enterprise based on specialised technical expertise distributed among the participants, accessed through a network of trusting relationships shaped by workplace social norms (Trevelyan, 2019). Perry et al (2017) in their study argue that the skill sets required for engineering jobs and leadership roles are often distinct. For example: engineers learn technical principles required for their specific engineering discipline, whereas effective leaders require strategy, communication and other skills. On the other hand, Walther et al (2017) point out that engineering and social work may seem an unlikely combination of disciplines but they share a range of remarkable similarities. The collaboration during emergencies and disasters is not always smooth and free from frictions (Uhr, 2017). Citing the case of 2011 Japan earthquake and the consequent Fukushima nuclear disaster triggered by it, Amir & Juraku (2014) state that over relying upon engineered-system robustness and underestimation of the disaster impacts from the technical experts had had harmful consequences. It clearly demonstrates the significance of engineers in times of disasters and emergency.

A number of studies have been carried out by various researchers on the matter of engineering and disaster managment. For example: Broadbent & Broadbnet (2013) studied the role of professional engineers for disaster management and argue that a disaster manager

has to develop an understanding and knowledge of dealing with these issues based on lessons learnt by experienced practitioners and from academic studies of past incidents. Likewise, Sharma & Sharma (2019) have studied the role of civil engineers in disaster management in India. Bozza et al (2017) have explored the concept of urban resilience thorugh the perspective of civil engineers. Despite the crucial significance of engineering leadership for disaster risk reduction, surprisingly the quantity of research works on the matter is limited. Many of the disaster prone nations have not devleved into such studies.

Nepal is one of the nations which needs to pay attention to this matter. Due to the coupling effect of the seismo-tectonic movement and the Asian monsoon, the occurrences of disasters in Nepal are very common (Adhikari & Gautam, 2022). It has witnessed some of the big disaster events such as the 2015 Gorkha Earthquake (Manandhar et al., 2022), the 2017 Terai Floods (Thapa et al., 2020) and the 2021 Melamchi Flood (Adhikari et al., 2023) which have claimed the lives of thousands of people and destroyed assets worth billions. Thus, implementation of proper engineering is pivotal for disaster management in Nepal. Notably, engineering is one of the highly reputed and well regarded professions in Nepal. It has formidable impact in the psyche of people due to its contribution to society and relatively secure and lucrative earning. Every year around 8,000 engineering graduates are produced from more than four dozens educational institutes throughout the nation (Online Khabar, 2023).

There have been plethora of studies (Guragain & Doneys, 2022; Thompson et al., 2020; Wanner, 2022) on the scientific, engineering and social aspects of disasters in Nepal. Likewise, different engineering aspects such as job satisfaction (Thapa & Shrestha, 2018), quality assurance of engineering education (Joshi & Joshi, 2015), gender issues in engineering (Liebrand & Udas, 2017), professional ethics (Shah & Alotaibi, 2018), employability (Sharma, 2023) and importance of linguistic skills for engineers (R. N. Shrestha et al., 2020) have been studied. Some studies for example by Upreti (2022) highlight the role of security forces in disaster management with references to Nepali security forces. The research conducted by (Shrestha & Pathranarakul, 2018; Shrestha et al., 2021), while discussing about the disaster management during 2015 Gorkha Earthquake, have noted the contribution of engineers in the response and reconstruction phase. However, the comprehensive coverage on the issues of engineers in DRR sector is missing in the prevailing literature. However, in the context of Nepal, the prevailing literature does not shed light into the issue of engineers in DRR sector. Thus, it is a matter of dire introspect that the role of one of the significant stakeholders i.e. the engineers is understudied in a disaster prone nation.

In this backdrop, the study aims to contribute to further explore the prevailing status and role of engineers for DRR. The overarching objective of the study is to analyse the engineering leadership for Disaster Risk Reduction in the context of Nepal. The specific objectives are: (i) To explore the roles of engineers in reducing the disaster risks (ii) To identify the prevailing challenges in the engineering sector. For the purpose a critical review of documents and policies related to engineering and DRR in the context of Nepal was carried out. Similarly, Key Informant Interview (KII) was conducted with engineers and policy makers to understand about the ground scenario.

The article is divided into four sections. After the introduction part, the methodology is discussed in the second section. The overall findings and discussions are highlighted in the third section which further delves into importance of engineering leadership for DRR and prevailing prospects and challenges. Finally, conclusion is presented in the last section.

2. Methodology

In this study, the mixed-method approach was applied to fulfil the research objectives. First of all, the literature related to engineering leadership and DRR were collected (Shown in Annex: Table-2). They were fetched from various sources such as the websites of Ministry of Home Affairs (MoHA), National Disaster Risk Reduction and Management Authority (NDRRMA) and national DRR portal. For peer reviewed articles relevant to the study, search was conducted in sites such as Google Scholar and Science Direct. Critical review of these studies was performed and the prevailing status of Engineers in DRR sector was analysed.

Likewise, Key Informant Interview (KII) was conducted with total sixteen participants (mostly engineers and policy makers representing different sectors such as governmental, private sector, International Non-Governmental Organizations. The interviews (Refer Annex: Table 3 for questions) were conducted at different times during August- October 2022 and October 2023 through in person meeting, telephone conversation and virtual chat (online). The participants include:

(i) Engineers (n=10) actively working in different sectors. Out of these participants, two each represented Gandaki , Lumbini and Bagmati province where as one each belonged to Koshi, Madhesh , Karnali and Sudurpaschim province; Out of the 10 engineers, there were four female interviewee. In terms of working area, out of the 10 participants, (n=3) were working

in earthquake sector, (n=3) in construction sector, (n=2) in flood management, (n=1) in landslide prevention and (n=1) in fire hazard control.

(ii) Senior engineers and DRR policy experts (n=6).

The overall methodology diagram is shown in Figure 1.

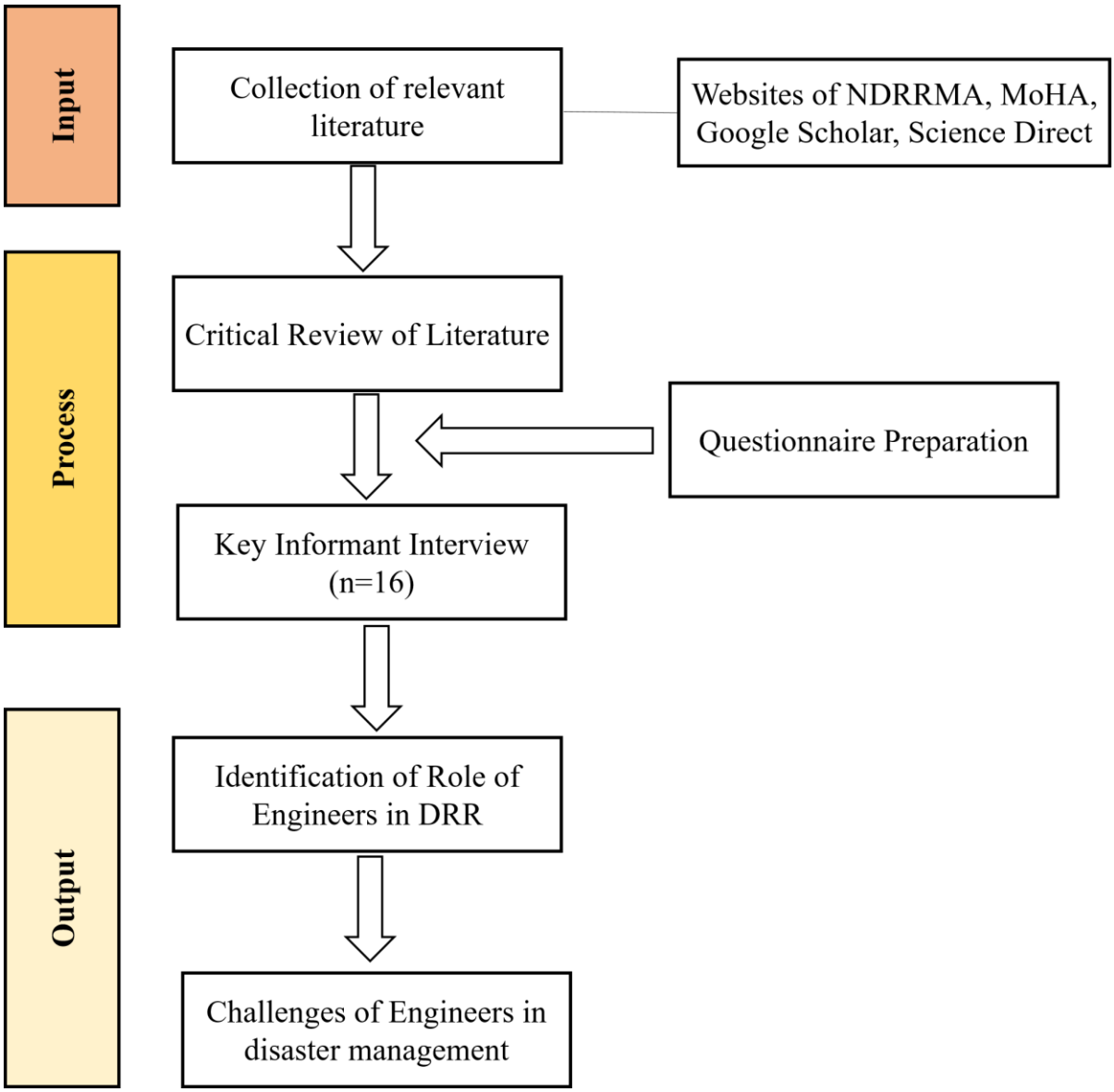


Figure 1: Overall Methodology Diagram

3. Results and Discussion:

3.1 Engineering Leadership for Disaster Management

One of the strategies of Disaster Risk Reduction National Strategic Plan of Action (2018 – 2030) clearly specifies: "to build capacity of engineers through training and awareness raising program for disaster resistant and better reconstruction". This clearly demonstrates the degree of significance being awarded to engineers in the policy making level. Some of the examples of contributions by different disciplines of engineering are demonstrated in Table-1.

Table 1: Examples of contributions by different discipline of engineering for DRR

SN	Discipline of Engineering	Contribution for Disaster Management		Examples
		Pre Disaster	Post Disaster	
1	Structural Engineering	- Formulate building codes for earthquake resistant structures - Effective implementation of the codes and proper investigation whether the codes are implemented - Design of structures such as embankments, dams for flood and tunnels and retaining walls for landslide	- Formulate and Implement the retrofitting and reconstruction codes - Design and reconstruct structures after the disaster has taken place - Carry out the research work on the effectiveness of building codes and pre disaster designs and update them as required.	Building Permit System in Kathmandu, Lalitpur metropolitan city and other urban municipalities

2	Geotechnical Engineering	- Investigation of subsoil in the earthquake and landslide prone areas - Assessment of liquefaction of soil before starting any projects (Sharma & Sharma, 2019)	- Carry out the research study of the soil in the landslide/earthquake site	The soil investigation in the landslide prone areas of Krishna Bheer of Dhading district
3	Electronic Engineering	- Establishment of a robust communication system in the Early Warning System (EWS) - Development of mobile applications for disaster data storage, update and assessment	- Develop a post disaster information and communication system for updating the data of the disaster victims	Development of Initial Rapid Assessment (IRA) mobile applications for quick and easy data record after the disaster event
4	Computer Engineering	- Development of software, applications useful for storing the disaster information -	- Develop a post disaster information and communication system for updating the data of the disaster victims	BIPAD and DRR Portal for information storing of each local governments
5	Transportation Engineering	- Identification of the proper evacuation route and shortest and safest path for transportation of relief and rescue materials (Lacuarin & Palmiano, 2010)	- Rapid reconstruction and maintenance of the damaged highways	Quick repair and maintenance of the Araniko Highway in Bhaktapur section after the 2015 earthquake

The relatable example for engineers regarding the preparedness of disaster is the implementation of earthquake resistant building codes while constructing new houses (Mesta et al., 2023). Many urban municipalities of Nepal have started to make it compulsory for the house owners to receive the municipal building permit. The civil/structural engineers in the respective local governments check and verify whether the buildings comply with the building code and whether the permit be given or not. The effective implementation of this system is very significant to reduce the loss due to future earthquake events. This practice, however, is still an alien notion in most of the rural municipalities of Nepal. Likewise, engineers belonging to the security forces such as Nepal Police, Armed Police Force and Nepal Army have been contributing in the rescue and reconstruction as well as the preparedness phase. In collaboration with the local governments, they have also conducted various simulation exercises and drills for flooding, fire and earthquake and fire hazards.

Moreover, it is well known that well developed information sharing and communication system is vital for disaster risk reduction(Shrestha et al., 2021). Computer and electronic engineers have been playing a lead role in the development of software system to store and update the nationwide disaster data in a single platform such as 'BIPAD' and DRR portal. Similarly, another example is the development of Initial Rapid Assessment (IRA) mobile application used for the collection of information such as the locality and impact of disaster within 24 hours of the disaster event (International Organization for Migration, 2020). It is easy to use, stores information quickly and provides the assessment report on the basis of provided information. This is helpful for the respective agencies to mobilize security forces for rescuing and searching for disaster affected people and distribute the relief materials.

The electronics and civil engineers in collaboration with other stakeholders can contribute through development of a robust early warning system especially for flood in the context of Nepal. Engineers have been working in team with various national and international agencies for developing EWS, Disaster Management Information System (DMIS) and contributing in enhancing preparedness and capacity of an individual and communities. There is a division under Ministry of Energy and water resources dedicated to Water Induced Disaster Management, led by

engineers which is aimed at strengthening the capacity of the nation and contributing in enhancing the resilience of society and nation.

One of the laudable contributions by engineers was during the response, reconstruction and recovery phase of the 2015 Gorkha Earthquake. The mega disaster caused 8790 casualties and 22,300 injuries; in the 31 affected districts, 498,852 private houses were fully destroyed and 256,697 private houses were partially damaged (Gautam & Cortés, 2021). For an underdeveloped nation like Nepal, it was a devastating blow in terms of human and ecSonomic loss. Immediately after the disaster took place, engineers (belonging to different discipline such as civil, computer, electronics and architect) were deployed to affected districts (Panthi et al., 2021). Diverse sets of roles and responsibilities had to be carried out by them. A group of senior engineers in collaboration with the government started formulating strategies to conduct the response and recovery actions post-earthquake. Whereas other groups led and coordinated the teams of young and recent passed out undergraduate engineers in the field level. Hundreds of them reached out to each and every earthquake affected villages. Their initial duty was to perform the damage and vulnerability assessment of structures, record the disaster data of each affected household and provide the output slip to the house owners. The immediate relief especially financial assistances were provided to house owners on the basis of assessment report. The government with the help of engineering experts published several design catalogues for reconstruction of earthquake resistant houses and repair and retrofit manuals for buildings that needed retrofitting(Shrestha et al., 2021). In the reconstruction phase, the engineers had been mobilized to monitor the construction process of individual houses, public buildings; impart trainings to mason and collect data and report to higher authorities.

It is to be noted that besides their own specialized fields, the engineers have to work in multidisciplinary teams which includes professionals from various sectors such as sociologists, economists and administrators. Heeding to voices from different sections and implementing measures for DRR initiatives is always a demanding task. Likewise, the engineering education needs a greater connection to practice from the first day (Passow & Passow, 2017). It needs more linkage to the society and there is need of inclusion of multidisciplinary skills such as negotiation, facilitation, understanding of other disciplines and sensitivity towards Gender Equality and Social Inclusion (GESI). For majority of the engineers, the Gorkha earthquake was the biggest disaster event of their lifetime as last such massive quake had taken place around eight decades back in 1934. The participation in earthquake response and reconstruction activity was crucial for engineers (especially the

young ones) in terms of developing leadership and making key decisions[1]. It offered them first hand opportunity to deal with challenges prevailing in the ground level, work with multidiscipline team, be familiar with GESI issues and use their skills to solve problems. Thus, proper exposure to challenges would further sharpen the engineering leadership and disaster management would be more effective.

3.2 Challenges:

Due to wider exposure of people to international arena, good opportunities in other sectors and easy admission due to a large number of engineering colleges, the reputation of engineering profession is not as it used to command till the late 1990s[2]. Furthermore, time and again there are news regarding the malpractices in the engineering sector. However, it would be gross injustice to the profession to generalize a conclusion on the basis of few incidents. Challenges are prevalent which are generic in nature i.e. applicable to whole engineering and others are specific to DRR. They are listed as follows:

i) **Lack of mainstreaming of DRR into the curriculum of engineering:**
Engineers who have passed their undergraduate do not necessarily seem to have the knowledge of hazard, risk and vulnerability, as the formal curriculum of the course does not have compulsory subject for DRR. Due to this many engineers are oblivious about the comprehensive knowledge of DRR despite having formal engineering degree. As a matter of fact, a senior academician who has influence in policy making in engineering education revealed that the leading educational institutions of engineering are back tracking from multidisciplinary course to a simple Masters in Civil Engineering Course undermining the international practices.

ii) **Lopsided capacity development trainings:**
The trainings for building codes is abundant which is a positive development but similar priority is not given to trainings for flood/landslide/GLOF risk assessment[3]. There have been initiations for imparting training on Geographical Information System (GIS). However such initiations mostly last for short span of time (2 to 3 days) for a course that requires detailed and longer duration (at least a week). The training programmes for Remote Sensing (RS) and machine learning with respect to DRR are almost non-existent. Another problem is the beneficiary

[1] Interview with engineer who was active in the field level during aftermath of earthquake
[2] KII with a senior civil engineer
[3] Opinion expressed by an engineer working in the sector of Remote Sensing

of such trainings work are mostly the government job holder engineers. The one representing private sectors are still lagging far behind in terms of exposure to capacity development.

iii) **Communication gap between engineers and public:**

It is a general problem in the engineering sector. However, the degree of communication gap seems to be more in the context of disaster of management. For example: the public tend to use the terms 'hazard' and 'disaster' interchangeably which actually have different meanings. Similarly, the concept of 'risk' and 'vulnerability' which is understood by the engineer may not match with the concept of public. Thus, due to technical jargons and varied definitions from the daily life, engineers struggle to properly communicate with the public.

iv) **Dearth of Coordination of NDRRMA with engineers:**

NDRRMA has been actively engaging a wider set of stakeholders for DRR and has been more visible. However there still prevails the dearth of coordination especially with engineers. An engineer working in DRR sector said that NDRRMA does not have done enough to reach out to at least the engineers working in DRR sector if not all engineers.[4] Similarly, there is lack of academia: Research and innovations in EWS, IEC material production, model shift homes development

4. Conclusions

Although engineers play a pivotal role in Disaster Risk Reduction, there is dearth of literature that explores this subject matter. That is why this research was carried out with an overall objective to analyze the engineering leadership for Disaster Risk Reduction in the context of Nepal. The specific objectives are: (i) To explore the roles of engineers in reducing the disaster risks (ii) To identify the prevailing challenges in the engineering sector. For the purpose, a mixed method was applied which included critical review of relevant literature and KII with engineers and policy makers. It was observed that engineers belonging to different disciplines have been contributing through various capacities for disaster management of Nepal. Furthermore, their contributions were listed out along with the relevant examples. Likewise the challenges faced by engineers in the DRR sector of Nepal was identified. Some of the major challenges are lack of mainstreaming of DRR notion in the engineering curriculum, lopsided capacity development programmes, communication gap with public and weak

[4] KII with engineer working in DRR sector

coordination with NDRRMA. Thus, it is the responsibility of the government to prioritize DRR capacity development for engineers. The experts and policy makers in engineering education sector need to incorporate the basic notions of disaster management as the compulsory topic. Likewise, trainings and awareness programmes should be launched to aware the public about disaster risk and reduce the communication gap with engineers. Further studies in the engineering leadership and DRR sector would contribute in effective implementation of disaster risk reduction.

References

Adhikari, B. R., & Gautam, S. (2022). A Review of Policies and Institutions for Landslide Risk Management in Nepal. *Nepal Public Policy Review*, *2*, 93–112. https://doi.org/10.3126/nppr.v2i1.48397

Adhikari, T. R., Baniya, B., Tang, Q., Talchabhadel, R., Raj, M., Budhathoki, B. R., & Awasthi, R. P. (2023). Evaluation of Post Extreme Floods in High Mountain Region: A Case 2 Study of the Melamchi Flood 2021 at the Koshi River Basin in Nepal. *Natural Hazard Research*. https://doi.org/10.1016/j.nhres.2023.07.001

Amir, S., & Juraku, K. (2014). Undermining disaster : engineering and epistemological bias in the Fukushima nuclear crisis. *Engineering Studies*, 37–41. https://doi.org/10.1080/19378629.2014.976570

Bozza, A., Asprone, D., & Fabbrocino, F. (2017). Urban Resilience : A Civil Engineering Perspective. *Sustainability*, 1–17. https://doi.org/10.3390/su9010103

Broadbent, M., & Broadbnet, S. G. (2013). The role of professional engineers in disaster management. *Forensic Engineering*, *166*.

Crosweller, M. (2022). Disaster management leadership and the need for virtue , mindfulness , and practical wisdom. *Progress in Disaster Science*, *16*. https://doi.org/10.1016/j.pdisas.2022.100248

Enia, J. (2020). Is there an international disaster risk reduction regime ? Does it matter ? *Progress in Disaster Science*, *7*, 100098. https://doi.org/10.1016/j.pdisas.2020.100098

Gautam, D., & Cortés, G. (2021). Reconstruction assistance in rural Nepal after the 2015 Gorkha Nepal earthquake through Aarma Parmah approach - A case study in Bijulikot , Ramechhap District. *Progress in Disaster Science*, *10*. https://doi.org/10.1016/j.pdisas.2021.100148

Guragain, U. P., & Doneys, P. (2022). Social , Economic , Environmental , and Physical Vulnerability Assessment : An Index-Based Gender Analysis of Flood Prone Areas of

Koshi River Basin in Nepal. *Sustainability*, *14*. https://doi.org/https://doi.org/10.3390/su141610423 Academic

International Organization for Migration. (2020). *DISASTER RISK MANAGEMENT LOCALIZATION MANUAL*.

Joshi, R., & Joshi, M. (2015). Quality Assurance in Engineering Education in Nepal : Issues and Challenges. *7th International Forum on Engineering Education (IFEE2015)*,.

Lacuarin, J. R., & Palmiano, H. S. O. (2010). The Role of Transportation Engineering in Disaster Management. *18th Annual Conference of the Transportation Science Society of the Philippines*.

Liebrand, J., & Udas, P. B. (2017). Becoming an Engineer or a Lady Engineer: Exploring Professional Performance and Masculinity in Nepal's Department of Irrigation. *Engineering Studies*, *9*(2), 120–139. https://doi.org/10.1080/19378629.2017.1345915

Mall, R. K., Srivastava, R. K., Banerjee, T., Mishra, O. P., Bhatt, D., & Sonkar, G. (2019). Disaster Risk Reduction Including Climate Change Adaptation Over South Asia : Challenges and Ways Forward. *International Journal of Disaster Risk Science*, *10*(1), 14–27. https://doi.org/10.1007/s13753-018-0210-9

Manandhar, B., Dongol, Y., & Ganapati, E. (2022). Governing the post-disaster recovery network in Nepal: Organizational challenges of public managers. *International Journal of Disaster Risk Reduction*, *81*(June), 103245. https://doi.org/10.1016/j.ijdrr.2022.103245

Mesta, C., Kerschbaum, D., Cremen, G., & Galasso, C. (2023). Quantifying the potential benefits of risk-mitigation strategies on present and future seismic losses in. *Earthquake Spectra*, *39*. https://doi.org/10.1177/87552930221134950

Online Khabar. (2023). *71.5% of BE graduates fail the engineer's licence test - OnlineKhabar English News*. https://english.onlinekhabar.com/fail-the-engineers-licence-test.html

Panthi, G. K., Bajracharya, A. R., Khanal, R., & Subedi, S. (2021). Types and Sizes of Structures in Rural Housing Reconstruction in the Socio-Economic Context of Nepal. *Vikas*.

Passow, H. J., & Passow, C. H. (2017). What Competencies Should Undergraduate Engineering Programs Emphasize? A Systematic Review. *Journal of Engineering Education*, *106*(3), 475–526. https://doi.org/10.1002/jee.20171

Perry, S. J., Hunter, E. M., Currall, S. C., & Frauenheim, E. (2017). Developing Engineering Leaders: An Organized Innovation Approach to Engineering Education. *EMJ - Engineering Management Journal*, *29*(2), 99–107.

https://doi.org/10.1080/10429247.2017.1298189

Shah, R. K., & Alotaibi, M. (2018). A Study of Unethical Practices in the Construction Industry and Potential Preventive Measures. *Journal of Advanced College of Engineering and Management*, *3*, 55. https://doi.org/10.3126/jacem.v3i0.18905

Sharma, A. (2023). Employability of engineering graduates in Nepal : Employers ' perspectives. *Journal of Management and Development Studies*, *32*(1), 26–38. https://doi.org/https://doi.org/10.3126/jmds.v32i1.56636

Sharma, A., & Sharma, N. (2019). Role Of Civil Engineers In Disaster Mitigation And Management- A Swot Analysis. *International Conference: Mangalmay Institute*, *December*.

Shrestha, B., & Pathranarakul, P. (2018). Nepal government's emergency response to the 2015 earthquake: A case study. *Social Sciences*, *7*(8). https://doi.org/10.3390/socsci7080127

Shrestha, L., Shakya, S. M., & Norris, A. (2021). Comparing Seismic Retrofitting Approaches of Traditional Stone Masonry in Mud Mortar Buildings in Nepal. *Vikas: Special Issue on Nepal's Recovery & Reconstruction*.

Shrestha, M. S., Gurung, M. B., Khadgi, V. R., Wagle, N., Banarjee, S., Sherchan, U., Parajuli, B., & Mishra, A. (2021). The last mile: Flood risk communication for better preparedness in Nepal. *International Journal of Disaster Risk Reduction*, *56*(June 2019). https://doi.org/10.1016/j.ijdrr.2021.102118

Shrestha, R. K., Parajuli, H. R., & Poudel, B. (2021). Building typologies and code compliance issues of reconstructed houses after 2015 Mw 7.8 Gorkha, Nepal earthquake: Experience from Dhading District earthquake. *Progress in Disaster Science*, *10*, 100155. https://doi.org/10.1016/j.pdisas.2021.100155

Shrestha, R. N., Awasthi, J. R., & Pahari, B. R. (2020). Impact of English Language Proficiency on the Quality of Job Execution of Engineers in and outside Nepal: A Study at a Glance. *Journal of the Institute of Engineering*, *15*(1), 250–256. https://doi.org/10.3126/jie.v15i1.27742

Thapa, P., & Shrestha, S. K. (2018). A Study of Job Satisfaction among Civil Engineers Working in Hydropower Sector in Consulting Firms. *Journal of the Institute of Engineering*, *14*(1), 165–169. https://doi.org/10.3126/jie.v14i1.20081

Thapa, S., Shrestha, A., Lamichhane, S., Adhikari, R., & Gautam, D. (2020). Catchment-scale flood hazard mapping and flood vulnerability analysis of residential buildings: The case of Khando River in eastern Nepal. *Journal of Hydrology: Regional Studies*, *30*(March), 100704. https://doi.org/10.1016/j.ejrh.2020.100704

Thompson, I., Shrestha, M., Chhetri, N., & Agusdinata, D. B. (2020). An institutional analysis of glacial floods and disaster risk management in the Nepal Himalaya. *International Journal of Disaster Risk Reduction*, *47*(July 2019), 101567. https://doi.org/10.1016/j.ijdrr.2020.101567

Trevelyan, J. (2019). Transitioning to engineering practice. *European Journal of Engineering Education*, *44*(6), 821–837. https://doi.org/10.1080/03043797.2019.1681631

Uhr, C. (2017). Leadership Ideals as Barriers for Efficient Collaboration During Emergencies and Disasters. *Journal of Contingencies and Crisis Management*, *25*(4), 301–312. https://doi.org/10.1111/1468-5973.12157

UNISDR. (2015). *Sendai Framework for Disaster Risk Reduction 2015-2030*.

Upreti, Y. (2022). Role of Security Forces in Disaster Management with references to Nepalese Security Forces. *Patan Pragya*, *10*(01), 217–227. https://doi.org/10.3126/pragya.v10i01.50767

Walther, J., Miller, S. E., & Sochacka, N. W. (2017). A Model of Empathy in Engineering as a Core Skill, Practice Orientation, and Professional Way of Being. *Journal of Engineering Education*, *106*(1), 123–148. https://doi.org/10.1002/jee.20159

Wanner, M. S. T. (2022). Change in policy regimes for disaster risk reduction in Fiji and Nepal. *International Journal of Disaster Risk Reduction*, *77*(April), 103030. https://doi.org/10.1016/j.ijdrr.2022.103030

Annex

Table 2: List of documents reviewed for the study

SN	Documents
1	Sendai Framework for Disaster Risk Reduction (2015-2030)
2	National Disaster Risk Reduction and Management Act, 2017
3	Nepal Disaster Risk Reduction National Strategic Plan of Action (2018-2030)
4	National Building Code (NBC): 105:2020
5	Vikas: A Journal of Development, 2021
6	Progress in Disaster Science: Nepal's Post Earthquake Reconstruction And Recovery Special Issue Vol I, 2021
7	Mainstreaming Disaster Risk Reduction into Construction works Resilient Infrastructure A Hands on Training to Engineers, 2021
8	Manual for Hands-on Training to Engineers on Slope Stabilization Techniques 2021
9	DRR Localization Manual

Table 3: Questionnaire for KII

SN	Questions
1	How do you view the present status of engineering leadership for DRR?
2	What are some of the prominent examples of engineer's contribution to DRR?
3	What are the challenges for engineer especially in the sector of disaster management?
4	In your personal experience what has been the memorable issue regarding the disaster management?
5	What could be the future way outs for DRR initiatives and engineering leadership to align with each other?

Waste Water Treatment Using Duckweed

Ajay Kumar Jha[1,*], Hari Bahadur Darlami [2], Aavas Pokharel[3], Narayan Rai[4]

[1, 2] *Department of Mechanical and Aerospace Engineering, Pulchowk Campus, Institute of engineering, Tribhuvan University, Nepal*

[3, 4] *Center for Pollution Studies, Institute of Engineering, Tribhuvan University, Nepal*

[1]akjha@ioe.edu.np, [2]haridarlami@ioe.edu.np, [3]pokhaavas@gmail.com, [4]075bme027.narayan@pcampus.edu.np

Abstract

The growth in production of waste water poses a great challenge in dealing with environmental sustainability. Various types of waste water treatment plants are developed already but most of them are technology hungry and requires great deal of management. Duckweed has a great potential in serving as a cheap and effective way of treating waste water. In this research paper, we investigate the effectiveness of duckweed cultivation in treating waste water. We conducted a controlled experiment in two ponds monitoring and analyzing water quality parameters over a two-month period. The experiment led to a significant decrease in harmful characteristics. Notable changes include pH of water reaching near seven, neutralization of electrical conductivity (560 µS/cm pond 1, 290 µS/cm pond 2) and total absorption of ammonia and iron. The measured parameters were compared with the WHO set guidelines and the result shows that the water quality significantly increased. Our finding suggest that duckweed can be valuable tool for wastewater treatment.

Keywords: duckweed, waste water treatment, water quality

1. Introduction

The ever-increasing burden of wastewater generation poses a significant challenge to global environmental sustainability. Conventional wastewater treatment methods, while effective, are often energy-intensive, expensive, and reliant on harsh chemicals. In this context, the humble

duckweed plant emerges as a promising and eco-friendly alternative. Unlike hydrophytes which cannot adapt well to high ammonia concentrated swine wastewater, microalgal and duckweed plants are more promising in the removal of nutrients (Xiang Li, 2020). These unassuming aquatic marvels, with their rapid growth rates and remarkable nutrient-absorbing abilities, present a unique opportunity for decentralized and sustainable wastewater treatment. It is an affordable technology which uses plants as environmental cleansers in wastewater treatment also serving as cheap manure and fertilizers (Ekta Chaudhary, 2014).

Duckweed, a collective term for several small, free-floating aquatic plants belonging to the Lemnaceae family, thrives in nutrient-rich environments. Their rootless existence allows them to readily absorb pollutants and excess nutrients directly from the water column. This natural filtering capacity makes them adept at removing organic matter, nitrogen, phosphorus, and even heavy metals from wastewater. Unlike conventional systems, duckweed-based treatment relies on natural biological processes, requiring minimal energy input and avoiding the use of harmful chemicals. Even if the plant is effective in controlling pollution, high protein content, and control of negative impact of traditional waste water treatment, their extensive use is still difficult due to the requirement of high amount of land area and ceasing of growth in winter (Bonomo L, 1997)

Furthermore, the rapid reproduction of duckweed allows for efficient biomass production, which can be harvested and repurposed into various valuable products, such as biofuel, fertilizer, or animal feed. This adds another layer of sustainability to the entire process, transforming waste into valuable resources (Bonomo L, 1997).

Given the multifaceted benefits of duckweed-based wastewater treatment, this research paper delves into the intricacies of this promising technology. We will explore the mechanisms by which duckweed purifies water, evaluate its effectiveness in treating different types of wastewaters, and assess its potential for real-world application. Through a comprehensive analysis of the scientific literature, field studies, and economic considerations, we aim to shed light on the transformative potential of these tiny titans in revolutionizing wastewater management and paving the way for a more sustainable future.

2. Materials and Methods

2.1 Location and Cultivation

The experiment was performed in two artificial ponds in the premises of Pulchowk Campus, Lalitpur. One of the test sites was the pond behind the Center for Energy Studies (CES), Pulchowk Campus (latitude 27°41'00.9"N, longitude 85°19'16.6"E) (Pond 2). The water already present in the pond was used as sample waste water. For the second site, two ponds were dug behind the campus canteen (latitude 27°40'52.2"N, longitude 85°19'25.4"E) with dimensions (5×5.4×0.7) m^3 (Pond 1). The waste water coming from the canteen was used as sample waste water. The waste water was not replaced during the whole period of experimentation.

Seeds and saplings of duckweed are placed in the ponds for cultivation. Duckweed is a rich source of nitrogen, phosphorus, potassium and calcium. Duckweed grows faster than most other plants. Generally, it doubles their mass in 16 hours to 2 days under favorable conditions. This cultivated duckweed is used for producing biofuel and biogas after its treatment with wastewater from the hostel and canteen. The duckweed is harvested using the manual skimming of the plant from the pond surface using net.

2.2 Operation and Sampling

Initially a series of tests were done on the wastewater and the results were recorded. Table *1* shows the characteristics that were obtained from the test. For Pond 1, Turbidity was found to be 7.7 NTU along with pH 6.49h and electric conductivity 1970 µS/cm. The total alkalinity as CaCo was 225.62 mg/l, total hardness as CaCo3 was 389.88 mg/l, Calcium hardness as CaCo3 was 171.55 mg/l, Magnesium hardness was 218.33 mg/l, Calcium as Ca was 68.69 mg/l, Magnesium content was 53.49 mg/l, total Iron as Fe was 17.64 mg/l, total Ammonia as N was 6.85 mg/l. Similarly, water from Pond 2 had the initial turbidity of 0.5 NTU, pH of 6.64 and electrical conductivity of 230 µS/cm. Total alkalinity as CaCo was 56.98 mg/l, total hardness as

$CaCO_3$ was 128.66 mg/l, calcium hardness as $CaCO_3$ was 122.81 mg/l, Magnesium hardness was 5.85 mg/l, Calcium as Ca was 49.17 mg/l, Magnesium content was 1.43 mg/l, total ammonia as N was 0.8 mg/l.

Table 1 Parameters of waste water before duckweed cultivation

Parameters	**Pond 1**	**Pond 2**	**WHO Limits**	**Methods**
Turbidity (NTU)	7.7	0.5	<5	2130 B APHA 22nd
pH	6.49	6.64	6.5-8.5	4500 H APHA 22nd
Electrical Conductivity (µS/cm)	1970	230	<1250	2520 B APHA 22nd
Total Alkalinity as CaCO (mg/l)	225.62	56.98	<500	2320 B APHA 22nd
Total Hardness as $CaCO_3$ (mg/l)	389.88	128.66	<500	2340 B APHA 22nd
Calcium Hardness as $CaCO_3$ (mg/l)	171.55	122.81		3500 Ca APHA 22nd
Magnesium Hardness (mg/l)	218.33	5.85		3500 Mg APHA 22nd
Calcium as Ca (mg/l)	68.69	49.17	<200	3500 Ca APHA 22nd
Magnesium as Mg (mg/l)	53.49	1.43	<150	3500 Mg APHA 22nd
Total Iron as Fe (mg/l)	17.64	0	up to 0.3	3500 Fe APHA 22nd
Total Ammonia as N (mg/l)	6.85	0.8	up to 1.5	4500 NH3 APHA 22nd
Chloride as Cl (mg/l)	260.09	19.12	up to 250	4500 Cl B APHA 22nd
Nitrate (mg/l)	28.27	7.41	<45	4500 NO3 B APHA 22nd

Sulphate (mg/l)	37.052	3.794	up to 400	4500 SO4 E APHA 22nd
TSS (mg/l)	5	5	100 PPM	2540 D APHA-AWWA-WEF 2017 23rd Ed
VSS (mg/l)				2540 E APHA-AWWA-WEF 2017 23rd Ed

Similar tests were conducted periodically to determine the improvement in the quality of water. During the process, the by-product is produced which is enriched with protein. This process was resumed only after the duckweed started regrowing.

3. Results and Discussion

After the preparation of test sites and sample waste water collection, duckweed seeds were introduced into them. The plant started to sprout in about 2 days. The initial quality of water was tested for both ponds and recorded. Table 2 shows the parameters that were tested for in the waste water after 63 days of the cultivation of duckweed. The results were then compared against WHO limits to observe the waste water treatment ability of duckweed plant.

Table 2 Parameters of waste water after duckweed cultivation

Parameters	**Pond 1**	**Pond 2**	**WHO Limit**	**Methods**
Turbidity (NTU)	0.3	0.2	<5 T	2130 B APHA 22nd
pH	6.74	7.01	6.5-8.5	4500 H APHA 22nd

Electrical Conductivity (µS/cm)	560	290	<1250	2520 B APHA 22nd
Total Alkalinity as CaCO (mg/l)	116.3	61.53	<500	2320 B APHA 22nd
Total Hardness as $CaCO_3$ (mg/l)	89.67	181.29	<500	2340 B APHA 22nd
Calcium Hardness as $CaCO_3$ (mg/l)	70.18	134.5		3500 Ca APHA 22nd
Magnesium Hardness (mg/l)	19.49	46.79		3500 Mg APHA 22nd
Calcium as Ca (mg/l)	28.1	53.85	<200	3500 Ca APHA 22nd
Magnesium as Mg (mg/l)	4.776	11.46	<150	3500 Mg APHA 22nd
Total Iron as Fe (mg/l)	0	0	up to 0.3	3500 Fe APHA 22nd
Total Ammonia as N (mg/l)	0	0	up to 1.5	4500 NH3 APHA 22nd
Chloride as Cl (mg/l)	50.68	27.73	up to 250	4500 Cl B APHA 22nd
Nitrate (mg/l)	5.44	3.39	<45	4500 NO3 B APHA 22nd
Sulphate (mg/l)	13.5	9.05	up to 400	4500 SO4 E APHA 22nd
TSS (mg/l)	80	80	100 PPM	2540 D APHA-AWWA-WEF 2017 23rd Ed

VSS (mg/l)	0	0	2540 E APHA-AWWA-WEF 2017 23rd Ed

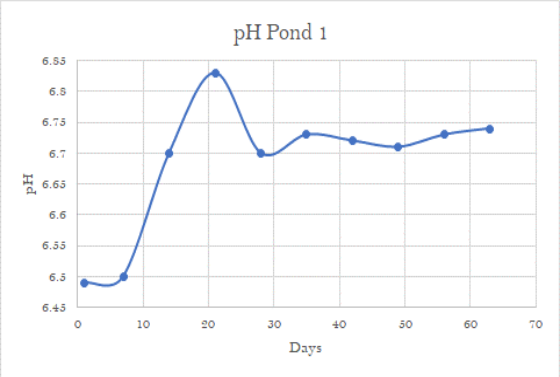
The result shows considerable change in the water characteristics. Both water samples were within WHO limit for safe water after plantation of duckweed. It shows that duckweed cultivation can be a good way to reduce water pollution. In both ponds pH levels rise from acidic to more neutral or basic level.

Turbidity of water of pond 1 reduced to 0.3 from 7.7 NTU. Conductivity reduced drastically to 560 µS/cm from 1970 µS/cm. Alkalinity of water dropped to 116.3 mg/l from 225.62 mg/l. Hardness level as $CaCO_3$, Calcium hardness and magnesium hardness also reduced to more safe levels, 70.18 mg/l and 19.49 mg/l respectively, along with reduction in Calcium to 28.1 mg/l, Magnesium to 4.776 mg/l, Nitrate to 5.44 mg/l and Sulphate to 13.5 mg/l. Iron content and Ammonia were not detected in the final water sample indicating complete absorption by duckweed.

Similarly, test pond 2 also shows improvement in the quality of water. The turbidity reduced to 0.2 from 0.5 NTU. pH neutralized to level 7.01. Electrical conductivity increased to 290 µS/cm. Alkalinity as CaCO increased to 61.53 mg/l and total, calcium and magnesium hardness all increased. Calcium and Magnesium contents also increased. But they all lie within the acceptable WHO limits.

3.1 Effect on the pH level

The pH of water on both the samples increased from more acidic to more neutral state (Figure *1*). Both the ponds were observed to be habituated by algae after about 3 days. The increase in pH can be associated to the depletion of carbon dioxide in water and, consequently, a high water pH. The drop in pH was due to the increase in duckweed coverage density to about 100%, which led to the depletion or disappearance of algae biomass.



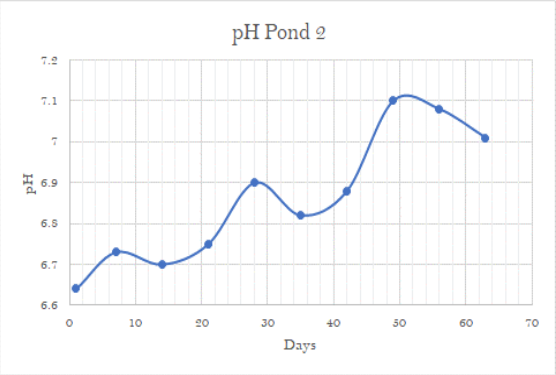
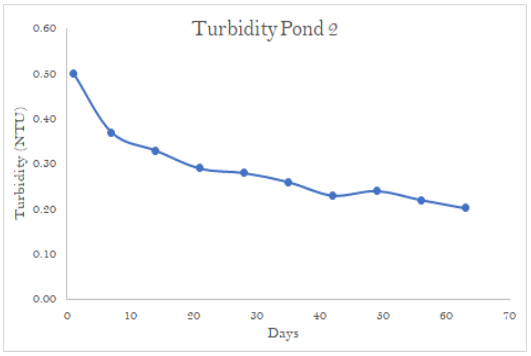


Figure 1 pH level against days

3.2 Effect on Turbidity

The Figure 2 reveals a clear downward trend in the water's turbidity as the number of days with duckweed cultivation increases. This suggests a strong link between the presence of these plants and improved water clarity. Two potential mechanisms likely contribute to this effect: firstly, the physical filtration provided by the duckweed's roots and leaves, which trap suspended solids and prevent their re-suspension. Secondly, the increased dissolved oxygen levels arising from duckweed photosynthesis could facilitate the decomposition of organic matter, further reducing turbidity.



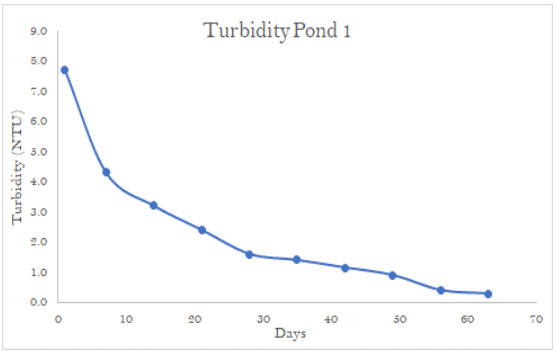


Figure 2 Turbidity (NTU) against days

3.3 Effect on Electrical Conductivity

In pond 1, the electrical conductivity is seen to reduce from 1970 µS/cm to 560 µS/cm. This can be explained by the fact that duckweed plant is efficient in removing dissolved ions like nitrates, phosphates and potassium. Pond 1 was filled with water coming from campus canteen which is high in calcium, chloride, nitrate, sulphate and magnesium. The duckweed plant can absorb these minerals reducing salinity, consequently, the electrical conductivity. While in pond 2, the electrical conductivity increases by some amount. This can be attributed to the presence of algae already in the pond. The growth of duckweed reduces the amount of carbon dioxide in the water which leads to elimination of algae. The dead algae releases ions like nitrates, phosphates and potassium which can increase the overall electrical conductivity.

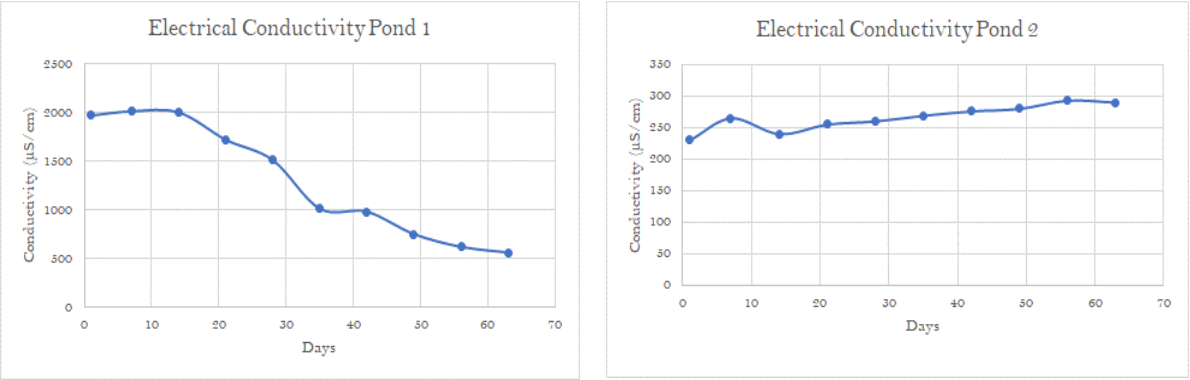


Figure 3 Conductivity (µS/cm) against days

4. Conclusion

Treatment of waste water from different sources is a major challenge in the present time to ensure environmental sustainability. Cultivation of duckweed was a simple, cheap and effective way to treat waste water and neutralize their properties. This study shows that duckweed can significantly improve water quality. Regular tests and monitoring prove that the water characteristics are within acceptable range set by WHO. Cultivation of duckweed can not only work as reasonable way to treat waste water, but can also serve as biomass for biogas production

due to richness in protein and nutrients. Further studies are necessary to understand the major advantages and application of duckweed.

Acknowledgements

Authors would like to express immense gratitude to EnergizeNepal and "Center for Pollution Studies (CPS), IOE" for providing the finance, opportunity and expertise to conduct this research via the project "Clean Energy Generation using Duckweed (PID: ENEP-RENPII-22-03. Authors would like to express gratitude to Dr. Bijay Thapa, Program Manager, EnergizeNepal, Mr. Subir Karn for their valuable inputs to this research.

References

Ankita Suhag, R. G. (2011). Biosorptive Removal of Heavy Metals from Wastewatr using Duckweed. *International Journal of Biomedical and Advance Research*.

B. Roman, R. B. (2019). A Beneficial By-Product of Ecological Wastewater Treatment: an Evaluation. *Ecological Engineering*.

Bonomo L, P. G. (1997). Advantages and Limitations of Duckweed-Based Wastewater Treatment Systems. *Water Science and Technology*.

Ekta Chaudhary, P. S. (2014). Use of Duckweed in Wastewater Treatment. *International Journal of Innovative Research in Science, Engineering and Technology*.

J.M. Dalu, J. N. (2003). Duckweed based wastewater stabilization ponds for wastewater. *Physics and Chemistry of the Earth*.

Juliet Selvarani, P. S. (2015). Performance of Duckweed (Lemmna minor) on different types of wastewater treatment. *International Journal of Fisheries and Aquatic Studies*.

Xiang Li, S. W. (2020). Microalgal and Duckweed Based Constructed Wetlands for Swine Wastewater. *Bioresource Technology*.

16th NATIONAL CONVENTION OF ENGINEERS

JANUARY 03-04, 2024

Engineering for National Prosperity and Effective Governance

Nepal Engineers' Association

Engineer Bhawan, Pulchowk, Lalitpur, G.P.O. Box: 604, Kathmandu, Nepal
Tel.: +977 1 5010251, 5010252, Email: info@neanepal.org.np
www.neanepal.org.np