8th SONEUK CONFERENCE PROCEEDINGS

Engineering for Environment

Society of Nepalese Engineers in UK

Saturday, 8th July 2023

Published by:
Society of Nepalese Engineers in UK (SONEUK)
With the guidance of the 8th SONEUK Conference Committee
and collaboration with the Nepal Engineers' Association
London
United Kingdom

ISBN 978-1-9196046-2-6

United Kingdom, 2023

Contents

Editorial

Engineering for Environment is about developing and implementing technologies and strategies that reduce the impact of human activities on the environment. It should aim to protect the natural environment and improve the quality of life for humans by addressing issues such as pollution, waste management and resource conservation with the help of effective engineering technologies.

Engineering has a significant role in protecting the environment by developing sustainable products, processes, and systems. Engineers have been working tirelessly to reduce the negative impact on the environment and promote a cleaner future. Therefore, investing more in engineering research and development is vital for a sustainable future. In this context, the Society of Nepalese Engineers in UK (SONEUK) is organizing its 8th SONEUK conference on Engineering for Environment on 8th July 2023 in London.

The conference proceeding comprises six peer-reviewed papers. It covers a wide range of engineering topics mostly related to Nepalese contexts. The papers present the future of Biomass energy, the implementation of electric equipment for sustainable construction, the role of concrete for sustainable development, and the highway infrastructure vulnerability due to climate change. Other papers highlight proving pedestrian crossing in Kathmandu metropolitan city, and one paper investigates the benefits and challenges of BIM adoption in Nepal. Together, these papers provide exciting and valuable information for readers on various aspects of engineering's impact on sustainable development.

Similar to our previous publications, we hope this proceeding will further enhance the exchange and dissemination of technical & academic knowledge to a broader audience within and outside SONEUK. It is acknowledged that there may be a lack of data in some areas covered in the proceedings, especially in the context of Nepal, to inform the factual content of the papers. We assume that the topics covered in the proceedings will provide a foundation for further discussion in enhancing research & development and innovative engineering approaches for sustainable development through the SONEUK platform. We welcome any feedback and constructive suggestions for improvements to be addressed in future proceedings.

As an editorial team, we are very honoured to facilitate the publication of the proceedings. We would like to thank all the authors and keynote speakers for their invaluable contributions. It has been a pleasant experience to put these papers together, and we hope you will find it interesting to read the papers too.

Ambassador's Message

नेपाली राजदूतावास
EMBASSY OF NEPAL, LONDON

AMBASSADOR

Message

I am pleased to learn about the publication of the proceedings of the annual event entitled "Engineering for Environment" as part of the 8th annual international engineering conference organized by the Society of Nepalese Engineers UK (SONEUK) in July 2023. On this occasion, I would like to extend my warm greetings and best wishes for the continued progress of SONEUK and congratulate all the members of this association on their overall growth and development.

Since its establishment, SONEUK has been instrumental in bringing together Nepalese engineers to discuss on topics of interest to Nepal. The engineering knowledge and experiences gained in the UK can be used for the much-needed development efforts in Nepal. I have found that SONEUK has a great interest in sharing the technological know-how and experiences in Nepal. SONEUK, as a respected Nepalese professional organization of engineers in the UK, is also contributing to the professional development and networking of its members through several academic conferences, seminars and interaction programmes.

I am confident that the annual international conference continues the tradition of bringing together Nepalese engineers and professionals from around the world for the benefit of Nepal. I value the efforts of SONEUK and their contributions to the humanitarian causes especially during the earthquake in 2015, COVID-19 pandemic and other natural disasters. The Embassy is pleased to collaborate with the Society of Nepalese Engineers UK for further utilization of knowledge, expertise and experiences in the development efforts of Nepal in the days ahead.

I would like to convey my best wishes for the success of the international conference organized under the auspices of SONEUK.

Gyan Chandra Acharya

EMBASSY OF NEPAL, 12A KENSINGTON PALACE GARDENS, LONDON W8 4QU
Tel: 020 7229 1594, Fax: 020 7792 9861 Email: officesecretary@nepembassy.org.uk

Chairperson's Message

Welcome to the eighth edition of the Society of Nepalese Engineers in UK (SONEUK) conference, an academic endeavour at the forefront of fostering technical excellence and collaboration within the Nepalese engineering community in the UK. This year, under the theme of "Engineering for Environment", we embark on a journey to explore engineers' critical role in creating a sustainable future for our communities and the planet.

The importance of community standards and inherent cultures cannot be overstated. As a migrant organization, SONEUK holds immense value in fostering self-realization and collective benchmarking for the Nepalese population spreading worldwide. Our diverse community is akin to a thriving forest, where different individuals and groups coexist, supporting and relying on each other. It is this coexistence that defines the wholesome natural value of our community.

Over the years, SONEUK has evolved into a platform that brings together Nepalese engineers from various backgrounds and provides them with opportunities to contribute to the engineering ecosystem in the UK and Nepal. Our conference has grown in stature and recognition, attracting contributions from talented engineers worldwide. We take immense pride that our technical festival has stood the test of time and continues to make a significant impact.

As we reflect on the past and look to the future, it is crucial to acknowledge the visionary leaders who have shaped SONEUK into what it is today. It is a testament to our collective strength and commitment to advancing engineering excellence.

I would like to extend my heartfelt gratitude to our convener, Mr Hari Nepal, for his exceptional efforts in curating a conference program that holds immense academic and research value for the engineering sector in Nepal. This conference not only marks the culmination of our tenure but also serves as a reminder of the opportunities and responsibilities that lie ahead. As we pass the torch to the next generation of leaders, we are confident that SONEUK will continue to thrive and make a meaningful impact on the engineering landscape. I would like to express my deepest gratitude to our members, volunteers, presenters, and organizers who have made this conference a reality. Your unwavering support and dedication have been instrumental in our collective success. We acknowledge that mistakes may have occurred along the way, and we humbly ask for your forgiveness while appreciating your understanding.

Engineering knows no boundaries of time and space. It is a passion that transcends borders and connects us all. As we gather here today, let us embrace our shared vision of engineering for the environment and work together to create a sustainable and prosperous future for our communities and future generations.

Rudra Koirala
Chairperson,
Society of Nepalese Engineers in UK

Providing Pedestrian Crossing Facilities in Kathmandu

Dr. Birendra Shrestha

Principal Transport Modeller, Transport for London, United Kingdom
Email: b.p.shrestha@hotmail.com

Abstract

Kathmandu, the capital city of Nepal, is the main hub for business, education, health and foreign travel. As a result, the population of Kathmandu is going up by a million within few years. This has led to the increased traffic both motorised as well as non-motorised. Even though there is a high number of the motorised traffic, walking is still the main mode of transport. However, the pedestrian facilities are in poor state in most places as motorised traffic gets priority when providing facilities.

There are different types of pedestrian crossing facilities that could be provided. These include zebra crossing, signalised pedestrian crossing and pedestrian footbridges or underpasses. The selection of an appropriate pedestrian facility depends on the traffic situation in the area. The most common forms of pedestrian facility available in Kathmandu are pedestrian footpaths along the road and the zebra crossings. In most places, the pedestrian footpaths are not properly maintained, and the Zebra crossings are hardly recognised and honoured by the drivers. In recent years, pedestrian footbridges are constructed to provide safe passage at busy roads. However, because of their design (a lot of steps to go up and down), they are difficult to use, especially for the mobility impaired people. Hence, to improve the environment of the most sustainable mode of transport, appropriate pedestrian facilities need to be provided. This paper reviews various pedestrian crossing facilities available and proposes a methodology to select an appropriate pedestrian facility for a location.

Keywords: Pedestrian crossing, pedestrian footbridge, Zebra crossing, signalised crossing

1. Introduction

Kathmandu, the capital city of Nepal, is the main hub for business, education, health and foreign travel. As a result, the population of Kathmandu is going up by a million within few years. This has led to the increased motorised traffic as well as non-motorised traffic mainly in the form of pedestrians. Even though there is a high number of the motorised traffic, walking is still the main mode of transport. United Nations Environmental Programme (UNEP, 2023) states that around 40% of the total trips of Kathmandu is estimated through walking. Despite this large proportion of pedestrian trips, it is difficult to cross a road at many places due to poor crossing facility. With increasing population of senior citizens and scarce pedestrian crossing facilities, pedestrian crossing is risky. As a result, there are numerous traffic accidents involving pedestrians.

In recent years, pedestrian facilities are getting some attention. However, the primary focus seems to be to alleviate traffic congestion rather than to provide safe and user-friendly crossing for pedestrians. Many of these pedestrian facilities are not located properly and are in poor state in most places. This paper reviews various pedestrian crossing facilities available and proposes a methodology to select an appropriate pedestrian facility for a location.

2. Pedestrian Crossing Facilities

A pedestrian crossing is a facility designed to assist pedestrians crossing a road with vehicular traffic. Pedestrian crossing facilities are required to accommodate a wide variety of user types, needs, and abilities. A pedestrian crossing can take many forms, ranging from ‘informal’ facilities, such as pedestrian ‘refuges’ in the middle of single carriageway roads, to ‘formal’ facilities such as the Zebra crossing, signalised pedestrian crossing and pedestrian footbridges or underpasses.

2.1 Zebra Crossing

A Zebra crossing is marked with black and white strips painted on the road surface. Such a crossing area gives more visibility of the crossing pedestrians and reassures pedestrians on the road. A Zebra crossing does not force traffic to stop by means of a traffic light but, in many developed countries including the UK, it does give pedestrians permanent right of way. When used in the right location (low, slow traffic flow), it involves the minimum delay for both pedestrians and motorists. Level access, either by dropped kerb or raised road crossing, is provided to improve accessibility (see Figure 1).

However, it can be argued that the Zebra crossing lacks safety protection for pedestrians because there is no clear signal indication to either pedestrians or vehicles. In theory, a pedestrian can step on the crossing when they arrive, having immediate right-of-way. However, in practice, pedestrians wait for a suitable gap in the traffic or until an approaching vehicle is clearly decelerating, before entering the crossing. Hence, where vehicle flow (the number of vehicles) is high, pedestrians can incur high waiting times. Conversely, where the pedestrian flow (number of pedestrians) is high, pedestrians may dominate the crossing and cause high vehicle delays where vehicle flow is high. Hence zebra crossing is suitable where vehicle flow is low.

Figure 1: A Zebra crossing in Orpington, UK

Zebra crossings are suitable urban areas where the vehicle speed is low and the pedestrian number is high. Such facility is not suitable for high speed road from safety point of view as well as traffic capacity point of view. In high speed road, there is confusion, severe accident could happen. Traffic capacity of the road being crossed could be reduced significantly if all drivers stop to giveway to the pedestrians.

Amongst the facilities, zebra crossing is the cheapest facility as it is mainly based on the painting the road surface. However, in the developed countries, it is made in level with the footpath and guided by flashing yellow lamps (also known as Belisha beacon). Even considering all those, it is the cheapest facility.

2.2 Signalised Pedestrian Crossing

Signalised pedestrian crossings allocate a clear right-of-way in the form of a green light. Hence they are more user-friendly for pedestrians who feel intimidated by the road traffic. With the increase in traffic signal installations in towns and cities around the world, signal controlled pedestrian crossing facilities are common in such places (see Figure 2).

The Local Transport Note 1/95 (Department for Transport, 1995a) recommends that signalised crossings are used “where there is normally a greater than average proportion of elderly or disabled pedestrians”, as well as where traffic flow is fast, heavy etc. In each case, level access, either by dropped kerb or raised road crossing, must be provided.

Signalised pedestrian crossing could take different forms depending on the way of providing green time to the pedestrian. In the UK, Pedestrian Light Controlled Crossing (Pelican) (Department for Transport, 1995b) and Pedestrian User-Friendly Intelligent crossings

(Puffin) (Department for Transport, 1995b) are the main examples of such signalised pedestrian crossing facilities installed in the UK.

Figure 2: A signalised pedestrian crossing in Orpington, UK

Pelican crossing is the most common type of pedestrian crossing in the UK. A Pelican crossing has a push button on a Pedestrian Demand Unit (PDU) for pedestrians to stop the traffic. Traffic signal then changes its aspect from red man phase to green man phase indicating pedestrians whether it is safe to cross. A flashing green man phase indicates that a pedestrian should not start to cross and, where provided.

Puffin is 'smarter' pedestrian crossing equipped with infra-red detectors to monitor pedestrians to allow them additional time to cross, where required. There is no flashing green man and the red and green men are displayed on the nearside of the crossing. Puffin is the most user-friendly signalised pedestrian crossing which has a provision to extend pedestrian green time for those who takes longer to cross – e.g. older people and people with reduced mobility.

Other types of signalised pedestrian crossings include Toucan, Pegasus and PCaTS. Toucan is similar to Puffin except the fact that cyclists are also allowed to use the crossing on their bike whereas Pagasus is designed with a special consideration for horse riders. PCaTS (Pedestrian Countdown at Traffic Signal) is another type of signalised crossing implemented in London. PCaTS (York et al, 2011) shows a visible countdown of the time remaining before the appearance of the "Red man" to give pedestrians a better understanding of the time available for them to complete crossing.

As a signalised pedestrian crossing provides specified time for pedestrians to cross a road, they are safer option than zebra crossing which depends on the driver's behaviour. As they are installed on the roadside, signalised crossings are relatively cheaper than footbridges. The main drawbacks of signalised crossings are that they reduce or perceive to reduce capacity of a road. However, if designed properly, mid-block crossing (in the middle of the

two junctions) can match the capacity of the downstream junction (a junction at the end of the road) and hence not reducing effective capacity of the network.

2.3 Pedestrian Footbridge or Underpass

Pedestrian footbridges are segregated facilities for pedestrians to cross a high speed road. Generally, such facilities are provided on a high speed road where non-segregated form of traffic could severely reduce the capacity and safety. In the UK, such facilities are provided on major roads such as arterial roads and motorways.

In terms of the construction, a footbridge is the costliest crossing facility as it needs a proper structure to support stairs and a footbridge over a road. In addition, footbridges provided with ramps to facilitate people with mobility issue need additional structure to support such structure (see Figure 3). To provide comfortable gradient, such footbridges need a lot of space to construct. Even though such facility is very good from the safety point of view, they are not that user-friendly as pedestrians need to climb up and down to cross a road taking a lot of time.

Figure 3: Pedestrian footbridge with ramps in Southampton, UK (Source: Googlemap, 2023)

A summary of these different pedestrian facilities are given in Table 1.

Table 1: Summary of pedestrian crossings compared against different aspects

	Zebra crossing	Signalised crossing	Footbridge
Construction (cost and duration)	*****	***	*
Land space	*****	*****	*
Pedestrian friendliness	***	*****	*
Pedestrian safety concern	**	****	*****
Segregation (traffic impact)	*	***	*****

Notes: ***** - Best suitable, * - Least suitable*

It is evident from Table 1 that these different types of pedestrian crossing facilities have vastly different characteristics in terms of the construction, pedestrian friendliness and their safety and traffic impact. It also shows that there is no one type of pedestrian crossing which is suitable for all the places.

3. Methodology for Selecting a Pedestrian Crossing Facility

The suitability of a pedestrian crossing depends on the various factors including road type, area/land use, pedestrian flow and vehicle flow. These are discussed in the following sub-sections.

3.1 Road type

Type of a road is the most important factor in selecting a type of pedestrian crossing. If it is a highspeed road (e.g., Highway) passing through non-built-up area, pedestrian footbridge is the obvious choice. However, if it is passing through a built-up area then the signalised pedestrian crossing is suitable.

3.2 Pedestrian Activities along the Road

In urban areas where there are more pedestrian activities happening hence need a level crossing to facilitate such activities. In such areas, zebra crossing, and signalised pedestrian crossing are the preferred options. Zebra crossing could be provided where there is high pedestrian flow and low vehicle flow. In other urban areas, signalised crossing is the most appropriate crossing. In places where there are no pedestrian activities along the road, the preferred option is a pedestrian footbridge in high-speed road or informal crossing in other places.

3.3 Pedestrian Flow

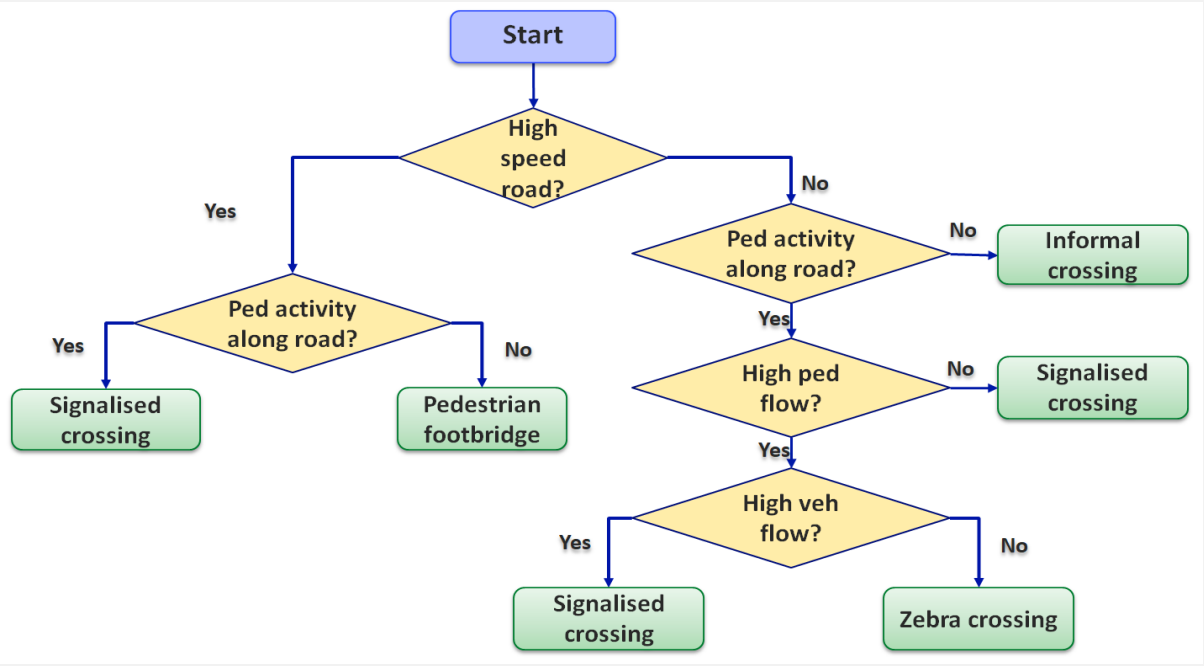

Figure 4: Proposed flowchart for selecting an appropriate pedestrian crossing

Pedestrian flow is another important criterion in selecting a type of the pedestrian crossing. Generally, zebra crossing is only suitable where pedestrian flow is high, and the vehicular flow is low. In other areas, signalised crossing is suitable.

3.4 Vehicle Flow

Vehicle flow is another important factor in selecting a type of the pedestrian crossing. Generally, zebra crossing is only suitable where the vehicle flow is low, and the pedestrian flow is high. In other areas, signalised crossing is suitable. Taking account of these factors, a flow chart is proposed (Figure 4) to streamline the process of selecting a pedestrian crossing type.

Based on this proposed flowchart (Figure 4), signalised pedestrian is the best option in the areas where there are pedestrian activities along the road.

4. Case Study of Pedestrian Facilities in Kathmandu

With the increase in both motorised traffic as well as the pedestrian volume, pedestrian crossings are provided in many places in Kathmandu. The most common types of pedestrian crossing facility in Kathmandu are zebra crossing followed by footbridges. The current situations of such facilities are discussed below.

4.1 Zebra Crossing

Zebra crossings are the most widely available pedestrian crossing facility in Kathmandu (see Figure 5). Even though such crossing area gives more visibility of the crossing pedestrians, unlike many countries, drivers do not always stop to give way to the pedestrian. It depends on the generosity of the driver. There are cases of pedestrian accidents at such places due to the drivers not giving way to the walking pedestrians.

Figure 5: Zebra crossing with refuges in Kupondol, Lalitpur (Source: Googlemap, 2023)

Even though the zebra crossings are widely available facilities, they are not maintained well in most of the cases. As being the cheapest option, such facilities are provided at most of the location without assessing its suitability. Again, in many places, such crossings are faded

due to the friction of the vehicle tyre enhanced by dirt (sand) on the road. In some cases, the zebra crossings are not properly located so that they do not lead to the walkable footpath (see Figure 6).

Figure 6: Zebra crossing leading to a pedestrian barrier in Thapathali (Source: Googlemap, 2023)

4.2 Pedestrian Footbridge

With increased number of vehicular traffic and pedestrian traffic, there are pedestrian footbridges constructed in places in Kathmandu to give safe passage to the pedestrian. To provide clearance to tall vehicles, such foot bridges are constructed very tall. As a result, pedestrians need to climb up and down a lot of steps when using such facilities. Even though such facility provides safe passage to the pedestrians, it is not user-friendly. The heights of these footbridges are difficult for even healthy person and virtually impossible to be used by senior citizens and others with mobility issues (see Figure 7 and 8). These seems to have been built to reduce disruption to vehicles rather than to provide safe and comfortable passage to pedestrians.

Figure 7: Pedestrian footbridge at Ratnapark, Kathmandu (Source: Googlemap, 2023)

Figure 8: Pedestrian footbridge at Koteshwor, Kathmandu (Source: Googlemap, 2023)

4.3 Signalised Pedestrian Crossing

Signalised pedestrian crossing is virtually non-existent in Nepal. One such example of pedestrian crossing is in the Teaching Hospital. However, that is not in the working condition as the traffic police is not operating as this increases the traffic jam in their view. Even though they are cheaper than footbridges, they are not installed at many places due to the lack of technological knowhow and the availability of the product in the local market.

As a signalised crossing shares the signal timing, they are perceived to reduce capacity of a link. However, if designed properly, mid-block crossing (in the middle of the link) can match the capacity of the downstream junction and hence not reducing effective capacity of the network.

Figure 9: Signalised pedestrian crossing at Teaching Hospital Maharajgunj (Source: Googlemap, 2023)

5. Discussion

From the review of the present pedestrian crossing facilities in Kathmandu, it is clear that they are not selected and located properly. To provide effective pedestrian facilities, the factors discussed needs to be taken into account. The flowchart developed in Section 3 should be able to streamline the selection process of pedestrian crossing. However, in Nepalese context where there is no proper road hierarchy, it is difficult to implement the pedestrian crossing according a road type. The ribbon developments along major highways (residential houses along the high speed roads) make this task even more difficult.

From the review of crossing facilities in Kathmandu, it is evident that zebra crossings are provided at many places without much consideration of its suitability. This is especially unsafe practice where the traffic speed is high and drivers do not stop willingly to allow pedestrian to cross. In other places, pedestrian footbridges are also provided in the inner urban area (e.g. the road around Tundikhel) where the pedestrian flow is very high and the vehicle speed is low. Such facilities are not suitable for senior citizens as well as those with mobility issues. The main focus of such footbridges is to reduce traffic congestion rather than providing safe passage to the pedestrians. As discussed in section 3, pedestrian footbridges are useful facilities in non-urban areas with high speed road. However, a ramp should be constructed along with the steps to facilitate people with impaired mobility. One such example is pedestrian footbridge in Butwal (a city outside of Kathmandu valley, in West Nepal) over Siddharth Highway (Figure 10).

Figure 10: Pedestrian footbridge with ramp in Butwal over Siddharth Highway

Based on the flowchart developed in Section 3, signalised pedestrian crossings are the best suited option for most of the locations in Kathmandu. Such crossings would have helped pedestrian while not delaying vehicular traffic excessively. There are various ways of optimising the available green time for both pedestrians as well as vehicles.

In Nepalese context, implementing signalised pedestrian crossing is not straightforward. One of the reasons is that there is no readily available product in the local market. A product imported from overseas could be expensive in terms of the installation and maintenance. However, if a careful consideration is given, such traffic signals for crossing facility could

be built in Nepal using the available technology and materials. Other important factor for the hindrance is the perception of the traffic police who controls traffic in Kathmandu. Current perception of road capacity being reduced by a signalised crossing needs to be changed. If a signalised pedestrian crossing is designed and installed properly at suitable locations, it could increase the road capacity by avoiding the unsafe interactions between pedestrians and vehicles. Furthermore, a mid-block crossing could be designed in a way to maintain the capacity at the downstream junction hence not affecting the network capacity.

6. Conclusion

This paper has described various pedestrian crossing facilities that could be implemented to help pedestrians crossing a road safely and comfortably. The appropriateness of these approaches depends on the traffic characteristics and pedestrian activities at the crossing location. A comparison of these crossings showed that the signalised pedestrian crossing is the best suited option in most of the places where there are pedestrian activities along the road. In addition to being cheaper than footbridges, pedestrian crossings are much more user-friendly for pedestrians. Even though the implementing signalised pedestrian crossing is not straightforward in Nepalese context, such traffic signals for crossing facility could be built locally. For implementing such pedestrian crossings in a standard way, pedestrian crossing design guidelines should be included in the design standards for urban roads in KMC or DOR design documents. As the population of senior citizen is growing, such user-friendly pedestrian crossings are needed more than ever to facilitate them to live a quality of life.

References

Department for Transport (1995a). The Assessment of Pedestrian Crossings, Local Transport Note 1/95

Department for Transport (1995b). The Design of Pedestrian Crossings, Local Transport Note 2/95

United Nations Environmental Programme (UNEP) (online report). https://www.unep.org/es/node/20145#:~:text=It%20is%20estimated%20that%20around,percent%20of%20the%20total%20trips (accessed 2023/05/01)

York I., Ball S., Beesley R., Webster D., Knight P. and Hopkin J. (2011). Pedestrian Countdown at Traffic Signal Junctions (PCaTS) - Road Trial by Transport Research Laboratory (TRL), Project Record: TfL 2481, May 2011. Downloadable from https://content.tfl.gov.uk/PCaTS-Note-3-PCaTS-Trial-Results-Report.pdf (accessed 2023/05/01)

Escalating Highway Infrastructure Vulnerability in Nepal due to Climate Change Effects

Prabhat Kumar Jha

Superintendent Engineer, Department of Roads, Ministry of Physical Infrastructure and Transport, Kathmandu, Nepal
M.Sc. in Geotechnical Engineering
Email: geoprabhat@gmail.com

Abstract

Nepal's warming is complex, and not homogenous across Nepal's surface area, nor defined consistently by altitude. Some regions (notably western Nepal) are believed to have experienced an increase in the frequency and intensity of extreme precipitation events. Evidence suggests that wet areas are becoming wetter, and dry areas are becoming drier. The Himalayan region has experienced increasing average annual precipitation at a rate of 6.5 mm/year between 1982 – 2006.Other factors affecting inter-annual precipitation variability include global climate phenomena such as El Niño-Southern Oscillation (ENSO) and the Indian Ocean Dipole. ENSO has been shown to have complex relationships with both drought and extreme precipitation. The national highway network is about 11178km and the rough estimation of the road assets under Department of Roads is 250 million USD, which is facing annual losses and damage of 15 million USD annually. The causes of road closure in monsoon is a) high rainfall intensity within very short period, b) steep topography and disturbed natural slope for the different construction works, c) inappropriate approach road construction from the highway, d) toe cutting by the river in riverside alignment, e) flood and landslide on or near the road. The associated challenges are suitable road alignment selection, geotechnical and hydrological analysis, local consultant / contractor expertise, construction sequence and time gap between activities, reluctance to adopt new effective measures. Climate change effects can be mitigated by proper realignment of existing highways, level rise of roadway, erosion control measures, cost effective slope stability measures and intensive application of bioengineering.

Key Words: Climate Change, Asset, Road Closure, Mitigation

1. Introduction

The transport sector has the potential to improve the lives and livelihoods of billions of people. However, as well as meeting people's needs today, the sector must be ready to respond to future generations' expectations which is the essence of sustainable development. The government policy for the transportation sector is to develop a sustainable, reliable, cost-effective, and safe transport system that contributes to environmental, social, and economic goals.

Our 2100 long term targets are to build all highway to 4 to 8 lane Asian Highway standard roads, multimodal transport system and to have federal capital – province capital & province capital- province capital transport with high speed transport modes, and to achieve road density (0.55 Km per Sq.km, base year 2018) to 1.00 Km per Sq.km. We are working to develop road network such that percentage of families with access to motor transport within 30 minutes of travel (82%, base year 2018) will be 99% by 2043/44[1].

Table 1: Nepal Highway Network (Road Length with Category and Pavement (In Kilometer)[2]

Road Classification	Province	BT	GR	ER	Total	UC	PL
National Highway	Province 1	1274.45	182.38	436.03	1892.86	226.89	855.49
	Province 2	547.33	183.69	183.72	914.74	0.00	158.53
	Province 3	1359.74	268.90	261.05	1889.68	33.01	406.07
	Province 4	530.24	75.16	694.57	1299.97	32.01	191.51
	Province 5	1428.90	165.11	791.09	2385.10	94.33	72.59
	Province 6	664.47	161.00	615.72	1441.19	21.00	671.36
	Province 7	1031.32	80.12	243.94	1355.38	80.00	694.55
	Sub-Total	6836.45	1116.36	3226.12	11178.92	487.24	3050.11
Grand Total		**6836.45**	**1116.36**	**3226.12**	**11178.92**	**487.24**	**3050.11**

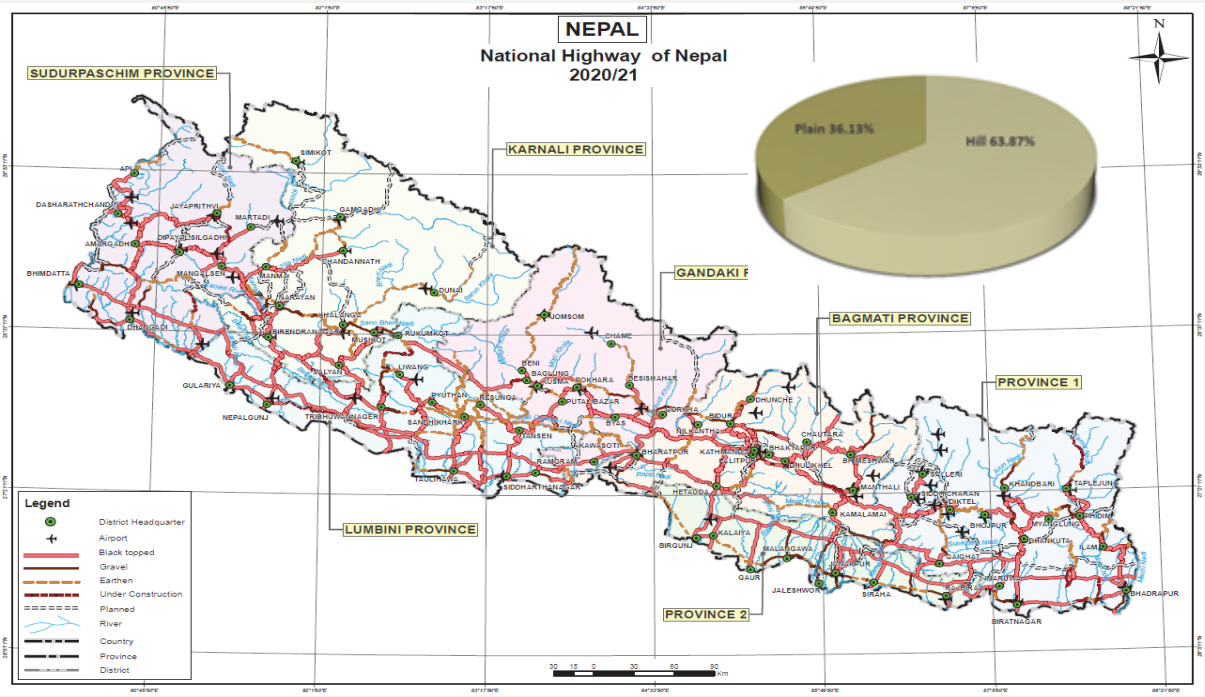

Figure 1: Nepal Highway Network[3]

Globally CO2, the major contributor to the greenhouse gas (GHG), emitted from the transport sector account for 23 per cent of global energy-related CO2 emissions. Within the transport sector, more than 71 per cent of CO2 emissions are from inland transport, including about 70 per cent from the road subsector alone.

The 2030 Agenda for Sustainable Development calls for urgent action to combat climate change and its impacts. Nepal is among the most vulnerable countries to climate change. It is at high-risk due to the country's fragile topography, the climate-sensitive livelihoods of the people and their limited adaptive capacity.

1.1 Observational Evidence and Prediction of Climate Change

Nepal's climate varies considerably both seasonally and according to altitude. Nepal can be divided into different climate zones according to altitude, ranging from the Terai region in the south at less than 500 m above sea level to the High Himalayan region in the north at over 5,000 m. Average temperatures decline from a peak of over 24°C in the south down to sub-zero temperatures in Nepal's highest mountains. Precipitation is spatially variable with some central and northerly pockets of the country receiving more than 3,000 millimeters (mm), the central and southern plains typically receiving 1,500 – 2,000 mm, and some high-altitude areas in the north receiving less than 1,000 mm.

Table 2: Observed Average Seasonal Mean Temperature of Nepal (1991-2020)[4]

Units: ℃	1991-2020				1961-1990				1931-1960				1901-1930			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
National	6.05	15.0	20.19	15.04	5.4	14.37	19.75	14.3	5.45	14.73	19.93	14.28	5.09	14.3	19.84	14.03
Highest: Central	10.81	19.48	23.66	19.36	10.13	18.9	23.26	18.7	10.17	19.2	23.4	18.64	9.79	18.75	23.29	18.34
Lowest: Mid Western	1.77	11.26	17.64	11.45	1.15	10.52	17.15	10.76	1.19	10.95	17.36	10.63	0.88	10.54	17.33	10.43

DJF - December, January and February, MAM - March, April and May, JJA - June, July and August, SON - September, October and November

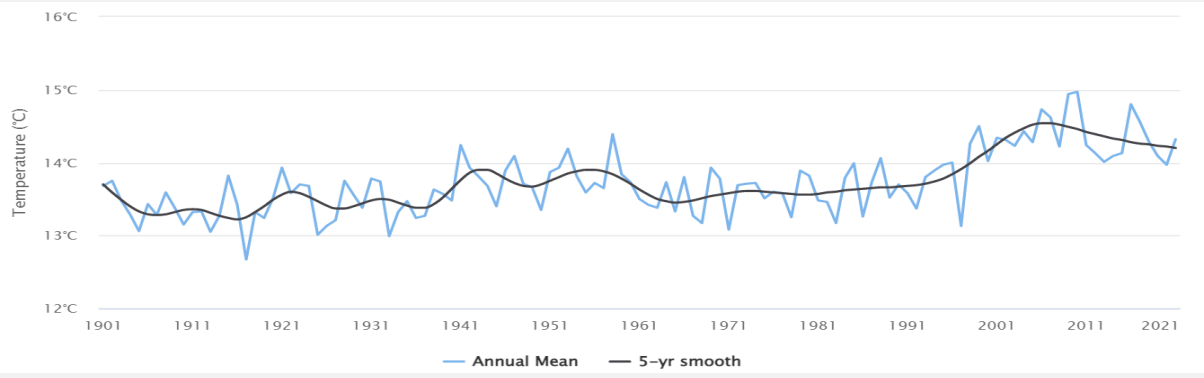

Figure 2: Mean Temperature rise since 1901[5]

Table 3: Observed Seasonal Precipitation of Nepal (1991-2020)[6]

Units: mm	1991-2020				1961-1990				1931-1960				1901-1930			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
National	50.99	193.92	763.43	242.68	48.66	178.78	821.91	263.21	51.1	156.86	870.61	263.84	51.74	163.01	885.8	265.39
Highest: Central	37.75	245.28	1054.29	339.74	36.4	215.42	1111.13	355.71	39.93	187.73	1211.44	363.18	38.72	186.67	1248.81	363.56
Lowest: Mid Western	56.41	133.53	490.09	148.45	54.19	132.44	543.15	170.92	55.8	116.66	561.85	165.59	57.38	125.99	559.11	171.81

Nepal's warming is complex, and not homogenous across Nepal's surface area, nor defined consistently by altitude. Annual precipitation rates in Nepal vary spatially and include both positive and negative movements. Some regions (notably western Nepal) are believed to have experienced an increase in the frequency and intensity of extreme precipitation events. The monsoon rainfall was more than 370mm from 1931 to 1960 while it was less than 360mm from 1961 to1990) but from 1991 to 2020, it is less than 350mm. The overall temperature rise is 0.33 deg. over last 90 year. Evidence suggests that wet areas are becoming wetter, and dry areas are becoming drier.

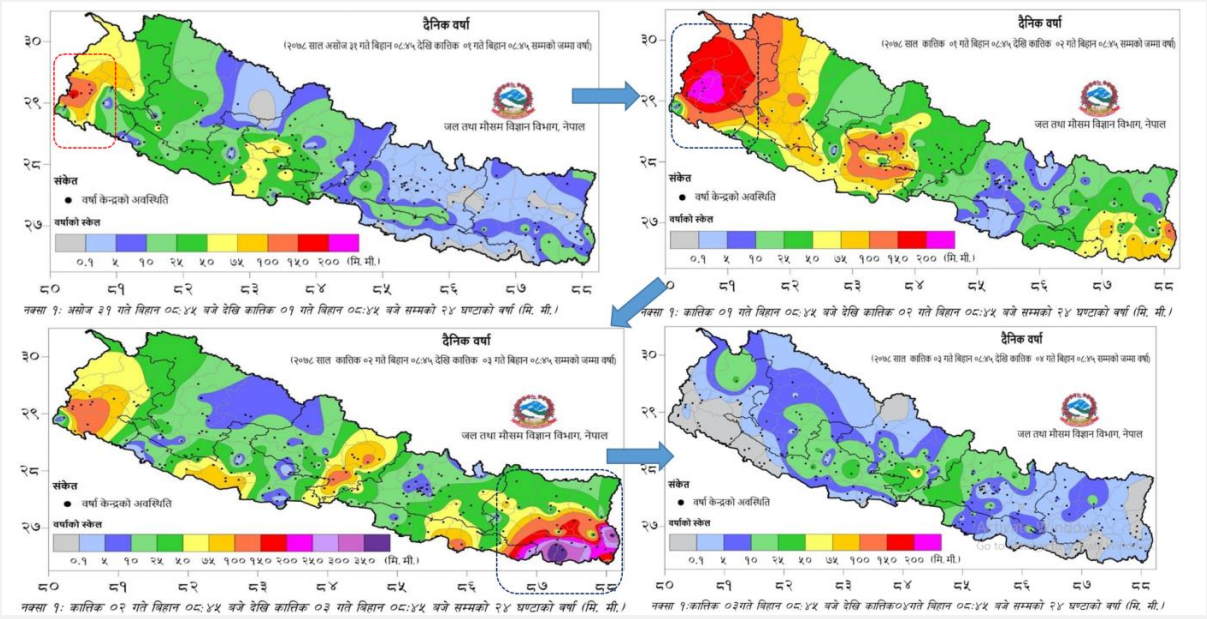

Figure 3: Example of Erratic Rain Fall 'Kartik-2078'[7]

The Himalayan region has experienced increasing average annual precipitation at a rate of 6.5 mm/year between 1982 and 2006. Other factors affecting inter-annual precipitation variability include global climate phenomena such as El Niño-Southern Oscillation (ENSO) and the Indian Ocean Dipole. ENSO has been shown to have complex relationships with both

drought and extreme precipitation.

Hilly regions of Sudurpashchim, Karnali, Gandaki, Bagmati and Province-1 are the hotspots for likely to experience increasing maximum and minimum temperature in the future. The change in annual maximum temperature will be in the range of 2.5°C to 5.5°C (hottest GCMs) and 2.0°C to 4.5°C (coldest GCM). The change in annual minimum temperature will be in the range 2.5 °C to 4.5 °C and 2.0 °C to 2.6 °C for hottest GCM and Coldest GCM respectively. The wettest GCM shows increase in precipitation by 10% to 55% for three periods. The wettest GCM shows increase in precipitation by 10% to 55% for three periods.

1.2 Second Nationally Determined Contribution in the Transport Sector

Nepal is committed to acting on climate change in line with the Paris Agreement, despite the country's negligible emissions. It is because efforts to limit global average temperature rise to 1.5°C would result in significantly lower risks for Nepal when compared to 2°C or higher. These risks are in addition to the existing impacts and vulnerabilities of climate change in the country.

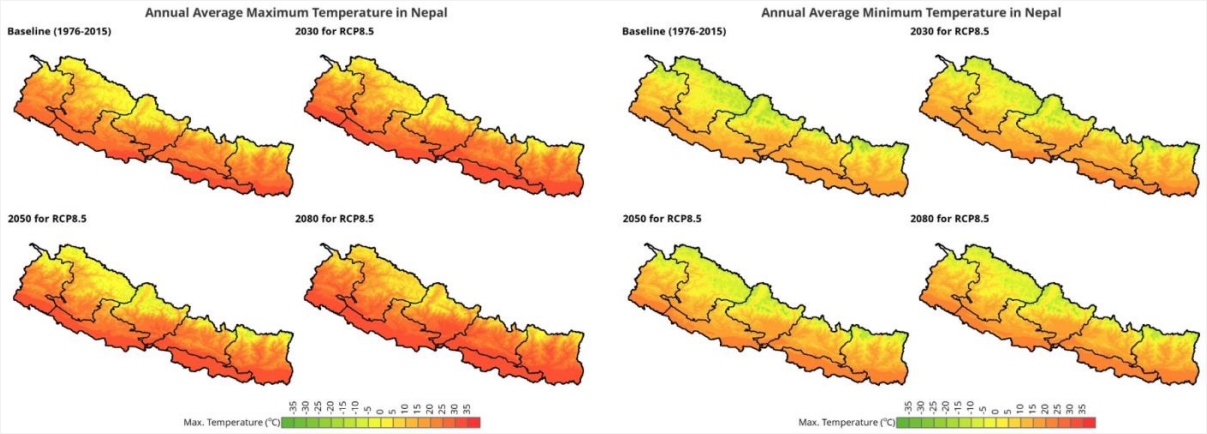

Figure 4: Increase and decrease of annual average temperature for RCP 8.5 (GCM-GFDL-ESM2M) [8]

The Government of Nepal hereby presents its enhanced Nationally Determined Contribution (NDC) under the Paris Agreement for the period 2021-2030, following Articles 4.2 and 4.11 of the Paris Agreement, and Decision 1/CP.21 paragraph 23 and 24, and other relevant provisions of the Paris Agreement. The NDC takes into account the principle of common but differentiated responsibilities and respective capabilities, in light of national circumstances.

In December 2020, the Government of Nepal submitted its second Nationally Determined Contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat and we are committed to act to achieve the commitments. The 2nd Second Nationally Determined Contribution (NDC) 2020 to curb the climate change impact and get resilience formulation was a country-driven process following the principle of Leave No One Behind (LNOB). The set targets are:

- Sales of electric vehicles (e-vehicles) in 2025 will be 25% of all private passenger vehicles sales, including two-wheelers and 20% of all four-wheeler public passenger vehicle sales in 2025. This would be around a 9% decrease in fossil fuel dependency. This target will reduce emissions by around 8% decrease in emissions.

- By 2030, increase sales of e-vehicles to cover 90% of all private passenger vehicle sales, including two-wheelers and 60% of all four-wheeler public passenger vehicle sales. As a consequence, energy demand for fossil fuels will decrease by around 28% decrease. This target will reduce emissions by around 28% decrease in emissions.

- By 2030, develop 200 km of the electric rail network to support public commuting and mass transportation of goods.

- Promote public electric mobility through policy incentives, including subsidy policies and other financial mechanisms.

- By 2025, ensure at least three provinces operate electric public transport, three provinces establish vehicle fitness test centres to monitor and regulate vehicular emissions, and all metropolitan cities have roads paved with bicycle & pedestrian lanes.

2. Climate Change Impacting Highway Infrastructure

Transport infrastructures is the lifelines of socioeconomic development, it is not surprising that about 33% of the annual development budget is spent on their development and maintenance. Floods, landslides, and siltation during the monsoon render many of these lifelines dysfunctional every year and their repair and reconstruction costs the nation dearly. In addition, damaged infrastructures impede the functioning of other economic sectors-sometimes for long periods-incurring a huge economic loss. The national highway network is about 11178km and the rough estimation of the road assets under Department of Roads is 250 million USD, which is facing annual losses and damage of 15 million USD annually.

Climate change, which forebodes ever more extreme events at ever greater intervals, is likely to pose a great threat to existing as well as future infrastructures. Increased instances of drainage congestion, scouring, inundation, slope instability, land subsidence, erosion, and collapse of structures are likely.

Higher temperatures can cause pavement to soften and expand. This can create rutting and potholes, particularly in high-traffic areas and can place stress on bridge joints. Heat waves can also limit construction activities, particularly in areas with high humidity. With these changes, it could become more costly to build and maintain roads and highways.

Transportation engineers typically refer to historical records of climate, especially extreme weather events, when designing transportation systems. For example, bridges are often designed to withstand storms that have a probability of occurring only once or twice every 100 years. However, due to climate change, historical climate is no longer a reliable predictor of future risk.

The Laskugad Bridge along the Mahakali Corridor was designed for 100 year return flood with sufficient free board, but due to torrentially rainfall on 9th Sept,2022 landslide on upstream of the bridge was triggered and the debris flow (combination of landslide debris and flood) raised river bed level. Finally, due to the lack of clearance between constructed bridge girder and river mud flow resulted the wash out of bridge superstructure (figure 5,6).

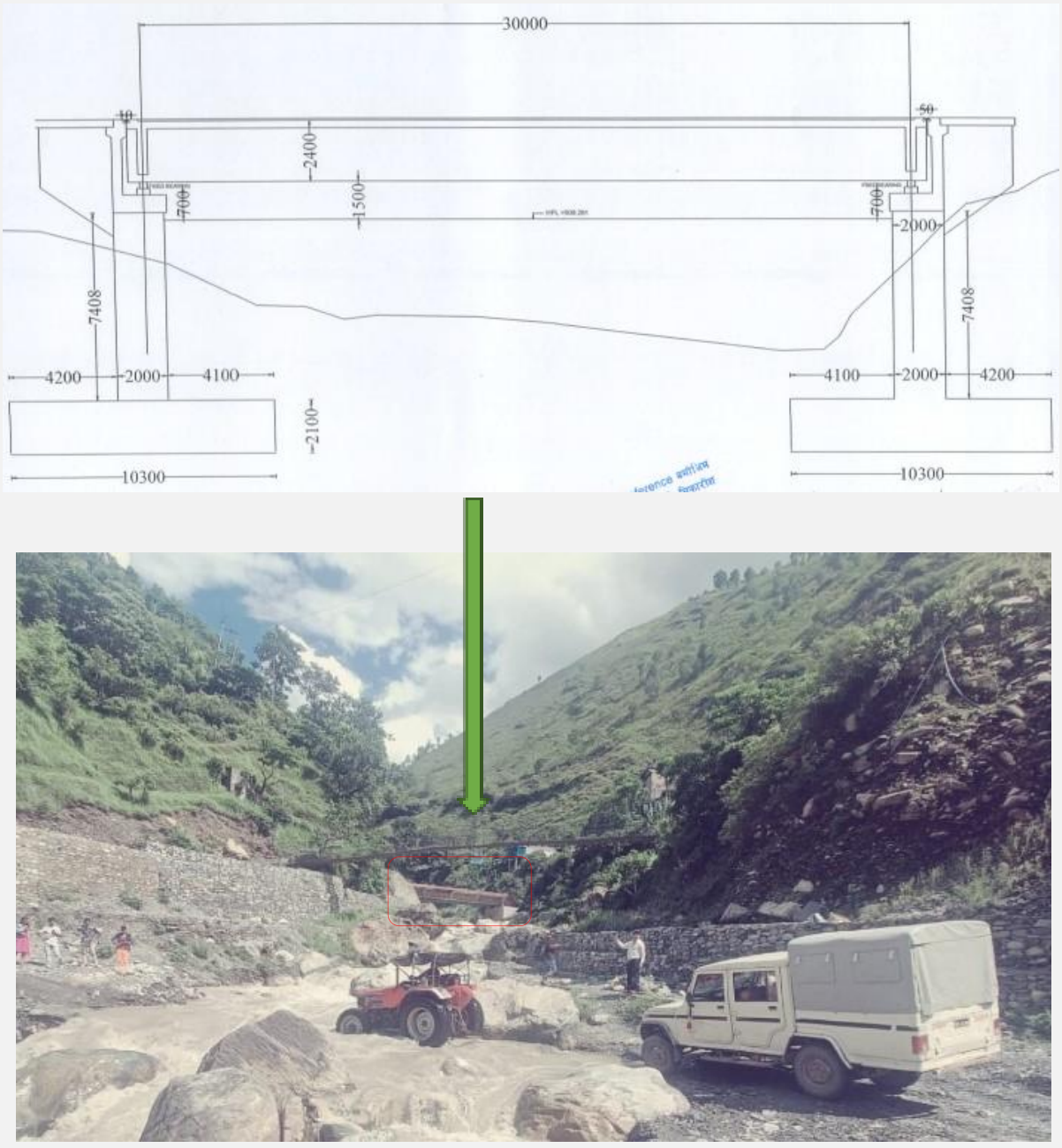

Figure 5: Laskugad Bridge along Mahakali Corridor before flood dated 9th Sept,2022

Figure 6: Laskugad Bridge along Mahakali Corridor after flood dated 9th Sept,2022

Table 4: Road Closure Data of Last 2 year (Major Roads)

Code	Blockage in Year 20/21	Road Closure per Event (days)	Blockage in Year 21/22	Road Closure per Event (days)
NH01	8	8	9	65
NH13	18	3	15	14
NH17	5	36	19	3
NH25	24	81	17	237
NH34	29	44	35	64
NH47	19	10	19	12
NH58	35	9	6	8
NH63	10	239	3	122

Figure 7: Representative evidence of Highway Infrastructure damage due to flood, landslide, and river toe cut resulting from extreme precipitation.

The evidence of road closure days of important highways reflects the accelerating impact on transport infrastructure damage extent and disruption of traffic movement. Also, river route highway as NH25, NH34, NH63 seems more vulnerable to the climate related damage.

3. Vulnerability of Nepal Highway Infrastructure

National Planning Commission has assessed the loss of transport infrastructure due to floods mass wasting as highly sensitive and impact will be in the form of fatigue, drainage including river structures, landslides & subsidence, silting scouring, hill-toe cutting, inundation & submergence, & obstruction of construction to the infrastructure (table 5,6).

Table 5: A Sensitivity Matrix for Disaster Risk Reduction [9]

Disaster Risk Reduction / Point of Entry	Anticipated Impacts	Loss of infrastructures					Loss of livelihood				Loss of lives and properties		
		Transportation	Drinking water & irrigation	Hydropower	Buildings	Transmission lines	Farm land	Livestock	Forests and grass land	Trade and Industry	Human deaths	Standing crops	Other properties
Floods		H	H	H	H	H	H	H	M	H	H	H	H
Drought		-	H	H	-	-	-	M	H	M	-	H	-
Epidemic		-	-	-	-		-	-	-		H	-	
Mass wasting		H	H	M	M	H	M	M	M	L	H	M	M
Sedimentation		L	M	M	-	-	M	-	M	-	-	H	-
Fire		-	-	-	M	L	-	-	H	M	H	-	M
Windstorms		L	-	-	L	M	-	-	H	-	H	H	-
Other stresses													

Table 6: A Sensitivity Matrix for Infrastructure [10]

Infrastructures / Point of Entry	Anticipated Impacts	Fatigue	Drainage including river structures	Landslides & subsidence	Silting	Scouring	Hill-toe cutting	Inundation & submergence	Obstruction of construction & power generation
Temperature		H	-	-	-	-	-	-	-
Windstorm		-	H	-	-	-	-	-	-
Flood		-	H	-	H	H	H	H	M
Sedimentation		-	-	-	H	-	-	-	H
Mass wasting		-	H	-	H	H	-	-	H
Rise in Ground water levels		M	-	H	-	-	-	-	M

The road physical vulnerability levels to hazard magnitude classes have been estimated by **Adpc** based on the simulated bottleneck lane disruption model and consideration of local factors, critical threshold of residing landslide deposit on a road surface (Table 7). The associated challenges are suitable road alignment selection, geotechnical and hydrological analysis, local consultant / contractor expertise, construction sequence and time gap between activities, reluctance to adopt new effective measures.

Table 7: Estimated Road Physical Vulnerability Levels to Landslide Hazard Magnitude Classes

Lane	Drainage	Hazard Magnitude Vs Damage/Disruption Probability				
		Magnitude	M-0	M-I	M-II	M-III
		Debris Flow/Slide	10 Cum	10-1000 Cum	1000-10000 Cum	>10000 Cum
Single Lane	Without side ditch		0.2	0.6	1	1
	With side ditch		0.1	0.5	1	1
Double Lane	Without side ditch		0	0.2	0.6	1
	With side ditch		0	0.1	0.5	1

4. Adaptation to Climate Change

Adaptation options in the transport sector has to be divided into engineering (structural) options (subsurface conditions, material specifications, cross section and standard dimensions, drainage and erosion, and protective engineering structures), and non-engineering options (maintenance planning and early warning, alignment, master planning and land use planning, and environmental management).

For infrastructure that is already in place, increasing maintenance contingency budgets in areas where climate change impacts are acute will allow more intensive supervision and monitoring of the most vulnerable areas. This can reduce road closures and more serious consequences of disasters. Furthermore, maintenance planning systems can include early warning systems to anticipate extreme events so that crews and contractors can be prepared for an upcoming high rainfall event and possible landslides. On the one hand, this will ensure that forced road closures are kept to a minimum. On the other hand, pre-emptive road closures may minimize losses of property and life. This suggests the presence of a trade-off between increased capital costs today with less operating expenditures and damages in the future.

Roads influence development patterns. Once a road is built into an area, economic growth and community development are encouraged by this access. It is therefore important to consider whether roads are opening development in areas that are hazard prone.

Where realignment is a plausible adaptation solution to protect transport infrastructure, care must be given to understanding the implications of resettlement of populations and economic activities. Realignment can imply resettling populations in other vulnerable areas, creating another more serious problem.

In some cases, it is plausible that sufficient risk allowance has been built into the project to account for climate change, or that the nature of the changes is too uncertain or minimal, or that the consequences of climate change are too severe to justify in situ adaptation. In the latter circumstance, a best course of action may to be to allow the infrastructure to deteriorate and be decommissioned. In other cases, the up-front capital investment associated with any technically feasible adaptation option may be so large as to outweigh any possible benefits associated with the climate proofing of the infrastructure. Not investing in adaptation in the context of a particular project may be the best course of action (from both a technical and economic assessment).

We need to adopt the twenty steps assessing adaptation needs and options[11]. Step 1: Screen the project exposure to climate change ,Step 2: Establish the adaptation objective, Step 3: Survey existing information and knowledge, Step 4: Identify and engage stakeholders, Step 5: Identify methodology and data needs, Step 6: Identify the required expertise, Step 7: Construct climate change scenarios, Step 8: Estimate future biophysical impacts, Step 9: Assign probabilities to identified impacts, Step 10: Identify vulnerabilities, Step 11: Identify biophysical drivers of vulnerabilities, Step 12: Identify socioeconomic drivers of vulnerabilities, Step 13: Identify all potential adaptation options , Step 14: Conduct consultations ,Step 15: Conduct economic analysis , Step 16: Prioritize and select adaptation option(s),Step 17: Establish arrangements for implementation , Step 18: Identify needs for technical support and capacity building, Step 19: Design monitoring and evaluation plan & Step 20: Feedback into policy-making and knowledge management processes.

5. Conclusion

The causes of road closure in monsoon are a) high rainfall intensity within very short period, b) steep topography and disturbed natural slope for the different construction works, c) inappropriate approach road construction from the highway, d) toe cutting by the river in riverside alignment, e) flood and landslide on or near the road.

Climate change effects can be reduced by proper realignment of existing highways, level rise of roadway, erosion control measures, cost effective slope stability measures and intensive application of bioengineering.

The long-term performance and reliability of transportation systems will increasingly need to consider and plan for climate change and extreme weather events. A range of tools and approaches to its engagement in building resilient transport systems is necessary which include (i) upstream sectorial and strategic spatial planning informed by assessments of risk and vulnerability; (ii) resilient infrastructure solutions, which comprise investments in physical infrastructure, new technologies, and community-based adaptation; (iii) enhancing the enabling environment through institutional and capacity support, awareness-raising, and finance to enhance the capabilities of the relevant stakeholders at the policy and regulatory level; and (iv) post-disaster risk and recovery support so that climate change risk and resilience are integrated into rebuilding efforts.

References

ADPC 2012: Climate Data Digitization and Downscaling of Climate Change Projections in Nepal | TA 7173-NEP: Strengthening Capacity for Managing Climate Change and the Environment

Department of Roads, Ministry of Physical Infrastructure and Transport 2023, viewed 15 Sept. 2022. https://ssrn.dor.gov.np/ssrn_map/map

Government of Nepal, National Planning Commission, Kathmandu, Nepal (2011). Climate-Resilient Planning. [Working Document]

Government of Nepal (2020). Second Nationally Determined Contribution (NDC)

Nepal Hydrological and Meteorological (2015). Study of Climate and climatic variation over Nepal

WB-ADB (2021). Climate Risk Country Profile: Nepal

WORLD BANK (June 2019). Improving the Resilience of Nepal's Strategic Roads Network (Criticality Assessment Report)

Role of Concrete in Sustainable Development – A Review

Pukar Siwakoti[*1], Jaya Nepal[1], Salim Barbhuiya[1], Bamdad Ayati[1]*

[1]Department of Engineering and Construction, University of East London, UK
**Corresponding author role: PhD Researcher, University of East London, UK*
M.Sc. in Geotechnical Engineering
**Corresponding Email: p.siwakoti66@gmail.co*

Abstract

Concrete is the second-most consumed material after water. Considering the amount of concrete consumed, it is responsible for a significant percentage of carbon dioxide (CO_2) emissions, energy consumption, and excessive use of natural resources. Cement and aggregate are essential ingredients in forming concrete, which offers strength, durability, and volume. However, cement production is a high-energy-consumption process that contributes around 5-7% of global CO_2 emissions. Likewise, every year, huge quantities of natural aggregates are used in concrete production, leading to the depletion of raw materials and the deterioration of the ecosystem. The problem has been aggravated by the rising population and the associated need for more infrastructure, and the issue is more critical in developing countries. Developing more environmentally friendly methods to produce sustainable concrete is crucial and will have a huge impact on making our planet more sustainable. This review paper aims to present a comprehensive summary of the current state of knowledge and understanding regarding sustainable concrete based on existing literature on the subject. This review paper focuses on identifying opportunities and potential strategies for achieving sustainability in the production of cement and concrete, such as using supplementary cementitious materials (SCMs), employing carbon capture technologies, adopting geopolymer concrete (GPC), and exploring alternative aggregates. Overall, the paper serves as a valuable resource for gaining insights into sustainable concrete and its significance in promoting sustainable development.

Keywords: concrete, sustainable development, carbon footprint, alternative material

1. Introduction

Concrete has emerged as the most commonly used material due to a variety of factors, such as the availability of raw materials for its production and its exceptional strength and durability in the construction of infrastructure and buildings; however, this comes with a high environmental cost. Recent years have seen an increase in concerns over the effects of concrete production on the environment, the second most often consumed substance after water by humans (Miller, 2018). Globally, the effects of producing concrete include 2-3% of the yearly energy consumption and 8-9% of CO_2 emissions (Monteiro et. al, 2017). The production of cement, the key ingredient in concrete, alone is responsible for 7% of global carbon dioxide emissions, making it a significant contributor to climate change (IEA, 2022). From 2015 to 2021, the cement industry's direct CO_2 emissions grew by an average of 1.5% each year; this means that a 3% annual decrease in CO_2 emissions will be necessary until 2030 for the industry to be in line to meet the Net Zero Emissions target by 2050 scenario (IEA,2022). Thus, quick actions are required to combat climate change by lowering carbon emissions during cement and concrete manufacture.

Not limited to CO_2 emissions, the consumption of natural resources is an additional significant issue related to concrete production. The production of 1 tonne of clinker required 1.22 tonnes of limestone and 0.31 tonnes of clay on average (Coppola et al.,2019). On the other hand, aggregate production has a significant environmental impact owing to the excessive use of non-renewable sources. For instance, in the US, approximately 0.45 GT of aggregate is utilised annually in the production of concrete, which is 46% of the total aggregate mined (USGC, 2020). According to world population data elaborated by Coffetti et al. (2022) from the United Nations (2019), the world's population will reach 8.5 billion in 2030 and 9.7 billion in 2050. Considering this scenario of population growth and fast urbanisation, it is projected that there would be a significant increase in the production and utilisation of concrete to meet these infrastructure demands and requirements. Forecasts indicate that the annual demand for concrete will exceed 18 billion m3 by the year 2050 (Adesina, 2020), compared to 14 billion m3 in 2020 (GCCS, n.d.). As a result, the greatest problem for the concrete industry is how to sustainably meet the rising demand for buildings and infrastructure resulting from a growing population. As climate change and other sustainability issues persist, understanding concrete's role in sustainable development and finding ways to mitigate its negative effects is crucial. Enhancing the sustainability of concrete is therefore a crucial and challenging task for both academic and industry researchers in order to fulfil the future demand for construction materials while conserving the environment. Consequently, the aim of this review paper is to outline the current stance regarding the contribution of concrete to sustainable development by examining the sustainable practices in the concrete industry, challenges, and potential future paths towards sustainable concrete.

In order to attain quality and consistency, this research has been carried out through a review of journals, conference papers, and websites published since 2011 in highly regarded publications. The chosen total number of references in this paper from 2011 to 2022 that are relevant to the topic is 37. When looking for publications, search terms such as "sustainable concrete," "sustainable development", "SCMs", "alternative fine aggregate", "alternative coarse aggregate", "environment", and "carbon footprint" are used. The data,

findings, and research gaps from all the papers have been recorded, investigated, and finally presented to fulfil the aim of this paper.

2. Sustainability in Concrete, Challenges and the Path Forward

There is an immediate need for robust and sustainable infrastructure for sustainable development. Being a commonly utilised construction material, concrete can play a key role in this endeavour. The use of sustainable concrete can not only improve the performance of concrete but also lessen its environmental impact. This section will address the accomplishments in terms of research and application in the production of sustainable concrete, as well as the associated challenges and suggestions for future direction.

2.1 Geopolymer Concrete

In 1978, Daidovits used the term "Geopolymer" to describe substances that have inorganic molecular chains or networks. By reacting sources of aluminosilicate material derived from thermally activated natural minerals (such as kaolinite or feldspar) or industrial waste (e.g., fly ash, slag, marble dust, etc.) with an alkaline activating solution (alkali hydroxide or alkali silicate), geopolymer (GP) is produced. This GP when mixed with fine and coarse aggregate geopolymer concrete (GPC) is produced. As a sustainable waste disposal option, GPC's capacity to substitute traditional concrete is reinforced by the reason that the industrial waste (e.g., fly ash, ground GGBS, rice husk ash, etc.) is suitable for usage as a component of GPC. It has been observed that the hardened and structural properties, and CO_2 emission of GPC outperform those of regular concrete. Ultimate strength was found to have enhanced by 34% than traditional concrete when 2.16% reinforcement was incorporated into heat-cured slender fly ash-based GPC columns (Nagan and Karthiyaini, 2014). The GPC beam's (reinforced with glass fibre) compressive strength, splitting tensile strength, and flexural strength were higher by 8–37%, 14–48%, and 12–35%, respectively (Srinivasan et al., 2014). As said, most traditional concrete manufacturing techniques cause greenhouse emissions, principally carbon dioxide. The eco-friendliness of GPC is one of the primary reasons why it is favoured over traditional concrete, the CO_2 emission for producing 1m3 GPC concrete is less than compared to traditional concrete (Fig. 1).

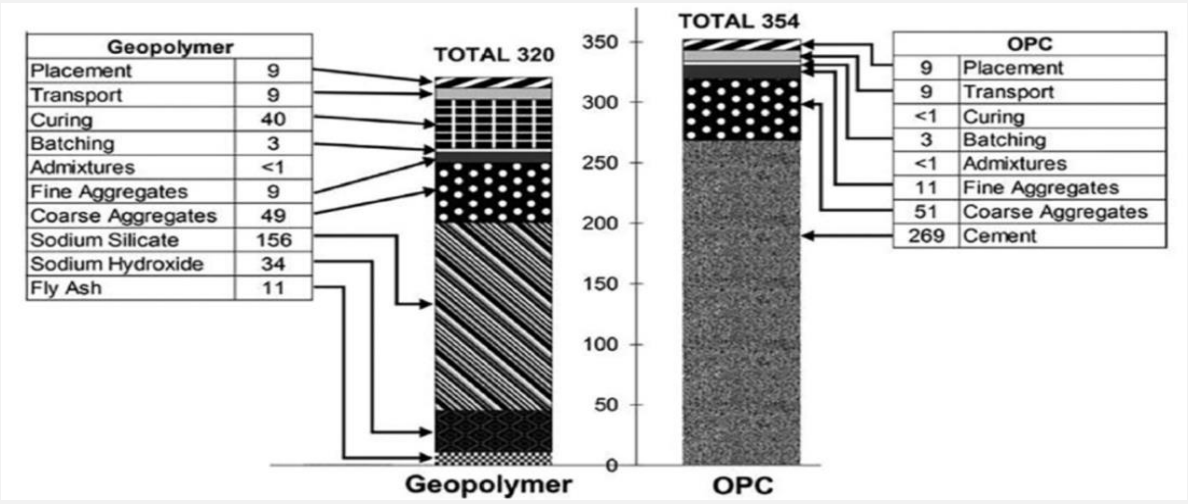

Figure 1: CO_2 emissions from raw material acquisition through the mixing of GPC and conventional concrete (Turner and Collins, 2013)

On the other hand, the majority of CO_2 emission on GPC shown in Fig. 1 is an alkaline activator (sodium silicate and sodium hydroxide) compared to other various raw materials. This can be ascribed to the intricate production process required. In terms of cost, due to the use of costly components such as NaOH and Na2SiO3 as an alkaline activator, it has been reported by Majidi (2009) that the cost of GPC is 10–15% higher than that of conventional concrete. Considering the resources, NaCl (Sodium chloride), water, Na_2CO_3 (sodium carbonate), fine aggregate, and energy utilised in the production of NaOH/KOH and Na2SiO3/KOH all go towards producing alkaline activators, making their contribution to GPC greater than that of other ingredients, and recycled alkaline activators (calcium carbide solution) can be the promising alternative (Danish et al., 2022). Similarly, the availability of industrial waste in producing GPC will be impacted in future considering the cost and availability, which will be discussed in the following section. The transportation of raw materials is considered a significant factor related to CO_2 emissions and associated costs. According to McLellan et al. (2011), GPC has the potential of lowering carbon dioxide emissions by 44 to 64% over conventional concrete; however, the transportation of the raw materials doubles the price. Therefore, to commercialise the utilisation of GPC, the research should focus on alternatives to (a) aluminosilicate materials, considering their availability; (b) alkaline activators, considering their production cost and impact on greenhouse gas emissions; and (c) sustainable transportation modes of raw materials.

2.2 Sustainable Cement Products

Innovative cement products offer new opportunities for sustainable concrete production and application. These products can be designed to meet specific performance requirements while reducing the environmental impact during concrete production and application. While the embodied energy associated with concrete manufacturing has been decreasing, the industry has utilised supplemental cementitious material (SCM) for many years. The main source of greenhouse gas (GHG) emissions from the production of concrete are the binder (cement), with clinker accounting for the majority of these emissions (nearly 90 per cent from generating concrete).

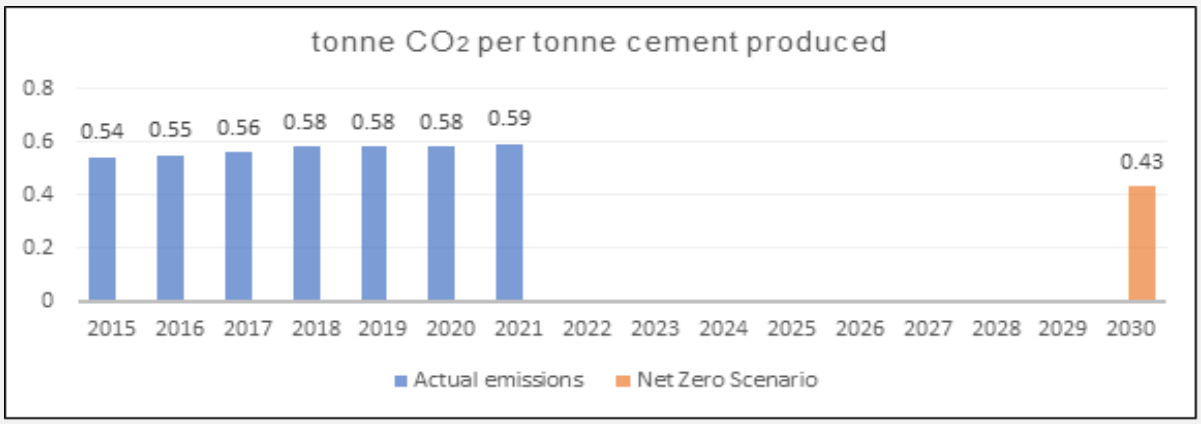

Figure 2: Direct emissions intensity of cement production in the Net Zero Scenario, 2015-2030 (IEA,2022)

Considering the net-zero scenarios, the CO_2 emission has to be below 27.11% by 2030, compared to 0.59 tonne CO_2 per tonne of cement produced in 2021, to be on track (Fig. 2).

A method that is even more productive and environmentally sustainable is the use of blended cement. Blended cement is produced by blending or inter-grinding varying proportions of clinker with one or more additions, such as FA (fly ash), granulated blast furnace slag (GBFS), natural pozzolans, slag, SF (silica fume), and other SCMs. Artificial pozzolans, bottom ash, FA, GBFS, glass cullets (GC), marble sludge, waste clays, and SF are recycled from other industries, whereas natural pozzolans, calcined sediments, and natural clays are extracted from natural resources. Cement mixtures have been used for decades. SCMs have a long history of usage in construction: Greeks and Romans utilised natural pozzolans (GCCA, 2020a); GBFS has been utilised since the 18th century (SCA, 2020); and FA was added to cement for the first time in 1937 AD (GCCA, 2020b). The effect of SCMs content on cement can significantly reduce the global warming potential (GWP), as shown in Fig. 3.

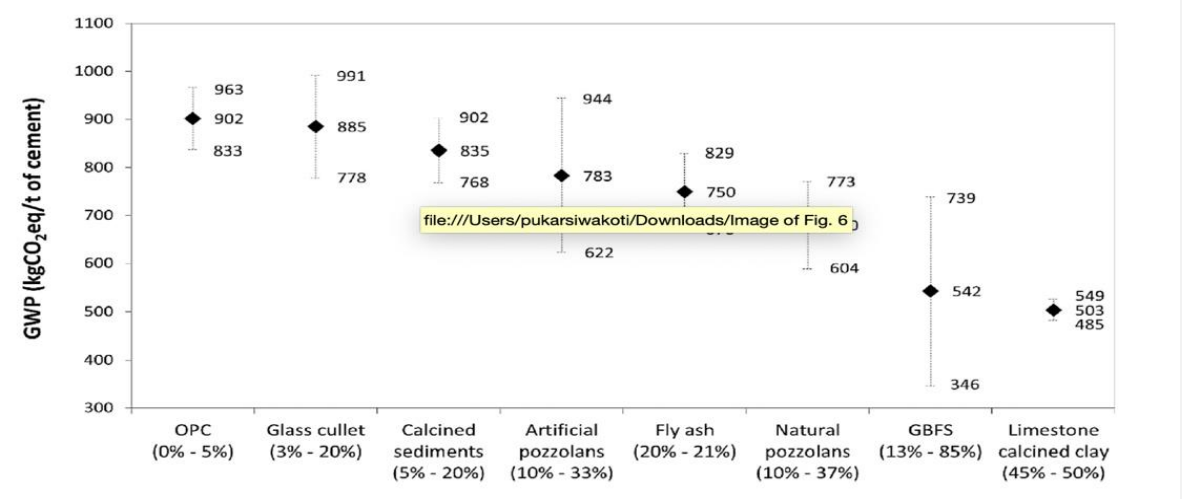

Figure 3: GWP of SCM- based cement (Rhaouti et al., 2023)

This is due to the fact that substituting clinker with SCMs reduces the decarbonation of limestone and kiln activities, which reduces GHG emissions. In comparison to the manufacturing of OPC, the emissions related to the use of FA as an SCM are less than 5%, and GGBS is around 10% of that of clinker-based cement (Miller, 2018). In addition, Mackechnie (2022) reported that carbon dioxide emissions from the production of Portland cement in New Zealand had decreased by 15% since 2005, despite a 13% rise in concrete output over the same period.

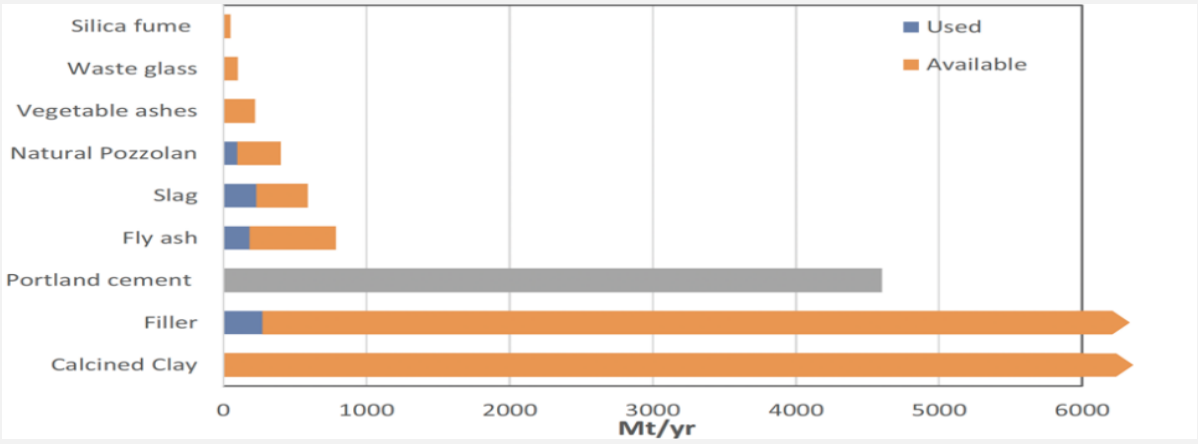

Figure 4: Approximate availability of potential SCMs and fillers in relation to cement production (Scrivener et al., 2018)

However, the application of these SCMs in cement and concrete preparation has yielded outstanding outcomes for sustainable development, but there are limitations associated with their long-term application. Although it is feasible to replace up to 70% of clinker with GGBS, the supply of slag continues to be a concern. Scrap steel recycling and more efficient steel-making technologies are anticipated to reduce blast boiler iron and slag production. Its availability has fallen from 17% of cement manufacture in 1980 to 8% of cement production in 2014 and is projected to fall below 8% of cement production (Scrivener et al., 2018). FA is a by-product of the coal-burning process during the production of electricity and can thus be considered a waste material. While there is more than 900 Mt/yr. present (Scrivener et al., 2018), the quality is quite varied, therefore now only approximately 1/3 is used in cement and concrete. Phase out of electricity generated from fired coal in many countries will significantly reduce the availability of FA. For example, in the first six months of 2016, the United Kingdom was short 0.2-0.30 Mt/yr of fly ash to meet demand, and the price increased from €10/t to €20–30/t (Global Cement, 2016). The tentative availability of potential SCMs and fillers in relation to cement is shown in Fig. 4. In this context, there has never been a greater need for new sources of SCMs, as existing SCMs become increasingly scarce and the need for SCMs to minimise carbon-dioxide emissions from concrete manufacturing increases.

Moving onto newer ones, Table 1 displays the numerous natural and industrial waste materials that have been the subject of research and can be considered for use as SCM. As an alternative to conventional SCMs, calcined clays, especially in conjunction with limestone, LC3 technology (50% Portland clinker, 30% calcined clay, 15% limestone, and 5% gypsum, known as LC3-50), offer the enormous application possibility as a partial substitution for clinker in cement and concrete (Scrivener et al., 2018; Sharma et al., 2021). And the reduction of GWP is estimated to be reduced by (45%-50%) (Fig. 3). Bauxite refinery residue (BRR), also known as red mud, is produced around 100-150 Mt/y (Juenger et al.,2019); however, its utilisation rate of less than 3% (Evans, 2016). The potential application of BRR as a binding agent is substantiated by the observation that several authors have documented the presence of silica, alumina, and iron in more than 50 %, a classification considered pozzolanic by the American Society for Testing and Materials (Qureshi et al., 2022).In 2017, SCMs replaced roughly 23% of clinker in Europe, and Cembureau estimates projected a rise of up to 35% by 2050, despite growing reports of shortages of supplemental cementitious materials due to changes in the energy and industrial sectors driven by the push towards sustainability (Coffetti et al., 2022). This highlights the need to identify and implement new SCMs in concrete manufacturing. Several recently discovered binding materials (Table 1) have been evaluated by researchers as promising and should be examined, and their implementation should be the subject of more study.

To minimise cement plant CO_2 emissions into the atmosphere, carbon capture technologies can be used. Carbon capture technologies such as Amine scrubbing, Full Oxy-Fuel combustion, partial Oxy-Fuel Combustion, Direct capture and Calcium Looping are presented by (Hills et al., 2015) are promising. Their review presented the carbon capture rate for cement plants as being expected to be higher than 90%, except for direct capture technology (about 64%). The main issue related to this technology is the option (ocean, depleted oil & gas reservoirs etc) involving the storage of collected carbon which is the most contentious. Incorporating CCUS (Fig. 5) technologies in cement production (as a key ingredient of concrete) has been a potential and active research area, even though it is

economically expensive (100–300 USD per tonne of CO_2 removal) (Coffetti et al., 2022). Research should be focused on proper utilisation rather than disposal of captured CO2. For instance, captured CO_2 by technology (Fig. 5) in a feedstock mixture for generating value-added commodities such as materials and chemicals for industrial use (Coffetti et al., 2022) and the production of artificial aggregate is gaining traction. Another barrier to the technology's wide-scale adoption may be the cement producer's lack of interest in retrofitting this technology due to potential factors such as (a) loss during installation's downtime (b), (c) land availability on existing cement plans, and (d) being expensive to install in existing plants. This can be promoted by providing subsidy packages and awareness of technology and environmental benefits from the government level to the cement producers.

Table 1: A summary of materials investigated or utilised as SCMs (Data extracted from Juenger et al. (2019)

SN	Material	Consumed as SCM (Mt/y)	Quantity Estimated (Mt/y)
1	Bauxite residue	0	100-150
2	Biomass ash	0	100-140
3	Clay	3	Large accessible reserve
4	Copper Slag	0 (few as filler)	30-40
5	Limestone	300	Large accessible reserve
6	Municipal solid waste incineration (MSWI) bottom ash	0	30-60
7	Steel Slag	0 (few as filler)	170-250
8	Waste glass	0 (or very few)	50-100

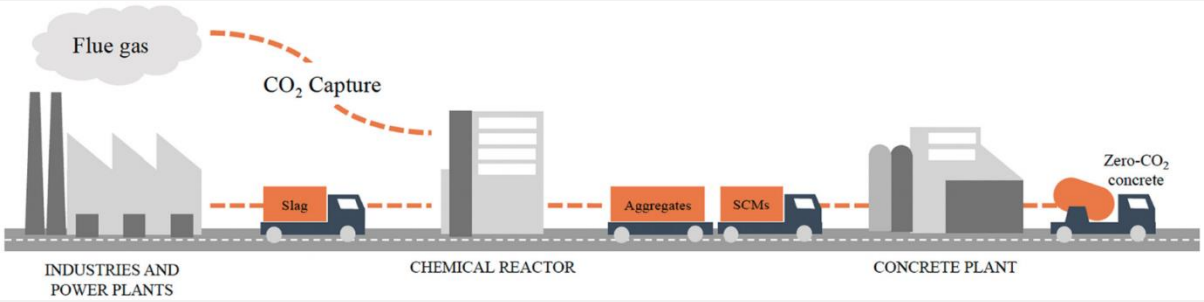

Figure 5: Process flow diagram for producing Zero- CO2 concrete using carbon capture, utilization and storage (CCUS) technology. (Coffetti et al., 2022)

2.3 Alternative Aggregate

Aggregate is the most important component of concrete, making up around 60-75% of the material by volume. It is also the most valuable non-fuel mineral commodity. According to the Organisation for Economic Co-operation and Development, the extraction of aggregates for the manufacturing of concrete is projected to grow by 55 Gt by 2060, from the current 25–30 Gt (Coffetti et al., 2022). By quarrying mountains, coarse aggregates are primarily extracted from natural resources such as stone. The most common fine aggregate used in construction is river sand. Massive extraction of natural materials is the primary cause of not only the depletion of natural resources but also the negative effects on human health

and the environment. The overexploitation of river sand as fine material has altered river patterns, eradicated beaches, polluted groundwater, and prompted the extinction of flora and fauna. Due to noise pollution and air pollution from dust created by machinery used to crush stones for coarse aggregate, there is a considerable risk of breathing problems and other health issues. Moreover, extensive land mining damages water quality and promotes soil erosion and changes in the natural ecosystem. Despite this, stone quarrying contributes to CO_2 emission through operations including mine mining, stone crushing, and aggregate transportation. Alternative aggregate reduces CO_2 emissions, energy consumption, and natural resource use, making concrete more sustainable.

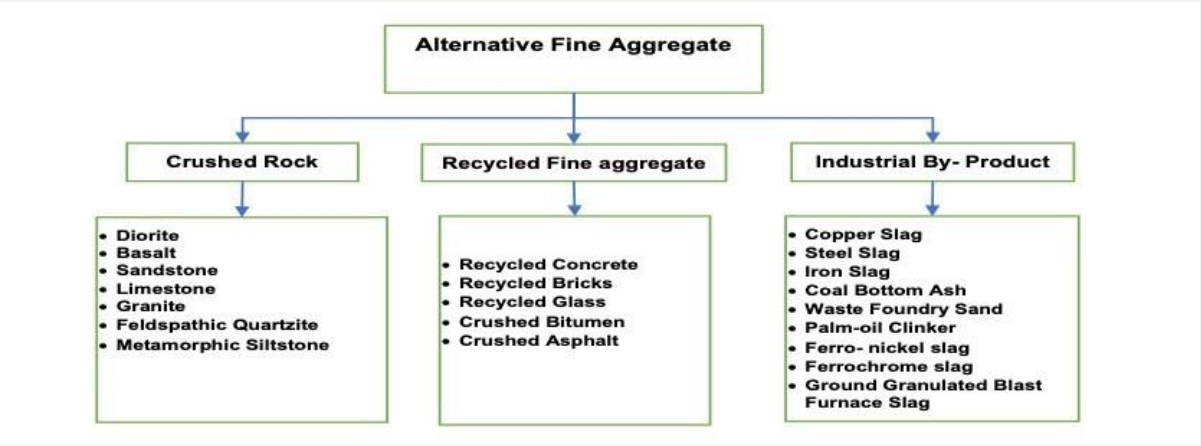

Figure 6: Alternative fine Aggregate (S.K., Singh & Chourasia, 2020)

Several forms of alternative fine aggregates include crushed rock sand (CRS), industrial by-products (IBP), and recycled fine aggregates (S.K., Singh & Chourasia, 2020), as shown in Fig. 6 of which have been researched by various researchers and can be expected to be implemented in the future. Recycled coarse aggregate(Duan et al., 2020), coconut shell (Bari et al., 2021), steel slag aggregate (Wang et al., 2020), ceramic waste aggregate(Amin et al., 2021), waste brick aggregate (Aziz et al., 2022), waste glass aggregate (Pauzi et al., 2021), and waste rubber aggregate (Alsaif et al., 2018) have been researched as potential replacements to natural coarse aggregate. In consideration of the mechanical properties, the findings were promising. According to wang et al. (2020), the compressive strength, tensile strength, and flexural strength of concrete made using steel slag aggregate increased by 34.35%, 3.77%, and 3.53%, respectively, at 100% replacement of natural aggregate. Similarly, Amin et al. (2021) found that the compressive strength of concrete using 20% replacement of natural coarse aggregate with ceramic waste was enhanced by 21.26%. In contrast to these results, the concrete strength reduction is observed in the case of concrete made by replacing natural aggregate with recycled coarse aggregate, waste brick, coconut shell, waste brick, waste glass, and waste rubber tyres (Duan et al., 2020; Alsaif et al., 2018; Pauzi et al., 2021; Aziz et al., 2022; Bari et al., 2021). The reduction in strength might be because of poor ITZ, poor surface texture, smooth surface texture, higher water absorption, etc. There are some challenges to its future implementation. For instance, due to the unavailability of low-cost procedures capable of transforming waste into aggregates and the lack of understanding about the effect of artificial aggregate characteristics on the performance of concrete, the usage of recycled aggregates is really quite minimal (Coffetti et al., 2022). There has been much study on waste foundry sand (WFS) and copper slag as

alternatives to fine aggregate, but further research is necessary for other waste products. The technical challenges related to the application of alternative aggregate mentioned by Coffetti et al. (2022) are excessive quantities of fines, unconventional geometries, and granulometric curves that result in high water consumption, significant shrinkage, and/or poor workability of concrete. Therefore, the study should be focused on these technical areas in order to be used on a larger scale as a replacement for natural aggregate.

3. Conclusions

a. The cement and concrete industries can play a considerable role in contributing to sustainable development by developing and implementing technologies that reduce greenhouse gas emissions and production costs.

b. The results from various researchers have demonstrated that there is a greater opportunity for the construction industry to effectively produce sustainable cement and concrete with drastically reduced environmental impacts, minimise waste, and employ renewable resources. This enables economically viable structures compatible with the environment, developing a resilient, sustainable, and prosperous future.

c. To minimise cement usage in the production of concrete, the conventional SCM would continue to be utilised. However, the availability of the most widely used SCMs(fly ash and GBFS) is uncertain in the future. Priority must be given to identifying, investigating, and implementing possible SCMs such as bauxite residue, calcined clay, MSWI, steel slag, biomass ash, waste glass, and limestone.

d. Carbon capture (capture CO_2 >90%) technology significantly lowers CO_2 emissions from cement production. Obstacles such as retrofitting, assuring both cement and capture plants compatibility, and lack of sustainable disposal or utilization method of captured CO_2 will lessen their implementation. In addition to this, this paper has identified that limited research has been done regarding the technique for utilisation of captured CO_2 compared to disposal. Thus, this paper identified this as a research gap.

e. The use of alternative aggregates improves the sustainability of concrete by reducing not only the use of natural raw materials but also CO_2 emissions and energy use. Therefore, the use of alternatives to natural aggregate, such as recycled coarse aggregate, coconut shell, steel slag, waste bricks, waste rubber tyres, ceramic waste, crushed stone sand, and recycled fine aggregate, in the performance of fresh and mechanical properties of concrete needs to be thoroughly investigated.

References

Adesina, A. (2020) 'Recent advances in the concrete industry to reduce its carbon dioxide emissions'. *Environmental Challenges*. 1, 100004. doi:10.1016/j.envc.2020.100004.

Alsaif, A., Bernal, S.A., Guadagnini, M. & Pilakoutas, K. (2018) 'Durability of steel fibre reinforced rubberised concrete exposed to chlorides', *Construction and Building Materials*. 188, pp. 130–142. doi:10.1016/j.conbuildmat.2018.08.122.

Amin, M., Zeyad, A.M., Tayeh, B.A. & Saad Agwa, I. (2021) 'Engineering properties of self-cured normal and high strength concrete produced using polyethylene glycol and porous ceramic waste as coarse aggregate', *Construction and Building Materials*. 299, 124243. doi:10.1016/j.conbuildmat.2021.124243.

Aziz, W., Aslam, M., Ejaz, M.F., Jahanzaib Ali, M., Ahmad, R., Wajeeh-ul-Hassan Raza, M. & Khan, A. (2022) 'Mechanical properties, drying shrinkage and structural performance of coconut shell lightweight concrete', *Structures*. 35, pp.26–35. doi:10.1016/j.istruc.2021.10.092.

Bari, H., Salam, M.A. & Safiuddin, Md. (2021) 'Fresh and hardened properties of brick aggregate concrete including coconut shell as a partial replacement of coarse aggregate', *Construction and Building Materials*. 297, pp.123745. doi:10.1016/j.conbuildmat.2021.123745.

Coffetti, D., Crotti, E., Gazzaniga, G., Carrara, M., Pastore, T. & Coppola, L. (2022) 'Pathways towards sustainable concrete' *Cement and Concrete Research*. 154, pp.106718. doi:10.1016/j.cemconres.2022.106718.

Coppola, L., Coffetti, D., Crotti, E., Gazzaniga, G. & Pastore, T. (2019) 'An Empathetic Added Sustainability Index (EASI) for cementitious based construction materials',*Journal of Cleaner Production*. 220, pp.475–482. doi:10.1016/j.jclepro.2019.02.160.

Danish, A., Ozbakkaloglu, T., Ali Mosaberpanah, M., Salim, M.U., Bayram, M., Yeon, J.H. & Jafar, K. (2022) 'Sustainability benefits and commercialization challenges and strategies of geopolymer concrete: A review', *Journal of Building Engineering*. 58, pp.105005. doi:10.1016/j.jobe.2022.105005.

Duan, Z., Singh, A., Xiao, J. & Hou, S. (2020) 'Combined use of recycled powder and recycled coarse aggregate derived from construction and demolition waste in self-compacting concrete', *Construction and Building Materials*. 254, pp.119323. doi:10.1016/j.conbuildmat.2020.119323.

Evans, K. (2016) 'The History, Challenges, and New Developments in the Management and Use of Bauxite Residue', *Journal of Sustainable Metallurgy*. 2 (4), pp.316–331. doi:10.1007/s40831-016-0060-x.

GCCA. (2020a)'Natural pozzolans' [online] Available at: https://gccassociation.org/cement-and-concrete-innovation/clinker-substitutes/natural-pozzolans/.

GCCA. (2020b). 'Fly ash', [online] Available at: https://gccassociation.org/cement-and-concrete-innovation/clinker-substitutes/fly-ash/.

GCCS | Staging. (n.d.). 'Cement and concrete around the world', [online] Available at: https://gccassociation.org/concretefuture/cement-concrete-around-the-world/.

Hills, T., Leeson, D., Florin, N. and Fennell, P. (2015) 'Carbon Capture in the Cement Industry: Technologies, Progress, and Retrofitting', *Environmental Science & Technology*, 50(1), pp.368–377. doi:https://doi.org/10.1021/acs.est.5b03508.

Hindawi, Nagan, S. & Karthiyaini, S. (2014) '*A Study on Load Carrying Capacity of Fly Ash Based Polymer Concrete Columns Strengthened Using Double Layer GFRP Wrapping*'',12 November 2014. A Study on Load Carrying Capacity of Fly Ash Based Polymer Concrete Columns Strengthened Using Double Layer GFRP Wrapping. doi:https://doi.org/10.1155/2014/312139.

IEA (2022), Cement, IEA, Paris https://www.iea.org/reports/cement, License: CC BY 4.0

Interior, 2020. Available at https://pubs.usgs.gov/periodicals/mcs2020/mcs2020.pdf.

Juenger, M. C., Snellings, R., & Bernal, S. A. (2019, August). Supplementary cementitious materials: New sources, characterization, and performance insights. Cement and Concrete Research, 122, 257–273. https://doi.org/10.1016/j.cemconres.2019.05.008

Lonth, C.F., Thomas, J. & Joseph, N. (2018) 'Mechanical Properties of Concrete Containing Brick Chips', *IOP Conference Series: Materials Science and Engineering*. 396, pp.012003. doi:10.1088/1757-899x/396/1/012003.

M. Monteiro, P.J., Miller, S.A. & Horvath, A. (2017) '*Towards sustainable concrete - Nature Materials*. 27 June 2017', *Nature*. doi:10.1038/nmat4930.

Mackechnie, D.J. (2022) '1 April 2022. BRANZ Build' https://www.buildmagazine.org.nz/index.php/articles/show/scms-reduce-concrete-emissions.

Majidi, B. (2009) 'Geopolymer technology, from fundamentals to advanced applications: a review', *Materials Technology*. 24 (2), pp.79–87. doi:10.1179/175355509x449355.

McLellan, B.C., Williams, R.P., Lay, J., van Riessen, A. & Corder, G.D. (2011) 'Costs and carbon emissions for geopolymer pastes in comparison to ordinary portland cement', *Journal of Cleaner Production*. 19 (9–10), pp.1080–1090. doi:10.1016/j.jclepro.2011.02.010.

Miller, S.A. (2018) 'Supplementary cementitious materials to mitigate greenhouse gas emissions from concrete: can there be too much of a good thing?', *Journal of Cleaner Production*. 178, pp.587–598. doi:10.1016/j.jclepro.2018.01.008.

Pauzi, N.N.M., Hamid, R., Jamil, M. & Zain, M.F.M. (2021) 'The effect of melted-spherical and crushed CRT funnel glass waste as coarse aggregates on concrete performance', *Journal of Building Engineering*. 35, pp.102035. doi:10.1016/j.jobe.2020.102035.

Qureshi, H.J., Ahmad, J., Majdi, A., Saleem, M.U., Al Fuhaid, A.F. & Arifuzzaman, M. (2022) '*A Study on Sustainable Concrete with Partial Substitution of Cement with Red Mud: A Review* 3 November 2022',. MDPI. doi:10.3390/ma15217761.

Rhaouti, Y., Taha, Y., & Benzaazoua, M. (2023) 'Assessment of the Environmental Performance of Blended Cements from a Life Cycle Perspective: A Systematic Review', *Sustainable Production and Consumption*,36, pp.32–48. https://doi.org/10.1016/j.spc.2022.12.010

S.K., K., Singh, S.K. & Chourasia, A. (2020) 'Alternative fine aggregates in production of sustainable concrete- A review' *Journal of Cleaner Production*. 268, pp.122089.doi:10.1016/j.jclepro.2020.122089.

Scrivener, K., Martirena, F., Bishnoi, S. & Maity, S. (2018) 'Calcined clay limestone cements (LC3)', *Cement and Concrete Research*. 114, 49–56. doi:10.1016/j.cemconres.2017.08.017.

Scrivener, K.L., John, V.M. & Gartner, E.M. (2018) 'Eco-efficient cements: Potential economically viable solutions for a low-CO2 cement-based materials industry', *Cementand Concrete Research*. 114, pp.2–26. doi:10.1016/j.cemconres.2018.03.015.

Sharma, M., Bishnoi, S., Martirena, F. & Scrivener, K. (2021) 'Limestone calcined clay cement and concrete: A state-of-the-art review', *Cement and Concrete Research*. 149, pp.106564. doi:10.1016/j.cemconres.2021.106564.

SRINIVASAN, S., KARTHIK, A. and NAGAN, S. (2014)' An investigation on flexural behaviour of glass fibre reinforced geopolymer concrete beams', *Int.J.Eng.Sci.Res.Technol.*, 3(4), pp. 1963-1968. https://citeseerx.ist.psu.edu/doc/10.1.1.685.7030

Turner, L.K. & Collins, F.G. (2013) 'Carbon dioxide equivalent (CO2-e) emissions: A comparison between geopolymer and OPC cement concrete', *Construction and Building Materials*. 43, pp.125–130. doi:10.1016/j.conbuildmat.2013.01.023.

U.S. Geological Survey (2020) 'Mineral Commodity Summaries 2020, U.S', Available at: https://pubs.usgs.gov/periodicals/mcs2020/mcs2020.pdf.

United Nations (2019) 'World population prospects 2019', [online] Available at: https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf

Wang, S., Zhang, G., Wang, B. & Wu, M. (2020) 'Mechanical strengths and durability properties of pervious concretes with blended steel slag and natural aggregate', *Journal of Cleaner Production*. 271, pp.122590. doi:10.1016/j.jclepro.2020.122590.

www.globalcement.com. (2016) 'Lower SCM supplies demand a change in approach', [online] Available at: https://www.globalcement.com/magazine/articles/994-lower-scm-supplies-demand-a-change-in-approach.

An Investigation of Benefits and Challenges of BIM Adoption in Nepal

Dr Raj Shah[*1] *and Bibek Shrestha*[2]

[1]Senior Lecturer and [2]PG Student, School of Civil Engineering and Built Environment, Faculty of Engineering and Technology, Liverpool John Moores University, Liverpool, UK
**Corresponding Email: r.shah@ljmu.ac.uk*

Abstract

The construction industry needs advanced construction methodology and Building Information Modelling (BIM) technology to reduce the problems faced by Architectural, Engineering and Construction (AEC) professionals. The BIM technology helps to improve quality, health and safety and reduces the project cost and delivery time. The BIM level 1, which is limited to 2D and only in a few cases 3D models in practice to design and construct residential and commercial buildings in Nepal. This paper has focused on providing insight into the BIM benefits and identifying potential barriers while adopting BIM technology in Nepal. A comprehensive literature review was conducted and 4DBIM (3D model plus schedule) of a multi-story residential building was developed as a case study in Nepal. The industry survey via focus group was conducted with AEC professionals using the 4DBIM and summarised the findings about the BIM benefits and challenges of BIM implementation in the AEC industry. The paper discusses the potential benefits of BIM applications, and the challenges when implementing it in Nepal and presents the comparison with the past studies. It is found that commercial and governmental projects are feasible to adopt the 4DBIM technology due to the competitive market and limited budgets. The paper concludes that the unavailability of BIM users and the lack of government policies for BIM adoption are key challenges in Nepal. A new policy of BIN use is critical; to achieve and exploit the full scale of BIM benefits and improve the project delivery in terms of quality of products and services, health and safety and project cost in AEC industry.

Keywords: BIM, 4D modelling, Clash Detection, 2D and 3D models, BIM adoption, Barriers

1. Introduction

According to the status of the Nepalese AEC industry, time and cost overrun are serious problems faced due to poor awareness, project management, and poor adoption of new and evolving technology such as BIM, modular and offsite construction (Mishra, 2018). The poor management of project risks from the initiation stage to the design, construction, and operation stage of project completion causes another factor in the project delay and cost overrun (Mishra, 2018). The Nepalese construction industry still follows traditional methods of construction practices. Chiluwal and Mishra (2017) presented hydropower construction project statistics that more than 74% of Nepalese AEC professionals do not use any software for cost management in the project. Currently, construction projects face higher variation orders due to changes in the design, scope, unsystematic estimate of the quantity and poor surveying reports (Koirala et al., 2021). Marasini (2018) recommended that implementing BIM in building and infrastructure projects in Nepal will improve the project performance from the design stage to the construction or operation of the project. This will help to reduce the above problems at a certain level by exploiting the benefits of BIM technology in the AEC industry.

The status of BIM adoption in Nepal is low (Maharjan, 2020). Niraula (2020) claimed that the Nepalese AEC industry has not implemented the BIM concept in construction projects.

Maharjan (2020) claimed that a lack of research on BIM and its further dimensions, very few AEC professionals are aware of BIM benefits, and its implementation is low. Niraula (2020) claims that the current AEC industry of Nepal is only using BIM for 3D visualization, and there is no trend toward incorporating BIM into the construction process. Maharjan (2020) discussed the status of BIM implementation and its barriers and recommended 4DBIM models to calibrate the actual benefits that BIM would yield in the Nepalese AEC industry. Nepal has a low level of BIM applications and awareness of its benefits. The past research has presented the findings of BIM benefits without conducting any experiments with a 4DBIM model in a real case study project in Nepal. Hence, the study attempts to explore the 4DBIM benefits and the problems while adopting in the AEC industry by developing a 4DBIM model using a real-life case study of a residential building. The paper presents the potential BIM benefits, and challenges of BIM adoption, and further examines various aspects of 4DBIM applications in Nepal.

2. Literature Review

2.1 Current Research

Van and Tolman (1992) presented their views on integrating different information about buildings into one model and introduced Building Information Modelling (BIM) concept. The definition is found similar in Eastman et al (2011) and Martins et al (2020), who describe BIM as a technology that allows different professionals to generate, exchange, and see other designers'/trades' project information which integrates the data into a single database and is not limited to 3D models and relates the building productivity process throughout its life span. A BIM model can be used for various pre-defined purposes known as use cases (Eastman et al, 2010). Qiu et al (2021) stated that BIM is a shared knowledge resource platform that enables collaborative work relating to the project with different stakeholders by data

interoperating using BIM applications or software. The above definitions are essential for what these include the BIM in other terms that commonly can help construction projects run smoothly and efficiently from start to completion.

The traditional construction sector focuses on the critical path approach and bars charts from examining the project timelines (Kamari et al, 2019). Modern practices adopt the novel concept of 4DBIM, which can simplify and solve various construction issues such as inconsistencies in schedule degree of detail, missing actions, schedule logic, and time and space conflicts. The 4DBIM model is the composition of a 3D model and additional time information. It stores basic information such as building components and materials, stories, grids, and elevation. The fourth-dimension model drafts additional dimensional information known as scheduling data or time elements (Bolshakova and Guerriero, 2018). It has reduced the misunderstanding caused by a lack of visualisation in traditional building sequence scheduling (Martins et al, 2020).

2.2 Benefits of 4DBIM

After a comprehensive review of existing literature, the benefits of 4DBIM found by past studies are summarised and presented in Table 1.

Table 1: Summary of 4DBIM benefits

Authors	4DBIM benefits
Malsane and Sheth (2015)	Visualization for communication and analysis
	Reducing delays and schedules issues
Candelario-Garrido et al (2017)	Ensures planning efficiency
	Control over project execution
Lee and Kim (2017	Connection of 4D model with 2D
	Minimization of errors and rework in design and construction
	control over schedule, quality, and cost
Park et al (2017)	Solution for information delay
	Visualization of real-time information to enhance data consistency
	Promotion of communication and collaboration among participants
Balakina et al (2018)	Optimization of the construction workflow
	Monitoring the site safety requirements
Crowther and Ajayi (2019)	Increment in planning efficiency
	Evaluation of planned and actual construction progress
Martins et al (2020)	Avoiding the construction delays
	Sufficient information to eliminate the re-scheduling issues
	Environmental assessment
Alzarrad et al (2021)	Identification of errors in the construction schedule
	Reduction of cost and duration

2.3 Barriers to 4DBIM adoption

Several studies have identified the possible obstacles to 4D implementation depending on several authors and country contexts. This paper has attempted to point out some of the barriers that might be the same condition in Nepal's AEC industry.

● Lack of 4DBIM Expertise: The 4DBIM model requires various software, so it becomes necessary to be an expert on it to implement them professionally (Martin et al, 2020; Zhou

et al, 2017). Ahmed et al (2014) showed that the availability of skilled professionals is the highest-ranked barrier to implementing 4DBIM in Qatar. Gledson and Greenwood (2016) quoted, "4D planning will only be successful if planners/contractors understand BIM technology and have suitable experience in construction practices".

- Lack of interest of client due to time and cost: Arrotéia et al (2021) mentioned from their pilot study that the client also seems dissatisfied with the time consumed during the preparation of design and cost of the design for 4DBIM in the Brazilian context. The design cost of the 4DBIM design model is comparatively expensive due to software and hardware access costs (Hamada et al, 2016).

- Incompetent Government supervision: Martins et al (2020) presented various literature to supporting government policies and regulations that have successfully accelerated BIM adoption. It is necessary to get high-level support to implement the 4DBIM technology in the construction industry (Ogunmahkinde and Umeh, 2018).

- Resistance to change: The traditional method dominates the project delivery system (Ghoddousi and Hosseini, 2012). Hosseini et al (2016) claimed that the lack of interest in the UK has mandated the BIM adoption for the AEC industry. The AEC industry has remarkable integrity with the construction industry and software changing the way of working culture is one key barrier to adopting 4DBIM in USA.

3. Research Methodology and 4DBIM Modelling

The study adopted a qualitative research methodology and adopted focus group interview for data collection methods. The focus group interview is selected in this study since it helps to engage participants' interests and get their views widely on the topics (Clarke and Braun, 2006). An industry survey was conducted via 3 sets of focus groups with construction professionals like designers, engineers, contractors and project managers using the 4DBIM model and showing functionalities to them to get views about the benefits and challenges of 4DBIM. The primary purpose of creating a 4DBIM model is to provide insight into BIM tools and their functionality, linked with their overall importance to the construction industry. Previously, the project was designed using level 1 BIM, which is confined to 2D design, and eventually developed into 4DBIM models containing architectural and structural models with the detection of clashes in the design stage and showing the construction simulation. After model development, the study progressed to a focus group study where the 4DBIM model is discussed with the different AEC professionals. The outcomes from the focus group study are organised into a thematic analysis which synthesises the raw data of the discussion into elegant themes and sub-themes. The procedures and steps that are involved while creating a 4DBIM model of a residential building are shown in Figure 1.

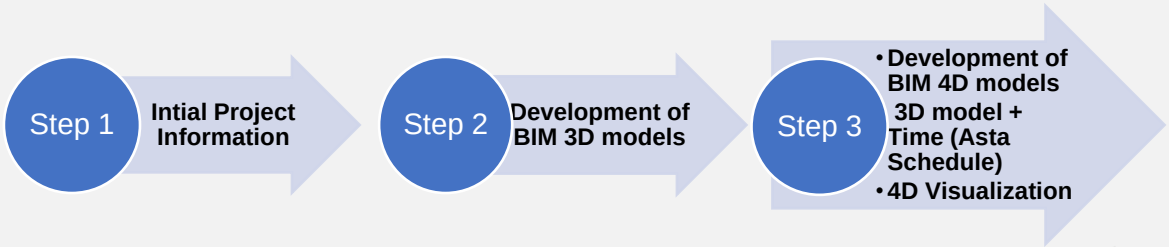

Figure 1: Key steps for 4DBIM model development and key inputs

***Step1**: Initial Project Information*

The 4DBIM model development starts with collecting initial information about the building, which helps to understand the building structure and project visualisation. Initially, we have the level 1 adopted BIM file limited to 2D AutoCAD file having all the details specified: the floor plans, section, elevation, door and window sizes, and structural drawing. For the 4DBIM model, this study has targeted developing a 3D architectural and structural model to detect clashes in the design and add time information to the different activities of the project. After finalising the activities and sequencing them practically, a 4D simulation is required to visualise the building construction process. The project had a deadline of 73 weeks with a proper analysis of risk due to the client's financial burden. The project had the overall scope of the architectural model, structural model, clash detection, and 4D simulation with the timeline.

***Step2**: Development of BIM 3Dmodel and Clash detection*

Due to its IFC file format export feature for generating a 3D model, Autodesk Revit 3D model (see Figure 2) was used for the case study project. Based on the level 1 BIM, AutoCAD-2D information was used as an initial layout in Revit to develop 3D, maintaining the original architectural design. Templates were used in defining each floor level, elevation, the section in the design, and the family library provides a variety of options for building components needed for the construction. Autodesk Navisworks helps to detect clashes between the beam and column (see Figure 3).

Figure 2: Revit 3D model

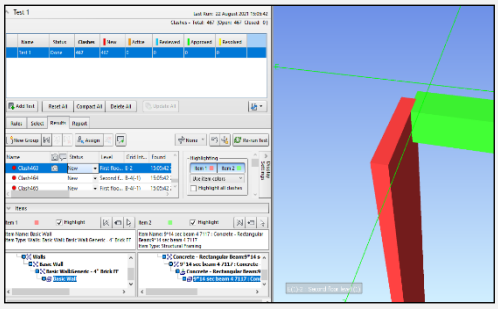

Figure 3: Clash detection

Navisworks was used to perform the clash detection functionality. In a building 3Dmodel, clash detection aids in discovering, inspecting, and reporting interference with other services. One of the most important advantages of BIM is the capacity to detect 'clashes' early in the project, which is easier, cheaper, and less time-consuming to resolve. The study detected 467 clashes between different services in the case study of the residential building project.

***Step 3**: Development of 4DBIM model*

The various activities were listed and sequenced on a practical basis. Based on the experience and judgment of the planned activities, milestones are set to track the project's progress and priorities. Each activity's duration is provided and linked with suitable links. The exported IFC format of 3DBIM model from Revit was opened in Asta Powerproject software (see Figure 4).

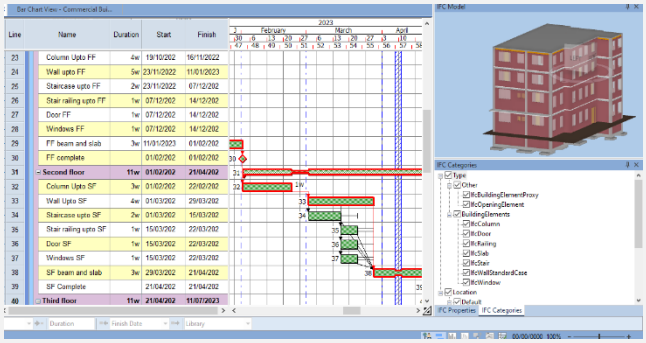

Figure 4: Project Scheduling on Asta Powerproject

The imported 3DBIM model into the Asta Powerproject was checked with all the information provided on the Revit. The 3D model components were linked with the related task schedule. For example, the wall components of the building in the 3D model connect to the construction activity on the timeline as shown in Figure 4. The critical path depicts the project activities in a graphical format, which aids in evaluating parallel activities, creating a delay control strategy, and exercising judgment. It aids in comparing planned and completed tasks. As a result, it provides a map of the project at the planning stage, indicating where to begin and what decisions must be made (Kim and Garza, 2005). A two-week delay in strap beam construction would extend the project by three weeks. This was compared with the actual progress to the planned progress in the project to know the time variation.

4. Data Collection and Analysis

The section discusses the data collection and analysis methods adopted in this study amongst AEC professionals in Nepal. The study was conducted industry survey via focus group method. The professionals having a minimum experience of five years in the building construction were selected as participants in the study. The participants from the different types of residential to commercial building construction were selected to gather their ideas and share current practices. Three focus group interviews were conducted with each group having three members of AEC professionals. The interviews were performed via online seminar. The interviews were recorded and saved in audio and video format.

All three focus group interviews lasted 2-3 hours which were started by showing how 4DBIM works to show class detection at design stage and construction simulation of work progress in respect of time. Ten qualitative questionnaires were asked relevant to the BIM benefits and challenges. The initial codes with the transcript were studied to become familiar with the data obtained from the interviews. The formation of themes requires further development of sub-themes. Based on the participant's perspective, themes and sub-theme were generated. Table 2 shows the generated themes and sub-themes under three major categories, which relate to the key objectives of the study. The thematic analysis is adopted in this study to demonstrate data from the focus group interview. The overall procedures need to be written into the paper to validate and analyse the relative findings from the thematic analysis (Clarke and Braun, 2006).

Table 2: Sub-theme and themes generated under three categories

Category	Themes	Sub-Themes
1. 4DBIM Benefits in Nepal	Introduces collaborative concept	Cloud-based working environment
		Early clash detection
		Integrated design
		Design and Build concept
	Efficient planning than other Traditional methods	Integrated 3D models and schedules
		4D simulated video
		Project schedules
		Project tracking
	Minimizing time, cost, and waste of materials	Early clash detection
		On-time delivery
		4D visualization
2. Applications of 4DBIM in Nepal	Suitability in Residential housing	High design cost
		Benefit analysis
	Demand in government or commercial building projects	Detailed design
		Few firms are aware and implemented
3. Barriers of 4DBIM in Nepal	Concept on design and construction	Municipal pass
		Architectural and structural requirements
		Competitive market
	Procurement system and contractor perspective	Petty contracts
		Fragmented works
		Multiple projects at the same time
	Expertise in 4DBIM	Training
		Availability of software
		Investment
	Government Policy	Standard BIM regulations
		BIM awareness

In summary, the codes are generated from the interpretative transcript of the interview. The codes are divided and grouped into sub-themes that provide meaning to the codes. The sub-themes are categorised into themes that are under three categories/objectives. Thus, the themes are classified into three main findings of this study, and these are discussed in the next section of results and discussions.

5. Results and Discussions

Each of the categories and themes as shown in Table 2 are briefly discussed with the participants' responses in the focus group study. The study suggests that the 4DBIM has big potential and challenges to BIM adoption in the Nepalese AEC industry, which are explained below.

5.1 4DBIM Benefits in Nepal

Introduces the collaborative concept: Mostly, the architects in the interview suggested that 4DBIM helps to collaborate while planning projects. The design needs to be changed many times, which is one of the challenging parts of designing. Within the "Cloud-based working environment," various personnel can work on the same file, reducing design errors and immediately detecting and rectifying mistakes. The participants have stated that "early clash detection" also involves the collaborative concept by identifying the clashes and dividing them into different respective team members, which can lessen the work overload for one member.

The majority of participants agreed that most of the AEC firms perform the non-collaborative design of the project but one participant in the focus group interview highlighted that there is a lack of coordination between the design team. The architect designed the project in AutoCAD 2D and structural engineer designed the structural part without proper communication between the architect and engineer. These situations create a demand for "integrated design." In addition, the concept of "design and build" is gaining popularity nowadays to fill the communication gap between designers and contractors.

Efficient planning on traditional methods: The project offers the benefit of scheduling and planning in 4DBIM. The 80% of participants in the focus groups confirmed that the 4DBIM provides better construction planning by showing "4D simulation video," "project schedules," and "project tracking." The video provides information visually to non-technical people and helps to detect errors in the planning stage. Mostly the participants from engineering firms and contractors have appreciated "project tracking" on the model presentation since it helps to measure the delivery of the project to the planned duration and expected time. Usually, there is a practice of scheduling the project activities through Excel or M.S. Project. All participants agreed that integrating the 3D model with the schedules is a new concept and will be very useful in Nepal.

Minimizing time, cost, and waste of materials: one of the participants from a contractor suggested that "on-time delivery" will significantly reduce the material storage space, waste, and cost of the materials. "Early detection of clashes" provides the detection of errors so that the project in execution can omit those errors by resolving those clashes in design. Participants have shared their experience of the errors in the design and their impact on performance. All the participants agreed that early clash detection would help to minimize materials waste and save time and cost. The time-based simulation of 4DBIM modelling would create a virtual construction scenario where the designers, engineers, and contractors can understand the construction and construction sequence.

5.2 Applications of 4DBIM in Nepal

Suitability in residential housing: The application of 4DBIM in residential building design and construction in Nepal is challenging based on interview findings. The study found that the preliminary design cost of residential housing is higher, and clients do not want to spend more money at the design stage due to the high cost of BIM consultants at the start. The 4DBIM technology requires considerable time and resources throughout the design phase. After implementing 4DBIM, the designer would expect more in return. The participants suggested that only a small number of residential dwellings have detailed designs and simple residential building plans rarely have MEP designs due to high cost. Most participants agreed that adopting 4DBIM in residential buildings would be challenging but some participants suggested that "cost-benefit analysis" could be an excellent way to change the thinking of people about the BIM benefits. Most participants agreed that Sketchup is easier to use than Revit, however every client nowadays wants to see their project designed in 3D but does not specify the requirement of 4DBIM.

Demand in government or commercial building projects: The participants have slightly experienced with 4DBIM or 5DBIM design in government projects. These projects usually demand "detailed design" and are complex nature of projects. Most of the participants have agreed on high-budget projects that are most suitable for applying 4DBIM in Nepal. In

addition, internationally funded projects even require proper BIM implementation projects. One of the participants shared the requirement for BIM adoption in the JICA funded reconstruction of a school project while conducting the interview within the focus group.

5.3 Barriers to the Adoption of 4DBIM in Nepal

Concept of design and construction: Participants agree that “municipality pass” requirements do not demand the 3D model or schedules/plans. The primary focus concerns the structural and architectural plans of the building. They confirm that only AutoCAD 2D showing the minimal structural requirements, plans, sections, elevations, and site plan is enough for a simple housing project. Participants have agreed that most building projects do not proceed beyond the "architectural and structural requirements". The "competitive market" of the AEC industry is another factor in the hindrance of 4DBIM adoption. The clients seek an economical design of the building. But to adopt the 4DBIM, there should be a policy for BIM adoption as a minimum requirement, so that the competitive industry can provide better business value to BIM innovative firms. Before implementing the 4DBIM concept on the projects, the feasibility of the competitive market is a primary consideration for all participants.

Procurement system and contractor perspective: The "petty contracts" are the subcontract of main contracts, and these are primarily small firms that are unaware of the adoption of new technology in the construction industry. It is tough to change the working culture since the most experienced contractors have no BIM experience and are reluctant to adopt changes. Hence, such a mindset hinders the adoption of BIM technology in construction. If the design is based on 4DBIM, it is difficult to trace the work in the execution. To trace the progress and implement 4DBIM, skilled human resources are required to adopt with the high initial cost.

Expertise in 4DBIM: Many architects, engineers, and contractors are not aware of the benefits of 4DBIM in Nepal. Those who are aware lack access to the relevant software. The purchase of the software is difficult due to the high initial cost. Advanced software like Navisworks and Revit require a big license fee to use professionally. Training is one of the essential requirements in getting expertise in such software, but it seems lacking due to difficulty in accessing the software which is free access. When users do not use that software, they cannot quickly adapt to professional careers. The other issue with adoption is that the return on investment is not satisfactory for innovative tools.

Government policy: The government guidelines highlight the specific codes to follow in Nepal while designing and constructing a building. However, a lack of the strategy supplied by government guidelines for BIM implementation in construction projects. The participants have proposed that government support with robust policies and procedures can better implement BIM technology like the literature cited by different countries where BIM adoption has gained insight due to government guidance. The government can implement pilot projects to show the 4DBIM concept from design till the closure of the project. Based on this demonstration, awareness will arise in the AEC field of Nepal.

6. Conclusions and Recommendations

The industry survey findings suggest that the current practices have severe issues with project budget cost, delivery time and quality of products and services. Past research and

experiments have shown that the 4DBIM can deal with cost, time, and quality. This paper discussed the findings from a case study experiment with the help of 4DBIM models developed for a residential building in Nepal. Professional interviews were conducted with 3 sets of focus groups, and it is found that the adoption of 4DBIM is essential and beneficial despite challenges in the Nepalese AEC sector. The high design cost of the 4DBIM is a critical problem for the adoption of BIM in residential housing. Government and commercial projects have some immediate relevance in Nepal since these projects have full support from government funding to invest in new technologies. Most construction and consultancy firms adopt the traditional design and planning approach due to initial barriers to using 4DBIM in Nepal. The lack of expertise in 4DBIM users and the easy availability of splintered software are other obstacles to BIM adoption. It is concluded that strong government support is needed to adopt BIM technology at levels 2 and 3 in the AEC industry because it is not an easy task and requires various policy guidelines to be changed and educate the AEC stakeholders about BIM technology. Due to the competitive market in the AEC sector and the high investment cost in BIM technology, small private firms are reluctant to adopt 4DBIM. The government pilot projects are the best way to demonstrate the BIM potential in the Nepalese construction industry to increase awareness of stakeholders of AEC and expedite the BIM adoption.

In future work, the integration of 4DBIM with energy analysis could be a new topic in the case of Nepal. The baseline model and the actual 4DBIM model are yet to be compared with the project cost, delivery time and skills of human resources. The location of the observers and the accurate 3D models have impacted the 4DBIM modelling process and measure benefits. Despite these limitations, this study has attempted to develop 4DBIM and demonstrated the benefits with a case study of a residential building project which was initially designed on AutoCAD 2D.

References

Alzarrad, M.A., Moynihan, G.P., Parajuli, A. and Mehra, M., 2021. 4DBIM Simulation Guideline for Construction Visualization and Analysis of Renovation Projects: A Case Study. Frontiers in Built Environment, 7, p.31.

Arrotéia, A.V., Freitas, R.C. and Melhado, S.B., 2021. Barriers to BIM adoption: A case study in Brazil. Frontiers in Built Environment, 7, p.16.

Balakina, A., Simankina, T. and Lukinov, V., 2018. 4D modelling in high-rise construction. E3S Web of Conferences, 33, p.03044.

Bolshakova, V., Guerriero, A. and Halin, G., 2018. Identification of relevant project documents to 4DBIM uses for a synchronous collaborative decision support. In Creative Construction Conf 2018 (pp. 1036-1043). Budapest University of Technology and Economics.

Braun, V. and Clarke, V., 2006. Using thematic analysis in psychology. Qualitative research in psychology, 3(2), pp.77-101.

Candelario-Garrido, A., García-Sanz-Calcedo, J., and Rodríguez, A.M.R., 2017. A quantitative analysis on the feasibility of 4D planning graphic systems versus conventional systems in building projects. Sustainable Cities and Society, 35, pp.378-384.

Chiluwal, K. and Mishra, A.K., 2017. Construction practice of small hydropower projects in Nepal. International Journal of Creative Research Thoughts, 5(4), pp.1417-1433.

Clarke, V. and Braun, V., 2006. Thematic analysis. The journal of positive psychology, 12(3), pp.297–298.

Crowther, J. and Ajayi, S.O., 2019. Impacts of 4DBIM on construction project performance. International Journal of Construction Management, pp.1-14.

Eastman C., Teicholz P., Sacks R. and Liston, K. (2011). BIM Handbook: A guide to building information modeling for owners, managers, designers, engineers, and contractors. John Wiley & Sons, Inc.

Ghoddousi, P. and Hosseini, M.R., 2012. A survey of the factors affecting the productivity of construction projects in Iran. Technological and economic development of economy, 18(1), pp.99-116.

Gledson, B. and Greenwood, D., 2016. Surveying the extent and use of 4DBIM in the UK. Journal of Information Technology in Construction (ITcon) 21 pp. 57-71. ISSN 1874-4753

Hosseini, M.R., Azari, E., Tivendale, L., Banihashemi, S. and Chileshe, N., 2016. Building Information Modeling (BIM) in Iran: an exploratory study. Journal of engineering, project, and production management, 6(2), pp.78-89.

Kamari, A., Schultz, C.P.L. and Kirkegaard, P.H., 2019. Constraint-based renovation design support through the renovation domain model. Automation in Construction, 104, pp.265-280.

Kim, K. and De La Garza, J.M., 2005. Evaluation of the resource-constrained critical path method algorithms. Journal of construction engineering & management, 131(5), pp.522-532.

Koirala, N., Sharma, P., Sapkota, L.P., Yogi, M., Pokharel, A. and Yogi, H., 2021. Variations Order of Building Construction Project a Case from Nepal. Nature, p.21.

Lee, J. and Kim, J., 2017. BIM-based 4D simulation to improve module manufacturing productivity for sustainable building projects. Sustainability, 9(3), p.426.

Maharjan, K. 2020. Status of Building Information Modelling (BIM) Application in Nepal, Master's Thesis. Tribhuwan University, Nepal

Malsane, S.M. and Sheth, A.Z., 2015. Simulate construction schedules using BIM 4D application to track progress

Marasini, R., 2018. Strategies for adoption of Building Information Modelling (BIM) in Nepal: Lessons Learned from UK and Other Countries. Innovative Technologies and Practices for Nepal, p.60.

Martins, S.S., Evangelista, A.C.J., Hammad, A.W., Tam, V.W. and Haddad, A., 2020. Evaluation of 4DBIM tools applicability in construction planning efficiency. International Journal of Construction Management, pp.1-14.

Mishra, A., 2018. Factors Affecting Performance and Time Extension of ongoing Construction Projects under Town Development Fund, Nepal. Journal of Advanced Research in Construction and Urban Architecture, 03(04), pp.7-25.

Niraula, N., 2020. Application of BIM in Nepal, Bachelor's Thesis, Metropolia University of Applied Sciences, Finland.

Ogunmakinde, O.E. and Umeh, S., 2018. Adoption of BIM in the Nigerian Architecture Engineering and Construction (AEC) industry. 42nd Australasian Universities Building Education Association (AUBEA).

Park, J., Cai, H., Dunston, P.S. and Ghasemkhani, H., 2017. Database-supported and web-based visualization for daily 4DBIM. Journal of Construction Engineering and Management, 143(10), p.04017078.

Qiu, Q., Zhou, X., Zhao, J., Yang, Y., Tian, S., Wang, J., Liu, J. and Liu, H., 2021. From sketch BIM to design BIM: An element identification approach using Industry Foundation Classes and object recognition. Building and Environment, 188, p.107423.

Van Nederveen, G.A. and Tolman, F.P., 1992. Modelling multiple views on buildings. Automation in Construction, 1(3), pp.215-224.

Zhou, Y., Ding, L., Rao, Y., Luo, H., Medjdoub, B. and Zhong, H., 2017. Formulating project-level building information modelling evaluation framework from the perspectives of organizations: A review. Automation in construction, 81, pp.44-55.

Enabling the implementation of electric equipment in Nepal for sustainable construction

Ramesh Ranabhat[1], Parakram Pyakurel[2], Ramesh Marasini[3]

[1] *Institute of Engineering, Pulchowk Campus, Nepal*
[2] *New Model Institute for Technology and Engineering, UK*
[3] *Buckinghamshire New University, High Wycombe, UK*
Corresponding email: ramesh.ranabhat@ioe.edu.n

Abstract

Electric vehicles (EVs) are increasingly used due to their potential to reduce greenhouse gas (GHG) emissions from the transportation sector and subsequently improve air quality. Construction industry uses significant number of equipment and by changing the power source of construction equipment from fossil fuel to electric could significantly reduce air pollution and GHG emissions, as well as enhance sustainability during the construction process. Nepal has already embarked on using electric vehicles for public transportation such as 3-wheeled vehicles (locally known as *Safa Tempo*). Likewise, around 100 electric buses and electric cars have been implemented in Nepal, particularly in Kathmandu. EVs not only improve environmental indicators but also lower the reliance on oil imports. Using the literature review and published data, this paper explores infrastructural requirements and policy supports to facilitate the implementation of electric construction machines in Nepal. From an infrastructural point of view, it is crucial to establish more electric vehicle charging points and battery recycling plants in Nepal to cover the requirements of construction equipment. From a policy perspective, this paper highlights the need for a tax subsidy and other financial incentives to promote electric construction machines.

Keywords: Electric construction equipment, Heavy-duty battery recycling, Infrastructural planning, Scenario analysis, Subsidy mechanism

1. Introduction

The construction industry in developing countries like Nepal plays a major role in economic development since it constitutes a significant portion of the gross national product and employment. Electric construction machines have been more versatile, easy to operate, clean, quiet, and comfortable (Davis, 2021). A study by McKinsey & Company (Forsgren et al., 2019) has estimated that the total cost of ownership of several electric construction machines are already around 20 percent lower than that of internal combustion engine-based machines. Doyle (2018) highlighting a case of replacing Caterpillar's D6T with D6 XE electric dozer suggest that the investment costs will be recovered within 2 years with typical application of 1500 hours per year. This highlights that implementing electric construction machines is paramount to combat climate change, reduce green house gas emissions and achieve the goal of a clean energy transition. Nepal realises the urgency of electric vehicles and has developed a national action plan for electric mobility (MoFE, 2021). Battery-powered vehicles are necessary to reduce Nepal's carbon footprint, and cut petroleum imports (Rijal, 2021).

According to the National Oil Corporation Limited (NOCL, 2021), 488,675 KL and 1,588,869 KL of petrol and diesel were imported in the fiscal year 2020–2021, amounting to an increase of approximately 20% over the last year. These imports were mainly used for the transportation sector. The use of heavy equipment in the construction field has increased by 21%. After the Gorkha earthquake in 2015, the majority of the privately owned construction companies are believed to have used heavy equipment for dismantling of the houses and to carry out associated infrastructure works. Additionally, the local government used the Backhoe Loader and Excavator for the road construction. Based on informal communications with local officials, it is estimated that about 19-36 litres of are diesel burned for an hour operation of these equipment. Considering average of 28 litres burned for an hour of operation and 1 litre of diesel in Nepal emits about 3.12 kg of CO_2 (Paudel et al 2021), one construction equipment running on diesel with average 1500 hours per year of operation emits about 131 tonnes of CO_2.Changing to EV, 42000 litres of diesel use per year per equipment will be avoided. This scenario shows that the uptake of EVs would not only provide environmental benefits but could also reduce the trade deficit for Nepal through reduction in oil imports.

Electric vehicles are also promoted by the Nepal Government with tax exemption. However, it has been informally argued that there is still a hidden 20%-35.6% Value Added Tax (VAT) for the import of batteries and accessories of heavy equipment. Government of Nepal has developed plans and policies for electric transportation and has electric vehicle (locally known as *Safa Tempo*) based public transportation to a limited degree, however, it is yet to develop plans and policies to implement electric construction machines.

Given the above-described context, this paper attempts to tackle a broad research question of how electric construction equipment can be made sustainable and effectively deployed in Nepal. Subsequently, the objective of this paper is to develop a high-level policy and implementation strategy for electrification of heavy equipment in Nepal by analysing existing status of heavy equipment and electricity infrastructure. Research on this topic is very limited and therefore lack of data limits the analysis presented in this study. However, the prospect of enhancing sustainable development and energy security through the

implementation of electric heavy equipment in Nepal motivates this research. The main contribution of this study is that it consolidates and analyses the limited existing data on heavy equipment in Nepal in order to develop a high-level approach to systematically plan for the implementation of electric construction equipment.

2. Construction Equipment Status

In order to understand the scale of the contribution of electric construction equipment, the first step would be to establish the number and types of construction equipment currently used in Nepal. Heavy equipment is mainly used in road and bridge construction and other large infrastructure projects such as hydropower plants. The construction equipment is owned by the Government as well as private companies in Nepal.

2.1 Heavy Equipment Division's Ownership

Table 1: Details of heavy equipment and the hours used annually at the Heavy Equipment Division

S. N.	Equipment Type	Unit	Hrs used annually
1	Hot Mix Plant	3	1700
2	Compressor Air	2	300
3	Crane Mobile	1	2500
4	Dozer Track	3	4500
5	Distributor Bitumen	1	13
6	Dumper Mini	22	400
7	Excavator Track	10	350
8	Lifter Fork	1	200
9	Grader Motor	3	32
10	Loader Wheel	10	111
11	Backhoe, Loader	9	4000
12	Pile Driver	1	34
13	Roller Steel	4	32
14	Roller Pneumatic	1	350
15	Roller Pedestrian	4	320
16	Roller Vibrating Self Propelled	4	230
17	Truck Crane Mounted	2	NA
18	Truck Flatbed	1	NA
19	Truck Tripping	27	NA
20	Mini Truck	1	NA
21	Tractor Trailer (Low-bed)	1	NA
22	Tanker Water	1	NA
23	Tractors	2	NA
24	Hydraulic Hammer Drill	1	NA

Under the Nepal Government's Department of Roads (DoR) and Ministry of Physical Infrastructure and Transport, there are eight heavy equipment division established. They are located at Itahari, Janakpur, Hetauda, Kathmandu, Pokhara, Butwal, Surkhet-

Nepalganj, and Godawari. These divisions are responsible for the construction works and oversee the operation of fleet of heavy equipment owned by DOR. Additionally they are focused to clear emergency situations of road blockade due to landslides, erosions, and other disasters on the localities of their jurisdiction.

According to the Heavy Equipment Division in Kathmandu, they own 24 types of active equipment. The types of equipment and their numbers are listed in Table 1, and Table 2 shows the construction equipment registered in Bagmati province.If the diesel consumption by the construction equipment is compared with electric charging, high operational costs are saved. Figure 1 shows the plot of percentage savings in operational costs of electrical construction equipment versus diesel. The price per litre diesel has been assumed as NRs175 (NOC) – (1GBP = 162 NRs approximately) and approximate hourly fuel consumption per hour data was collected for each type of equipment. An electric vehicle charging cost is considered as 10 NRs per unit and the total cost of full charge for a typical construction equipment is assumed as 600 NRS. Information provided in new construction equipment reviews suggest that the full charge will last 4 to 6 hours; a conservative value of 4 hours of operations per charge is used in the calculation. This estimate is very crude and should be considered as indicative scenario only. As compared to diesel fuel, the operating costs savings in fuel for electric construction equipment are in the range of 76 to 96%, which is very significant. As the number of hours used are very high for Dozer Track and Backhoe Loader, just replacing these two categories of construction equipment to electric, significant cost savings and reduction in CO_2 emissions can be achieved.

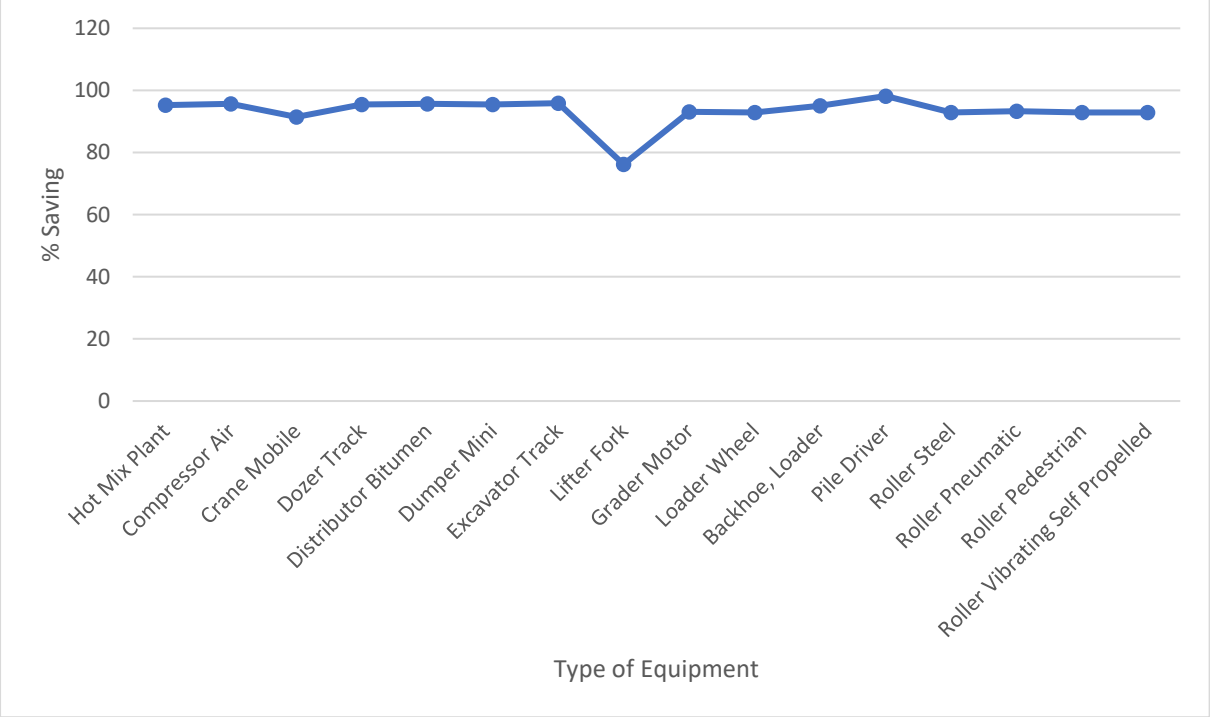

Figure 1: Operating cost saving for Electric Construction Equipment Vs Diesel Engine

Table 2: Heavy Equipment Registration in Bagmati Province, Nepal

S. N.	Fiscal Year	Crane & Dozer	Excavator	Loader, Grader &Roller	Total
1	Till 057/58	15	51	9	75
2	058/59	5	10	16	31
3	059/60	18	9	40	67
4	060/61	6	7	4	17
5	061/62	14	56	2	72
6	062/63	28	34	0	62
7	063/64	40	51	26	117
8	064/65	98	191	0	289
9	065/66	278	313	70	661
10	066/67	78	378	148	604
11	067/68	7	129	113	249
12	068/69	2	45	66	113
13	069/70	6	43	119	168
14	070/71	3	49	104	156
15	071/72	12	105	167	284
Total		610	1471	884	2965

2.2 Heavy Equipment Entrepreneur's Association of Nepal's Ownership

Heavy Equipment Entrepreneur's Association of Nepal (HEAN) is a professional body to regulate the heavy equipment market in Nepal. The aim of this association is to organise all entrepreneurs who are involved in heavy equipment business and act to coordinate between government and other stakeholder. This is the body responsible for making uniformity in the hire rate of heavy equipment. Beside the governmental entity, there are nearly 6,000 units of construction equipment owned by about 500 private hiring firms and contractors in Nepal (Bharti & Jha 2018).

3. Strategic Considerations for Electric Construction Equipment

This section discusses the approach to enable the rapid deployment of construction machines in Nepal. The approach presented below is based on infrastructural prerequisites. The key requirements include: sufficiency of electricity supply, access to charging points and their required numbers, incentives for construction organisations for investment in electric vehicles, battery replacement and recycling.

3.1 Sufficiency and Reliability of Electricity Supply

Nepal has no fossil fuel reserves, such as coal, natural gas, and petroleum products. The share of petroleum products could be reduced if the country increased its hydroelectricity production. About 92.8% of the population across Nepal now has access to electricity from the national grid (NEA annual report, 2021). The number of NEA's consumers has reached to 4.77 million. The Government of Nepal (GoN) has set a target to provide electricity access to the entire population by FY 2023/24. The total available energy in NEA's system increased to 7741 GWh in 2020 of that is delivered throughout the country through national grid

infrastructure. Data presented in the public reports show that the country has reached an installed capacity of 2,577 MW in 2023 with 2,493 MW connected to the national grid. With the power purchase agreements (PPA) agreed projects the total energy capacity of 6366 will be reached in near future and including the PPA applications in progress, the total projected capacity will be 18,106 MW (Table 3).

The GoN policy of "Quit LPG Gas and Use Electricity", maximum use of EVs, long-term irrigation electrification in the Terai and Hilly region and promotion of industries will increase the domestic electricity consumption per capita to 400 kWh. White paper by the Ministry of Energy Water Resource and Irrigation (MoEWRI, 2018) highlights that there will be increase in the per capita electricity consumption by up to 700 kWh in the next five years and 1500 kWh within ten years by changing the present energy consumption pattern and expanding the area of electricity consumption.

Table 3: Electricity supply capacity (NEA annual report 2021/2022)

S.N.	Status	Numbers	Capacity (MW)
1	Projects under operation	132	1,531.8
2	Projects under construction	141	3280.9
3	Projects under Different Stages	84	1553.4
PPA concluded projects			6,366.1
4	PPA Applications	269	11,739.8
	Total		**18105.9**

Table 3 shows the status of hydropower, indicating the large number of hydropower projects at different stages of construction. The data show that hydropower will be able to provide sufficient electricity for EV charging stations. The total electricity supply capacity as presented on Table 3 confirms that NEA will have the capacity to provide reliable and quality electricity supply to its consumers by improving its existing transmission and distribution infrastructure across the country. Distribution and Consumer - Services Directorate (DCSD) has started to automate existing 33/11 kV substations. All new 33/11 kV substations will be fully automated or unmanned.

Fifteen (15) Nos. of 33/11 kV substations will be upgraded with Substation Automation System (SAS), and sixty-six (66) numbers of other substations will be upgraded adopting the n-1 contingency criteria to enhance the reliability of the distribution system.

Acceptance Testing Laboratory will be established at Kharipati, Bhaktapur for testing the electrical equipment up to 33 kV voltage level. Some of the major projects for transmission distribution and substation expansion are as follows.

- Malekhu 132 kV Substation Expansion Project
- Koshi Corridor 220 kV Transmission Line
- Barhabise 400 kV DC Transmission Line of length 44 km
- Barhabise-Lapsiphedi 400 kV DC Transmission Line of length 46 km
- Lapsiphedi-Duwakot 132 kV DC Transmission Line of length 14 km and
- Barhabise GIS substation (220/132 kV, 160 MVA (3x53.33 MVA) & 132/11 kV 5 MVA)

Table 4: Province-wise Electrification Status (NEA,2019)

S.N.	Province	33/11 kV substation	
		Nos.	Capacity (MVA)
1	Koshi	32	419.95
2	Madesh	26	349.4
3	Bagmati	19	136.7
4	Gandaki	18	137.6
5	Lumbini	28	324.5
6	Karnali	6	23.5
7	Sudur Paschim	21	123.1
	Total	150	**1514.75**

By assuming power factor of 0.8 and transmission efficiency of 40%, this roughly translates to available capacity of about 485 kW. In recent years, NEA has been extensively increasing grid access to rural areas of the country to intensify electrification and improve Nepal's generation and transmission system scenario. According to NEA 2020 annual report, Nepal will have a surplus electricity supply from the hydropower plants.

3.2 Charging Ports and Stations

The Government of Nepal (GoN) is taking several initiatives to promote Electric Vehicles (EVs) and create a favourable environment for EV ecosystem. Nepal Electricity Authority (NEA) is anchoring EV ecosystem development through deployment of Public Charging Stations (PCS). Table 5 shows the location of 50 new charging stations planned in 2021/22. The public charging stations are about 80km apart. Including NEA and Private motor company, 107 Electric charging stations are available throughout the country.

Table 5: Location of details of planned Charging Stations for 2021/22 (NEA, 2021)

Kathmandu Valley (7)	7 Locations
Province 1 (5)	Damak Bhadrapur, Kankai, Biratnagar, Itahari
Province 2 (7)	Birgunj, Simara, Chandranigahapur, Dhalkebar Janakpurdham Bardibas Rajbiraj
Bagmati except Kathmandu (13)	Malekhu (2 stations), Sindhuli (2 stations), Hetaunda (2 stations), Bharatpur (2 stations), Muglin-Kurintar (4 stations), Banepa
Gandaki (6)	Nawalpur, Damauli, Shyanja, Pokhara (3 stations)
Lumbini (8)	Nepalgunj, Bhalubang, Dang, Rupandehi, Bardaghat-Sunawal (2 stations)
Karnali (1)	Surkhet
Sudur Paschim (3)	Mahendra Nagar, Dhangadhi, Dadeldhura
Total: 50	

Figure 2 shows the location of charging points as advertised by meromotor.com (an automobile marketplace that provides services of automobile buy/sell and lease). Out of 52 locations evaluated in this study, there are Type I: 25; Type II: 2 and Type III: 25 stations. Type I and II are AC chargers and Type III charger are DC fast chargers (20 and 50kW power output). For construction equipment charging, Type III would be more suitable. Electric construction equipment can work for 4 to 8 hours per full charge depending on heavy or medium to light working conditions.

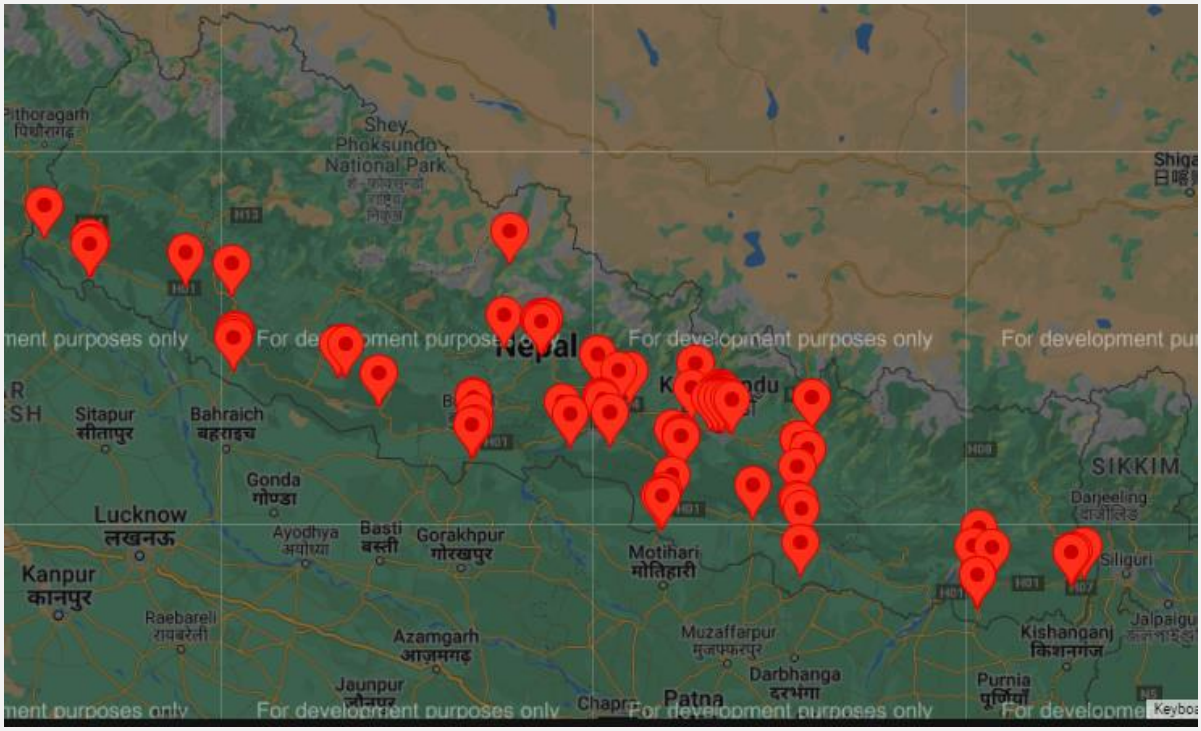

Figure 2: Location of Charging Stations in Nepal (Source: Meromotor, n.d.)

3.3 Battery Manufacturing and Recycling in Nepal

One of the enablers of construction equipment electrification is the capability to produce and recycle batteries required by the HGV. There are less than 10 battery manufacturers which include: Green Energy Nepal (Birgunj); Baba Battery Industries (P) Ltd; Power Tech Nepal (P.) Ltd. (Kapilvastu); Kulayan Battery Sanobharyang (Kathmandu); Asian Batteries Pvt. Ltd., (Nepalgunj); Shree Jagadamba Battery Udyogh Pvt. Ltd and Jagdamba Pvt Corporation Ltd. These local manufacturers are basically focusing on household scale PV systems. They do not have the required infrastructure and technical manpower for the generation and maintenance/ recycle of batteries used by the EVs. To fulfil this gap, Alternative Energy Promotion Centre (AEPC) commissioned a study and produced a report in 2018 in support with RERA/GIZA, however, its recommendations for the need of robust battery management plan has still not been implemented. For the promotion of Nepali products and capacity development of national manufacturers, government should provide proper guidance, support, and incentives. On the other hand, there is no single battery recycling plant that could be cited in this study. This highlights a significant concern that batteries are not recycled in Nepal, contributing to land pollution.

3.4 Local Capacity Building for Repair and Maintenance

With the increasing use of EVs for construction, training, and capacity building for maintenance of electric construction machines will be essential. As the maintenance for electric transport vehicles would require similar facilities, it is reasonable to consider there will not be any specific requirements for the construction equipment provided these service centres are located within a reasonable distance from the location of construction projects.

4. Policy Support

4.1 Tax Subsidy

Heavy equipment used in construction activities, such as excavator, dozer, loader, roller, leveller and crane may be allowed to be imported temporarily for a period not exceeding one year on the condition of taking back such vehicles and by collecting customs duty at a flat rate of Rs. one thousand five hundred per diem in lieu of customs duty, excise duty and VAT (Department of Customs, 2020).

Other considerations will be:

- Removal of import tax for electric construction machines, subsidized battery charging tariff
- Subsidy mechanism for different types of construction machines, training for capacity building,
- Tax holiday for companies

As stipulated in the Income Tax Act 2002, the applicable corporate tax rate for enterprises undertaking electricity generation is 20% and an income tax of 1.50%. The corporate tax is waived for first 10 years and then next five years only 10% will be included. For future years, full corporate tax of 20% is applied. 20-35.6% Value Added Tax for the import the batteries and accessories.

4.2 Clean Development Mechanism (CDM)

The CDM (United Nations Framework Convention on Climate Change, 2017) allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO2. These CERs can be traded and sold, and used by industrialised countries to a meet a part of their emission reduction targets under the Kyoto Protocol. The mechanism stimulates sustainable development and emission reductions, while giving industrialised countries some flexibility in how they meet their emission reduction limitation targets. The CDM is the main source of income for the UNFCCC Adaptation Fund, which was established to finance adaptation projects and programmes in developing country. Parties to the Kyoto Protocol that are particularly vulnerable to the adverse effects of climate change. The Adaptation Fund is financed by a 2% levy on CERs issued by the CDM.

Before fiscal year 2020/2021, electric vehicles had an excise duty of 10% and customs duty was completely waived. Due to provision of special rebates, the electric vehicle demand in the Nepali market has been rising since the ease of taxation by the government on the two wheelers and four wheelers in the electric segment. In fiscal year 2020/2021 the excise duty increased to 80% and customs duty from 10% to 40% based on the capacity of the vehicles results stagnant on the demand. Similarly, the Fiscal Year 2022/23. The government has fixed only 1% customs on public electric vehicles but 13% VAT and 5% tax are additional (Samriddhi Foundation 2022). Annual charge for the heavy construction equipment is NRs 20,000.

5. Scenario Analysis

The next step of this study is to conduct a scenario analysis to strategically plan for implementing electric construction equipment in Nepal. The first step is to estimate the total fossil fuel (primarily diesel) saving in a scenario where all existing traditional construction machineries are replaced with electric machineries. The second step is then to estimate the total electrical energy required per year to power all the electric machineries. Subsequently, battery demand needs to be estimated to identify the number of battery recycling plants required to meet the battery demand. Proportion of batteries that need to be imported also has to be estimated. The total number of charging stations required also must be evaluated.

Once the above steps are carried out, cost benefit analysis is required for strategic planning. Net Present Values and Discounted Payback Periods also need to be estimated for different scenarios. It is noteworthy here that major costs include purchase of new electric construction machineries, retrofitting of existing traditional machineries to convert them to electric machineries, and costs of establishing charging stations. Likewise, major benefits include cost saving of traditional fossil fuels and the Greenhouse Gases (GHG) emissions saving. Existing Clean Development Mechanism (CDM) of Nepal may be utilised to convert the GHG emissions saving into cost savings.

Eventually, scenario analysis needs to be carried out to identify the impacts of government subsidy in saving fuel costs and GHG emissions saving. This can be carried out by evaluating several scenarios of the subsidies, e.g., subsidy of 5%, 10%, 15% and 20% on cost savings. Such scenario analysis is important to make policy decision on the proportion of government subsidy based on benefits achieved.

6. Conclusions

The use of electric equipment is in its infancy in the construction industry and there is a lack of study about the scale of equipment used and the environmental benefits they could bring to Nepal. Our preliminary analysis shows that there is a great scope of cost reduction, GHG emissions saving and energy security by the deployment of electric construction equipment.

Tax subsidy, monetary carbon benefits via Clean Development Mechanism (CDM) and Government support for the establishment of prerequisite infrastructure such as charging points and battery recycling plants are major policy insights gained by this study. We recommend the Government of Nepal to consider these policy instruments to enhance environmental protection, reduce long term cost, improve sustainability and enhance energy security.

This study will be extended by collecting granular data and conducting scenario analysis based on the approach presented in this paper (Section 5).

References

Bharti, E. R., & Jha, T. (2018). Assessment of Hiring Business of Heavy Equipment in Nepal.

Davis, A. (2021). Electrification of construction equipment set to continue. *Highways Today*. [online] https://highways.today/2021/06/07/electrification-construction-equipment/.

Doyle, M. (2018). How Cat's electric drive D XE dozer delivers max torque, big payback, https://www.equipmentworld.com/equipment/article/14970340/caterpillars-d6-xe-electric-drive-dozer-explained (Accessed on 08/05/2023).

Department of Customs(2020). Customs Tariff. Government of Nepal.

https://customs.gov.np/storage/files/1/Custom%20Tariff/Customs%20Tariff%20%202077%20(2020-21)%20Eng.pdf.

Forsgren, M., Östgren, E., Tschiesner, A. (2019). Harnessing momentum for electrification in heavy machinery and equipment. *McKinsey & Co.* [online] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/harnessing-momentum-for-electrification-in-heavy-machinery-and-equipment.

Meromotor (n.d.). *Location of Charging Stations in Nepal*. https://meromotor.com/charging-stations-in-nepal

MoFE (2021). *Assessment of Electric Mobility Targets for Nepal's 2020 Nationally Determined Contributions (NDC)*. Ministry of Forests and Environment, Government of Nepal. [online] https://www.mofe.gov.np/downloadfile/E-mobility%20Assmnt%20NDC%202020_1623998131.pdf.

Nepal Oil Corporation Limited (NOCL, 2022). Import of Petroleum Products [in KL except LPG] for 2021-22. http://noc.org.np/import.

Paudel, P., Sapkota, S. Gyanwali, K and Adhikari, B. (2021). Comparison of vehicular fuel consumption and CO2 emission before and during the covid-19 pandemic in Kathmandu valley. *Journal of Innovations in Engineering Education*, JIEE 2021, 4(1), pp. 10-17.

Poudyal, R., Loskot, P., Nepal, R., Parajuli, R., Khadka, S. K. (2019). Mitigating the current energy crisis in Nepal with renewable energy sources. *Renewable and Sustainable Energy Reviews*, 116.

Rijal, D. (2021). The road to electric transportation in Nepal. *Nepali Times*. [online] https://www.nepalitimes.com/latest/the-road-to-electric-transportation-in-nepal/.

Samriddhi Foundation (2022). Tax Policies for Electric Vehicles in Nepal. https://samriddhi.org/blog/a-look-at-tax-policies-for-electric-vehicles-in-nepal.

United Nations Framework Convention on Climate Change (2017). Clean Development Mechanism: Tool5. https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-05-v3.0.pdf.

Review on Future of Biomass Energy: A Case of Nepal

Dr. Ramhari Poudyal[1] and Suraj Regmi[2]

[1] Board of Director, Safa Urja Nepal and Associate Professor Tribhuvan University, Kathmandu Engineering College, Nepal
[2] Deputy Manager, Nepal Electricity Authority
Corresponding Email: ramhari.podyal@safaurja.com

Abstract

According to the International Energy Agency (IEA), biomass energy is vital to the global energy mix, accounting for 15-65% of all primary energy demand. However, much of this energy is used inefficiently and with significant pollutant emissions, primarily by the over 2 billion people who cook using straight biomass combustion. In contrast, modern primary assessments of future universal energy supply predict that biomass energy will play a much more significant role by the end of the 21st century in achieving the Sustainable Development Goals (SDGs) under the Paris Agreement. Biomass energy must be modernised and converted into more convenient forms, such as biogas and bioelectricity, to ensure more substantial and sustainable use. The post-COVID-19 and Paris Agreement requirements to decarbonise society up to 2030 make modernising biomass energy even more critical. This article focuses on the future of biomass energy in developing countries, specifically Nepal, as a case study. Nepal is rich in biomass resources, and the government has implemented various policies and initiatives to promote the use of biomass energy, such as the National Rural Renewable Energy Program and the Biogas Support Program. Despite these instrumental efforts, the potential of biomass energy in Nepal remains largely untapped. The article will identify the gaps and barriers to tapping the vast Bio-mass Energy potential and proposes several recommendations to modernise biomass energy in Nepal, including developing sustainable biomass supply chains, promoting energy-efficient biomass technologies, and strengthening policy and regulatory frameworks. Biomass energy has significant potential for achieving global energy and climate goals. Modernising biomass energy in developing countries such as Nepal can play a vital role in achieving this potential. With the right policies, investments, and technological innovations, biomass energy can be an essential part of the clean energy transition in the 21st century.

Keywords: Biomass, Energy Security, Renewable Energy, Safer cooking

1. Introduction

This paper aims to showcase the issues and problems related to the future of biomass energy in Nepal and the methodology used to address them. The key findings of this research will be presented to provide valuable insights and inform policy decisions.

Nepal's energy mix in 2018 was dominated by traditional biomass, accounting for 68.51% of the total, followed by fossil fuels (25.71%), other renewables (2.13%), and grid electricity (3.65%) (Aryal and Dhakal, 2022). However, there has been a gradual shift towards using Liquid Petroleum Gas (LPG) stoves in rural areas, replacing biomass stoves (Sharma and Shrestha, 2023).

This study considers the global, regional, and national context to explore the future of biomass energy in Nepal. It examines the potential of biomass energy to meet the country's energy demands and contribute to its sustainable development. The research methodology involves analysing existing literature, exploring international practices in biomass energy generation, and evaluating the challenges and opportunities associated with renewable energy production.

Key findings from previous studies emphasise the need to increase biomass energy generation capacity, improve collection and transportation systems, and promote biomass energy use in rural areas with low electrification rates (Joshi et al., 2011; Gurung et al., 2013). Lessons learned from international practices, such as those in the UK and Europe, can also provide valuable insights for Nepal (Department for Business, Energy & Industrial Strategy, 2021).

The energy sector in Nepal faces various challenges, including low energy generation capacity, weak transmission and distribution systems, high energy import costs, and low electrification rates, particularly in rural areas (Poudyal et al., 2019b). Nepal's geopolitical position, sandwiched between India and China, further complicates its energy security situation (Lou, 2021). To reach SDG 7 (Poudyal, 2021) and decarbonise the worldwide energy system, sustainable energy sources such as biomass, green heating, and energy efficiency measures must be implemented. Decarbonisation and economic growth are not commonly exclusive. The most thriving societies of the future will also be the ones most sustainable.

The Energy Trilemma Index 2022, released by the World Energy Council, ranks countries based on their energy security, equity, and environmental sustainability. Nepal ranks 113th out of 125 countries in the index, indicating a poor performance in terms of energy security (World Energy Council, 2022). Only 6.9 % of the population of Nepal has access to renewable source of energy up to Mid May 2022 ((Ministry of Finance , 2022). Nepal also relies on India because the Run dominates the Nepalese Integrated Power system – off- River Types hydropower projects, generating only 30 % of its installed capacity in the dry season. According to Nepal Electricity Authority annual report of 2021/22 1543. 28 GWh of energy has imported from India (Nepal Electricity Authority , 2022). Similarly, Nepal imported 536028 MT of Liquid Petroleum Gas (LPG) in the 2021/2022 Year (Nepal Oil Corporation , 2023). These data reflect Nepal seems vulnerable in energy security. Due to the rapid expansion of road network in the rural areas the uses of LPG are rapidly increasing because of easy transportation. The Figure 3 shows of status of import of Liquid Petroleum Gas (LPG) in the last five years. The petroleum products first goods which is increasing trade deficits of Nepal every year.

Considering the significance of biomass energy in addressing Nepal's energy security and sustainability, this study aims to provide up-to-date information and data to inform future policies and initiatives. By exploring the potential of biomass energy and its implications, this research seeks to contribute to the country's energy sector and support its economic growth and development.

The motivation behind this research stems from the global energy crisis and the need for renewable energy sources to mitigate it. The Paris Agreement and Sustainable Development Goals call for urgent action to reduce greenhouse gas emissions and promote sustainable energy production, providing additional impetus for investigating biomass energy (Energy Agency, 2021).

Nepal's abundant biomass energy potential presents an opportunity for sustainable development, reduced reliance on fossil fuels, and improved energy access. Studying biomass energy in Nepal can provide valuable insights into challenges and opportunities associated with renewable energy production, which can inform policy decisions and promote sustainable energy practices globally.

Despite some limitations, such as competition for feedstock between energy and food production, and potential air pollution from traditional biomass combustion, biomass energy remains a promising option due to its renewability, local sourcing benefits, and reduced greenhouse gas emissions. Advanced biomass energy technologies and sustainable feedstock sourcing practices are crucial for maximising the potential of biomass energy.

In summary, this article focuses on the future of biomass energy in Nepal, addressing the country's energy challenges and exploring biomass resources' opportunities. The methodology involves literature analysis, an international practices review, and an examination of the challenges and prospects associated with renewable energy production. The findings aim to inform policy decisions, provide recommendations, and guide future work in Nepal's energy sector.

In this part, the first literature reviews are illustrated. 2nd, methodology has been discussed, in 3rd, key results from data and literature are presented. Lastly, the Conclusion, Recommendations, Policy insight and future work have been presented.

2. Literature Review

In Nepal, a significant proportion of the country's energy demand is met by fuelwood (78%) and agricultural residues and animal dung (12%) (Poudyal et al., 2019b). However, the traditional use of biomass for cooking contributes to indoor air pollution, leading to numerous deaths globally. According to the World Health Organization (WHO), over 4 million people die annually from illnesses caused by household air pollution from solid fuels such as wood, crops, and animal dung (Poudyal et al., 2019b). Studies have also found alarming levels of carcinogen benzo(a)pyrene, equivalent to smoking 20 packs of cigarettes per day, in some women in India during cooking activities (Larson, 1993).

Sustainable development challenges encompass various dimensions, including social, technological, economic, and environmental. These challenges were addressed under the United Nations' "The 2030 Agenda for Sustainable Development," which includes seventeen specific goals agreed upon under "the Paris Agreement" in 2015 (United Nations, 2015).

The first American biomass gasification plant, the Joseph C. McNeil Generating Station, was established in Burlington, Vermont 1998. This plant utilises low-quality trees and harvest residue to generate approximately 50 megawatts of electricity, meeting the energy needs of Burlington, Vermont's largest city (Vermont Energy Investment Corporation, 2000).

Kibria et al. (2016) comprehensively review renewable energy technologies in developing countries, including their implementation's benefits, challenges, and policy implications. Rupf et al. (2015) thoroughly analysed the barriers and opportunities for biogas dissemination in Sub-Saharan Africa using case studies.

3. Methodology

This part provides an understanding of the research methodology adopted during the study in the Review on the Future of biomass energy: a case study of Nepal. This research is based on the secondary data available from the relevant literature. Secondary sources include government websites, magazines, newspapers and related associations, white papers, and policy databases, including the World Bank, ADB, National Planning Commission, Ministry of Energy, Ministry of Finance, Nepal Oil Corporation, IEA, IRENA, and Bloomberg. The entire methodology of the research is illustrated in Figure 1.

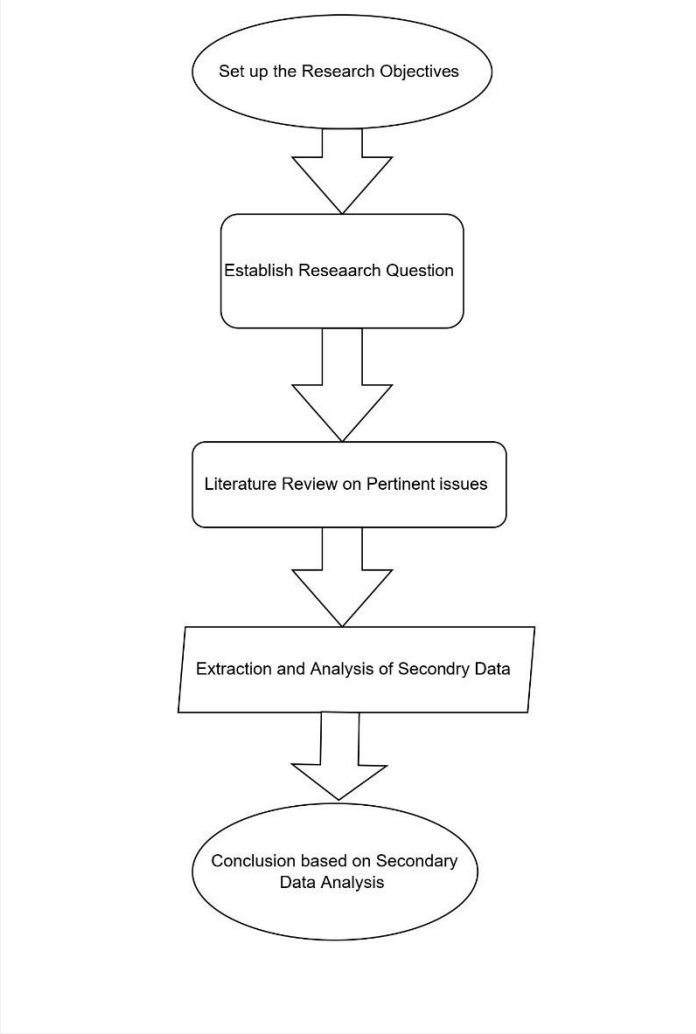

Figure 1: Flow diagram of research

4. Result and Discussions

Nepal's energy consumption pattern heavily depends on traditional energy sources, particularly biomass, which includes wood, agricultural waste, and animal dung. These traditional sources account for around 78% of Nepal's total energy consumption.

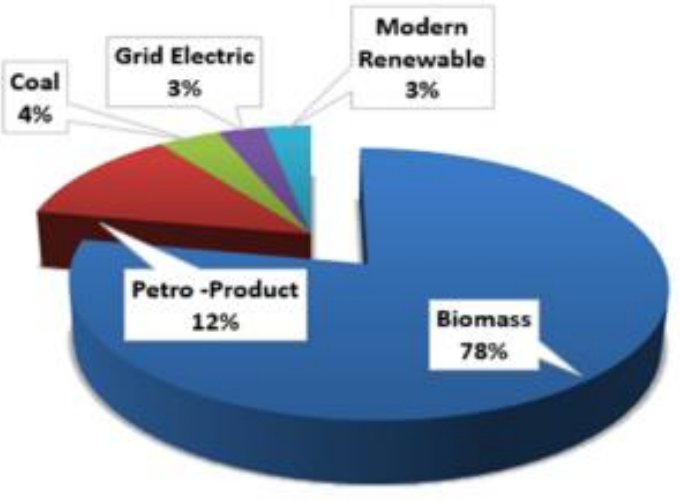

Figure 2: Energy Scenario of Nepal

Hydropower is Nepal's largest source of clean energy. Nepal has significant hydropower potential, with an estimated capacity of around 83,000 MW. However, the actual installed capacity is much lower, with only around 2300 MW of installed capacity.

Nepal also imports significant petroleum products, including diesel, gasoline, and kerosene, primarily used for transportation and cooking. Petroleum products account for around 12% of Nepal's total energy consumption.In recent years, Nepal has been making efforts to boost its use of renewable energy sources, particularly solar and wind power. However, these sources account for only a tiny percentage of Nepal's total energy consumption.

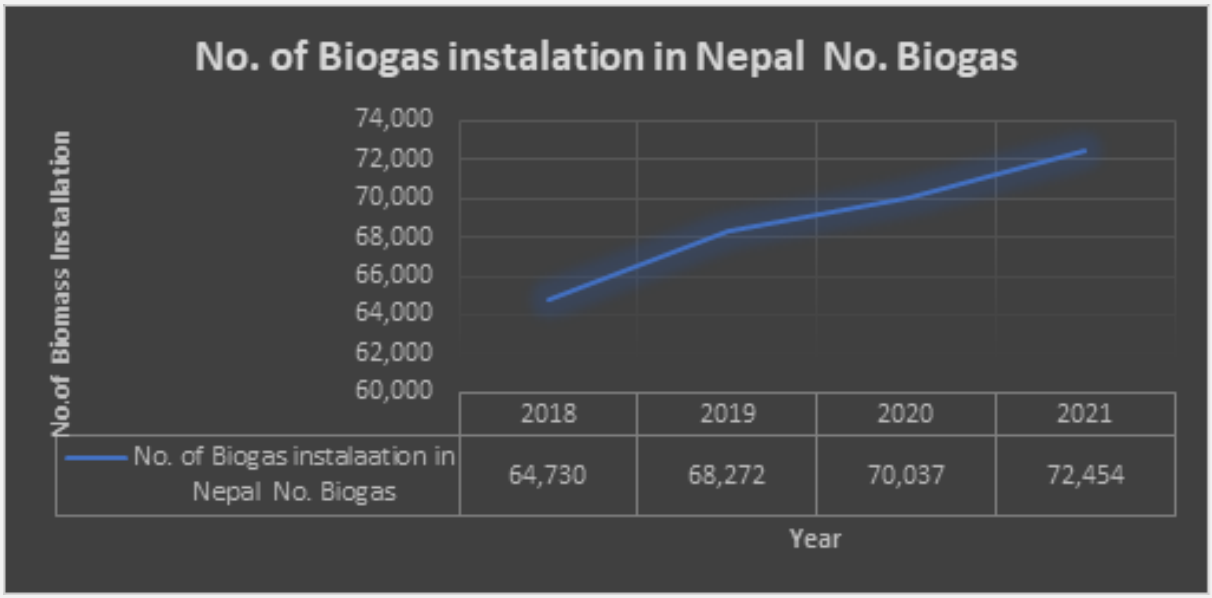

Figure 3: No. of Bio-mass development in Nepal from 2018 to 2021(Source: Alternative Energy Promotion Center,2021)

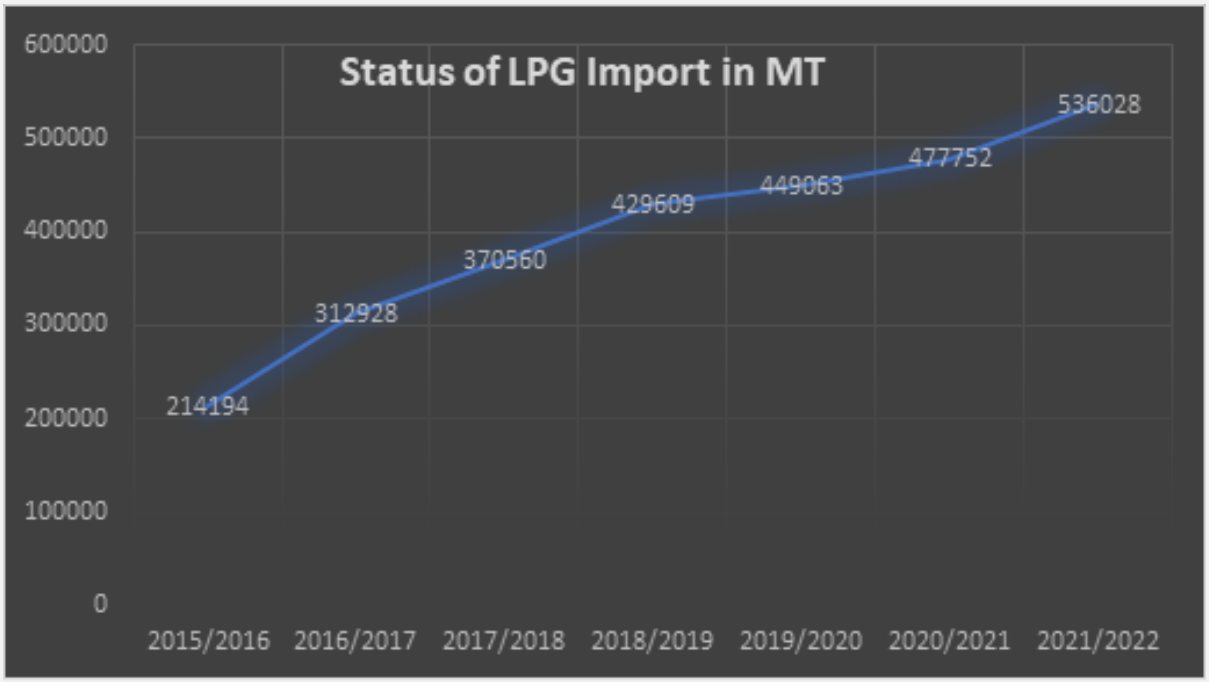

Figure 4: Status of LPG import in Metric Ton from 2015 to 2022(Source: Nepal Oil Corporation, 2023)

Figure 4 shows the data of LPG imports by Nepal in the last five years, which seems to be increasing. It also shows that the import of LPG doubled in the four years. It is the number one commodity increasing the trade deficit and the increasing trend.

The Government of Nepal has introduced the Biomass strategy to replace fossil fuels with the promotion of Biomass Energy (Alternative Energy Promotion Center , 2017) ;however, this strategy was not materialised as per the plan.

The key results from the data and literature indicate that Nepal faces significant challenges in meeting its energy demands, which profoundly impacts its economic performance and development. The electricity imported from India is mainly generated by burning dirty coal, contributing to the country's environmental challenges. Despite the challenges, significant opportunities exist to invest in renewable energy technologies that can change Nepal's energy and economic situation while promoting sustainability. The right mix of renewable energy sources is needed to suit the needs of people in both urban and rural areas, and investments in small and abundant renewable energy projects can promote economic activity and improve lifestyles in remote areas. The article discusses the potential of biomass energy as a sustainable and renewable energy source to meet global energy demand. Figure 3 represents the share of the world’s total energy supply by sources in 1973, and Figure 4 illustrates the share of the world’s total energy supply by sources in 2019. It presents Nepal as a case study and highlights the importance of promoting biomass energy in rural areas with low electrification rates. Table 1 enumerates the Total Biomass consumption of Nepal. Figure 2&3 Energy sector of Nepal & No. of Biomass development in Nepal. The article also identifies the need to improve the collection and transportation of biomass feedstocks and increase biomass energy generation capacity.

Table 1: Total Biomass consumption of Nepal (Source: CBS, 2021)

Particulars		
Total Population of Nepal	29,164,578 .00	
Total Household of Nepal	6666937	
No. of HH using Kerosene Stove	7.5 % of Total HH	500020
No. of Household	13.2 % of Total HH	880035
HH using wood stove alone	Biomass consumption 2.62 tons/year /HH	1310053 tons/ Year
HH using Gas Stove	Biomass consumption 1.50 tons/year /HH	1320053 tons/Year
Total Bio-Mass consumption of Nepal		2630106 tons/year

Table 2: Energy potential from Agricultural residues (Source: Agriculture Census, 2021)

Animal	Population(Thousand)	SpecificVolatile Production (KGVS/head/d)	Specific Biogas Yieldm^3/Kg/VS	Theoretical Biogas production		Recoverable potential of biogas		Viable potential of biogas for energy	
				10^6 / Yr	PJ/yr	10^6 / Yr	PJ/yr	10^6/Yr	PJ/yr
Cattle	25262	2.67	0.31	6838	152	3419	126	2393	88
Buffalo	11264	2.01	0.475	205.4	44.0	1027	22	718	15
Pig	1256	0.59	0.49	91.6	2.01	45	1	22	0
Sheep	3818	0.3	0.49	75	4.16	37	2	0	0
Goat	5,413	0.33	0.49	395	8.29	347	4	0	0
Chicken	50,430	0.33	0.49	165	2.08	132	2	14	14
Duck	1256	0.02	0.281	1.1	1.1	0	0	0	0
Total									104

Table 3: Biogas potential from animal waste in Nepal as per Agricultural Census, 2021

Animal	Population (Thousand)	Specific Volatile Production (KG VS/head/d)	Specific Biogas Yieldm^3/Kg/VS	Theoretical Biogas production		Recoverable potential of biogas		Viable potential of biogas for energy	
				10^6 /Yr	PJ/yr	10^6 /Yr	PJ/yr	10^6 /Yr	PJ/yr
Cattle	25262	2.67	0.31	6838	152	3419	126	2393	88
Buffalo	11264	2.01	0.475	2054	44.0	1027	22	718	15
Pig	1256	0.59	0.49	91.6	2.01	45	1	22	0
Sheep	3818	0.3	0.49	75	4.16	37	2	0	0
Goat	5,413	0.33	0.49	395	8.29	347	4	0	0
Chicken	50,430	0.33	0.49	165	2.08	132	2	1.4	1.4
Duck	1,256	0.02	0.281	1.1	1.1	0	0	0	0
Total									104.5

5. Conclusion, Recommendations, Policy Insight and Future Work

The article highlights the potential of biomass energy in Nepal as a renewable energy source and emphasises the need to replace fossil fuels, particularly petroleum, with biomass in the mobility sector. However, the paper does not comprehensively explain the specific methods and strategies to achieve this transition. Therefore, the conclusion and recommendations section should address this gap by guiding how biomass can effectively replace fossil fuels in Nepal.

From the data shown in Table 2 and Table 3, which is extracted from of latest Agriculture Census,2021, Nepal has the potential of 223.317 PJ from the agricultural residues and104.5 PJ energy from biogas from animal waste, which can replace the Liquid PetroleumGases (LPG) which helps to reduce our trade deficit with India can save millions of dollars. So, biomass can be the cheapest locally availableenergy source for Nepal.

Biomass Energy Potential: The study acknowledges Nepal's significant biomass energy potential and its role in ensuring energy security, particularly for landlocked countries.

Environmental Considerations: While biomass energy offers advantages over conventional fossil fuels, it is crucial to consider the environmental and resource implications associated with biomass production and utilisation.

Technological Transformation: The article highlights the need for sound technology and infrastructure to facilitate the large-scale adoption of biomass energy in Nepal.

Cost Competitiveness: Establishing cost competitiveness is a challenge in biomass energy implementation. Further research and policy efforts should focus ondecision support to guide biomass energy development in Nepal and other developing countries.

Advantages and Challenges:

Biomass energy offers several advantages, including its renewability, local availability, and potential for rural electrification. However, its effective utilisation requires overcoming technology, resource management, and economic viability challenges. Developing sound technologies and cost-competitive solutions is crucial to scale up biomass energy production in Nepal.

Replacing Fossil Fuels with Biomass Energy:

To achieve a sustainable energy future, exploring the possibilities of replacing fossil fuels, particularly petroleum, with biomass energy in Nepal is essential. While the paper initially lacked a clear explanation, a proposed methodology can guide the transition process. A comprehensive energy mix assessment and modelling exercise can help determine the required energy mix for the next 10-20 years, with biomass playing a significant role in minimising the carbon footprint and achieving net-zero or carbon-negative status.

Carbon Absorption Capacity and Utilisation:

Assessing Nepal's total carbon absorption capacity and current extraction levels is crucial. Understanding these factors enables a better estimation of how biomass energy can contribute to carbon sequestration and help offset the carbon emissions associated with other fuel sources. Nepal can contribute significantly to global climate change mitigation

efforts by utilising biomass as a renewable and carbon-neutral energy source. For this, we need more thorough studies in the future.

References

Aryal, S. and Dhakal, S. (2022) 'Medium-term assessment of cross border trading potential of Nepal's renewable energy using TIMES energy system optimisation platform', Energy Policy, 168, p. 113098. Available at: https://doi.org/10.1016/j.enpol.2022.113098.F

Asia Biomass Energy Cooperation Promotion Office (2020) Biomass Stoves are Becoming Popular in Nepal / Asia Biomass Energy Cooperation Promotion Office - Asia Biomass Office, Asia Biomass Energy Cooperation Promotion Office. Available at: https://www.asiabiomass.jp/english/topics/0912_06.html (Accessed: 10 January 2020).

Basu, P. (2013) 'Biomass Cofiring and Torrefaction', in Biomass Gasification, Pyrolysis and Torrefaction. Available at: https://doi.org/10.1016/b978-0-12-396488-5.00010-1.

Bhujel, K.B. (2014) 'Market situation of Bio-Briquette in Kathmandu, Nepal', The Initiation [Preprint]. Available at: https://doi.org/10.3126/init.v5i0.10254.

Department for Business, E.& I.S. (2021) The Domestic Renewable Heat Incentive – ensuring a stable scheme: government response to consultation. London.

Department for Business, Energy & Industrial Strategy, U. (2021) Biomass Policy Statement, Department for Business, Energy & Industrial Strategy, UK. London.

Energy Agency, I. (2021) Renewables 2021 - Analysis and forecast to 2026.

Galik, C.S. et al. (2021) 'Opportunities and barriers to forest biomass energy: A case study of four U.S. states', Biomass and Bioenergy, 148, p. 106035. Available at: https://doi.org/10.1016/J.BIOMBIOE.2021.106035.

GoN Economic Survey of Nepal (2015) 'Government of Nepal', (April).

Gurung, A. et al. (2013) 'Roles of renewable energy technologies in improving the rural energy situation in Nepal: Gaps and opportunities', Energy Policy [Preprint]. Available at: https://doi.org/10.1016/j.enpol.2013.06.097.

Gurung, A. and Oh, S.E. (2013) 'Conversion of traditional biomass into modern bioenergy systems: A review in context to improve the energy situation in Nepal', Renewable Energy, pp. 206–213. Available at: https://doi.org/10.1016/j.renene.2012.06.021.

Herington, M.J. and Malakar, Y. (2016) 'Who is energy poor? Revisiting energy (in)security in the case of Nepal', Energy Research and Social Science, 21, pp. 49–53. Available at: https://doi.org/10.1016/j.erss.2016.06.025.

Joshi, B. et al. (2011) 'Lignocellulosic ethanol production: Current practices and recent developments', Biotechnology and Molecular Biology Review [Preprint].

Khatiwada, D. et al. (2012) 'Power generation from sugarcane biomass - A complementary option to hydroelectricity in Nepal and Brazil', Energy [Preprint]. Available at: https://doi.org/10.1016/j.energy.2012.03.015.

Larson, E.D. (1993) Modernising biomass energy.

Lou (2021) Nepal's strategic role in India and China's energy tussle. Available at: https://lightson.substack.com/p/nepals-strategic-role-in-india-and (Accessed: 27 March 2023).

National Population and Housing Census 2011 (National Report) Central Bureau of Statistics (2011) 'National Population and Housing Census 2011 (National Report) Central Bureau of Statistics'.

Nepal, M., Nepal, A. and Grimsrud, K. (2011) 'Unbelievable but improved cookstoves are not helpful in reducing firewood demand in Nepal', Environment and Development Economics, 16(01), pp. 1–23. Available at: https://doi.org/10.1017/S1355770X10000409.

Poudyal, R. et al. (2019a) 'Mitigating the current energy crisis in Nepal with renewable energy sources', Renewable and Sustainable Energy Reviews, 116, p. 109388. Available at: https://doi.org/10.1016/j.rser.2019.109388.

Poudyal, R. et al. (2019b) 'Mitigating the current energy crisis in Nepal with renewable energy sources', Renewable and Sustainable Energy Reviews. Elsevier Ltd. Available at: https://doi.org/10.1016/j.rser.2019.109388.

Poudyal, R. (2020) British Library EThOS: Renewable energy and other strategies for mitigating the energy crisis in Nepal. Swansea University. Available at: https://doi.org/http://isni.org/isni/0000000506663240.

Poudyal, R. (2021) 'COVID-19 impacts on energy systems in Nepal:Implications for SDGs', in M.N.B.– Coordinator et al. (eds) Engineering Challenges and Opportunities: Post COVID-19. London: Society of Nepalese Engineers in UK, p. 96.

Rupf, G. V. et al. (2015) 'Barriers and opportunities of biogas dissemination in Sub-Saharan Africa and lessons learned from Rwanda, Tanzania, China, India, and Nepal', Renewable and Sustainable Energy Reviews, 52, pp. 468–476. Available at: https://doi.org/10.1016/j.rser.2015.07.107.

Sapkota, A. et al. (2014) 'Role of renewable energy technologies in rural communities' adaptation to climate change in Nepal', Renewable Energy, 68, pp. 793–800. Available at: https://doi.org/10.1016/j.renene.2014.03.003.

Sharma, B. and Shrestha, A. (2023) 'Petroleum dependence in developing countries with an emphasis on Nepal and potential keys', Energy Strategy Reviews, 45, p. 101053. Available at: https://doi.org/10.1016/j.esr.2023.101053.

Shen, D.K. et al. (2009) 'Analysis of Wood Structural Changes under Thermal Radiation', Energy and Fuels, 23(2), pp. 1081–1088. Available at: https://doi.org/10.1021/ef800873k.

United Nations (2015) TRANSFORMING OUR WORLD: THE 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT UNITED NATIONS UNITED NATIONS TRANSFORMING OUR WORLD: THE 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT.

Villarroel-Schneider, J. et al. (2022) 'Energy self-sufficiency and greenhouse gas emission reductions in Latin American dairy farms through the massive implementation of biogas-based solutions', Energy Conversion and Management, 261, p. 115670. Available at: https://doi.org/10.1016/J.ENCONMAN.2022.115670.

World Energy Council (2022) World Energy Trilemma Index 2022, World Energy Council.

Yadoo, A. and Cruickshank, H. (2012) 'The role for low carbon electrification technologies in poverty reduction and climate change strategies: A focus on renewable energy mini grids with case studies in Nepal, Peru and Kenya', Energy Policy [Preprint]. Available at: https://doi.org/10.1016/j.enpol.2011.12.029.

SONEUK 5th Executive Committee and Advisors

Mr Rudra Koirala, Chairperson

Mr Hari Nepal, Vice-Chairperson

Dr Ravi Chandra Koirala, General Secretary

Mr. Sagyan Kharel, Secretary

Ms. Priyanka Regmi, Treasurer

Mr. Manoj Pun, Member

Mr. Darpan Gautam, Member

Mr. Sujan Sharma

Mr. Tulsi Phuyal

Ms. Nitisha Shrestha

Ms. Kusma Thapa

Advisors

Mr. Sanyukta Shrestha

Mr. Krishna Kishor Shrestha

Mr. Ghanashyam Paudyal

Mr. Shailendra K Shrestha

Prof. Keshav Dahal

Prof. Hom Dhakal

Dr. Birendra Shrestha

Ass. Prof. Ramesh Marasini

Dr. Bidur Ghimire

Mr. Laxman Ghimire

Mr. Rajkumar Tripathi

Mr. Umesh Parajuli

General Members

Aashish Pradhan
Aayush Bashyal
Ajit Bastola
Akshaya Chapagain
Alina Shrestha
Alka Bajracharya Vaidya
Amit Bastakoti
Amit Bura
Amit Ghimire
Amoda Nand Jha
Ananta Devkota
Anil Narayan Shrestha
Anima Dhakal
Animesh Upreti
Anjana Shrestha
Anjan Dev Dhakal
Anjani Phuyal
Arjun Pradhan
Arun Kumar Yadav
Asha Burathoki
Ashish Poudel
Ashok Kumar Chapagain
Ashok Rai
Asim Chalise
Ayushma Tuladhar
Bandana Pradhan Shrestha
Bed Bhattarai
Bhabendra Muktan
Bhesh Raj Kafle
Bhupesh Mishra
Bhuwan Bhatta
Bibek Koirala
Bibek Thakali
Bibek Tiwari
Bidur Chapagain
Bidur Ghimire
Bidur Rajbhandari
Bigendra Bhari
Bijan Shrestha
Bijaya Bajracharya
Bikash Rana
Bikesh Vaidya
Bimal Bhurtel
Bimal Ranjit
Binay Limbu
Binaya Rajbhandari
Binesh Khadka
Binod L Amatya
Bipin Gyawali
Bipul Dhakal
Birendra Shrestha
Bishal Rana
Bishal Thapa
Bishnu Neupane
Bishnu Sharma Nepal
Bodh Raj Pandey
Boz Raj Baral
Brahmananda Sapkota
Chandra Gurung
Chandra Prajapati
Chandra Shrestha
Chandra Shrestha
Chet Bahadur Thapa
Chintan Poudel
Dandi Raj Adhikari
Darpan Gautam

Debendra Dahal
Deepak GC
Deepak K Kaphle
Deepak Pandey
Deepesh Shrestha
Dilesh Lamsal
Dinesh Tuladhar
Dipendra Awasthi
Dipendra Pathak
Dipendra Shrestha
Dipu Bhurtyal
Dipu Manandhar
Divit Kandel
Dizen Madhikarmi
Dol Raj Gurung
Durga Khanal
Durlav Khanal
Ekta Sapkota
Gambheer Shankar Lal Shrestha
Ganesh Thapa
Geeta Lamsal
Ghanashyam Paudyal
Ghanendra Gurung
Gopal Neupane
Gopal Pandey
Govinda Ghimire
Gyanendra Acharya
Hari Hamal
Hari Krishna Neupane
Hari Krishna Poudel
Hari Nepal
Hari Rimal
Harit Pokheral
Hom Dhakal
Iirish Marahatta
Ishwor Shrestha
Jaya Acharya Nepal
Jeevan Pokhrel
Jiban Bajracharya
Jitendra Shakya
Kailash Bhusal
Kamal Somai Magar
Kanhaiya Bhagat Koiri
Keshav Bhattarai
Keshav Dahal
Keshav Pokharel
Khem Basel
Khem Paudel
Khim Thapa
Kishor Thapa
Krishma Tamrakar
Krishna Chakhun
Krishna Kishor Shrestha
Krishna Neaupane
Kul Prasad Marahatta
Kushmita Kunwar
Kusma Thapa
Kusum Sharma Parajuli
Laxman Ghimire
Lekh Nath Kharel
Lenish Poudel
Lukash Manandhar
Madhusudan Kayastha
Mahesh Dhakal
Mahesh Sinkemana
Mani Ram Bhandari
Manish Shrestha
Manisha Raut
Manoj Pun
Manoj Shrestha
Meen Gurung
Megha Paudyal

Mohammad Ansari
Monica Ghimire
Naba Raj Adhikari
Narad Bhandari
Narendra Pradhan
Narendra Shrestha
Naresh Dev Panta
Naresh Thapa
Nhyoumila Tuladhar
Nibedita Gautam
Nikesh Neupane
Nikita Kharel
Nilesh Dangol
Nilesh Mandal
Nir Maharjan
Nirmal Baral
Nirvan Shrestha
Nischal Ranabhat
Nischal Tamrakar
Nitisha Shrestha
Nodan Ghale
Ojesh Singh
Om Krishna Shrestha
Om Kumari Thapa
Padma Amatya
Pooja Bhagat
Pooja Gurung
Poonam Pathak
Prabin Limbu
Prachanda Karmacharya
Pragati Giri
Prajakti Gautam
Prakash Bhujel
Pramila Pokharel Nepal
Pramod Dhakal
Pramod Gurung
Pranita Shrestha
Pravin Kumar Ghimire
Preja Poudyal (Khanal)
Prem Lamsal
Priyanka Regmi
Pukar Siwakoti
Punya Prasad Regmi
Purna Gurung
R C Adhikari
Rabin Giri
Rabin Khadka
Rabindra Thapa
Rachana Shrestha
Raj Ghale
Raj Kapur Shah
Raj Pathak
Rajan Lamichhane
Rajendra Kharel
Rajesh Pathak
Rajiv Rajbhandari
Rajkumar Tripathi
Rakesh Sah
Ram Babu Thapa
Ram Chandra Pandey
Ram Hari Poudyal
Ram Krishna Adhikari
Ram Krishna Sitaula
Ram Kumar Shrestha
Ram Raj Sharma
Ramananda Puri
Ramesh Marasini
Ramesh Rijal
Ramji Pahari
Ramraja Rawal
Ranjita Khanal
Rashmi Rana

Ravi Chandra Koirala
rishi Ram Parajuli
Rishi Ram Parajuli
Rosha Marahatta
Roshan Bhattarai
Roshan Pokhrel
Roshan Thing
Ruby Shrestha
Rudra Koirala
Rudra Poudel
Sabin Bhattarai
Sabin Maskey
Sachida Chaturbedi
Sagyan Kharel
Sahiba KC
Samana Shrestha
Samen Maharjan
Samir Karmacharya
Sandeep Gurung
Sandeep Upadhyaya
Sangita Pokhrel
Sangita Sunuwar
Sangyog Neupane
Sania KC
Sanjita Adhikari
Santosh Mandal
Santosh Pandey
Santosh Sapkota
Santosh Wasti
Sanyog Rajbhandari
Sanyukta Shrestha
Saral Tripathi
Saroj Koirala
Saru Prajapati
Saurav Tiwari
Shailendra Kajee Shrestha
Shankar Chaudhari
Shankar chhetri
Shankar Dhakal
Shankar Ghimire
Shant Shrestha
Sharada Prasad Kalakheti
Shiva Sedai
Shovana Tuladhar Sthapit
Shyam Kumar Thapa Chhetri
Shyam Thapa
Sohan Ghimire
Subash Parajuli
Subhash Shrestha
Subin Chitrakar
Subodh Timilsina
Sudeep Dumre
Sudhir Dhakal
Sudib KC
Suhani Singh
Sujan Kansakar
Sujan Rajbhandari
Sujan Sharma
Sujan Shilpkar
Sujan Shrestha
Sujan Sikrikar
Sujeet Sharma
Suman Baidya
Suman Kumar Kunwar
Suman Lama
Suman Rizal
Sumit Shrestha
Sunil Rizal
Sunil Shrestha
Suraj Prasai
Suraj Rai
Suraj Thapa

Suresh Jamarkattel
Surya Kandel
Suryanath Ghimire
Sushant Kharel
Sushant Pant
Sushant Satyal
Sushil Khatiwada
Sushil Pradhan
Suyesh Bhattarai
Suyog Katuwal
Sweesa Shrestha
Tara Prasad Lamsal
Tekendra Limbu
Tika Ram Ale
Tri Tuladhar
Tribeni Pradhan
Trisha Pradhan
Tulsi Phuyal
Uday Shiwakoti
Udip Rai
Umesh Deusali
Umesh Parajuli
Urmi Sengupta
Utkarsha Ghimire
Vijay Gurung
Yogendra Muni Bajracharya
Yogendra Shiwakoti
Yogesh Acharya
Yuba Raj Neupane
Yukta Shrestha
Yukti Gurung

SONEUK

Would like to thank all the sponsors for their contributions to make this conference possible.

Congratulations to SONEUK

I am truly delighted to see the growth of the SONEUK & now it is organising its 8th conference on "Engineering for Environment" in collaboration with NEA, Nepal. Its commendable job & the team SONEUK led by Er Rudra Koirala deserves all the appreciation. On this occasion, I would like to convey my best wishes to all the participants and guests & congratulate the conference team.

Subodh Timilsina

Director, PMPS Consulting LTD

Boundary House, Cricket Field Road, Uxbridge, UB8 1QG

Tel - +44 ( )01895 450 647 Mob - +44 (0)7863 124 180

Email - subodh@pmpsuk.com Web – www.pmpsuk.com

It is an honour to support SONEUK's initiative towards an innovative and flourishing Nepal.

As a member, I would like to convey my best wishes for their future endeavors.

Ghanashyam Paudyal

BE (Civil) MSc (Eng) CEng MICE, MIEAust CPEng

It provides me an immense satisfaction to be able to support the SONEUK Conference since last couple of years.

Congratulations and Best Wishes to entire team members for future endeavors.

Rudra Koirala

It provides me an immense satisfaction to be able to support the SONEUK Conference.

Congratulations and Best Wishes to entire team members for future endeavors.

Shailendra Kajee Shrestha

Congratulations to SONEUK for another big achievement.

My best wishes for all future endeavours.

Dr Binod Lal Amatya

Best Wishes for 8th SONEUK Conference.

Birendra Shrestha

Thank you SONEUK for the opportunity to convene the team for the 8th SONEUK Conference.

Best Wishes to SONEUK and entire team members for future endeavors.

Mr. Hari Nepal

It provides me an immense satisfaction to be able to support the SONEUK Conference.

Congratulations and Best Wishes to entire team members for future endeavors.

Khim Thapa

Congratulations and best wishes to SONEUK and its entire team for all future endeavours

Dr Bidur Sharma Chapagain
Structural Engineering

Congratulations to SONEUK for another big achievement.

My best wishes for all future endeavours.

Dr Ravi Chandra Koirala

Best Wishes to all SONEUK Members.

978-1-9196046-2-6

www.soneuk.org / info@soneuk.org