9th SONEUK CONFERENCE PROCEEDINGS

Innovation in Engineering and Technology

Society of Nepalese Engineers in UK

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Editorial

Innovation in Engineering and Technology drives progress and shapes the future across multiple disciplines, impacting various aspects of our lives. The importance of continuous innovation cannot be overstated as it not only fosters technological advancements but also addresses pressing global challenges. With this in mind, the Society of Nepalese Engineers in UK, SONEUK proudly presents its 9th conference, themed "Innovation in Engineering and Technology," held on 22nd June 2024 in London.

The proceedings of this conference comprise six peer-reviewed papers, each contributing valuable insights into different areas of engineering and technology. These papers highlight the profound impact of innovative engineering solutions and explore a diverse range of topics relevant to both Nepal and the global community. "A Comparative Study on Reinforced Concrete Structure Response with NBC" analyzes the structural integrity of NBC-compliant constructions, emphasizing safety and durability. The "Non-motorized Transport (NMT) System in the Kathmandu Valley" paper examines how NMT can alleviate traffic congestion, reduce pollution, and promote sustainable mobility. The paper on "Neurotechnology and Brain-Computer Intelligence" discusses advancements in neurotechnology and AI, showcasing their transformative potential in healthcare and assistive technology. "Bioengineering and Disaster Risk Management" presents bioengineered solutions to enhance resilience and reduce vulnerability to natural disasters. The paper on "Racial Bias in AI-generated Images" investigates ethical issues in AI, advocating for fairness and diversity in AI technologies. Finally, "Automatic Reactive Power Control Using TSC-TSR" outlines the benefits of implementing automatic reactive power control to improve power system stability and reliability.

Together, these papers offer a comprehensive overview of the latest innovations in engineering and technology, highlighting current advancements and setting the stage for future research. We hope this proceeding will enhance the exchange and dissemination of technical and academic knowledge within and outside SONEUK. While there may be gaps in data, particularly in the context of Nepal, the topics covered provide a solid foundation for further discussion and innovation in sustainable engineering approaches. We welcome any feedback and constructive suggestions for future improvements.

As the editorial team, we are honored to facilitate the publication of these proceedings. We extend our heartfelt thanks to all the authors and keynote speakers for their invaluable contributions. It has been a rewarding experience compiling these papers, and we hope you find them as interesting and informative as we do.

Mr Hari Nepal - Coordinator
Prof Hom Nath Dhakal
Mr Krishna Kishor Shrestha
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Ambassador's Message

AMBASSADOR

नेपाली राजदूतावास
EMBASSY OF NEPAL
LONDON,U.K.

Message

I am pleased to learn about the publication of the proceedings of the annual event entitled "Innovation in Engineering and Technology" as part of the 9th annual international engineering conference organized by the Society of Nepalese Engineers UK (SONEUK) in collaboration with the Nepal Engineers' Association (NEA) and the American Society of Nepalese Engineers (ASNEngr) in June 2024 in London.

Since its establishment, I am happy to note that SONEUK has been instrumental in bringing together Nepalese engineers, professionals and enthusiasts to discuss topics of varied interest to Nepal every year. I believe that these conferences have served as an important platform to share the knowledge and experiences gained in the UK for the much-needed development efforts in Nepal. I have found that SONEUK has always been committed to sharing the technological know-how and experiences as well as advancing engineering and technological innovation in Nepal. As a responsible Nepalese professional organization of engineers in the UK, SONEUK is also contributing to the professional development and networking of its members through several academic conferences, seminars and interaction programmes.

I am hopeful that the annual international conferences bring together the Nepalese engineers and professionals from around the world for the benefit of Nepal. I appreciate the efforts of SONEUK and their contributions especially during the Nepal earthquake in 2015, COVID-19 pandemic and other natural disasters. The Embassy is happy to collaborate with the Society of Nepalese Engineers UK for further utilization of knowledge, expertise and experiences for the development 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.

04 June 2024

Gyan Chandra Acharya

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Chairperson's Message

It is my immense pleasure to extend a warm welcome to you all to the Proceedings of the 9th Annual International Conference organized by the Society of Nepalese Engineers in UK (SONEUK) on the 22nd of June 24 at Harris Academy Orpington, London, UK in collaboration with the Nepal Engineers' Association (NEA) and the American Society of Nepalese Engineers (ASNEngr). In today's interconnected world, where technological innovation plays a crucial role in addressing societal challenges, and particularly in context to technological development of Nepal, our conference focused on "Innovation in Engineering and Technology" provides a pivotal platform for knowledge sharing, collaboration, and networking.

My sincere gratitude is to all participants, keynote speakers, session chairs, reviewers, and volunteers whose contributions have been powerful elements in shaping this conference. All presentations during the conference including our Keynote Speaker Mr. Jitendra Bothara, our Ex-Chairperson Mr Sanyukta Shrestha and our founding Chairperson Mr. Krishna Kishor Shrestha are now key assets of the conference and proceedings. The diversity and depth of the presentations also reflected the commitment and intellectual vigor of our engineering/ technical professional community.

I would like to express my heartfelt gratitude to our Chief Guest, Mrs. Roshan Khanal, DCM/ Counsellor at the Nepali Embassy to the UK, whose presence and inaugural address enriched the event and underscored the importance of international collaboration in advancing engineering innovations. My heart-felt thanks go to the SONEUK Conference Committee Coordinator Mr. Hari Nepal and his Committee members for their year-long planning, hardworking and dedication in organizing this flagship event, which not only mirrored the latest advancements in innovation of engineering disciplines but also provided a platform for networking and forging new and young professional members of the Society.

As we reflect on the successes of this conference, let us also look forward to our successive tenth and future conference editions that promise to be even more enriching and impactful. I encourage all participants to continue their scholarly endeavors and innovative pursuits, ensuring that our contributions lead to tangible advancements and solutions for the benefit of the Society and its members. I also urge all other members (who could not attend this conference despite their interest) to come forward to present, support and play a significant role within the Society for its continuous promotion and sustainability.

I am confident that the proceedings of this conference will inspire and empower us all to contribute positively to our fields and to society at large.

Best wishes for continued success in our endeavors.

Warm regards,
Rudra Koirala,
Chairperson, Society of Nepalese Engineers UK

Message from Chairperson of ASNEngr

On behalf of the American Society of Nepalese Engineers (ASNEngr) and its members, we would like to extend our warmest greetings and heartfelt congratulations on the occasion of your 9th Annual Conference, "Innovation in Engineering and Technology".

We truly appreciate the immense effort and dedication put forth by your organizing committee in ensuring the collective success of this conference. Your commitment to fostering innovation and advancing the field of engineering and technology is truly commendable.

As fellow engineers, we understand the importance of collaboration and knowledge sharing in driving progress and innovation. We are excited to see the great strides that will be made during this conference and the valuable insights that will be shared amongst participants.

Congratulations once again to SONEUK on this occasion. We eagerly look forward to strengthening our collaborative efforts and exploring opportunities for mutual growth and development in any upcoming events.

Wishing you a successful and enriching conference.

Er. Surya Thapa
President,
American Society of Nepalese Engineers, ASNEngr

Message from Chairperson of NEA

On behalf of the entire Nepal Engineers' Association, I extend my congratulations and best wishes for the resounding success of the forthcoming 9th SONEUK Conference.

There's a famous expression which says:

"Keep your best wishes and your biggest goals close to your heart and dedicate time to them every day. If one truly cares about what they do and works diligently at it, there's almost nothing one can't accomplish".

Therefore, I sincerely wish the time, hard work and dedication Society of Nepalese Engineers in UK (SONEUK) has put into this conference and the aspiration and goals SONEUK has from this conference all come to fruition.

Thank You.

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

A Comparative Study on Reinforced Concrete Structure Response with NBC 105:2020 and IS 1893:2016

Rabin Gurung

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Abstract

This research examines and compares the effects of using the Nepal Building Code (NBC) and the Indian Standard (IS) code on the design of low-rise residential buildings with three stories and a staircase cover. The most recent versions, NBC 105:2020 and IS 1893:2016, are used in the analysis. The study uses a simplified method (equivalent static analysis) with Extended Three-Dimensional Analysis of Building System (ETABS) software to compare how the two codes influence the building's response to earthquakes. Key factors examined include base shear (total force at the base due to earthquake), storey displacement (movement of each floor), and storey drift (deformation between floors). The findings show that the NBC model leads to a heavier building structure, with higher base shear, storey displacement, and storey drift. This is mainly due to differences in how the codes account for live loads (occupancy weight) and lateral loads (earthquake forces). As a consequence, the NBC model requires more longitudinal reinforcement (steel bars in concrete) which can increase the overall cost of construction. Despite the cost implication, the study recommends using the NBC 105:2020 code. This is because it specifically considers the earthquake risks in Nepal and incorporates safety factors adapted to the country's construction practices.

Keywords: National Building Code, Indian Standard Code, Base Shear, Storey Displacement

1. Introduction

Nepal Himalaya located in a seismic-prone zone frequently experiences seismic activities, large earthquakes occur over certain time intervals due to collision of the Eurasian and Indian tectonic plates (Sapkota *et al.*, 2013). The Earthquake tremors in 1255, 1810, 1866, 1934, 1980, 1988 and the most recent was on 2015 A.D (Chaulagain *et al.*, 2018) ranging from weak to strong has caused enormous losses in terms of casualties, and the country's economy. Thus constructing seismically resistant structures is crucial to reduce casualties by considering the impact of earthquake loads during the analysis and design of the structures.

There are numerous seismic codes available based on particular country's topography and geological conditions such as Indian Standard (IS) of India (IS 1893(Part 1), 2016), Japanese Seismic Design Code of Japan, Eurocode of Europe, American Standard Codes of America. Nepal also has NBC 105:1994 as a building code up to 2020 for the design of seismic resistant buildings. After the devastating earthquake of 2015, necessity for advancements in seismic technology with extensive research proposed NBC 105:2019 later implemented as NBC 105:2020 eliminating insufficiencies within the 1994 NBC 105. After the implementation of NBC 105:2020, some municipalities have started using it whereas many other still use IS 1893:2016 (Pokhrel *et al.*, 2023). Indian Standard Code hasn't been updated since 2016 and the National Building Code (NBC) was revised in 2020 resulted in building code comparison especially in terms of seismic provisions have gained considerable momentum in the case of active seismic regions and help to form a most effective and economical building design. Building code comparison by (Pandit *et al.*, 2019), (Banjara *et al.*, 2021), (Shrestha *et al.*, 2021), (Adhikari *et al.*, 2022) has focused on seismic parameter comparison and (Pokhrel *et al.*, 2023) has correlated both seismic and economic parameters.

This paper aims to compare earthquake parameters for analysis and design of three story residential building with stair cover using both NBC 105:2020 and IS 1893:2016 codes. ETABS has been used for design and analysis. This prototype residential building highlights the differences that may arise from implementing NBC (National Building Code) over the IS (Indian Standard) code. Results from this comparison can be used by decision makers for sustainable practice.

Indian Standard Code (IS)

IS 1893:2016 is sixth revision adopted by Bureau of Indian Standard for Earthquake Resistant Design of Structures (BIS 2016) based on deterministic hazard analysis with respect to recorded time history. It has divided India into four seismic zones. According to this standard the seismic force is calculated using Equivalent Static and Dynamic Analysis methods. It recommends the use of the basic seismic coefficient or modal response spectrum as per three subsoil types, Subsoil type-I, Subsoil type-II, and Subsoil type-III as Hard, Medium and Soft soils. The design horizontal seismic coefficient (Ah) is determined based on the building's height, soil conditions, seismic zone, importance factor, and response reduction factor. The design seismic base shear is obtained by multiplying the design horizontal seismic coefficient with the seismic weight of the building. The seismic load is calculated by considering the dead load and a percentage of the live load based on its magnitude.

Nepal Building Code (NBC)

In 1994, the Nepal National Building Code (NBC) was formulated by the Department of Urban Development and Building Construction (DUDBC). NBC 105:1994 underwent a significant revision in 2019 to enhance its seismic provisions. This revision process was triggered by the Gorkha Earthquake and aimed to incorporate updated earthquake-resistant design principles. The updated code, NBC 105:2020, introduced several key changes, including the adoption of a Probabilistic Seismic Hazard approach and the creation of a Seismic Hazard Map for Nepal. Additionally, Peak Ground Acceleration (PGA) values were revised for various cities and municipalities. The revised code categorizes subsoil into four types: A, B, C, and D. It mandates that structures must withstand design seismic forces while maintaining their integrity, stability, and load-bearing capacity. The code also includes provisions for seismic zones, importance factors, spectral shape factors, and elastic site spectra to calculate the horizontal base shear coefficient. The base shear is then determined by multiplying this coefficient by the seismic weight of the structure. The code provision for IS and NBC is illustrated in Table 1.

Table 1: Code Provisions For IS Code and NBC Code

Code Provision	IS 1893:2016	NBC 105:2020
Time Period	Ta = 0.075 $H^{3/4}$	T = K_t $H^{3/4}$ Where, K_t = 0.075
Storey Drift/ Displacement	0.004 * storey height	$\frac{0.025H}{R\mu}$ where $R\mu$ is the Ductility Factor
Base Shear	V_B = Ah *W	V = C_D(T) * W
Load Combination	1) 1.2[DL+LL±($ELx \pm 0.3ELy$)] 2) 1.2[DL+LL±(0.3ELx ± ELy)] 3) 1.5[DL+LL±(ELx± ± 0.3ELy)] 4) 1.5[DL+LL±(0.3ELx ± ELy)] 5) 0.9[DL+LL±(ELx± ± 0.3ELy)] 6) 0.9[DL+LL±(0.3ELx ± ELy)]	1) 1.2DL + 1.5LL 2) DL+λLL±(Ex± 0.3Ey) 3) DL+λLL±(0.3Ex± Ey)

2. Methods

The three and a half story residential building as illustrated in Table 2 was analysed and designed. Comparison was made between two seismic design codes: IS 1893:2016 and NBC 105:2020. Two models were prepared in ETABS, one for IS 1893:2016 and the other for NBC 105:2020, respectively. Both these models had identical sectional properties. Column and beam elements were represented as line elements, whereas floor slabs were modelled as shell elements. All the joints in the frame were assumed to be rigid. The frames were interconnected using a rigid diaphragm in the horizontal plane. The seismic resistance of the prepared model was checked.

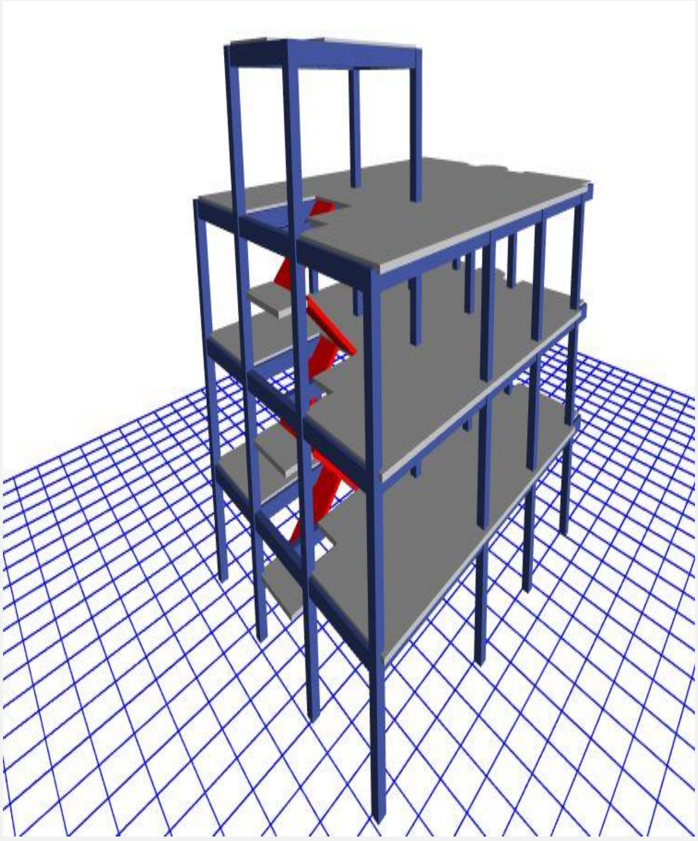

Figure 1: 3D Model of Building

The structure is analysed by the linear elastic theory to calculate internal actions produced by anticipated design loads. The zonal factors and soil type for buildings assumed to be located in Kathmandu Valley are adopted from respective codes as illustrated in Table 3. The analysis is carried out using state of art three dimensional structural analysis programs like ETABS. The design loads in Table 2 was considered as per the relevant codes of practice comprise dead load due to permanent structures, live load due to occupancy of the structure and seismic load due to anticipated earthquake possible at the proposed location. A number of load combinations are considered to obtain the maximum values of design stresses.

Table 2: General Description of Prototype Building

Parameters	General Description
Types of building	Residential Building
Plinth Area	82.014m2
No. of story	G+2 with stair cover
Building Height	11.58m
Floor Height	2.87m
Size of Beam	230x350 mm [9"*14"]
Size of Column	305x305 mm [12"*12"]
Depth of Slab	127 mm [5”]
Type of Staircase	Dog legged
Type of Footing	Isolated and Eccentric with Strap Beam
Depth of foundation	1.5m
Support Condition	Fixed
Width of wall	230 mm [9"]
Width of the partition wall	100 mm [4"]

Concrete type	M 20
Grade of Steel	Fe 500
Specific Weight of RC	20 KN/m^3
Specific Weight of Infill	19.4 KN/m^3
Bearing Capacity of soil	150 KN/m^3
Various Loading and Standard	
Live load	3 KN/m^2 (Balcony/Staircase) 2KN/m^2 (Room)
Floor finish	1.015 KN/m^2
Roof live load	1.5 KN/m^2
Earthquake load	As per code

Table 3: Site Parameters

Parameters	IS 1893:2016	NBC 105:2020
Seismic Zone	V (0.36)	Kathmandu (0.35)
Soil type	III (Soft soil)	D (Very Soft soil)

3. Results and Discussion

The primary objective of structural design is to ensure that the structure can reliably endure all anticipated loads and meet serviceability criteria, such as deflection and crack limitations, throughout its intended lifespan. The predefined level at which safety and serviceability requirements are considered acceptable and structural failure is avoided is referred to as a "limit state." The aim of the design is to achieve acceptable probabilistic so that the structure will not become unfit for its intended use; that is, it will not reach a limit state.

Time period of the structure depends on stiffness and on the mass of the structure. With increase in height of structure the time period is higher depicting the flexibility of the structure. The time period on seismic analysis of the modal lies between 10-20% of the difference between consecutive modes. The fundamental translation time period of the analysed structure was calculated using the approximate relationship suggested by code and was compared with the natural period from the FEM tool (ETABS).

Base shear has a vital role in the seismic analysis as it influences all the analysis parameter of the structure. The comparison of seismic loads and base shear is also the major objective of this study. Base shear estimates the maximum expected lateral force on the structure's base. Figure 2 and Figure 3 represent seismic loads and base shear values from NBC 105:2020 and IS 1893:2016. It shows that NBC 105:2020 has more seismic weight and base shear than IS 1893:2016.

This variation in seismic weight is due to variation in the live load factor in the two codes. According to the IS code, for a live load greater or equal to 3 KN/m^2 , the live load factor is 0.25; for greater than 3 KN/m^2, the live load factor is 0.5. For the NBC code, the live load coefficient is 0.6 for storage and 0.3 for other purposes. The variation in base shear is caused by a combination of factors. These include the differing live load factors, zone factors (which account for earthquake intensity in different regions), seismic weight, and the specific values set by each code for parameters like response spectrum coefficient, ductility factor (a measure of a structure's ability to deform without breaking), and over-strength factor (a factor that accounts for the reserve strength in a structure).

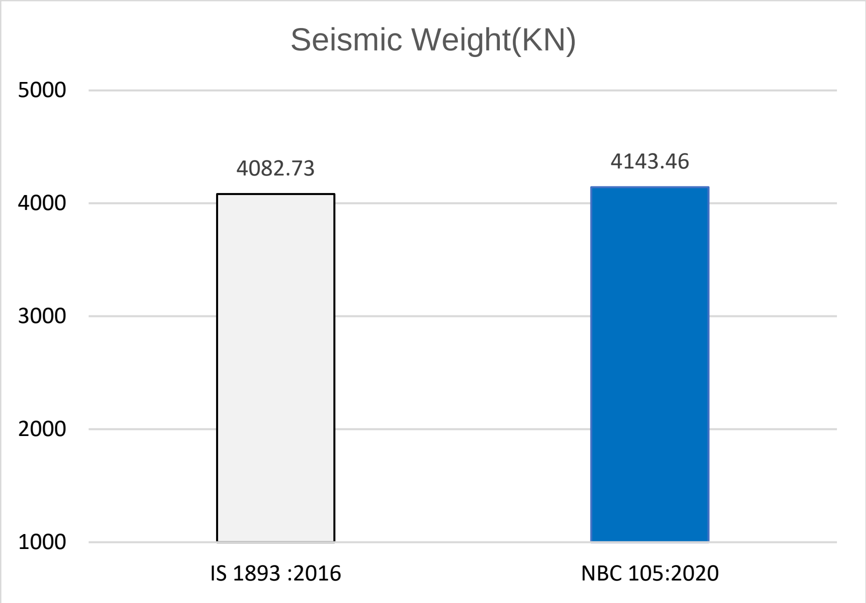

Figure 2: Seismic Weight Comparison

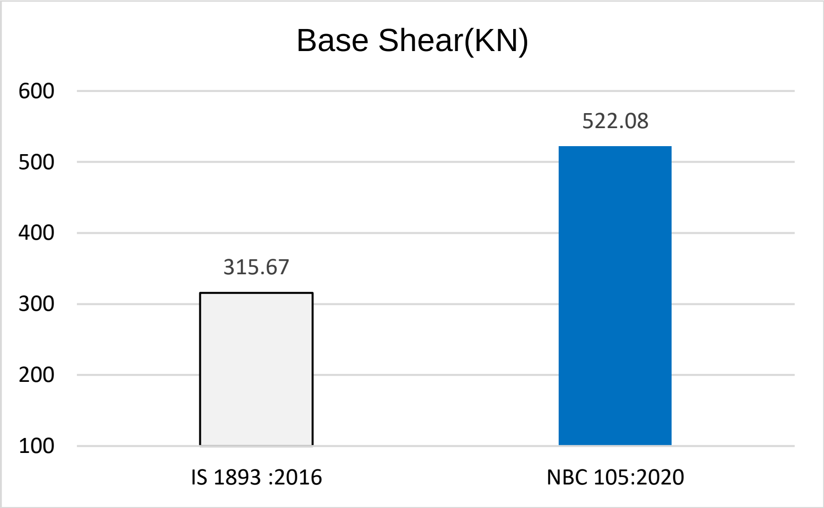

Figure 3: Base Shear Comparison

Figure 4 illustrates how the displacement of each floor (storey) in a symmetrical building changes with height under an earthquake load applied in the X-direction. The figure shows that the NBC 105:2020 results in the greatest displacements compared to IS 1893:2016 when the earthquake load was applied in the X-direction. This larger displacement is expected because NBC specifies the highest lateral load for this scenario. Story drift, which is the movement of one floor relative to the one below it, is calculated for each floor in Figure 5. Story drift is an important indicator of potential building damage, particularly non-structural damage. It can also be used to estimate the building's lateral stiffness. The figure reveals that the largest story drift for the X-direction earthquake load occurs in the first floor (storey 1) when using the NBC code.

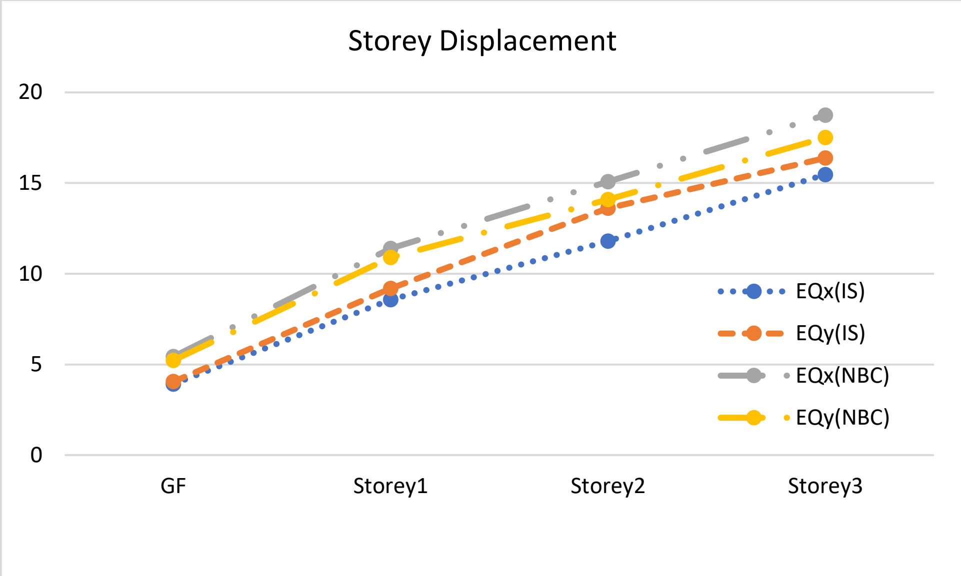

Figure 4: Storey Displacement Comparison

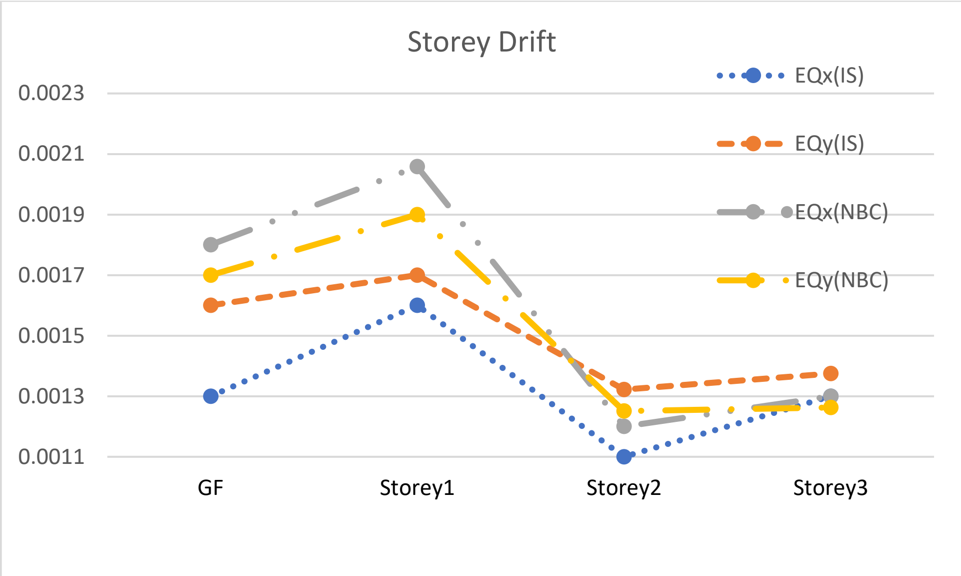

Figure 5: Storey Drift Comparison

4. Conclusion

This study compared the response of reinforced concrete structures designed according to the Nepal National Building Code (NBC 105:2020) and the Indian Standard (IS 1893:2016, Part 1). The results indicated that the NBC code generally results in stiffer structure. This is due to the NBC 2020 provisions for earthquake-resistant design, which lead to higher design base shear forces. Consequently, buildings designed using NBC 105:2020 may experience:

Greater Storey Drift and Displacement: Due to the stiffer response, structures designed to NBC standards exhibit slightly higher lateral displacements under seismic loads,
Increased Reinforcement Requirements: To accommodate the higher design loads, NBC 2020 designs specify a larger amount of steel reinforcement.These findings suggest that NBC 105:2020's earthquake-resistant design provisions may result in slightly more expensive

construction due to increased reinforcement requirements. However, this approach offers potentially better performance during seismic events, which is crucial for regions with high earthquake risk. It is also important to note that this study focused on a single building type, and further research is recommended to compare the codes across different building configurations and sizes for a more comprehensive understanding.

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Non-motorised Transport (NMT) System in the Kathmandu Valley (Transport series -2)

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Abstract

Nepal's urban population, which now constitutes two-thirds of the country's total population as of the 2021 Census, has grown rapidly, particularly in the Kathmandu Valley. This urban expansion has been accompanied by a surge in private vehicle ownership, especially motorcycles, leading to critical urban mobility challenges. These include longer travel times, chaotic pedestrian environments, and an unregulated public transport system, all of which contribute to increased pollution, declining public health, and significant economic costs.

Non-motorised transport (NMT), including walking and cycling, is vital to Kathmandu's urban transportation, accounting for 42% of all trips. Previous studies by organisations such as JICA and ADB have proposed various measures to promote NMT in the Kathmandu Valley, though these initiatives have primarily focused on town centres.

Despite the recognised importance of NMT infrastructure in national transport strategies and policies, there remains a significant gap in planning, projects, and initiatives from federal, provincial, and local transportation authorities. Indian cities, such as Karnataka and Chennai, provide valuable models with their Draft Active Mobility Act and NMT initiatives.

Recent research highlights a natural commuter preference for walking and other modes during the first and last legs of their journeys. This has led to an increased reliance on informal transportation modes, such as three-wheeler autos, ridesharing, taxis, and motorcycles. Achieving sustainable urban transportation requires the development of safe and accessible NMT infrastructure, aligned with modern transport planning principles that advocate for a shift from traffic-focused to people-centric approaches. Cities like Seoul and Singapore have successfully transitioned from car-cantered to people-oriented transport policies, demonstrating the potential of this paradigm shift.

To support this transformation, it is recommended that authorities allocate at least 10% of the transportation infrastructure budget to NMT and establish a dedicated department for its oversight. Additionally, prioritising pedestrian and cyclist safety through the provision of essential infrastructure, such as intermodal transitions, dedicated NMT bridges, and crossings, is crucial. Other important considerations include creating interconnected networks of walkways and cycle paths, utilising river and stream corridors, developing alternative pathways, and repurposing existing roads for shared use. Integrating non-motorised modes with enhanced public transportation and exploring the introduction of mass rapid transit (MRT) should be key components of the government's strategy.

Keywords: Non-motorised Transport (NMT), pedestrian walkway, cycleways, public transport, traffic, congestion, and mobility.

1. Introduction

The Kathmandu Valley (KV) is experiencing rapid population growth and housing expansion, accompanied by a surge in private vehicle ownership, particularly motorcycles. This phenomenon has exacerbated urban mobility challenges, including prolonged travel times, heightened pollution levels, and inadequate public transport coordination. These challenges entail economic costs. In light of these pressing issues, transportation studies advocate for the integration of mass transit systems, such as underground and elevated metro rails, in tandem with enhancements in infrastructure for non-motorised transport (NMT) alternatives like walking and cycling. The adoption of sustainable transport systems, encompassing both mass transit and NMT options, is essential to effectively address the entrenched traffic congestion in the Kathmandu Valley.

This paper aims to investigate strategies for promoting sustainable transportation options, specifically pedestrian and cycling transport, in the Kathmandu Valley. Key areas of exploration include:

- Examination of existing transportation studies and policies, with a focus on the disproportionate allocation of resources towards NMT.
- Advancing the design of urban roads to prioritise safety for pedestrians and cyclists.
- Enhancing public transportation systems to encourage higher volumes of walking trips within the Kathmandu Valley.
- Assessing the disparity between existing infrastructure provisions and the demand for NMT trips.
- Evaluating current transport policies and plans to advocate for prioritisation of NMT-based transportation.
- Introducing innovative concepts for NMT planning to foster sustainable urban mobility in the Kathmandu Valley.

Commuters are naturally inclined towards walking and other modes for initial and final legs of their journeys (RTPI, 2021). This has led to the use of informal transport such as three-wheeler autos, ridesharing, taxis, and motorcycles.

The key to achieving long-term sustainability in urban transportation lies in the development of safe and accessible non-motorised transport (NMT) infrastructure. This aligns with modern transport planning principles, shifting from a focus on traffic to a people-centric approach. It effectively reverses the current transport volume pyramid. In other words, it transforms to active transportation. This approach is being experimented with in Seoul's city. It represents a paradigm shift from car-cantered to people-oriented policies.

2. Urban Growth in Kathmandu Valley (KV)

Nepal is one of the top five countries experiencing the fastest rates of urbanisation globally (UN DESA, 2018). The Kathmandu Valley has undergone significant urbanisation, with the built-up area increasing from 2.94% in 1967 to 24.7% in 2011 (UTIKV, 2017). The urban growth can be attributed to economic opportunities, the conversion of rural areas into urban spaces, and accessibility to public services. The urban population of Nepal is expected to increase from 2.7% in 1950 to 37% by 2050 (UN DESA, 2018).

The Kathmandu Metropolitan City's population has been growing at a rate of over 4% since the late 1970s (World Bank, 2013). Urban development is projected to continue through infilling in existing urban areas and in fringe areas according to a spatial modelling of Kathmandu population growth (Thapa & Murayama, 2011). As a result, the built-up area in the Kathmandu Valley has increased significantly from 1989 to 2019 (Figure 2.1).

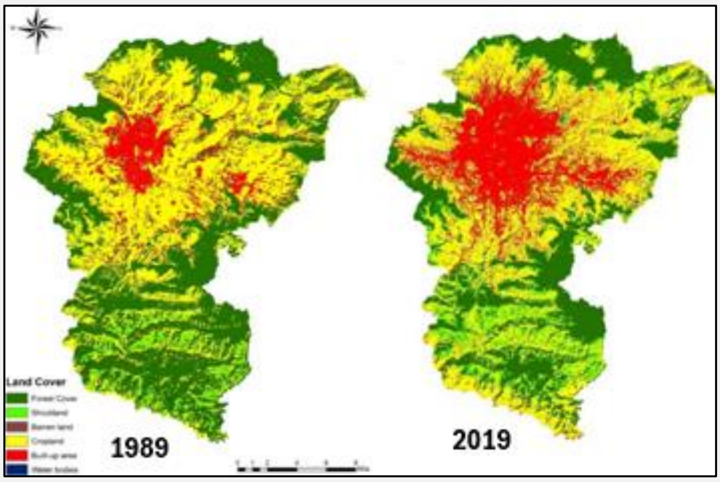

Figure 2.1 Increase of Built-up Area in the KV (Thapa & Murayama, 2011)

Table 2.2 displays the projected population for three districts in the Kathmandu Valley by CBS in 2014. In the KMRTC (2012) and KSUTP (2018) study reports, it was suggested to adopt data plus an additional 30% for the floating population. The 2041 population for the KV districts is extrapolated based on CBS projections for 2031.

Table 2.2 Estimated Future Population in KV Districts (CBS, 2021 and KMRTC, 2012)

	2011	2021	2031	2041
Kathmandu	1,744,240	2,017,532	2,784,194	3,647,294
Lalitpur	468,132	548,401	729,373	1,006,535
Bhaktapur	304,651	430,408	606,875	934,588
Total (KV)	2,517,023	2,996,341	4,120,442	5,588,417

3. Road Network in KV

3.1 Road Network

Road networks in the Kathmandu Valley consist of strategic roads and local roads, including national highways, ring roads, feeder roads, and urban roads. All roads are managed by two jurisdictions: the Department of Roads (DOR) and the Ministry of Federal Affairs and Local Development (MoFALD). In 2016/17, these two jurisdictions managed 472.97 km of strategic roads and 1,116.43 km of local and urban roads.

The functional category of roads is determined by design standards, width, lanes, traffic volume, and speed, and different categories are illustrated in a digital Road Network map (Figure 3.1).

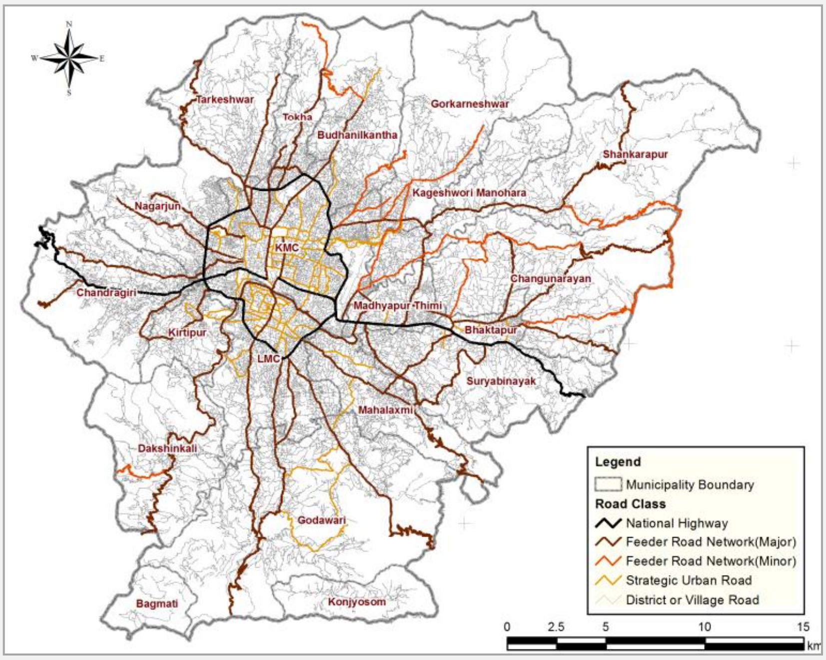

Figure 3.1 Digital Map of Road Network in KV (JICA, 2012)

3.2 Kathmandu Road Widening

In the Kathmandu valley, a substantial number of existing urban roads were recently widened, adding up to a total length of around 300km (Khanal P. et al, 2017). The primary objective of this undertaking was to alleviate traffic congestion; however, it had the opposite effect and worsened the traffic situation in the city. The road expansion plan was primarily geared towards accommodating vehicles, and it disregarded the needs of non-motorised traffic.

Despite the significant public investment in this project, which was solely aimed at expanding the road network, there was a lack of focus on the development of sustainable infrastructure, such as pedestrian walkways and cycleways. As a consequence, the transportation system in Kathmandu continues to heavily rely on private cars and motorbikes, with limited options for pedestrians and cyclists.

3.3 Development of River Corridors

The article "Road Expansion and Urban Highways: Consequences Outweigh Benefits in Kathmandu" (Khanal P. et al, 2017) sheds light on the development of the river corridors in Bagmati, Bishnumati, and Dhobighat in Kathmandu. According to the authors, while this development has the potential to rejuvenate the city's river systems and enhance the urban environment, the focus on road expansion and urban highways has led to negative consequences that outweigh any potential benefits.

Development of river corridors in Kathmandu did not consider the consequences and overlooked the importance of prioritising pedestrian and cycleway infrastructure alongside the roads. It is evident that people are walking on the roads (Figure 3.2). Although this presents a significant issue, it is noteworthy that there are some pedestrian bridge crossings over the rivers, which is a positive aspect.

Figure 3.2 Dhobi Khola River Corridor Roads (Photo by Giri GR, 2019)

3.4 Improvement of bottlenecks

Several junction and intersection improvements recommended by the Department of Roads (DOR) as outlined in the report (KSUTP, 2017) aim to enhance the level of service for both vehicular and pedestrian traffic across the entire network of intersections along the arterial axes of the East-West Corridor and North-South Corridor within the Kathmandu Valley. Additionally, these improvements are intended to play a significant role in alleviating traffic congestion and improving safety throughout the city. The proposed intersections are listed below and illustrated in Figure 3.4.

The following works are on-going under the DOR components:

- Improvement of 32 intersections including signalisation at 22 locations.
- Installation of 6 pedestrian signals and 25 CCTVs for traffic surveillance.
- Establishment of a Traffic Management Centre (TMC) for centralised control.
- Construction of 2 bridges over the Bishnumati River.

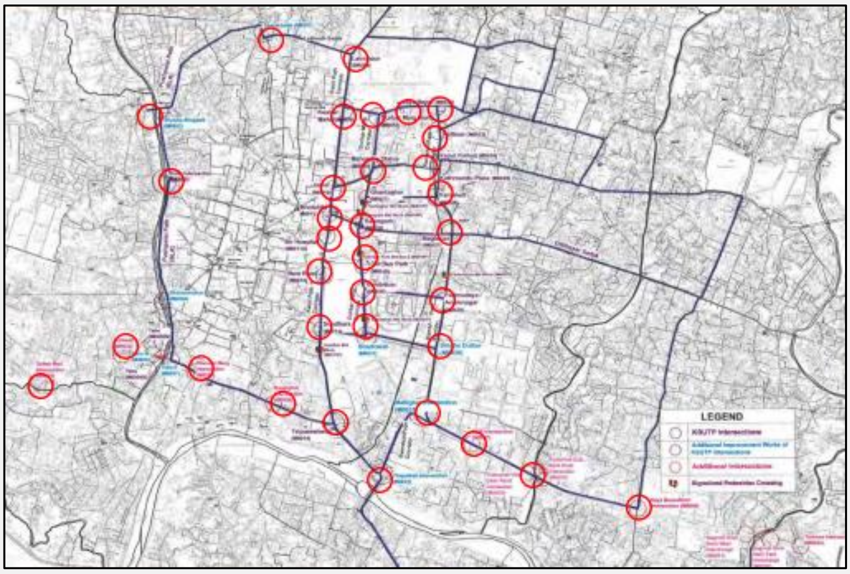

Figure 3.4 Location Map of Improvement Intersections (KSUTP, 2017)

However, there is a notable absence of consideration for the pedestrian network, as provision of continuous footways along the KV roads have not been designed, and cycleways are scarcely mentioned in the context of non-motorised transport.

4. Vehicle Fleet in KV

4.1 Vehicle Growth

In 2016/17, 37% of all registered vehicles in Nepal were located in the Bagmati Zone according to the Department of Transport Management (DOTM 2016/17). In 2018/19, there were almost 1.1 million vehicles operating in the Kathmandu Valley, accounting for 34% of all vehicles (DOTM 2019/19), in Nepal. The rest of the vehicles, around 2.1 million, were located outside the valley and primarily consisted of motorcycles, cars, buses, mini/micro buses, three-wheelers, and Safa Tempos. The rate of motorisation in the Kathmandu Valley had been increasing, with a 30.41% increase in fiscal year 2015/16 and a 26.64% increase in fiscal year 2016/17.

4.2 Vehicle Fleet Characteristics

Based on the 2019/20 vehicle data (Figure 4.1), out of the 3.82 million registered vehicles in Nepal, 3 million are motorcycles, which account for a significant proportion (79%) and their numbers have increased each year. The number of public transport vehicles, including buses, mini/micro buses, and tempos, is less than 192,784 (5.04%), which is lower than the combined number of cars, jeeps, vans, and pickups, which was 341,669 (8.94%).

Due to a lack of adequate public transportation, motorcycles are the primary mode of transportation for middle and low-income urban and rural populations to reach short distances at a lower cost and in less time. This is why the growth of motorcycles is significantly higher compared to other types of vehicles.

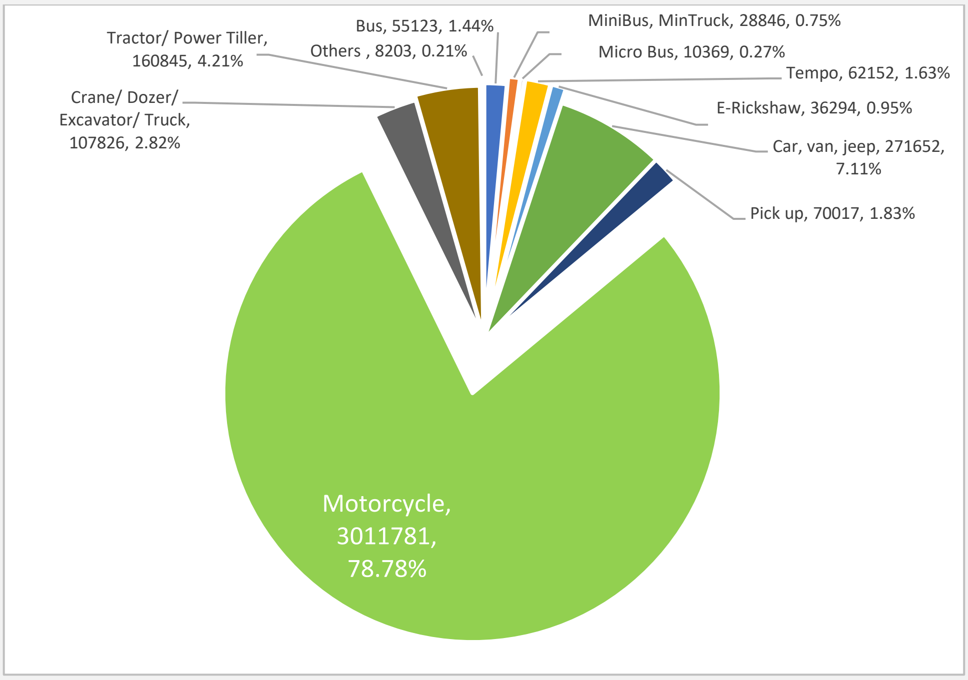

Figure 4.1 Share of vehicles (%) registered in Nepal until 2016/17 (DOTM)

In 2014, a survey (Ghimire, 2014) was conducted to count vehicle for 12 hours for estimating vehicular emission in the Kathmandu Valley, which shows private vehicles - 85% (motorcycle – 77.5%), PT vehicles - 12.5% and other utility vehicles - 2.5 %. Increased in number of motorcycles (77.5%) indicates there is dire need of modal shift from private to public transport facility in the valley.

It is noteworthy that motorcycles are so prevalent in Kathmandu that the Kathmandu Metropolitan Police has emphasised the need to manage them in order to alleviate traffic congestion in the valley.

5. Transport in KV

5.1 Public Transport (PT) in KV

In the Kathmandu Valley, over 200 public transport routes are served by various vehicles, including buses, minibuses, microbuses, and three-wheel tempos (JICA, 2012). While the Department of Transport Management (DOTM) oversees route permits and planning, transport operator associations exert significant influence, leading to a lack of regulation and resulting in disorganised and inconsistent public transport, negatively affecting both commuters and non-motorised transport (NMT).

The Intermediate Public Transport (IPT) sector, or informal transport, in Kathmandu mostly consists of small privately operated vehicles providing low-performance services such as micro-buses and tempos for non-work/work trips. These vehicles often lack proper route licenses and operate informally, leading to poor regulation and management. Nepal Government amends Industrial Enterprises Act to include ride-sharing as a service-oriented industry. Few private bus companies such as Sajha yatayat, Mahanagar Yatayat, and Metro Yatayat Bus, have introduced with big size buses in the Valley roads.

5.2 PT Improvement

The lack of a clear plan and program for coordination with Public Transport (PT) owners and route structuring, as well as the absence of PT infrastructure such as bus laybys and lanes, highlights the need for the improvement of bus-based public transport in the Kathmandu valley.

The existing public transport system in KV has several problems, including duplication of routes, uncoordinated operators, low-capacity vehicles environmental degradation, poor quality of service, inadequate passenger facilities, weak regulation, and poorly maintained vehicles (KSUTP, 2018). A recent study on transport in Kathmandu has revealed that the number of routes in the valley can be significantly reduced from 200 to 66. A three-tier route hierarchy of public transport routes is proposed, with 8 primary, 16 secondary, and 40 low occupancy vehicles operating on tertiary routes (Maya Fact Sheet, 2014). Pilot schemes have been tested on two routes: New Bus Park via Samakhusi and the Central Business District (CBD) to Sinamangal (KSUTP, 2018). The projected traffic for the project scenario estimates that 388 microbus trips and 682 Safa tempo trips will be replaced by 160 bus trips (KSUTP, 2020).

To improve the public transport system in the KV, the Department of Transport Management (DOTM) has planned to implement a GPS-based Vehicle Tracking System for PT Vehicles, like London's iBus, which will provide real-time information on public transport. Mobile apps for route information, schedules, fares, and updates on all public transport will also be made available.

To enhance improvement in PT management, it is crucial to take insights from experiences in cities like London and Seoul (Harnis & Mizokami, 2011): foster collaboration between authorities and operators through strategic partnerships, implement a clear demarcation between planning responsibilities and operational tasks, entrust planning duties to the authority while empowering operators to execute operational functions effectively.

The World Bank is funding Nepal's Urban Mobility through the Kathmandu Valley Public Transport Authority (KV-PTA) to promote decarbonisation via sustainable multimodal transport. A separate public transport division is proposed within the DOTM, and 32 road intersections have been identified for traffic flow improvements.

5.3 Electric Mobility in KV

In 1973, trolley buses were introduced in Kathmandu valley as the first electric vehicles but were discontinued in 2009. However, e-Tuk-Tuk or e-rickshaws, also known as Safa Tempo, have been a successful example of public electric vehicles in the city since 1996 (Bhattarai & Shahi, 2021). The government has set a target of a 20% reduction in transport sector emissions and has launched the 'Electric Mobility Program' in collaboration with the Global Green Growth Institute to support sustainable transportation (GGGI, 2018), and WB funded programme for e-mobility on three-wheeler vehicle. It is also noted that rCityunning electric buses is 39% cheaper than diesel buses.

The import numbers of E-scooters, EV taxis, and EV cars have been increasing in the KV in recent years, despite changes in government tax policies over time. Electric mass transit is designed to achieve two sustainability objectives: reducing reliance on fossil fuels and promoting a modal shift away from private vehicles, including motorcycles and cars.

6. Non-motorised Transport in KV

6.1 Walking and Cycling

Pedestrianisation, designated as vehicle-free zones, is implemented in the core historic and tourist areas of the Kathmandu Valley (Figure 6.1). There are few components of pedestrianisation schemes (e.g. heritage walking) that have been implemented in Kathmandu under ADB supported transport projects. Ongoing footway enhancements are currently underway in Kathmandu Metropolitan City.

Figure 6.1 Kathmandu: Vehicle free zone (Pedestrianised) and Footway Improvement

Pedestrians are forced to walk on narrow and poorly maintained footways (Figure 6.2) and even on roads. For most low-income commuters, urban mobility including walking and cycling are the only affordable mode of transport, but there is no NMT focused urban transport planning.

Figure 6.2 Kathmandu: Footways Encroached and Narrowed

Lalitpur Metropolitan City (LMC) has introduced a cycle lane (Figure 6.3 a) within the shared space of the carriageway. Cyclists pedal along with vehicles, which is not safe. However, LMC is working to promulgate New Cycle Law 2020 to guarantee cycling is the safest mode of transport in the metropolis. (Figure 6.3a). Kathmandu Metropolitan City (KMC) has been revisiting the Maitighar to Tinkune pedestrian and cycle shared route to rectify issues related to its design and construction materials (Figure 6.3-b).

Figure 6.3 a) Cycle Lane in Lalitpur City, b) Tinkune-Maitighar Cycle Lane

Walking trip share in the Kathmandu Valley is significantly high although it has been reduced from 53.1% in 1991 to 38.8% in 2022 (Figure 6.4). The footway network should be strategically planned alongside roads, inside residential areas and river corridor roads.

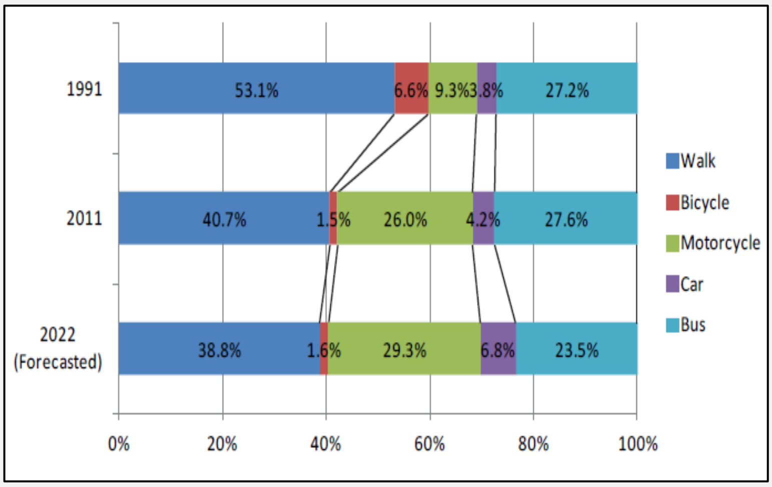

Figure 6.4 Travel Mode Share in in KV (JICA, 2012)

6.2 Need of NMT Improvement

A study undertaken by Clean Air Network Nepal (CAAN) and Clean Energy Nepal (CEN, 2003) has revealed that pedestrian facilities in Kathmandu are in extremely poor condition and not user-friendly to physically disabled people (Cabrido, 2011).

Kathmanduites could benefit from: preserving the city's unique character, creating pedestrian-friendly environments, avoiding car-centric infrastructure, and adopting a bottom-up planning approach. Sidewalks are sacrificed for cars, partly because they are perceived for just pedestrian movement and building access. Pedestrians bring life to the city; street vendors and shopkeepers create economic vitality; children and street performers make the city lively (Khanal, 2021).

Sidewalks in Kathmandu suffer from several significant issues, including narrowness, congestion, and frequent obstructions such as electric poles, cables, bins, vendor stalls, and motorcycle parking. Additionally, there are abrupt changes in sidewalk levels, making navigation challenging (Thapa & Maharjan, 2018). The overall cleanliness and safety of sidewalks are compromised by factors such as potholes, inadequate street lighting, and waste accumulation.

State of Pedestrian Infrastructures

Furthermore, essential pedestrian facilities and amenities are lacking, contributing to an unpleasant walking experience. The scarcity of crosswalks and traffic lights further exacerbates safety concerns for pedestrians. As highlighted by Thapa (2018), these conditions collectively render pedestrian movement in Kathmandu not just hazardous but potentially fatal.

In essence, transforming Kathmandu's pedestrian infrastructure demands a comprehensive and collaborative approach that prioritises the well-being and mobility of all citizens. Only through sustained commitment and action can the city truly become a safer, more liveable, and inclusive urban environment for everyone.

6.3 Modal Trip Share in KV

Based on the year 2011 trip distribution data (JICA, 2012) shown in Figure 6.5, the highest share of trips is made by walking, accounting for 40.7% of trips. This is followed by bus and motorcycles, which make up 27.6% and 26% of trips, respectively. The categories of car and bicycle have the smallest share of trips, accounting for only 4.2% and 1.5%, respectively. The "bus" category includes trips made by tempo, microbus, minibus, medium-bus, and large-bus, while the "car" category includes trips made by car, taxi, and truck.

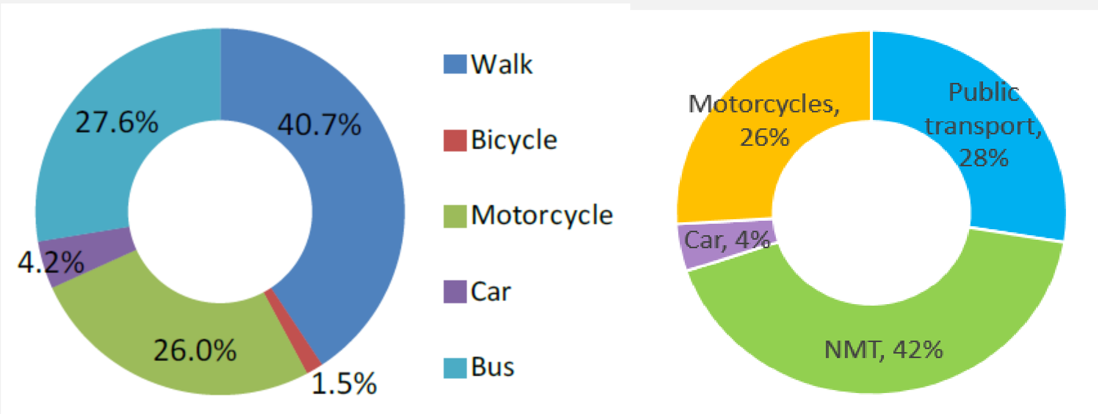

Figure 6.5 Year 2011 Modal Trip distribution in KV (JICA, 2012)

The report compares modal trips and infrastructure provision for various travel modes in Figures 6.6a and 6.6b, respectively, and concludes that while non-motorised trips account for 42% of all trips, the provision of infrastructure such as footways and cycleways is inadequate, which makes it challenging for pedestrians and cyclists to travel, particularly low-income commuters. Nonetheless, some initiatives have been taken to improve cycling infrastructure and implement pedestrianisation schemes in the city. To address the issue, the report (JICA, 2012) recommends creating a pedestrian network plan and promoting non-motorised transport to reduce vehicles and improve air quality. Given the gentle topography and adequate trip lengths, bicycles have the potential to become a means of daily transportation in Kathmandu Valley. Emphasis should be placed on prioritising NMT (Non-Motorised Transport) infrastructure in urban transport planning.

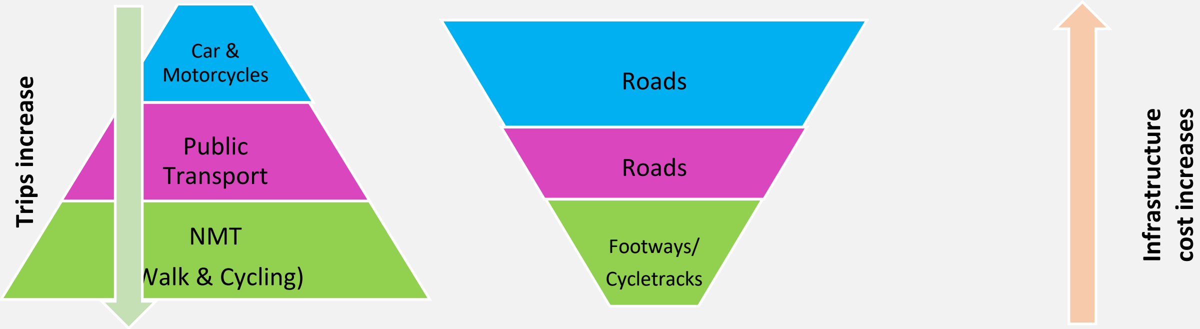

Figure 6.6 a) Modal Trips b) Infrastructure in KV (JICA, 2012)

6.4 NMT Experiences in Chennai

In Chennai, despite poor pedestrian and cycling infrastructure, one-third of all trips in the city are made on foot and cycle, and public transport trips also involve walking or cycling (for first/last miles). To address this, the Chennai Municipal Corporation has set ambitious goals to build safe footpaths on 80% of streets, increase walking and cycling trips to over 40%, and eliminate pedestrian and cyclist deaths by 2018 (ITDP, 2014). The policy prioritises pedestrians, cyclists, and public transport over private vehicles.

Figure 6.7 below compares an old footpath, which was narrow and cluttered with utility boxes, with a new, wider footpath that provides continuous pedestrian space. The adoption of the new NMT policy aims to reclaim space from cars and prioritise pedestrian access. The Kathmandu Valley could also consider adopting this policy to prioritise pedestrian and cyclist access over private vehicles.

Figure 6.7 Footway Improvement: Before and After (Dilip, 2024).

7. Transport Studies and Policies

7.1 Transport Studies

Over 30 years various transport studies were carried out by various international agencies such as JICA, ADB and World Bank, it varies from data collection, urban road development, traffic surveys, origin/destination surveys, junction surveys, urban transportation system including mass rapid transit (Table 7.1).

Table 7.1 Transport Studies (1993-2022).

	Institutions	
	JICA	ADB, WB & ESCAP
Reports	JICA 1993: A Study on Kathmandu Valley Urban Road Development.	ADB 2014: Public Transport Restructuring, Kathmandu Sustainable Urban Transport Project.
	JICA 2000: Kathmandu Junctions survey.	ADB 2018: Mass Transit Options and Prioritisation Study (KSUTP).
	JICA 2012: Data Collection Survey on Traffic Improvement in Kathmandu Valley.	WB 2013: National Transport Management Strategy 2070, Draft Version.
	JICA 2017: The Project on Urban Transport Improvement for Kathmandu Valley.	ESCAP, 2022: A Comprehensive Public Transport and MRT Plan in Kathmandu Valley.
	JICA 2019: Data Collection Survey on Urban Transport in Kathmandu.	ESCAP, 2022: National Strategy for Electrification of Public Transport in Nepal.

All the study reports and data serve as crucial references for addressing public transport issues in the Kathmandu Valley. It is imperative for the government to actively manage traffic and transport data, plan for systematic data acquisition, and conduct further studies to understand and address transportation needs effectively.

Recently, a study project has been agreed upon between Ministry of Physical Infrastructure and Transport (MoPIT) and JICA to identify high-demand mass transit routes in the Kathmandu Valley. This project will consider existing multiple studies on mass rapid transit options for the Kathmandu Valley.

It is important to note that the government has not yet made any decisions regarding independent studies conducted separately for NMT (Non-Motorised Transport).

7.2 Metro Rail Studies

The necessity of a Mass Rapid Transit (MRT) system in the Kathmandu Valley is underscored by the significant congestion cost of Rs 116 billion (Chand, SJB, 2018), a metro rail projected opening year of BS 2030 (Dalkmann, 2012, UN ESCAP, 2012), and travel demand forecasts using JICA's model (JICA, STRADA), highlighting the urgent need to address rising population, vehicle growth, and associated costs of living and healthcare. The following MRT studies are summarised in Table 7.2 below.

Table 7.2 Metro Rail Studies (JICA, 2012 & ADB, 2018, Amatya et al., 2020*)*

Metro Rail Study	Nos of lines	Orbital lines	Length (km)	Nos of stations	Cities covered
KMRTC MRT (JICA, 2012)	5 main	1	66	57	Kathmandu Lalitpur
KSUTP MRT Study (ADB, 2018)	5 main	1	91.6		Kathmandu Lalitpur Bhaktapur Banepa
GKV Metro Rail (2020)	5 main / 2 branches	2	192.5	103	Kathmandu Lalitpur Bhaktapur Banepa
MOPIT/JICA (2023)	2 main	0	N/A	N/A	Kathmandu Lalitpur

According to the modelling outcomes (KSUTP MRT Study (ADB, 2018), the modal share of MRT is determined to be 28.4%, indicating a corresponding reduction in other trips by the same percentage.

7.3 Transport Policy Documents

The need for sustainable transport components, such as a walking and cycling network, inclusive and accessible urban public transport, Mass Rapid Transit (MRT), Bus Rapid Transit (BRT), and Kathmandu Metrorail Project, is emphasised in the numerous plans, policy documents, and strategy papers, as outlined in Table 7.3.

Table 7.3 Transport Policy Documents (Various sources, Pokharel, Acharya, 2015).

Documents	**Main issues of transport**
शहरी क्षेत्र सार्वजनिक यातायात (व्यवस्थापन) प्राधिकरण ऐन, २०७९	❖ Urban Area Public Transport Management Authority Bill
Kathmandu Valley Master Plan (2015-2035)	Inclusive & accessible Public Transport Mass rapid transit (MRT), bus rapid transit (BRT), automated guided transit (AGT) Walking and cycling network. Operate (under BOOT model) transportation system
National Urban Development Policy (2017)	Promote sustainable Public Transport Prepare transportation management plan
Strategic Plan for Transport Infrastructures (2073 - 2078)	५. काठमाडौं उपत्यका भित्रको पूर्व-पश्चिम तथा उत्तर-दक्षिण लामा रुटहरू फर्पिङ-बूढानिलकण्ठ, थानकोट- धुलिखेल तथा चक्रपथ जस्ता संभाव्य रुटहरूमा मेट्रो रेल संचालनका लागि १ वर्षमा विस्तृत अध्ययन सम्पन्न गरी निर्माण कार्य आरम्भ गरिनेछ।
National Environmentally Sustainable Transport Strategy (2014)	Provision of mass transit in Kathmandu (high-capacity bus, LRT) Invest for pedestrian and NMT infrastructure in Kathmandu and other cities
13th Plan Policy paper	Private investment will attract through PPP to construct Metro rail in KV
The Fifteenth Development Plan (Fiscal Year 2019/20 – 2023/24)	Kathmandu Metrorail Project: 77km metro rail by F/Y 2030/31 Estimated Cost: Rs 470 bln As a National Pride Project to develop electric Railways as secure, reliable, fast and environment-friendly public transport in an urban area.
Kathmandu Valley Development Authority (KVDA) - 20 years plan (2015-2035)	Central Kathmandu will be easy to get around with a walking and cycling network, and transit routes connecting to the urbanising municipalities.

While these plans and policies exist on paper, their implementation has not materialised. There is a lack of interconnection between them, and the transport plans and strategies of various line agencies under federal and provincial authorities, as well as municipalities, are not aligned with the government's overarching vision and strategies.

However, the transport system policies emphasise mass rapid transit, promote electric mobility, and address the need for non-motorised transport (cycling and pedestrian) infrastructure.

7.4 Need of NMT Act and Policy

Active Mobility Bill: Recognising the importance of promoting active mobility modes such as walking and cycling in urban areas, the Directorate of Urban Land Transport (DULT) in Karnataka State, India, has released the Active Mobility Bill (Rajesh & Francis, 2022). This bill prioritises the safety of pedestrians and cyclists and ensures equitable access to road infrastructure.

Chennai NMT Policy: In 2014, the Chennai Corporation Council adopted a non-motorised transport (NMT) policy to promote walking, cycling, cycle rickshaws, pushcarts and other forms of mobility powered by humans (ITDP India, 2014).

Nepal should focus on developing an NMT (Non-Motorised Transport) act and policy, drawing from the Public Roads Act of 2031 (1974). Meanwhile, Lalitpur Metropolitan City is working to promulgate the 'New Cycle Law 2020' (Ojha, 2019), and it has also passed the draft of the Lalitpur Cycle Act 2076 (Ojha, 2019).

8. Integrated Transport

Integrated transport (Figure 8.1 a) refers to a coordinated system that combines different modes of transportation. A successful integrated transport system should result in higher demand for public transport, with a knock-on reduction in congestion and pollution (ITS, 2012).

- In the Kathmandu Valley, all modes of transport are partially integrated, with no coordination in terms of timetables and ticketing.
- Modal shift infrastructure is not planned. Provision of infrastructure, such as bays/stops for buses, tempos, taxis, car/motorcycle parking, bicycle stands, passenger waiting areas, and pedestrian crossings, is essential for transport integration.
- It is recommended to increase investment in traffic technology for control and safety in the KV transport system.

In the proposed integrated transport system with mass rapid transit (MRT) in the Kathmandu Valley, illustrated in Figure 8.1 a), the Ministry of Physical Infrastructure and Transport (MoPIT) and JICA have collaborated to finalise the optimal routes with the highest traffic and determine the necessary forms of MRT.

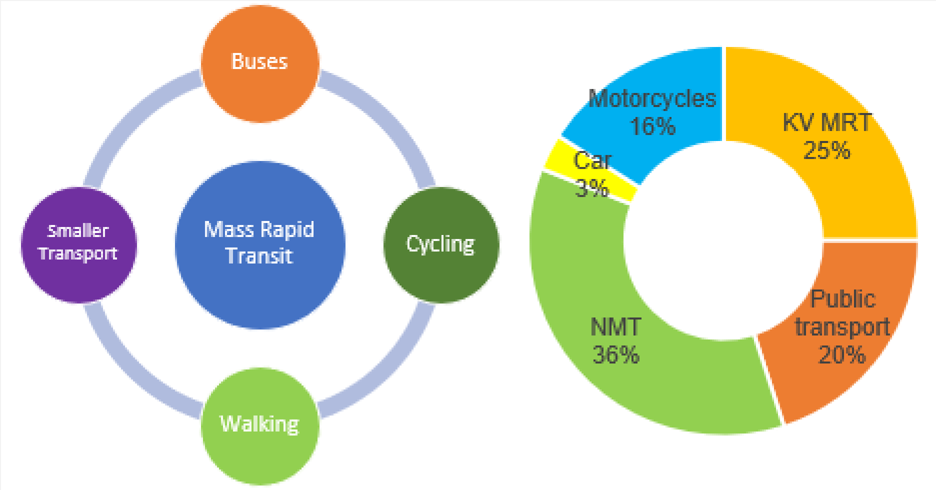

Figure 8.1 a) Integrated Transport Components, b)MRT absorbs 25% trips

Integration with MRT: According to KSUTP modelling outcomes, the proposed MRT system will absorb 28% of total trips (KSUTP/ADB, 2018). The scenarios with and without the KV metro rail are illustrated in Figure 8.1 b) The integration of metro systems is expected to absorb the growing number of motorcycle trips, alleviate traffic congestion, and increase the number of public transport users (Shrestha et al., 2021).

9. Sustainable Transport

A sustainable urban transportation system can be achieved through land use planning, opportunities for walking and cycling (NMT) transport by reducing adverse impact on the environment with balanced integrated transport system (UN ESCAP, 2012). While the current transportation system in the Kathmandu Valley is primarily based on public transport (PT), there are limited provisions for non-motorised transport (NMT). Enhancing NMT infrastructure is essential to alleviate traffic congestion.

9.1 Sustainable transport hierarchy

Traditionally, cities in the Kathmandu Valley were designed with a focus on walking and communal spaces. It is advisable to revise the Road Users Hierarchy to prioritise sustainable transportation options such as walking and cycling over vehicular roads. Following the Scottish Government's draft National Transport Strategy, which prioritises 'walking and wheeling' over private cars, authorities should invest in sustainable infrastructure (Figure 9.1). The JICA 2012 report on Traffic Improvement in Kathmandu Valley also recommends advancing sustainable urban mobility through the development of non-motorised transport (NMT) infrastructure.

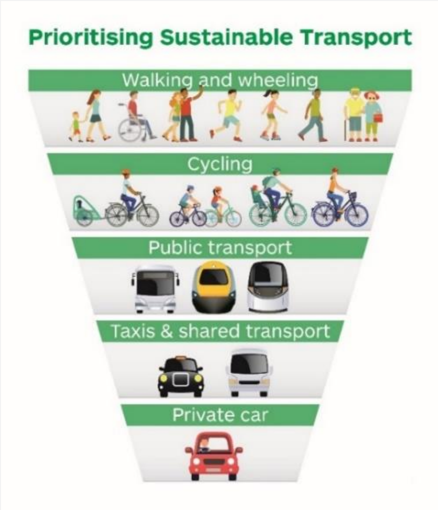

Figure 9.1 Sustainable Transport Hierarchy

9.2 Avoid-Shift-Improve (ASI)

The A-S-I approach (GIZ, 2019), initially developed in Germany (Figure 9.2), serves as a structured framework for implementing policy measures aimed at reducing the environmental impact of transportation and enhancing the quality of life in urban areas. This approach emphasises the demand side and provides a comprehensive strategy for designing an overall sustainable transportation system. Few examples of ASI tools, applicable to KV are illustrated in Figure 9.2 below.

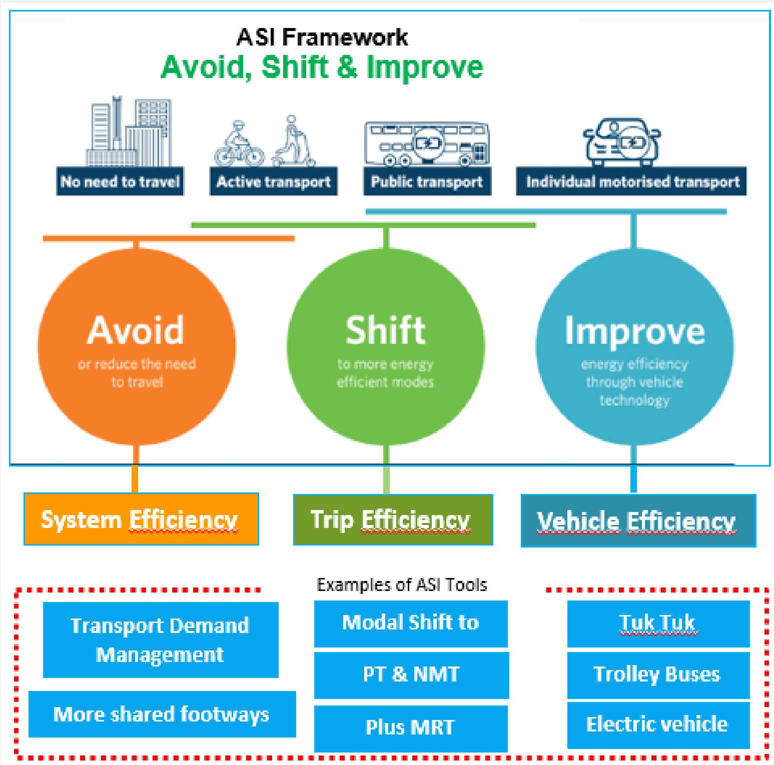

Figure 9.2 Avoid-Shift-Improve *(ASI) Instruments (GIZ, 2019)*

9.3 Seoul's Vision for Urban Transportation

Seoul has outlined a strategy for a 'Paradigm Shift from Car-Centric to People-Oriented Policies,' as illustrated in Figure 9.3 (Yi & Hee, 2016). By comparing the ratios of infrastructure provision for cars, public transport, and pedestrians/cyclists across past, present, and future scenarios, it is evident that urban transport policies are progressively prioritising investment in public transport and pedestrian/cycling infrastructure while decreasing emphasis on roads. This serves as a notable example of successful transportation initiatives.

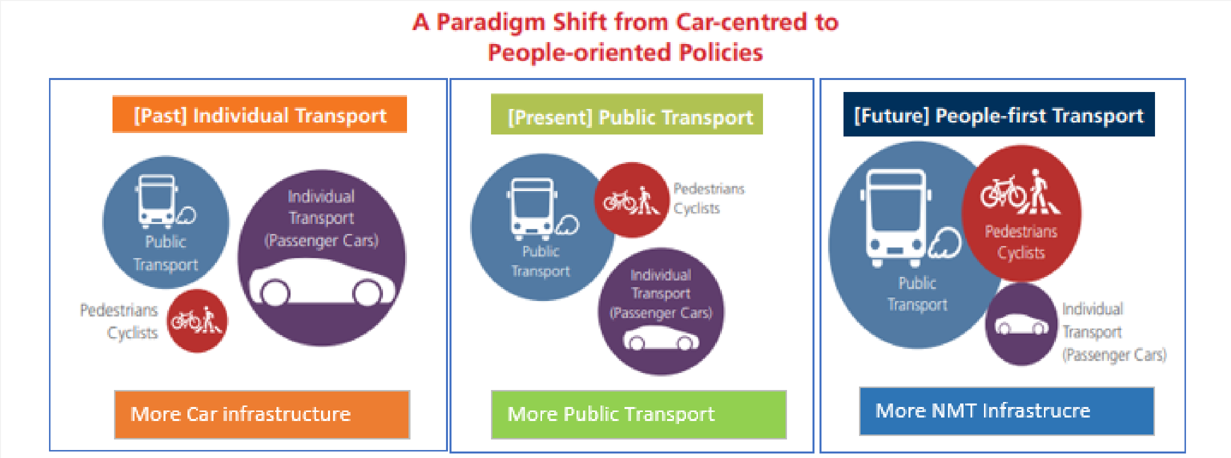

Figure 9.3 Lessons from Seoul and Singapore (Yi & Hee, 2016)

Authorities in the Kathmandu Valley should draw lessons from sustainable transport policies outlined in A-S-I instruments, Seoul's paradigm shift, and the 'Sustainable Transport Hierarchy'. These examples highlight the necessity of redefining transportation strategies in KV to prioritise people-centric and sustainable modes of transport, such as pedestrian pathways and cycle lanes.

10. NMT Network Development in KV

The Kathmandu Valley (KV) lacks adequate pedestrian infrastructure and cycling lanes, especially between public transport stops and major destinations. This deficiency necessitates improvements for a continuous non-motorised transport (NMT) network.

Building walkways and cycle paths along riverbanks and river corridor roads is feasible and complements NMT tracks along the road network. A case study of the Dhobi Khola Corridor (Chitrakar, 2002) highlighted the need for cycle tracks and footpaths along river corridors. The Asian Development Bank (ADB) financed cycle and pedestrian lanes along the Bagmati River over a 20 km stretch.

Constructing more river-crossing bridges for NMT would enhance the network, making cities more pedestrian- and bicycle-friendly, in line with UN ESCAP's NMT vision (2012).

The NMT Network Development in Kathmandu Valley (KV) includes the following initiatives: development of a cycle network, pedestrian network, and intermodal transfer facilities.

To complete footway network and create footways, the following methods are employed:

- Completing the existing network of footways and cycle lanes on primary, secondary, and tertiary public transport routes.

Creating shared footways on residential roads and roads with footways (Figure 10.1), which will redefine 'roads' for public use as mentioned in Public Roads Act (GON, 2035). This involves making one-way carriageways, declaring low-speed zones within residential areas, using reflective road markings and studs, and providing traffic signs to restrict heavy and large vehicles.

Figure 10.1 New Footway introduced on Road

- Creating new networks of footways and cycle lanes along river corridors (Figure 10.2).

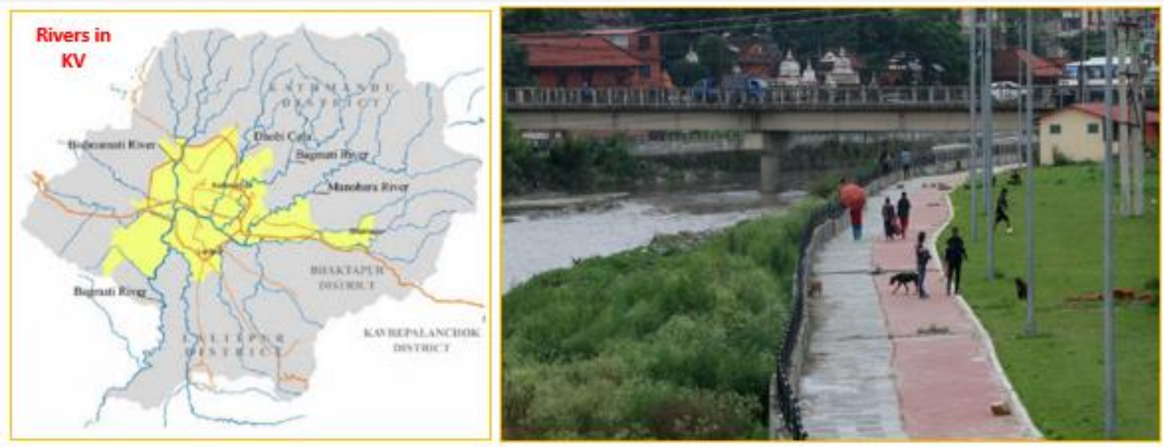

Figure 10.2 a) River System in KV b) Footway & Cycleway Bagmati river (ADB)

Some improvements required for NMT network development include enhancing intersections, upgrading river crossing signals, installing pedestrian signals and pedestrian bridges, and designing road cross-sections with appropriate pedestrian walkways and cycle lanes.

11. Conclusions and Recommandations

The Kathmandu Valley faces significant urban mobility challenges due to rapid urban growth and increased private vehicle ownership, particularly motorcycles. This has resulted in increased travel times, pollution, and unregulated public transport, negatively impacting public health and the economy. Despite numerous transportation studies emphasising the expansion of city and road networks, public transportation routes, and non-motorised transport (NMT) initiatives, current efforts remain isolated and insufficient.

Key recommendations to address these challenges include:

Institutional Reform: Establish separate sections for NMT and public transport within municipalities and relevant authorities to ensure focused and effective management.

NMT Planning: Implement sustainable transport strategies prioritising active and efficient transport modes such as walking and cycling.

Legislation: Advocate for and enact laws to protect and develop NMT infrastructure to provide a legal framework supporting these initiatives.

Budget Allocation: Allocate at least 10% of the transportation infrastructure budget to NMT to ensure sufficient funding for development and maintenance.

Traffic Technology: Invest in modern traffic technology to manage NMT traffic and reduce accidents, enhancing the safety and efficiency of non-motorised transport.

Specific measures for promoting NMT include developing interconnected pedestrian and cycling networks, allocating shared carriageway space, ensuring continuous and wider sidewalks, prioritising pedestrian traffic at crossings, increasing funding in traffic technology, and implementing a 30kph speed limit on shared roads.

To improve urban mobility, alleviate traffic congestion, and enhance public health, the way forward involves prioritising active mobility and public transport over traditional private vehicle use. Emphasising the immediate provision of mass rapid transit (MRT) systems will be crucial in achieving these goals, as MRT is expected to absorb about 28% of vehicle and motorcycle trips, offering a sustainable solution to the valley's transportation issues.

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Neurotechnology and Brain Computer Intelligence Shaping the Future of Biomedical Progress. Emerging AI Revolution in Healthcare and Assistive Technology

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Abstract

This review work examines how neurotechnology and brain-computer intelligence are revolutionizing the field of biomedical advancement. Unprecedented opportunities for comprehending, interacting with, and enhancing the human brain have been made possible by recent developments in these domains. This paper explores the many uses of neurotechnology and clarifies how it affects clinical treatments, biomedical research, and cognitive improvement. The incorporation of brain-computer interfaces (BCIs) has been crucial in the deciphering of neural signals, stimulating creative methods for neuroprosthetics, and opening the door to new therapeutic approaches for neurological conditions. The study looks into the societal ramifications and ethical issues surrounding the quick development of brain-computer intelligence, even as it heralds amazing possibilities and explores developed products in this field with their market outlook and evolutions, economic analysis. An extensive summary of the issues that need to be resolved as these technologies develop is given, including worries about privacy, cognitive enhancement, and the possibility of unforeseen consequences. The study also addresses the function of ethical and governance frameworks in directing the responsible development and application of neurotechnologies, highlighting the necessity of public-private partnership in research and policymaking.

Keywords: Brain Computer Interfacing, Neurotechnology, neuroprosthetics

1. Introduction

Developments in brain science and artificial intelligence (AI) will have a profound effect on society. Adoption of new technologies carries a number of risks, even though technologies built on those advancements can have enormous positive social effects. This article first discusses how artificial intelligence (AI) and brain science have coevolved and the advantages of AI inspired by the brain for scientific advancements, healthcare, and sustainability. Next, we examine potential hazards associated with those technologies, such as deliberate misuse, self-governing armaments, cognitive augmentation via brain-computer interfaces, sneaky impacts of social media, inequality, and entrapment [1]. Numerous studies have looked at AI's technical performance in an experimental setting. These studies only partially address the questions raised by using it in a real-world setting for care and services. This viewpoint paper uses the health technology assessment core model to compare the expectations of the health sector for the use of AI with the risks that should be mitigated for its responsible deployment, thereby providing decision makers with comprehensive and systemic assistance. Because payers—that is, organizations and agencies within the health system—play a pivotal role in the financing, regulation, and reimbursement of innovative technologies, the analysis takes a payers' perspective. This paper argues that rather than being viewed as a distinct collection of technological tools, AI-based systems should be viewed as a lever for the transformation of the health system [2]. The past ten years have seen a huge increase in medical data along with breakthroughs in deep learning and computational hardware (GPUs, cloud computing, and GPUs). Artificial Intelligence (AI) techniques could be used to analyze medical data produced from large molecular screening profiles, individual health or pathology records, and public health organizations in order to expedite and prevent drug discovery pipeline failures. Drug design is facilitated by open-source databases and AI-based software tools; related issues include molecule representation, data collection, complexity, labeling, and discrepancies between labels [3]. This paper investigates the transformative potential of artificial intelligence, 3D printing, and nanomedicine. Artificial intelligence (AI) has revolutionized drug development by personalizing therapies and predicting their effectiveness. Prescriptions, intricate paperwork, and tailors can all be 3D printed to aid in compliance. In nanomedicine, nanoparticles are used to improve solubility and deliver medications more precisely. The effectiveness and role of 3D printing in personalized medicine, AI-driven target identification and tailored treatment, and enhanced drug delivery via nanomedicine are some of the themes that will be covered in the future. Many people will benefit from these developments, which promise to change healthcare. The study's findings provide a comprehensive analysis of impending developments in the pharmaceutical sector and also touch on advances in 3D printing and nanomedicine [4]. The main motivation behind current neuroscience research is the desire to understand the basic workings of the human mind. In order to achieve this goal, advanced techniques and engineering systems that can probe and stimulate neural pathways—from individual cells in small networks to connections throughout the entire brain—are needed. In this context, recent studies lay the groundwork for a wide spectrum of innovative neurotechnologies that allow for distinct modes of operation [5].

1.1 Related Works

This study gives the first analytical methodology for predicting the spread of neurotechnologies to both the commercial and military sectors in the United States and China. While China began its experiment later and with less finance, we discovered that it has other advantages that made early adoption more likely. We also identify national security dangers implied in later adoption, such as the failure to establish international ethical and legal standards for BCI usage, particularly in wartime operational contexts, and data privacy problems for individuals who use technology developed by foreign entities (Koshal et al. 2022).

This paper seeks to provide a picture of the current state of the art, as well as a motivated prognosis of the most likely changes over the next two decades. First, they examine the primary neuroscience technologies for observing and manipulating brain activity, both of which are required components of human cognitive enhancement. They also compare and contrast such technologies based on their particular properties (e.g., spatiotemporal resolution, invasiveness, mobility, energy requirements, and cost), which influence their current and future roles in human cognitive enhancement (Cinel, C., et al. 2019).

The authors analyzed 25,336 information of BCI papers from Scopus to determine the field's development. The study shows that BCI articles in China have grown exponentially since 2019, outpacing those in the United States, which began to fall around the same time. The implications and reasons for this trend are examined. Furthermore, we thoroughly examined the constraints and dangers that limit the utilization of BCI capabilities. A typical BCI architecture is postulated to handle two key BCI risks, privacy and security, in order to make the technology financially feasible for society (Maiseli et al. 2023)

Researches have been carried out in BCI and neurotechnological fields similarly various kind of products developed have been reviewed by researchers as in [1-8]. We aim to contribute to the review the recent advancements in the world or neural systems and biomedical progress with highlighting the major recent advancement in this field as well as the future trends finally, with impact on economic and financial sector with analysis on market trends.

2. Materials and Methods

We use a thorough methodology in this review work to examine the functions and effects of Brain-Computer Interface (BCI) systems, with an emphasis on current developments and the difficulties faced by this quickly developing field. The first stage will involve a thorough review of the literature, including articles from conferences, scholarly journals, and other pertinent publications. By offering a historical perspective and insights into the current state of BCI applications across various domains, including healthcare, neurology, and human-computer interaction, this will lay a strong foundation.

Building on the review of the literature, the paper categorizes BCI applications according to their various roles in a methodical manner. An in-depth analysis covering domains such as healthcare applications, neuroprosthetics, communication interfaces, and other areas where BCI systems are making major contributions will be made easier with the help of this structured categorization. Our classification attempts to provide a comprehensive picture of the various roles that BCI plays in the current research and application environments.

2.1 Comprehending Brain-Computer Intelligence (BCI)

BCI is an innovative technology that creates a direct channel of communication between the brain and outside gadgets. It makes it possible to convert brain activity into meaningful commands that can be used to operate assistive technology like computers and prosthetic limbs. In order to develop BCI systems, neuroscience, computer science, and engineering are integrated, promoting interdisciplinary cooperation to decipher the intricacies of the human brain.

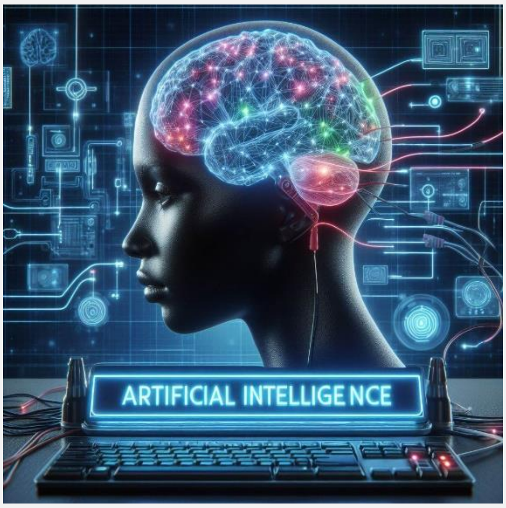

Fig 1. BCI and AI relationship illustration

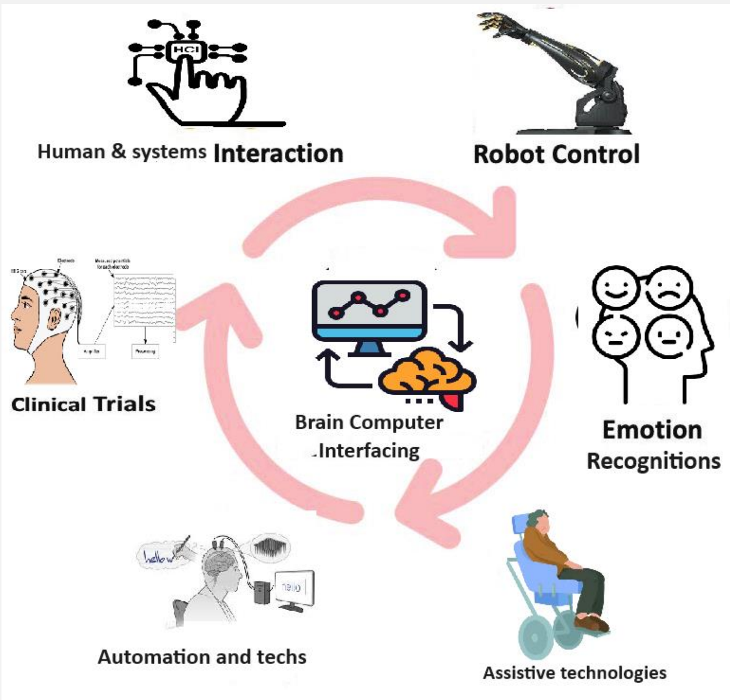

Fig.2. Brain Computer Interfacing applications

2.2 Neurotechnology: Unveiling the Inner Workings of the Brain

The term "neurotechnology" refers to a wide range of instruments and gadgets intended to observe, control, and comprehend the intricate workings of the nervous system. Modern imaging methods like electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) provide scientists previously unheard-of insights into brain activity, opening the door to more precise diagnosis and treatment plans.

The various emerging technologies in Biomedical field are Artificial Intelligence and Machine learning based disease detection/ predictions. The autonomous robots and assistive technologies. The various nanotechnologies systems which are still under research and similarly, Brain Computer Interfacing based systems.

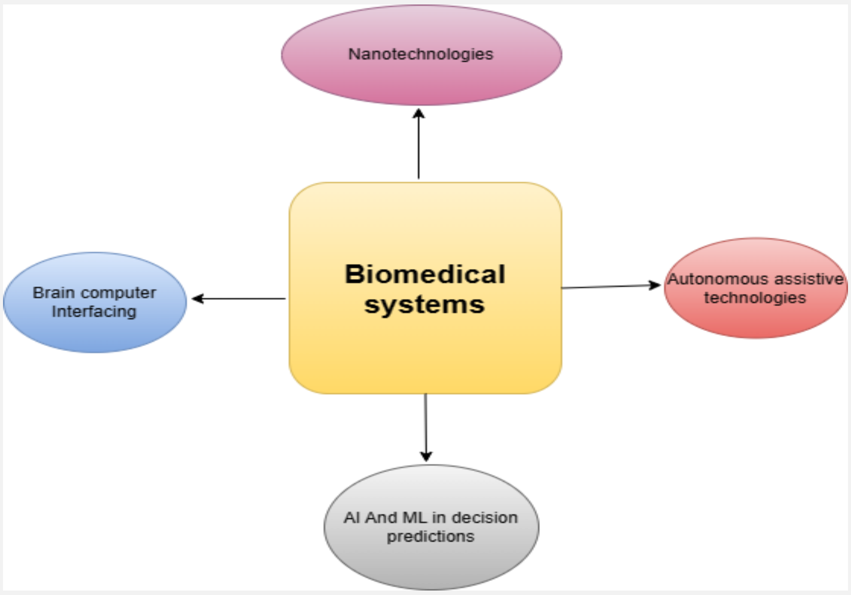

Fig 3. Various field of Biomedical systems

We explore the changing landscape of developing biomedical areas in this study work, concentrating on four important topics. First off, illness prediction and detection are being transformed by artificial intelligence (AI) and machine learning (ML). Large-scale information are analyzed by these technologies to find patterns and markers that point to diseases, enabling early diagnosis and individualized treatment regimens. Second, the way that healthcare is delivered and patients are cared for is changing due to autonomous robots and assistive technologies. These inventions boost human capabilities in medical jobs while improving efficiency and precision, from surgical helpers to caregiving support.

Thirdly, intriguing pathways for tailored medication distribution, imaging, and diagnostics are provided by nanotechnology systems. Researchers want to create more potent treatments with fewer adverse effects by utilizing nanoscale materials and electronics. Finally, systems for Brain-Computer Interfacing (BCI) create direct channels of communication between the brain and outside apparatus. These interfaces have enormous promise for improving our knowledge of brain functions and helping people with impairments regain their motor ability. All things considered, the new wave of biomedical technologies promises better patient outcomes, tailored treatments, and increased diagnostic accuracy, ushering in a new era of healthcare innovation.

3. Results and Discussions

The various application and roles including challenges can be discussed by the significant finding sin the following sector. There is a huge role of artificial Intelligence and emerging automation technologies in the field of human computer interface, neurotechnology.

3.1 Applications in Medicine

The combination of neurotechnology and BCI offers enormous promise for the medical field. These technologies are transforming healthcare, from the diagnosis of neurological disorders to the rehabilitation of people with motor impairments.

Fig 4. BCI in medicine

BCI is enhancing the quality of life for people with disabilities through the use of assistive communication devices, brain-controlled exoskeletons, and prosthetic limbs that are controlled by neural signals.

3.2 Improving Cognitive Abilities:

Research on Brain-Computer Interface (BCI) extends beyond the domain of medicine to the field of improving cognitive abilities. The application of BCIs to improve learning, memory, and decision-making is being studied by researchers. This makes room for cognitive enhancement therapies, which may prove advantageous for people suffering from neurodegenerative diseases or age-related cognitive decline.

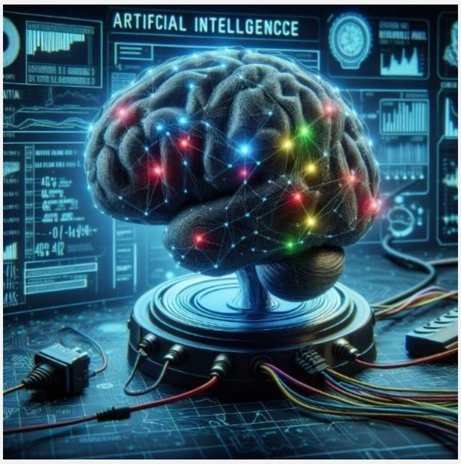

Fig 5. Human mind controlled with AI

3.3 Recent advancements

Recent advancements have been made in the field of BCI technologies including the neuralink developed projects which have been successful in emerging as a new breakthrough in the field of BCI, and Human Computer Interaction.

i. Neuralink developed First Brain Chip Implant in Humans

Neuralink has accomplished a remarkable feat: a human patient has had its brain-computer interface successfully implanted. This is a historic moment for the company. The clinical trial has the potential to change the lives of people with severe movement impairments. It is primarily focused on participants with quadriplegia and ALS who are 22 years of age or older. By enabling thought-based device control, Neuralink's wireless brain-computer interface technology seeks to empower these people. Through innovative advancements in neurotechnology, this remarkable breakthrough offers hope for those facing paralysis by creating opportunities for increased autonomy and improved quality of life (Vázquez,, et al. 2020)

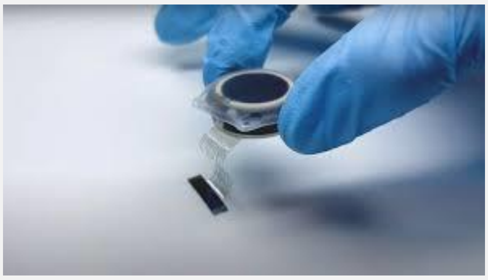

Fig 6. Implant chip

ii. Interoception

"Interoception"—the perception and understanding of internal body signals like heartbeat, hunger, and breathing rate—is one idea that is receiving more and more attention. Our internal barometer, or interoception, directs our reactions to the outside world by taking into account the needs and conditions of our bodies.

Recent studies on interoception, a field of neuroscience that has received little attention, are revolutionizing our knowledge of a variety of mental health issues in addition to our comprehension of how the brain functions.

Iii. From Thought to Text: AI Converts Silent Speech into Written Words

The semantic decoder is a cutting-edge artificial intelligence system that can convert brain activity into continuous text. For those suffering from conditions like strokes, the technology has the potential to completely change communication.

This non-invasive method converts thoughts into text without the need for any surgical implants by using data from fMRI scanners. Half the time, this AI system is able to accurately convey the essence of a person's thoughts, despite its imperfections.

Iv. Psychedelics Unlock Learning Windows in the Brain

The ability of psychedelic drugs to reactivate "critical periods" in the brain, when the brain is most sensitive to environmental learning signals, is an amazing property that researchers have discovered.

Psychedelics have the ability to reopen these periods, which are typically linked to skill development like language acquisition, for variable amounts of time.

This discovery reveals novel molecular pathways impacted by psychedelics and may have therapeutic implications for ailments like stroke and deafness.

3.4 Emerging trends in BCI

3.4.1 Decoding of thoughts

Many facets of human function, including ideas, feelings, and physical acts, are controlled by the brain. The majority of factors are internal, but some, like rage, are visible to others. By decoding these internal signals, technologies such as Brain-Computer Interfaces (BCI) hope to improve lie detection and even allow thought-based machine control. The precision of converting ideas into legible language, transforming dreams into concrete forms, tracking thoughts and sleep cycles, and even retrieving a dying person's will are among the issues raised. The future of BCI may entail directly translating thoughts into physical objects and enabling remote control of machines via brain signals, raising concerns about security and privacy that will need to be addressed through universal standards (Maiseli et.al 2023).

3.4.2 Extension of human memory

Interesting considerations about the possible role of BCI in bringing Stephen Hawking's theory of uploading the human mind into a computer to reality arise. In particular, it raises questions about how memory signals could be taken out of the brain and decoded so that they could be stored in a computer and used to essentially extend human memory. More research into capturing human behaviors and attributes for scientific study may be made possible by recent developments in brain-computer interface (BCI), which have demonstrated promise in converting brain signals into actionable data representing human intents. But in doing so, ethical issues need to be properly considered.

In terms of how BCI might progress in the future, one potential is the creation of portable memory devices that might be linked to BCI equipment to allow for the extraction or injection of data into the brain. With the use of this technology, therapy sessions could be improved by giving counselors precise insights about the behaviors and characteristics of their clients. To realize this vision, though, will need extensive interdisciplinary research as well as a strong ethical framework to direct the process of creation and application (Maiseli et.al 2023).

3.4.3 Automation and control

Brain-Computer Interface (BCI) technology is showing signs of promise. It could be useful in the automation and control sectors, especially for home automation for those with physical disabilities. It is expected that as technology develops, it will positively affect industrial manufacturing processes and may even contribute to the fourth industrial revolution. With potential applications in non-contact control and automation systems, BCI applications could be incorporated into production systems via secure wireless networks to automate operations. To ensure smooth interaction with intelligent sensors and solve the inherent limits of BCI technology, however, further research is required in this regard (Maiseli et.al 2023).

3.4.4 Applications of Nanotechnology in Healthcare Sectors

- **Nanotechnology in Gene Therapy**

Gene therapy aims to replace damaged genes with functional ones, frequently introducing the healthy gene into stem cells through the use of vectors. Because stem cells are long-lived and self-renewing, they are excellent targets. In order for an organism to successfully express genes throughout its life, vectors need to be effective, immune system-hiding, and specialized. Despite their widespread use, viral vectors like as lentivirus and adenovirus carry certain dangers, including the possibility of immunological reactions and insertional mutagenesis.

Since non-viral nanostructures have less potential to cause cancer and to induce an immune response, such as nanoparticles (NPs), they present a safer option. NPs are used for non-viral gene transfer because of their small size, positive charge, and high surface-to-volume ratio. Genes in illnesses like cancer and autoimmune conditions. It is possible to achieve gene silence with them. Nanostructures such as NPs help get around the problems siRNA has with consistent delivery and absorption.

Several studies have demonstrated the effectiveness of nanostructure-based complexes in distributing siRNA to treat diseases including cancer and rheumatoid arthritis. Moreover, genetic materials can be conjugated or encapsulated with NPs for efficient gene delivery, protecting them from phagocytosis and enzymatic digestion. Research continues to be conducted to develop novel strategies for utilizing nano-technology based therapy (Anjum S et.al 2021).

- **Nanotechnology in Targeted Drug Delivery**

Drugs may be delivered to specific locations in the body using nanovectors, which holds great potential for treating a range of illnesses. This tailored delivery is essential, particularly when hydrophobic medications contain potentially hazardous solvents. These solvents have the potential to pollute bodily fluids if they are discharged into other parts of the body. Drug dosages are need to be lower because nanostructures allow for the exact, controlled release of medications in the right proportions. Because of their microscopic size, they can potentially improve cancer treatments by deeply penetrating tumor cells.

Three essential elements are needed to create an efficient drug delivery nanovector: a particle core, an exterior biocompatible protective layer, and a connecting molecule for enhanced bioactivity. Nanovectors are modified before drug delivery, for as by covering them with ligands like peptides, antibodies, and folic acid. To improve specificity, ligands are affixed to nanovectors so they will bind to the intended spots only. Since tumor cells frequently overexpress different types of surface receptors, it is important to attach various ligands to minimize unintentional binding to receptors in other sites. Scientists are actively investigating nanotechnology-based nanosystems for effective targeted medication delivery to tackle numerous critical diseases because of their unique features and modifiability during drug loading. In the sections that follow, targeted medication delivery examples using nanovectors are covered (Anjum S et.al 2021).

- **Treating Cardiovascular Diseases through Nanosystems**

Cardiovascular disorders continue to be the world's greatest cause of death. While heart disease therapies have been shown to increase survival rates, they have not been able to fully regenerate the heart, particularly after a heart attack. By incorporating pro-angiogenic and anti-apoptotic genes into genetically modified stem cells, stem cell therapy holds potential for therapeutic angiogenesis by increasing the cells' rates of secretion and survival. Biocompatible nanoparticles (NPs) effectively transfer genes to stem cells without inducing an immune response, in contrast to viral vectors. Numerous nanostructures, such as liposomes and polymers, have been shown to be effective in delivering genes. Research has also shown that employing chitosan alginate nanoparticles to carry growth factors can improve the function of cardiac tissue after myocardial infarction.

Superparamagnetic iron oxide nanosystems (SPIONs) and quantum dots enable long-term tracking and cell internalization, and NPs also present opportunities for stem cell tracking and monitoring. Targeted drug delivery has been used to treat hypertension, a disorder with many related consequences. Nanocarriers such as lipid carrier NPs, solid lipid NPs, polymeric NPs, liposomes, and nanoemulsions have been used in this regard. Although there are many potential uses, more study on the effects of nanovectors on living cardiovascular systems is required before they can be used safely in humans (Anjum S et.al 2021).

- **Nanotechnology and Bone Regeneration Technology**

Nanotechnology is the manipulation of materials at molecular and atomic scales—extremely small scales. With the goal of developing more accurate and focused materials to encourage bone formation, it is being used more and more in bone regeneration. For example, research is being done on the use of nanoparticles to enhance the efficacy of medications by delivering them directly to places that require therapy. Furthermore, scaffolds that imitate the structure of bones can be created thanks to nanotechnology, which directs the formation of new bone and promotes regeneration. Advanced 3D printing methods with nanomaterials enable the production of extremely precise and personalized implants for bone restoration.

A lot of attention is being paid to treating bone weakness, which has led to studies on the creation and structure of bones using nanotechnology. Researchers are working to create body-compatible nanostructured alternatives to bone grafts. If these projects are successful, they may revolutionize the field of regenerative technology—which fixes broken bones and muscles. In order to improve bone tissue engineering, biomineralization research aims to incorporate bone elements into collagen fibers to create compositions with particular mechanical properties. Furthermore, research is directed toward the development of prosthetic joints and nanoscale coatings for the stabilization of bone growth processes. All things considered, the application of nanotechnology to bone regeneration presents encouraging opportunities for quicker healing, stronger bones, and fewer issues(Malik S et.al 2023).

3.4.5 Challenges and Ethical Issues

Although brain-computer interfaces (BCI) and neurotechnology have enormous potential benefits, there are drawbacks and ethical issues to be aware of. Concerns about data security, privacy, and possible misuse of neurotechnology bring up significant issues that need to be carefully thought through. In order to ensure that these technologies are developed and used responsibly, regulatory guidelines and ethical frameworks are essential. Given the BCI components, five research avenues can be pursued: cognitive psychology, medicine, biomedical electronics, signal processing, and engineering. These directions require multidisciplinary research in which researchers collaborate closely to overcome the BCI sub-challenges. Psychologists and medical doctors should explain the fundamental workings of the brain; scientists should create effective signal acquisition devices and algorithms for processing brain signals (feature extraction, classification, and translation); and engineers should create physical BCI applications and evaluate their performance against predefined standards (Maiseli et, al. 2019).

3.4.6 The Future Outlook

Exciting prospects lie ahead for neurotechnology and BCI. It is anticipated that developments in machine learning and artificial intelligence (AI) will improve the precision and effectiveness of BCI systems. Better signal processing algorithms, device miniaturization, and greater accessibility will probably move these technologies out of research labs and into practical applications.

Working together, researchers, engineers, clinicians, and ethicists will be essential going forward. To fully utilize BCI and neurotechnology, it will be necessary to strike a balance between innovation and moral issues.

4. Conclusions

To conclude, Neurotechnology and brain-computer intelligence represent the cutting edge of biomedical innovation, providing new perspectives on and means of interacting with the human brain. There could be a significant influence on healthcare, rehabilitation, and cognitive enhancement. Responsible development and cooperative efforts can open the door to a future where these technologies contribute to bettering human well-being and our understanding of the brain, our most complex organ. However, ethical concerns and challenges still exist.

A revolutionary change in healthcare is being brought about by the development of artificial intelligence (AI), machine learning (ML), and other cutting-edge technologies. These developments have the potential to completely transform patient care, illness diagnosis, and treatment. These technologies are changing the face of healthcare, from autonomous robots that streamline surgical operations to AI-driven diagnostics that enable early intervention. Moreover, brain-computer interface technologies enable people with disabilities to regain mobility and independence, while nanotechnology systems provide tailored medication delivery with fewer adverse effects. As these technologies develop further, incorporating them into healthcare systems could lead to better patient outcomes, more accessibility, and higher standards of care all throughout the world.

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Bio Engineering and Disaster Risk Management

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Abstract

Asar 7, 2080 landslide in the districts of Panchthar, Taplejung and Sankhuwasabha of Koshi Pradesh caused significance loss of property and livelihood. Research have shown that bioengineering helps to stabilize slope and also reduces soil erosion and thus helps to prevent landslides. This study aims to determine how bioengineering helps to minimize the risk of disasters during the monsoon in hilly regions of Nepal.

Based on a review of literature on the problems faced due to erosion of soil which causes slope failure, measures were discussed through online survey. Based on the survey, a method was discussed which includes the combination of small civil engineering structures and vegetative measures to control soil erosion.

The results indicate that vegetative measures when combined with minor structures were effective in slope stabilization at minimum cost. Cost analysis performed demonstrated that the method was economical through the use of locally available resources and manpower due to its simplicity in structure.

Based on obtained results and discussion, it is recommended that bioengineering measures are suitable for controlling natural calamities like landslides, mass wasting, etc.

Keywords: Landslide, Bioengineering, Slope stabilization, Soil erosion, Hilly regions of Nepal

1. Introduction

Bioengineering involves the application of biological and ecological principles to design and implement solutions that mitigate the impact of disasters on ecosystems, communities, and infrastructure. The principles of bioengineering in disaster risk management revolve around leveraging natural processes, biodiversity, and ecosystem services to reduce vulnerability to disasters and enhance resilience. These principles guide the design and implementation of nature-based solutions that complement traditional engineering approaches. It utilizes living organisms, natural materials, and ecological processes to enhance resilience and reduce vulnerability to natural hazards such as floods, landslides, hurricanes, and wildfires. The combination of bioengineering and small civil engineering structures represents a paradigm shift in disaster risk management, departing from traditional, rigid approaches towards flexible, nature-based solutions. When combined with small-scale civil engineering structures such as check dams, gabions, and retention ponds, these natural elements create a robust network of protection that is both resilient and sustainable. Vegetation measures play a crucial role in enhancing the performance of civil engineering structures by providing additional stability, reducing hydraulic forces, and promoting biodiversity. For example, vegetated riparian buffers can mitigate the erosive impact of riverine floods, while green roofs and living shorelines offer effective stormwater management and coastal protection. This dynamic combination harnesses the power of nature and human ingenuity to mitigate risks, protect communities, and preserve ecosystems in the wake of calamitous events. By synergizing vegetation measures with carefully designed infrastructure, we can forge a path towards a more resilient and sustainable future.

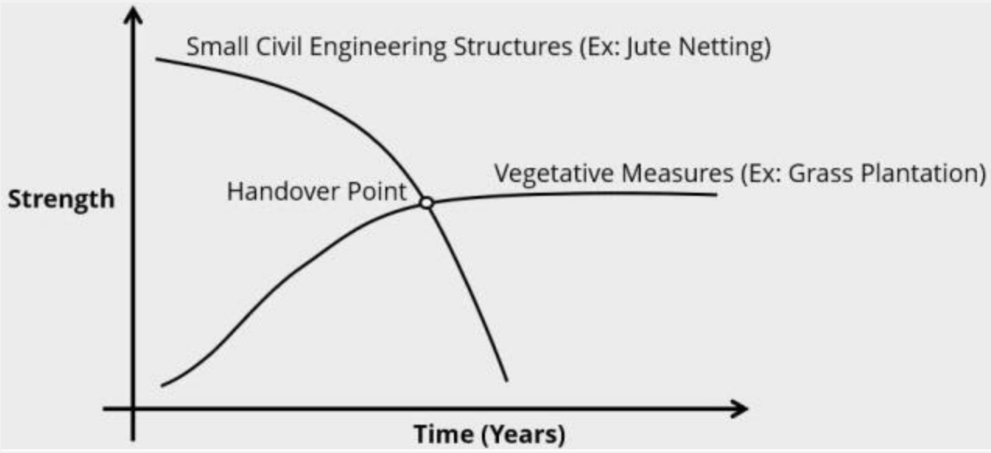

Fig 1: Principle of Bioengineering (by Vivek Dhakal)

2. Literature Review

In recent years, the intersection of bioengineering and disaster risk management has garnered increasing attention as societies grapple with the escalating impacts of natural disasters. Bioengineering, which involves the application of engineering principles to biological systems, offers innovative approaches to mitigate risks, enhance resilience, and promote sustainable development in disaster-prone areas. This literature review explores the integration of bioengineering techniques and technologies into disaster risk management strategies, aiming to synthesize existing research, identify key trends and challenges, and provide insights into future directions for research and practice. Studies by Ghose and Pal

(2017) and Nabiollahi et al. (2018) emphasize the effectiveness of vegetative buffers, such as riparian vegetation and grass strips, in reducing soil erosion, flood runoff, and sediment transport. Similarly, gabions, check dams, and retention ponds are commonly employed to stabilize slopes, control erosion, and manage surface water runoff. Studies by Mazzorana et al. (2012) and Jain et al. (2019) highlight the effectiveness of these structures in reducing flood damage and enhancing slope stability, particularly in mountainous regions prone to landslides and flash floods. Methodological approaches vary across studies, ranging from field experiments and numerical modeling to remote sensing and GIS-based analysis. While field experiments provide valuable insights into the performance of bioengineering interventions under real-world conditions, numerical modeling allows for the prediction of their effectiveness at larger scales. Remote sensing techniques, such as LiDAR and satellite imagery, enable researchers to assess landscape dynamics and monitor changes in vegetation cover over time.

3. Study Area

The study focuses on three districts: Taplejung, Panchthar, and Sankhuwasabha, which recently experienced a devastating landslide due to inadequate geotechnical practices. These districts are situated in a region known for its seismic activity and are part of the Main Central Thrust (MCT) zone, where the Indian plate overrides the Eurasian plate. The geological configuration in this area has resulted in extensive folding, faulting, and fracturing of rocks, significantly heightening the susceptibility to landslides. The occurrence of such disasters underscores the urgent need to assess the effectiveness of bioengineering solutions in mitigating landslide risks in this highly vulnerable region. By studying these districts, we aim to understand the significance of bioengineering techniques in addressing the challenges posed by natural hazards in seismically active areas like the Main Central Thrust zone.

Fig 2: Koshi Pradesh

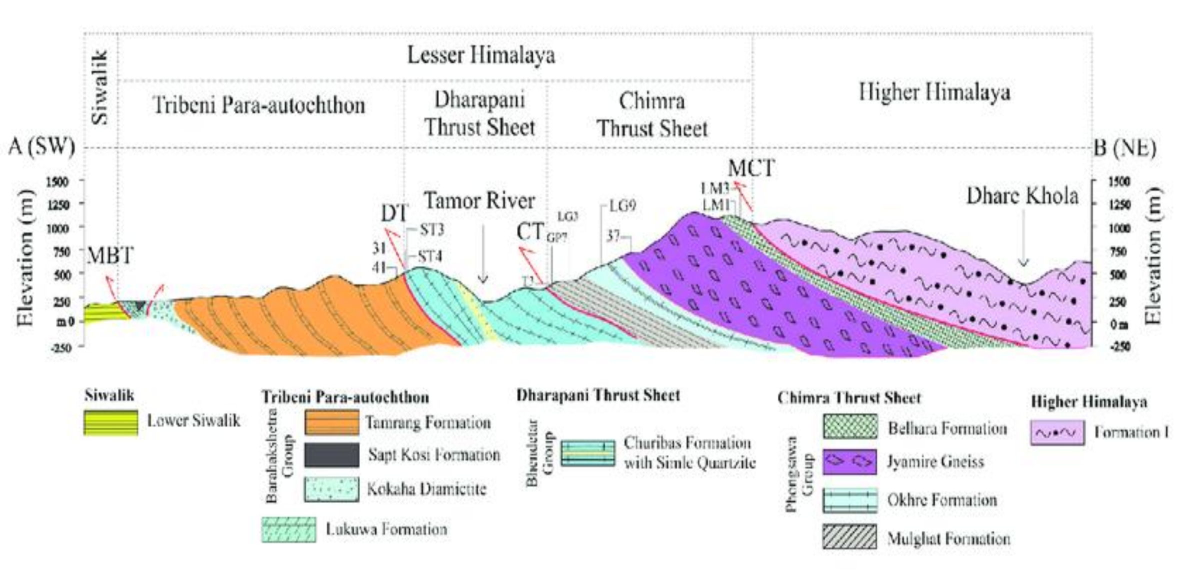

Fig 3: Main Central Thrust (by Drona Adhikari)

4. Methodologies

The combination of vegetation and small civil engineering structures are efficient at minimizing destructions from natural calamities at a higher extent.

4.1. Vegetation

4.1.1. Riparian Buffers

Riparian buffers are vegetated strips of land along the banks of rivers, streams, and water bodies. These buffers help stabilize banks, reduce erosion, filter pollutants, and provide habitat for wildlife. By intercepting runoff and trapping sediment, riparian buffers can mitigate the impacts of flooding and protect water quality.

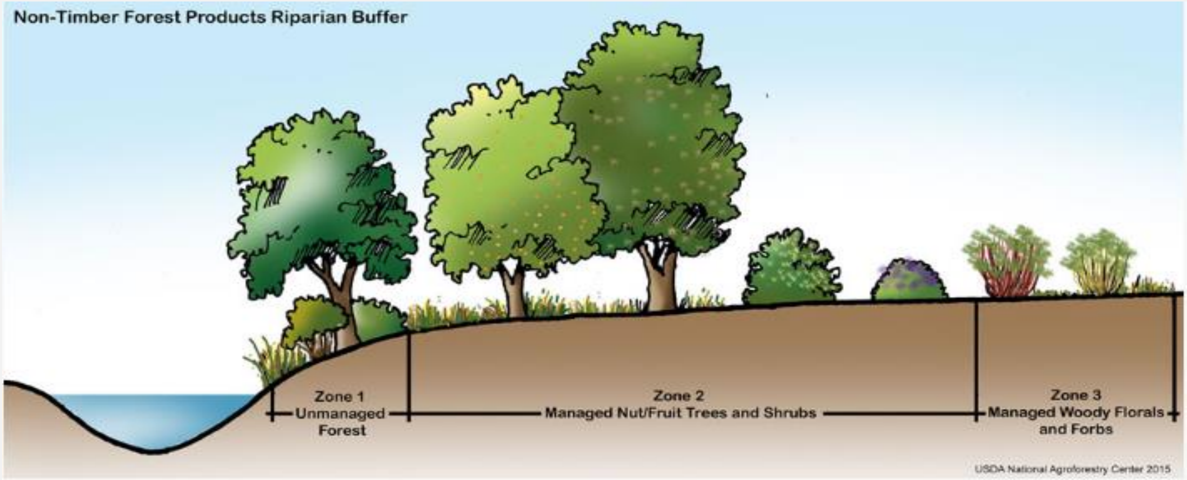

Fig 4: Riparian Buffer

4.1.2. Vegetated Retaining Walls

Vegetated retaining walls are structures designed to stabilize slopes and prevent soil erosion while incorporating vegetation for aesthetic and ecological benefits. These walls are typically constructed using engineered materials such as gabions, concrete blocks, or geogrids, which are then vegetated with plants to enhance stability, reduce surface runoff, and blend with the surrounding landscape.

Fig 5: Vegetated Retaining Wall

4.1.3. Terracing and Slope Stabilization

Building terraces and stabilizing slopes with vegetation can minimize the risk of landslides and soil erosion in hilly or mountainous regions. Terracing involves constructing series of level steps on steep slopes, which can be planted with vegetation to enhance stability and reduce surface runoff.

4.1.4. Grass strip and Contour strip

Grass strips and contour strips are erosion control measures used to minimize soil erosion and surface runoff on agricultural lands. Grass strips are planted perpendicular to the slope, while contour strips are planted parallel to the slope, both serving to intercept runoff, slow water flow, and reduce soil loss. These strips can be implemented along agricultural fields, roadways, or construction sites to mitigate erosion.

Fig 6: Grassed and Contour Strip

4.1.5. Live Fences and Hedgerows

Live fences and hedgerows are vegetated barriers composed of trees, shrubs, or grasses planted along property boundaries or field margins. These natural barriers help reduce wind and water erosion, provide habitat for beneficial insects and wildlife, and enhance landscape aesthetics. Live fences and hedgerows can serve as effective erosion control measures in agricultural and rural landscapes.

4.1.6. Grassed Waterways

Grassed waterways are natural or constructed channels planted with grass or other vegetation to convey runoff and reduce soil erosion on agricultural lands. These channels help slow water flow, trap sediment, and prevent gully erosion by providing a stable and vegetated conveyance for runoff.

Fig 7: Grasses Waterway

4.1.7. Reinforced Turfs

These systems typically consist of reinforced turf mats or grids installed on slopes, which are then vegetated with grasses or other ground cover plants. Reinforced turfs enhance slope stability, reduce surface erosion, and promote vegetation establishment, making them effective measures for landslide prevention and soil erosion control.

4.2 Civil Engineering Structures

4.2.1. Soil Nailing

Soil nailing is a technique used to reinforce and stabilize soil slopes or excavations. It involves installing closely spaced bars (usually made of steel) or other reinforcing elements into the slope or excavation face. These bars are grouted into pre-drilled holes, effectively "nailing" the soil in place. Soil nailing provides lateral support to the soil mass, preventing slope failure, landslides, and erosion.

Fig 8: Soil Nailing

4.2.2. Silt Fences and Erosion control blanket

Silt fences and erosion control blankets are temporary sediment control devices used to prevent soil erosion on construction sites and disturbed areas. Silt fences are installed downslope to intercept sediment-laden runoff, while erosion control blankets are laid over bare soil surfaces to protect against erosion until vegetation establishes.

Fig 9: Erosion Blanket Control

4.2.3. Check Dams

Check dams are small, low-profile structures built across gullies, drainage channels, or streams to reduce water flow velocity, control erosion, and promote sediment deposition. They are typically constructed using rocks, logs, or other natural materials arranged in a series of staggered layers.

4.2.4. Rock Toe Protection

It involves placing large, durable rocks or concrete blocks along the base of the slope or structure to absorb and dissipate the energy of incoming water. Rock toe protection helps prevent scouring, undercutting, and slope failure by providing a stable foundation and erosion-resistant surface.

Fig 10: Rock Toe Protection

4.2.5. Gabion Walls

Gabion baskets are wire mesh boxes filled with rocks or other materials used for slope stabilization, erosion control, and bank protection. They are effective in reducing erosion by dissipating energy from flowing water, preventing scouring, and stabilizing slopes and embankments.

Fig 11: Gabion Wall

5. Case Studies of Panchthar, Sankhuwasabha and Taplejung

5.1. Factors contributing to susceptibility of natural calamities

5.1.1. Excessive Rain

These districts experience a monsoon climate, characterized by heavy rainfall during the summer months (June to September). Intense rainfall can saturate the soil, increase pore water pressure, and trigger landslides, especially in areas with steep slopes and shallow soils.

5.1.2. Steep landforms

The steep slopes and high elevations of these regions make the area susceptible to landslides, particularly during periods of intense rainfall or seismic activity.

5.1.3. Variation in geological composition

The district's geological composition consists of a mix of sedimentary, metamorphic, and igneous rocks. Variations in rock types, weathering characteristics, and geological structures influence the susceptibility to landslides in different parts of these districts especially Sankhuwasabha.

5.1.4. Hydraulic Fracturing

The rock slopes of these regions are subjected to high pore water pressures. Elevated pore water pressure can induce hydraulic fracturing or the initiation of new fractures within the soil or rock mass. As water pressure exceeds the tensile strength of the material, it can induce the formation of cracks or fractures, further weakening the slope and promoting landslide initiation.

5.2. Bioengineering for natural calamity mitigation

5.2.1. Excessive rain

Grassed waterways, consisting of vegetated channels planted with grass species, are designed to convey stormwater runoff and reduce erosion on agricultural land and hillsides. In addition, small-scale civil engineering structures such as **contour bunds** and **vegetated retaining walls** have been constructed to stabilize slopes and prevent soil loss. These measures help in managing disaster risks associated with heavy rainfall, soil erosion, and landslides, thereby protecting livelihoods and infrastructure in the region

5.2.2. Steep Landfoms

Soil nailing is a technique used to reinforce and stabilize soil slopes or excavations. It involves installing closely spaced bars (usually made of steel) or other reinforcing elements into the slope or excavation face. These bars are grouted into pre-drilled holes, effectively "nailing" the soil in place. Soil nailing provides lateral support to the soil mass, preventing slope failure, landslides, and erosion.

5.2.3. Variation in geological composition

The slope reinforcement techniques such as **soil nailing**, **rock bolting**, **retaining walls**, and **slope terracing** to improve slope stability and reduce the risk of failure in areas with variable geological compositions.

5.2.4. Hydraulic Fracturing

Installing **surface drainage systems**, erosion control measures, and vegetation buffers helps to intercept runoff and stabilize slopes. Similarly, the proper implementation of groundwater monitoring and dewatering techniques where necessary to reduce pore water pressure in saturated slopes.

6. Cost Analysis

6.1. Initial Investment

The initial investment required for small civil engineering structures predominantly encompasses the utilization of locally available materials. This includes stones for gabion walls, timber, vegetation, and semi-skilled manpower. Leveraging these resources not only minimizes costs but also ensures a sustainable approach to construction in the study area. By utilizing indigenous materials and semi-skilled labor, the initial financial outlay can be optimized while simultaneously fostering local economic development and environmental stewardship.

6.2. Operation and maintenance cost

The operation and maintenance costs associated with minor civil engineering projects are typically minimal due to the limited use of machinery components. Unlike larger-scale projects that rely heavily on machinery, minor projects implemented in the study area require minimal ongoing maintenance. As a result, the associated operational expenses are negligible. This characteristic further underscores the cost-effectiveness and sustainability of utilizing bioengineering techniques for landslide mitigation in the study area.

6.3. Lifecycle Analysis

Civil engineering projects implemented through bioengineering methods exhibit a more sustainable lifecycle compared to traditional methods. By incorporating bioengineering techniques, such as the use of natural materials and vegetation, these projects not only provide effective landslide mitigation but also contribute to the long-term ecological health of the surrounding environment. For example; Bioengineering projects utilize locally available natural materials, such as stones, timber, and vegetation, which have minimal environmental impact during extraction and processing compared to conventional construction materials like concrete and steel.

6.4. Risk Reduction Analysis

Bioengineered solutions prioritize the use of natural materials and vegetation, which enhance the stability of slopes and soil. By leveraging natural processes, such as root reinforcement and soil binding by vegetation, bioengineered structures are better equipped to withstand erosive forces and mitigate the risk of landslide occurrence. For example; unlike rigid structures associated with traditional methods, bioengineered solutions can flexibly respond to changes in soil moisture, slope dynamics, and vegetation growth, ensuring ongoing effectiveness in landslide risk reduction over time.

6.5. Cost Benefit Analysis

The comparison between bioengineering and traditional methods reveals that the cost required for mitigating natural calamities is significantly lower with the implementation of bioengineering techniques. Based on above comparisons, the cost required for mitigating natural calamities is significantly less with the help of bioengineering.

7. Conclusion

The adoption of bioengineering measures is a suitable approach for controlling natural calamities such as landslides and mass wasting in hilly regions. By harnessing the inherent resilience of ecosystems and combining it with innovative engineering solutions, communities can enhance their capacity to withstand and recover from disasters, thereby fostering a more sustainable and resilient future. The findings indicate that the integration of vegetative measures with minor civil engineering structures proves to be a cost-effective solution for slope stabilization. Similarly, a comprehensive cost analysis reveals that the proposed method utilizes locally available resources and semi-skilled manpower, resulting in minimal initial investment and operation costs. This paper analyzes the effectiveness of bioengineering techniques in stabilizing slopes and reducing soil erosion, thereby aiding in landslide prevention. By leveraging vegetative measures and small civil engineering structures, the study aims to ascertain their role in minimizing disaster risks during the monsoon season in hilly regions of Nepal.

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Racial Bias in AI-generated Images: A Case Study on Nepalese Faces

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Abstract

Since its breakthrough in the 1960s, AI art gradually started leaving computer laboratories through the 70s. From 2024, visual generative AI has exponentially risen through several easily available online applications. Following a review of recent research on racial bias and its presence in elimination from AI algorithms, this paper considers variables like text prompts, iterations, and choice of text-to-image generators in analysing Nepalese faces as a case study. It makes important observations on categorised sets of AI-generated images to conclude how AI bias can enter a learning system through training and re-training by users who act as a medium for transferring the racial bias from the real world to the artificial world.

Keywords: Generative AI, text-to-image, AI bias, racial bias, Nepalese face

1. Visual Generative AI

1.1 Brief History of AI Art

Artificial Intelligence (AI) has been defined by different scholars differently but most of them agree that it is a system that imitates humans in the way they think or act rationally (Bellman, 1978; Haugeland, 1989; Rich and Knight, 1991). While AI has developed along several of its branches since its inception in the mid-1950s, mankind's inherent interest in automating creativity got due priority. The use of AI in creating artworks started as early as in the 1960s at the University of California, San Diego (McCorduck, 1991). While AI applications to generate graphical works like AARON were extensively being researched inside laboratories, it gradually made its public appearance after a decade in the early 1970s at exhibitions like the 1972 show titled 'Three behaviours for the partitioning of space' held at the Los Angeles County Museum of Art (Grimes, 2016). By the early 1990s, AI art progressed to a competitive level; not only fetching recognition to its creators but also progressing from stills to moving images, thereby generating machine-made animations through applications like the Electric Sheep (Whitelaw, 2004).

Development and continuous refinement of Large Language Models (LLMs) have made it possible for traditional AI to shift from discriminative data-driven tasks to more creative models that generate content like text ranging from literature to programming codes which was limited to human abilities until late. GPT-4 for instance was developed by OpenAI using an unprecedented scale of computing and data (Bubeck et al, 2023). Generative Artificial Intelligence (GAI) deals with the production of novel and realistic content based on the prompt by its user (Banh and Strobel, 2023). ChatGPT is by far the most widely known generative AI tool which surprised the world by carrying out complex tasks in the most sophisticated way. On the other hand, its inherent limitations like generating wrong information and data biases have been discussed in the past (Baidoo-Anu and Ansah, 2023). Besides AI-enabled text generation, an emerging branch of generative AI is the Visual Generative Artificial Intelligence (VGAI) or Generative Art which deals with generating image or video with the textual input from its users. Generative art has been defined as the art created after an artist ceding some degree of control to an autonomous system (Galanter, 2019).

1.2 Text-to-image Generators

While AI-enabled text generating models use language models like GPT-3, GPT-4 and PaLM 2, AI-enabled image generating models employ the users to feed text input which guides AI to deliver a visual output. Since they evolve on their own after passing the stage of training provided by humans, their accuracy and reliability have been questioned. Previous research has suggested the elimination of unintended bias and misinterpretations to improve the accuracy and reliability of Generative AI (Combs et al, 2024). Text-to-image generators accept natural language as input to process it using deep learning before providing digital images as output. Known as a *prompt*, the natural language input by users has been studied for enhancement using an evolutionary algorithm (Wong et al, 2023).

Perhaps the most popular Visual Generative AI model is the DALL-E which has been revised as DALL-E 2 and DALL-E 3. Released by OpenAI in 2021, DALL-E uses GPT-3 as its LLM but modified to generate images. While DALL-E 2 considered concepts, attributes and styles, DALL-E 3 improved the understanding of more nuance and detail. DALL-E is a deep neural network model based on Transformer architecture. The major workhorse of Transformer architecture is a technique called (self-)attention, - capable of predicting part of input text as more relevant wherein to shift its focus to generate the output image. The data-driven approach of the deep neural network model makes it hard to align with human values, hence it can be questioned whether the data-driven approach is a point of entry for machine bias.

At this stage, it can be useful to understand how DALL-E works. An input into a text encoder is called a text prompt. A text encoder is trained to map the prompt to a representation space. Mapping of the text encoding to its corresponding image encoding is performed by a model called the prior that captures the semantic information of the prompt. A resulting image representation of this semantic information is stochastically generated by an image decoder. Other popular text-to-image generators also include *Photosonic, Jasper Art, Midjourney* and *NightCafe*.

2. The AI Bias

2.1 Source of Bias in AI Algorithms

AI algorithms are fast emerging as a promising alternative to human-aided decision-making in a growing number of fields. While it can hugely reduce the costs and improve the level of analysis through the handling of large-scale data beyond human capacity, it is equally important to consider points where the training process can be misled to capture an unrealistic reflection of the real world. This is no less important for Visual Generative AI models as they can generate images that are different from reality, easily noticeable through a first gaze. Such an output can get outright disapproval from the users and it cannot be guaranteed that repeated trials or modified inputs can correct the bias once embedded in the learning system.

When we investigate the possibility of an AI algorithm being biased, its source is no other than the society we live in. It is the input or sample data extracted from the real world that already comes with inherent bias and discrimination. It is said to be rooted in the psychological, social, and cultural dynamics of our society which is transferred to the training data of AI models (EAFR, 2022). However, this limitation of Generative AI is not an additional fault in the model but a legacy from the traditional discriminative AI. Apart from *data bias*, there is also the possibility of an *algorithmic bias* which is independent of the dataset used for training (Mehrabi et al, 2022). It is an outcome of overfitting and not learning the data distribution correctly (Ferrara, 2023). A third kind of AI bias called *cognitive bias* is known to be generated from people's selection of data under the influence of their experiences and preferences (IBM, 2023). However, this research will be limited to data bias for the scope of this paper.

2.2 Consequences of AI Bias

In a purely technical environment, AI bias is known to impact efficiency and optimise algorithmic performance (Mooney, 1996). When the bias derived from the dataset is about actual humans, the AI-enabled system will also deliver social discrimination like those against a certain religion, race, and sex among others (Fuchs, 2018). Various metrics to measure biases in AI algorithms have been studied, leading to proposing robust cross-disciplinary collaboration embedding technical, legal, social, and ethical dimensions as a solution to bias and discrimination (Ferrer et al, 2021).

While we have termed data bias in AI systems as derived from faulty data provided by a biased human society, it is also true that when the biased system is used by a new community, its users can absorb the bias from AI and propagate it across the user community. This creates more harm by simply multiplying the social bias in the real world which will mostly impact the already marginalised communities. Recent research has found that people tend to incorporate AI bias in their future decisions even after they are not exposed to the biased AI system for instance being guided by fake AI suggestions from the past (Leffer, 2023). However, it can also be argued that AI-generated imagery is reflective of the real world if it has continued to retain the bias. It thus acts as a rare medium to illustrate the bias that exists in society as well as a quantifiable metric to voice for social change. There are various types of discrimination which form the skewed perspective of the society we live in. Those identified in generative art include ageism, sexism, racism, classism, conservatism, urbanism, and anachronism among others (Thomas and Thomson, 2023).

3. Racial Bias

1.1 Introduction to Racial Bias

Racial bias is different to racism. While *racism* is the belief that a certain race is superior or inferior, *racial bias* on the other hand is our prejudice from unconscious preconceptions or experiences. Oxford University's catalogue of bias defines racial bias as 'a distortion arising from systematic, institutional, interpersonal or individual forms of explicit (conscious) or implicit (unconscious) prejudice against individuals or groups based on social constructs of race or ethnicity' (Naicker and Nunan, 2023). While we tend to be aware of racism as an anti-social behaviour, racial bias is not easily detectable as it can unconsciously influence our decisions and understandings. While racial bias has been studied in various fields like medicine, education, management, and governance, its awareness and control over AI algorithms can influence all other fields in due course.

Several complex factors contribute to racial bias. Besides psychological research on the individual level, evidence of systematic racial bias from the interpersonal to the cultural levels has also been studied (Sinner-Dorkenoo et al, 2023). Human ability to recognise other-race faces is always poorer than that of own which is called the *other-race effect* or ORE (Meissner and Brigham, 2001). It has been suggested that mainly perceptual and socio-cognitive factors contribute to ORE (Hugenberg et al, 2010). Recent academic research has shown that AI-enabled image generators like *MidJourney* showed racial bias by building images of journalists and reporters who are almost always white individuals (Thomas and Thomson, 2023b).

1.2 Towards the Elimination of Racial Bias

If humans are prone to ORE, it can be said that AI algorithms that are trained by datasets provided or selected by human contributors cannot be free from racial bias as well. While the need for getting rid of racial bias from generative AI has been mostly studied for health systems, for instance, its importance in visual generative AI needs no exaggeration. In today's world, the overdose of multimedia information in cyberspace faces the challenge of its reliability and the risk of false data leading to unfavourable results is ever-increasing.

An interesting method proposed to reduce uncertainty from generative AI involves the conversion of text-to-image followed by the reversal of image-to-text or automated captioning. The text prompt can then be compared with the caption output to normalise the uncertainty in visual generative AI (Combs et al, 2024). Based on sentiment analysis, previous research has shown that AI systems show slightly higher sentiment intensity predictions for one race or one gender (Kiritchenko and Mohammad, 2018). Similar text analysis can be conducted over images once they are auto-captioned and equated to their text equivalent.

Regardless of the method employed, it can be argued that elimination of bias may not be possible in entirety, whether it be in humans or machines. Efforts can be made, however, to reduce this human-inflicted bias in generative AI through expert interventions and deliberate iterations of datasets that aim towards normalising racial bias. As is true with all training systems, the quality of datasets eventually decides the fidelity of the system.

2. A Case Study of AI-generated Nepalese Faces

2.1 Methodology

A test was carried out to generate Nepalese faces using different user prompts, iterations, and platforms. A total of four iterations were carried out for each of the user prompts. Three different text-to-image generators were tested for all user prompts and integrations. The images thus generated from each prompt, iteration and platform were indexed and grouped into different categories for further analysis. Sets of images were provided to test observers to rate the results.

2.2 Selection of Image Generators, Text Prompts and Iterations

A total of three text-to-image generators were used as shown in Table 1 with their abbreviations.

Table 1: Text-to-image generators used for this research

S.no	Text-to-image Generator	Abbreviation
1	DALL-E 3	DE
2	Stable Diffusion	SD
3	Adobe Firefly	AF

DALL-E 3 and Stable Diffusion are industry leaders that power most of the other text-to-image generators in the market. They are the pioneers in visual generative AI with a strong community base. DALL-E 3 was tested through the portal *Dall-e Free* (https://www.dall-efree.com) powered by *Dreamvibe AI*. Stable diffusion was tested through *DreamStudio* portal (https://beta.dreamstudio.ai/generate) powered by *Stability AI*. On the other hand, Adobe Firefly (https://firefly.adobe.com) is a more recent launch which is smoothly integrated into professional image processing tools like *Adobe Photoshop* and *Adobe Illustrator* and hence comes with a huge potential to make a wide impact on the graphics and creative industry. Adobe Firefly was tested directly through Adobe's Firefly portal using an Adobe enterprise edition of *Creative Cloud*.

A total of seventy-two images were produced using six different user prompts from Table 2 for four iterations on three separate image generators from Table 1.

Table 2: Text prompts used for this research

S.no	Text Prompt
1	*Nepal, face*
2	*Nepali, face*
3	*Nepal, people*
4	*Nepali, people*
5	*Nepal, people, face*
6	*Nepali, people, face*

2.3 Image Indexing

Each image was indexed using the following convention:
Generator Code (G) – Prompt Code (P) – Iteration Number (I) such that,

G = DE for DALL-E 3, SD for Stable Diffusion, and AF for Adobe Firefly
P = 1 to 6 representing prompts from Table 2
I = 1 to 4 representing each iteration number

e.g., DE-1-4 is the indexed-image for the 4th iteration for the prompt *"Nepal, face"* on DALL-E 3.

2.4 Image Sets

A group of indexed-images were collected to form an *image-set*. An image-set was represented as {comma-separated list of indexed-images} or abbreviated as G-P-I where one of the three variables in the naming convention is specified as X, meaning any.

e.g., {**DE-6-X:** DE-6-1, DE-6-2, DE-6-3, DE-6-4} is an image-set generated using all four iterations of 6th text prompt or *"Nepali, people, face"* on DALL-E 3, as shown in Figure 1.

Figure 1: Image-set {DE-6-X: DE-6-1, DE-6-2, DE-6-3, DE-6-4}

Another example {**SD-1-X:** SD-1-1, SD-1-2, SD-1-3, SD-1-4} is an image-set generated using all four iterations of the 6th text prompt or *"Nepal, face"* on Stable Diffusion, as shown in Figure 2.

Figure 2: Image-set {SD-1-X: SD-1-1, SD-1-2, SD-1-3, SD-1-4}

Finally, image-set {**AF-2-X:** AF-2-1, AF-2-2, AF-2-3, AF-2-4} is generated using all four iterations of the 2nd text prompt or *"Nepali, face"* on Adobe Firefly, as shown in Figure 3.

Figure 3: Image-set {AF-2-X: AF-2-1, AF-2-2, AF-2-3, AF-2-4}

2.5 Categories of Image Sets

A group of image-sets were collected to form an *image-set-category* based on the variable being Generator (GR), Text Prompt (TP) or Iteration (IR).

An image-set-category was represented as [comma-separated list of image-sets] or abbreviated as G-X where G(=GR), X:1, 2, 3; G(=TP), X:1,2,3,4,5,6; G(=IR), X:1,2,3,4}.

e.g., IR-2 = [DE-X-2, SD-X-2, AD-X-2]
= [{DE-1-2, … DE-6-2}, {SD-1-2, … SD-6-2}, … {AF-1-2, … AF-6-2}]

Where IR-2 is an image-set-category using 2nd iteration of all six text prompts from Table 2 on all three generators from Table 1.

Three groups of image-set-categories were used to study the results as per the variables involved in the research viz., prompt, iteration and generator as shown in Table 3.

Table 3: Groups of image-set-categories used for this research

Variable	Image-set-category	Image-set-category Group
Generator	GR-1	[{**DE-1-X:** DE-1-1, … DE-1-4}, {**DE-2-X:** DE-2-1, … DE-2-4}, … {**DE-6-X:** DE-6-1, … DE-6-4}]
	GR-2	[{**SD-1-X:** SD-1-1, … SD-1-4}, {**SD-2-X:** SD-2-1, … SD-2-4}, … {**SD-6-X:** SD-6-1, … SD-6-4}]
	GR-3	[{**AF-1-X:** AF-1-1, … AF-1-4}, {**AF-2-X:** AF-2-1, … AF-2-4}, … {**AF-6-X:** AF-6-1, … AF-6-4}]
Text Prompt	TP-1	[{**X-1-1:** DE-1-1, SD-1-1, AF-1-1}, {**X-1-2:** DE-1-2, SD-1-2, AF-1-2}, {**X-1-3:** DE-1-3, SD-1-3, AF-1-3}, {**X-1-4:** DE-1-4, SD-1-4, AF-1-4}]
	TP-2	[{**X-2-1:** DE-2-1, SD-2-1, AF-2-1}, {**X-2-2:** DE-2-2, SD-2-2, AF-2-2}, {**X-2-3:** DE-2-3, SD-2-3, AF-2-3}, {**X-2-4:** DE-2-4, SD-2-4, AF-2-4}]
	TP-3	[{**X-3-1:** DE-3-1, SD-3-1, AF-3-1}, {**X-3-2:** DE-3-2, SD-3-2, AF-3-2}, {**X-3-3:** DE-3-3, SD-3-3, AF-3-3}, {**X-3-4:** DE-3-4, SD-3-4, AF-3-4}]
	TP-4	[{**X-4-1:** DE-4-1, SD-4-1, AF-4-1}, {**X-4-2:** DE-4-2, SD-4-2, AF-4-2}, {**X-4-3:** DE-4-3, SD-4-3, AF-4-3}, {**X-4-4:** DE-4-4, SD-4-4, AF-4-4}]
	TP-5	[{**X-5-1:** DE-5-1, SD-5-1, AF-5-1}, {**X-5-2:** DE-5-2, SD-5-2, AF-5-2}, {**X-5-3:** DE-5-3, SD-5-3, AF-5-3}, {**X-5-4:** DE-5-4, SD-5-4, AF-5-4}]
	TP-6	[{**X-6-1:** DE-6-1, SD-6-1, AF-6-1}, {**X-6-2:** DE-6-2, SD-6-2, AF-6-2}, {**X-6-3:** DE-6-3, SD-6-3, AF-6-3}, {**X-6-4:** DE-6-4, SD-6-4, AF-6-4}]
Iteration	IR-1	[{**DE-X-1:** DE-1-1, … DE-6-1}, {**SD-X-1:** SD-1-1, … SD-6-1}, {**AF-X-1:** AF-1-1, … AF-6-1}]
	IR-2	[{**DE-X-2:** DE-1-2, … DE-6-2}, {**SD-X-2:** SD-1-2, … SD-6-2}, {**AF-X-2:** AF-1-2, … AF-6-2}]
	IR-3	[{**DE-X-3:** DE-1-3, … DE-6-3}, {**SD-X-3:** SD-1-3, … SD-6-3}, {**AF-X-3:** AF-1-3, … AF-6-3}]
	IR-4	[{**DE-X-4:** DE-1-4, … DE-5-4}, {**SD-X-4:** SD-1-4, … SD-5-4}, {**AF-X-4:** AF-1-4, … AF-5-4}]

3. Observations

3.1 Based on the Prompt Variable

In general, generative AI is known to improve its results when text prompts are not too less, and the words selected are more specific. This was demonstrated in the difference between the two-word and three-word prompts. For instance, image-sets SD-5-X and SD-6-X that used three-word prompts showed consistently better results over SD-1-X and SD-2-X that used two-word prompts, which is demonstrated in the comparative Figure 4 below.

Comparing the image-set SD-1-X with the rest of the image-set-category GR-2, the adjective *'Nepali'* was more descriptive of the noun *"face"* than having another noun *'Nepal'* in the text prompt. SD-1-X comprised more abstract compositions merging the concepts of "Nepal" and "face", whilst borrowing historical references from traditional art and religion of Nepal.

AF fell into the same issue of merging an aspect of "*Nepal*", i.e., snow leopard, with the concept of "*face*" in attempting to generate images for the prompt *"Nepal, face"*. It fell short of understanding the prompt as *a human face from Nepal* before merging two different nouns to derive a combined meaning. The importance of the presence of a descriptive prompt can also be highlighted by comparing the difference in output by the same generator AF shown in Figure 5.

Figure 4: Image-sets SD-1-X, SD-2-X, SD-5-X and SD-6-X from Image-set-category GR-2

Figure 5: Image-set {AF-1-X: AF-1-1, AF-1-2, AF-1-3, AF-1-4} for the Prompt "Nepal, face"

3.2 Based on the Iteration Variable

Increasing the number of iterations on two of the generators viz., DE and SD showed that they followed a routine output that maintained the frequency between single and multiple faces. This was not true for the third generator AF which consistently produced single faces per iteration. AF maintained this for more than one text prompt and iterations. This output was based on the abesnce a singularity specifier "a" before the text prompt. Over more iterations it was found that both male and female faces were picked by all three generators, discarding the possibility of gender bias.

3.3 Based on the Generator Variable

A comparison between Figures 1, 3 and 4 shows that generators DE and SD showed Nepali faces almost always in rural settings and Himalayan communities, mostly inhabiting the northern region. They completely ignored Nepalese communities from central or southern regions and more urban areas of the country. Ageism was noticed in images generated by DE which mostly included the elderly population. DE also paralleled the Nepalese nationality with an imaginary tribal community with tattooed faces which is not representative of the overall population of Nepal as in Figure 1.

In contrast, AF showed minimum racial bias by generating Nepalese faces representing distinctly different ethnicities wearing different costumes and in different backdrops. For the prompt *"Nepali face"*, two versions of AF showed different approaches to generate the images. AF 2 took an abstract approach by merging the faces with the flag of Nepal while AF 3 consistently generated faces that looked like from Nepal. This comparison is shown in Figure 6 below.

AF-2-X generated by AF version 2 *AF-2-X generated by AF version 3*

Figure 6: Comparison of Image-set AF-2-X generated by AF versions 2 and 3

In April 2024, Adobe claimed that AF3 is an improved generative AI image model for faster ideation and content creation, adding that the new version was more photorealistic and could generate greater variety for a single prompt (Adobe, 2024). Although AF 3 is still a beta version, this research shows that it has an improved understanding of the text prompts as compared to other popular generators or even its predecessor version AF 2.

3.4 Further Observations

In its purest form, i.e., before any additional manipulation, generative AI did not produce images of Nepalese people wearing what is considered the national dress or ethnic costumes. This perhaps is more realistic because, unlike the social stereotype of showing Nepalese people wearing Nepalese costumes, the AI output did reflect the commonplace. However, when users refine the results by choosing the traditional costumes or feed reference images that show the characters wearing traditional costumes, they can re-train the AI system with the introduction of their element of bias. In this way, user feedback can become a means to correct racial bias in AI training datasets. Hence it is recommended that AI systems include human intervention for result improvement. Regular audit of the generated result in light of AI biases is also highly recommended.

It can be argued that the generation of Nepal-related content using merely a few words has become much easier following the availability of Generative AI over the Internet. Some think that it can risk many jobs in the creative industry but this opinion is divided by the notion that the value of man-made can further rise over what is artificial. As we have seen in the above discussions, Generative AI can help a lesser-known country like Nepal to have some visual representation. However, sensitive issues introduced by AI bias cannot be ignored as the true construction of the Nepalese image to the world is equally important.

4. Conclusions

In today's world, communities are more progressive and ethical issues are of utmost importance. Since the audience to images can be more than readers of literature over the Internet, due diligence towards sensitive topics like racial bias should be of prime concern for text-to-image generators. Based on the observations drawn from AI-generated images of Nepalese faces, it can be concluded that descriptive text helps the AI algorithms derive correct meaning out of the prompts. Improved understanding of text prompts can generate more satisfactory results, making them more reliable and accurate, and hence also more suitable for commercial and general use. Furthermore, racial bias may not be related to variables like prompt and iteration but is attributed to the generator which in turn relies on its training data. Concerning racial bias, AI systems are the true reflections of our real-life world where racial bias is deep-rooted.

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Automatic Reactive Power Control using TSC_TSR

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Abstract

Reactive power compensation is crucial for preserving voltage stability, improving transmission efficiency, increasing system capacity, optimizing power factor, and mitigating voltage instabilities in modern power systems. Reactive power often arises in instances of poor power factor, primarily caused by lagging load currents when connecting heavy inductive loads to the system. Additionally, during periods of minimum loads, low current flow through the transmission line may result in voltage amplification at the receiving end (Ferranti effect). To address these issues, a reactive power control system utilizing a parallel configuration of a thyristor-controlled reactor (TCR) and a thyristor-switched capacitor (TSC) is proposed. This system ensures smooth current control by absorbing or compensating reactive power as needed, achieved through the adjustment of thyristor firing angles via a microcontroller. This approach aims to prevent voltage fluctuations and enhance overall system performance, offering potential applications in long-distance transmission lines. A MATLAB simulation and hardware prototype consisting of 5 branches of capacitor and a reactor branch is developed that exploits the benefits of concept of reactive power compensation using TSC-TCR and results depicts the achievement of voltage stability.

Keywords: Reactive Power, Voltage Regulation, TSC-TSR

1. Introduction

Unlike active power, Reactive power is not an useful power but is essential in maintaining the stability, reliability, and efficiency of electrical systems. With the ongoing expansion of the electrical network in the utility industry and the continuous growth of social dependency on electricity, reactive power control plays a vital role in the system performance.

Nonlinear loads such as induction motors and VFDs increase the reactive power demand because of their inherent inductive nature. Additionally, capacitors used for power factor correction can interact negatively with harmonics leading to resonance conditions to further impact reactive power demand. Hence, the dynamic nature of the power system can lead to voltage drops and power fluctuations, which can affect the performance of electrical devices and violate statutory limits (Hossin et cal,2022).

Reactive power fluctuations can create voltage instabilities as power system voltage is closely dependent on it. Thus, to monitor and maintain stable, secure, controlled, high-quality electric power, reactive power compensation techniques are widely used.

The shunt type of FACTS Controllers is used to either absorb or inject reactive power into the system and maintain reactive power balance. Shunt reactors and shunt capacitors, the control of their operation performed by thyristor switch are used to achieve this action.

1.1 Thyristor Controlled Reactor (TCR)

A Thyristor-Controlled Reactor (TCR) is a reactor, usually with an air core, controlled by a bidirectional thyristor valve. A TCR (Thyristor Controlled Reactor) is kept parallel to the fixed capacitor. The basic objective of this configuration is to dump the excess reactive power generated by the capacitor in the TCR.

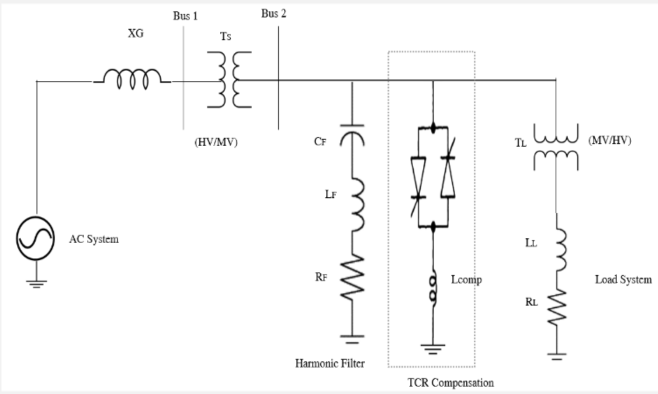

Fig 1.1: Thyristor Controlled Reactor

Fig 1.1 shows the single-phase thyristor-controlled reactor branch, which includes an inductor *L* and a bidirectional thyristor switch.

1.2 Thyristor Switched Capacitor (TSC)

The configuration of a Thyristor Switched Capacitor (TSC) is similar to that of a TCR. A power capacitor to generate reactive power is connected in series with a bidirectional thyristor used as switch and in general, a reactor (inductor) to limit the current.

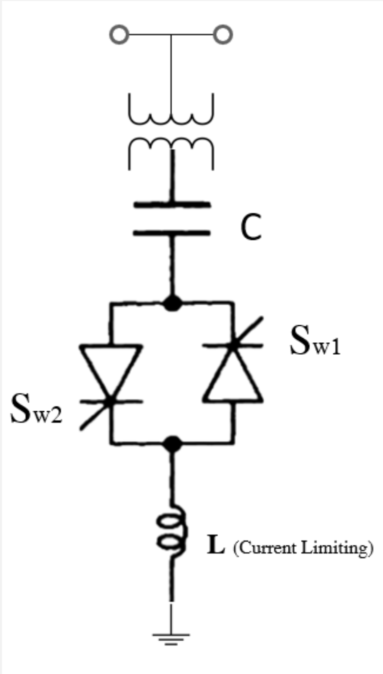

Fig 1.2: Thyristor Switched Capacitor

The single-phase branch is depicted in Fig. 1.2 and is made up of capacitor C, thyristor switches Sw1 and Sw2, and a small component called reactor L. Reactor L is used to restrict the rate at which current rises through the thyristors and also to avoid resonance with the network. Through the thyristors' suppression of the gate trigger pulses, the capacitor is replaced. Even though it hasn't been fully discharged, the capacitor in the stand-by state instantly becomes ready for a new connection when it loses the voltage that is supplied by resistance R.

1.3 Combination of Thyristor Switched Capacitors and Thyristor Controlled Reactor (TSC-TCR)

The parallel and concurrent configuration of TSC and TCR act as TSC-TCR that performs the dual objective of generating reactive power and absorbing excess reactive power.
Fig 1.3 shows a Combination of both TSC and TCR. The choice of the product must be the cost-effective and also good in quality and in response, which strongly depends on the cost evaluation of the losses. In the thyristor-switched capacitor scheme the total reactive power is split into a several parallel capacitor bank. The reactive power from the compensator follows the load or terminal voltage variations in a step. A continuously variable reactive power can be achieved by using a thyristor-controlled reactor in combination with thyristor-switched capacitor banks. The harmonic generation will be low, because the controlled reactor is small compared with the total controlled power. A continuous change in the control order from fully lagging to fully leading current is obtained by TSC-TCR combination. The operation of the controlled reactor is in perfect coordination with the switched-capacitor banks (Rajput, 2018).

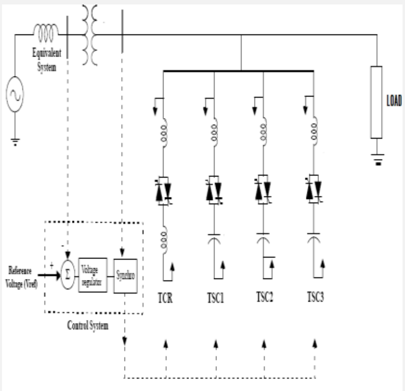

Fig 1.3: Combination of Thyristor Switched Capacitors and Thyristor Controlled Reactor (TSC-TCR)

1.4 Characteristics of TSC-TSR

There are some Positive Characteristics of the combination of TSC-TSR which can be listed as below.

- Continuous control
- Practically no transients
- Low losses
- Flexibility in control and operation

In addition, there is a Negative Characteristics which is Low generation of harmonics

2. Methodology

At First firing angle is determined as below:

$I_L = \frac{Vm}{wL}(1 - \frac{2\delta}{\pi} - \frac{Sin2\delta}{\pi})$ ($\because$ δ is firing angle)

We have from equation,

$Q_{TCR} = I_L^2 * X_L$

$Q_{TCR} = [\frac{Vm}{wL}(1 - \frac{2\delta}{\pi} - \frac{Sin2\delta}{\pi})]^2 * X_L$

Using the MATLAB curve fitting tool, different graphs were plotted for different range of firing angle and the equation of the firing is obtained.

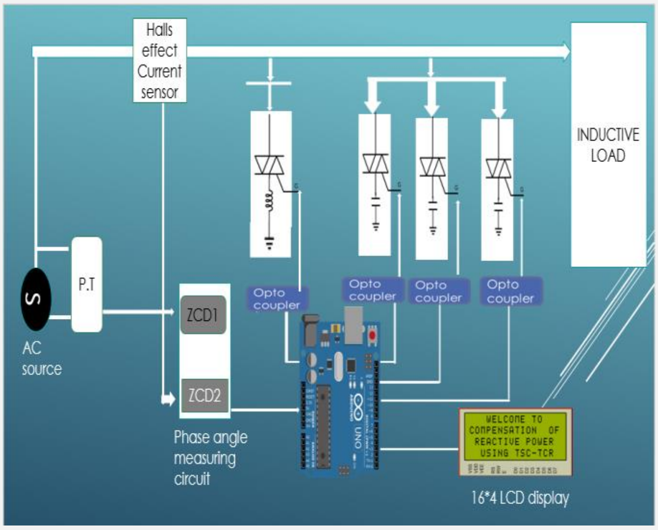

Fig 2: Detailed diagram of TSC-TCR with load for hardware implementation

The operation of TSC-TCR is controlled by the Arduino Mega controller unit as depicted in figure 2. Our goal is for the TCR branch to absorb the excess reactive power generated by the TSC branch so that the load fully utilizes the reactive power. Arduino generates the necessary firing angle for the above control operation (Chaurasiya et. Al 2018).

The supply of 5v to the Arduino is given by a source either power bank or USB adaptor. The hall effect sensor senses the current and sends the signal to zero cross detector 1 (ZCD1) whereas P.T. converts into low voltage and sends to zero cross detector 2 (ZCD2). The phase measuring circuit (ZCD1 and ZCD2) measures the phase difference between voltage and current and sends to the Arduino. Measuring the phase difference, the Arduino triggers the required TSC branches and produces the required firing angle and fires the thyristor of TCR branch in order to absorb the excess reactive power. The display unit shows the parameters send by Arduino.

3. Circuit Diagram

Fig 3 shows the circuit diagram of TSC-TCR branch with load. This circuit has been implemented in the Proteus.

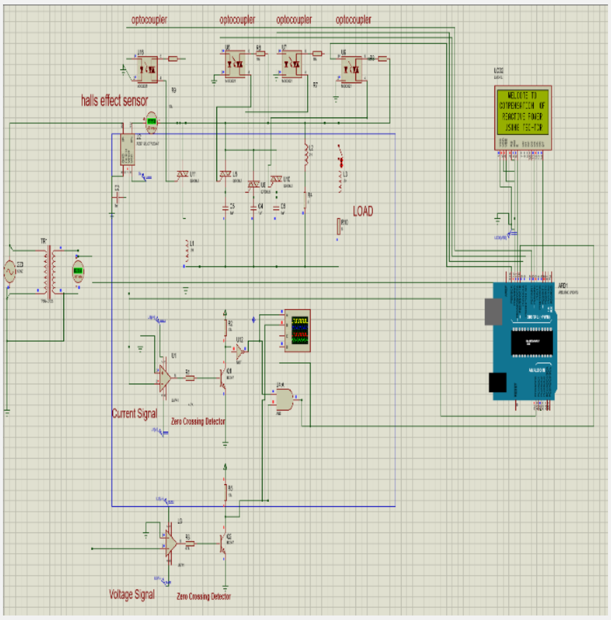

Fig 3: Protues Model Simulink of TSC-TCR with load

The figure above is tested in the Proteus Simulink model. It consists of several components as shown in fig. 3. It consists of a Hall Effect sensor and a PT (230/6.6) connected in series & parallel respectively with phase & neutral as shown in fig 3. The TSC and TCR are connected between phase & neutral with two thyristors in an anti-parallel manner for both reactor & capacitor. Then the load is connected to the circuit. The main requirement of the hall effect sensor & PT is to measure current and voltage. The output of the hall effect sensor and PT is sent to the zero cross detecting circuit. Zero detecting circuit consists amplifier, transistor, NOT gate and an AND gate.

The final output is taken from the AND gate, which is of square wave for each positive half cycle and is sent to the Arduino port A1. The coding is done is Arduino such that it produces the exact firing angle to trigger the thyristor of TCR branch such that the power factor of the system increase. The opto-coupler is used to isolate the low voltage with high voltage. The Arduino sends the high signal (1) to the opto-coupler to ON the TSC branch. The opto-coupler transfers electrical signals from low voltage circuit to high voltage circuit by using light. Such that it prevents high voltages from affecting the system receiving the signal.

4. Matlab Simulation

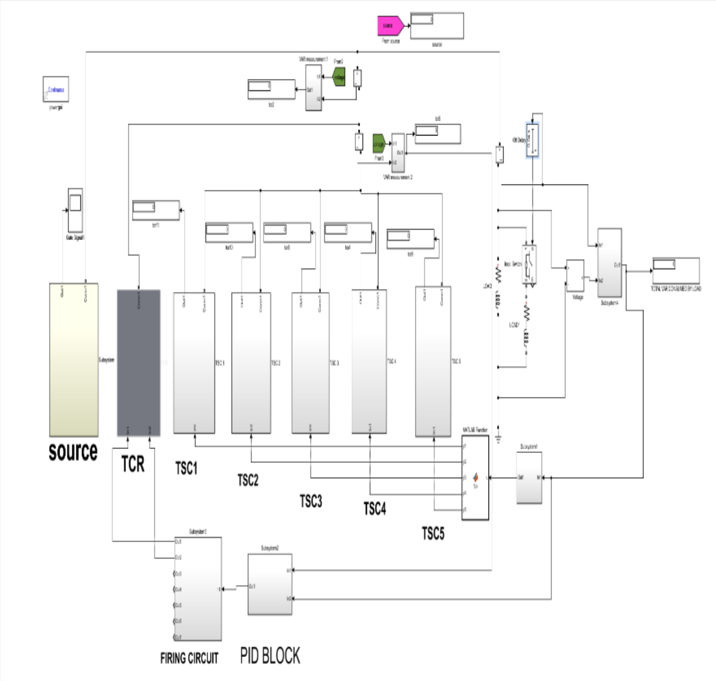

Fig 4.1: A closed loop MATLAB Simulink Model for compensation of reactive power using TSC-TCR

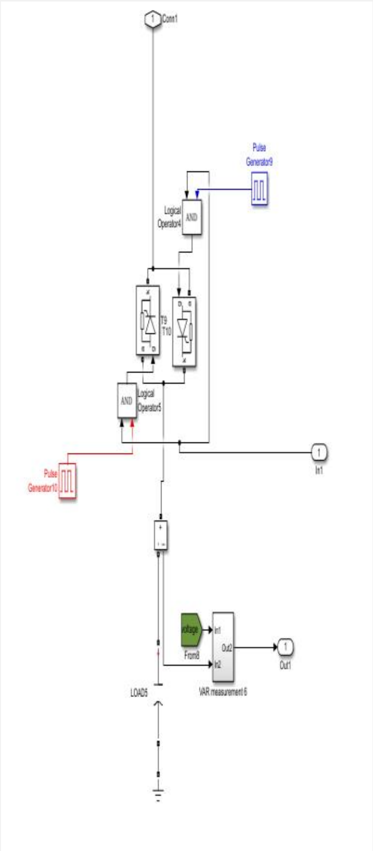

Fig 4.2: Simulink Model of TSC branch

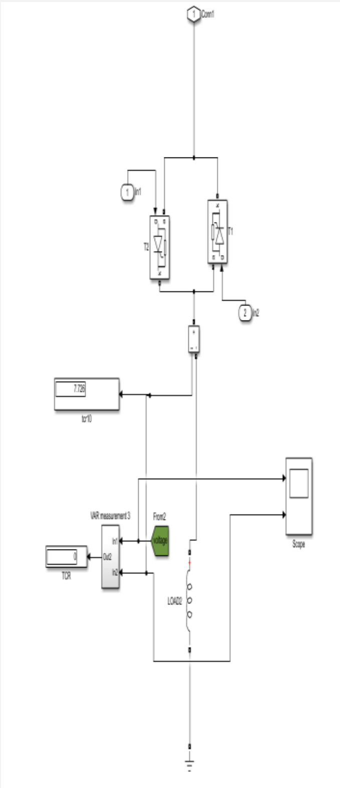

Fig 4.3: Simulink Model of TCR branch

Figure 4.1 above is the MATLAB Simulink model.

In this model, there are five branches of TSC and a TCR as shown in figure 5.1. When the load is connected the reactive power required to be consumed by the load is calculated and send to logical block. This block calculates the required no. of branches using the formula and sends logic high 1 to turn ON the branches.

Calculating no of branches required by:

$$N= \frac{\text{Total VAR consumed by load}}{\text{Capacity of single TSC branches}}$$

Then at the same time PID controller senses the difference in the reactive and generates a value of firing angle of the thyristor pair in TCR branch, which in turn varies the amount of reactive power supplied by TSC-TCR. The firing angle is send to the firing circuit and the circuit fires the TCR branch. Thus, the reactive power is controlled in closed loop by TSC-TCR combination in MATLAB Simulation.

5. Results:

- Initially the Load reactive power is 1500 VAR
- No. of TSC branches ON: 3 (as each branch produces 600 VAR)
- Reactive Power Generated: 1800 VAR
- Excess of reactive power generated = 300 VAR
- TCR branch consumes this excess of VAR (i.e. 1800-1500 = 300 VAR)
- After t=2 sec, Load reactive power is increased to 2773 VAR by adding 1273 VAR Load
- Excess of reactive power generated = 227 VAR
- TCR branch consumes 227 VAR
- No. of TSC branches ON :5 (as each branch produces 600 VAR)
    - Reactive Power Generated: 3000 VAR
    - Excess of reactive power generated = 227 VAR
    - TCR branch consumes this excess of VAR (i.e. 3000- 1273 = 227 VAR)

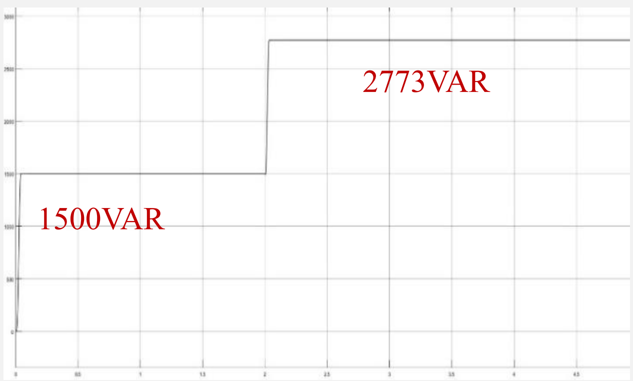

Fig 5.1: Plot of Reactive power consumed by Load

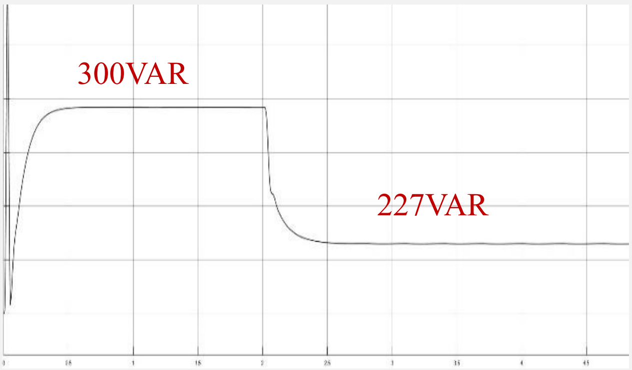

Fig 5.2: Plot of Reactive power consumed by TCR Branch

6. *Hardware* model

Fig 6: Hardware Model of combination of TSC-TCR Branch

The hardware model of the automatic reactive power control using the combination of TSC-TCR branch was practiced. The assembling of different parts are shown in Fig 6.

7. Conclusion

Hence, it is concluded that TSC-TCR will successfully control the dynamic performance of power system and voltage regulation of the power system. In transmission system, frequent load variation is occurred which cause voltage variation at the load-side and sensitive electronics equipment may be damaged. Therefore, use of TSC-TCR will be more beneficial to implement it in industries, distribution and transmission systems for voltage control, voltage balancing and stability improvement. Hence, by TSC-TCR, which had been attuned to the arising load, a successful compensation was reached with a power factor near to unity.

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