Promoting cultural change in engineering practices for the Development of Nepal: Learning from the UK

(Proceedings of 5th SONEUK Conference)

Society of Nepalese Engineers UK

London

2020

Content

Editorial

Engineering sector plays a very important role in the developments of Nepal. However, for realising long term benefits and ensure sustainable development, the engineering projects need to follow available best practices to deliver them more efficiently, safely and economically. In this context, Society of Nepalese Engineers in the UK (SONEUK) is organising 5th SONEUK Conference on "Promoting cultural change in engineering practices for the Development of Nepal: Learning from the UK" on 25th April 2020 and this publication comprises the papers submitted for the conference. The papers provide some examples of experience and expertise gained by hundreds of Nepalese Architect and Engineers working in various areas such as academia, government organisations, consulting firms and contractor services in the UK and Nepal. We hope that the publication of this proceeding will further enhance the exchange and dissemination of technical knowledge to wider public outside of SONEUK family including fellow engineering practitioners in Nepal.

This publication contains a total of 7 papers which were peer-reviewed using the available resources within the SONEUK to make it to a standard of publication. The papers in the proceedings include various topics in engineering – information technology, transport, building construction, building information technology, building materials and sustainable energy. The content of papers range from modest to advanced technological applications with current practices in the UK and present some examples of the projects in Nepal. All the papers, wherever possible, has made an attempt to relate the UK practices to - Nepalese context for their effective adoption. In several areas covered in the proceedings, it is acknowledged that there is lack of data in the context of Nepal to inform the content of the papers. It is envisaged that the topics covered will act as the starting point for a discussion on how expertise available in the UK and other countries could be utilised in future for research and development through the SONEUK as a platform.

We are overwhelmed with positive responses and feedback that we received for our first publication as a formal proceedings of the SONEUK conference last year. This second publication represents the continuity of SONEUK efforts to contribute to the development of engineering sector in Nepal. The theme of the conference this year is to learn the lessons from UK to promote cultural change in engineering practices to deliver the projects more efficiently, safely and economically. We welcome any feedbacks and constructive suggestions so that it can be addressed in the future proceedings.

We, as editorial team, are very honoured to facilitate the publication of the proceedings. We would like to thank all authors for their valuable contributions. It has been a pleasant experience to put these papers together and we hope you will enjoy reading the papers too.

Dr Birendra Shrestha, Transport for London – Coordinator
Dr Ramesh Marasini, Buckinghamshire New University
Mr Krishna Shrestha, Jacobs
Prof Keshav Dahal, University of the West of Scotland
Mr Narad Bhandari, Network Rail
Prof Hom Dhakal, University of Portsmouth
Dr Bidur Ghimire, Wood Group

EMBASSY OF NEPAL
12A KENSINGTON PALACE GARDENS
LONDON W8 4QU

Message from the Ambassador of Nepal to the United Kingdom, His Excellency Dr. Durga Bahadur Subedi

I offer my warm greetings and best wishes for the health and happiness as well as peace, progress and prosperity of all the members of the Society of Nepalese Engineers in the United Kingdom. I take this opportunity to acknowledge and appreciate the untiring efforts of the SONE, UK for unity, solidarity and welfare of the Nepalese Engineers residing in the United Kingdom and for promoting people to people relationship between Nepal and the United Kingdom.

I am very delighted to witness that the Nepalese Engineers in the United Kingdom have, not only received employment but also received recognition, respect and honour from both the government and people of the United Kingdom. It is my sincere belief that the SONE, UK is one of the best, well- organized, renowned and respected Nepalese professional organizations in the United Kingdom. I am pleased to note that the SONE, UK is engaged in the professional development and networking of its members since a decade or so. It is organizing a number of professional development activities through several academic conferences, seminars and interaction programmes.

The Embassy of Nepal highly values and appreciates the sustainable works and activities of the SONE, UK which is focusing on various aspects of engineering methods, technology and systems as well as on the application and knowledge transfer. These works and activities of the SONE, UK are, directly or indirectly, related and relevant to the development of Nepal.

I wish to state that the Government and people of Nepal are observing this year as 'Visit Nepal' Year. On this occasion, I would like to request and encourage all the members of the SONE, UK to support and publicize the Visit Nepal Year Campaign of the Embassy of Nepal and to highlight Nepal as a safe, secure, peaceful, beautiful and best value tourist destination of the present day world.

The Embassy of Nepal is pleased to work with the SONE, UK for supporting the endeavours of the Government of Nepal for achieving the national aspiration of 'prosperous Nepal and happy Nepali' by the utilization of huge knowledge, skills, expertise and experiences of Nepalese Engineers residing in the United Kingdom.

I wish the SONE, UK a great success.
Long live Nepal-Britain relations!

Dr. Durga Bahadur Subedi
Ambassador Extraordinary and Plenipotentiary

7 February 2020

Tel: 020 7229 1594, **Fax:** 020 7792 9861 **Email:** officesecretary@nepembassy.org.uk

Chairperson's message

As a chairperson of the Society of Nepalese Engineers, UK (SONEUK), I am delighted to introduce the second technical publication of SONEUK covering a range of engineering disciplines. I am very glad to see a range of papers from modest to advanced technological applications of current practices in the UK and some examples of the projects in Nepal. I would like to congratulate all authors who contributed to this publication. It is a great pleasure that I thank the SONEUK Seminar and Conference Committee for the outstanding job they have done. The conference has grown to become the most important and international technical conference. I would like to thank all members who have continuously supported by sponsoring the publication of the paper. I see this as a culmination of love and passion of all SOEUK members to keep this institution going to a new height.

I am honoured to have a strong team of the 3rd Executive Committee of SONEUK with other teams of advisors, fund raising, social and entertainment, external affairs, IT management & publication and charity coordinator who have continuously supported to run all extra activities (just to remind a few: **MOU signing**, **proceedings publication, joint technical presentation with Institution of Civil Engineering, ICE**) apart from our regular ones: annual get together (Bhela), training & talks, seminar etc. SONEUK have reached another milestone by hosting cross organisation joint technical presentation with ICE Kent in February 2020.

Apart from the technical interactions amongst its members, in the current climate of COVID-19, SONEUK was able to organise a webinar to discuss COVID-19 related health issues. More importantly, in this difficult period, SONEUK was able to support **charitable work for the National Innovation Centre (NIC)** in Nepal lead by Dr Mahabir Pun**.** SONEUK donated **NRS 10,15,000** (Ten Lakh Fifteen thousand rupees) to NIC to produce Personal Protective Equipment (PPE) and distribute them freely to the health workers in Nepal. Such charitable work was only possible with the generosity of SONEUK members who always have Nepal in their heart. I would like to thank all members for making contributions to such noble work.

The time has become tough due to the unprecedented spreading of corona virus disease COVID 19. Several NHS workers and family members across the world have lost their lives. We also lost SONEUK founder executive committee member Er Kedar Panta. May god give them eternal rest and the family the strength to bear the greatest pain. I would like to request all members to follow the government guidance and the NHS advise. We are grateful to all front-line workers for your dedication. You have all put your own lives at risk for saving the people of this world. You are special people and we are blessed to have you.

I would like to thank the distinguished personnel Ambassador of Nepal to UK, Dr. Durga Bahadur Subedi. I also thank the Technical Conference & Seminar Organising Coordinator and Vice Chairperson Dr Birendra Shrestha for his relentless work to make this publication possible.

I also extend gratitude to my entire team and members including your families, who supported to the society. I would like to appeal to all SONEUK members and families to continue to support our society. We will be focusing on capacity building of our organisation and protecting and advancing interests of SONEUK engineers.

Shailendra Kajee Shrestha

Chairperson
SONEUK

Lessons Nepal can learn from the UK in Data and Cyber Security

Sanyukta Shrestha
director, yantrakala ltd, UK
sanyukta@yantrakala.com

Abstract

Cybercrime has been studied for almost half a century around the world. As Nepal enters its second decade in providing cybersecurity to its population that is rapidly being penetrated by cyber connectivity, the importance of legal measures is paramount. In order to achieve a commendable Global Cybersecurity Index which is essential for the growth for national economy and foreign investment, continuous improvement of cyber law through technical amendment and public debates is essential. While Nepal has its own share of challenges to face as a developing country, a lot can be learnt from the United Kingdom as one of the most cyber-secure countries in the world, and the EU as the safest region for cyber-trade. The UK's national-level priority for General Data Protection Regulation and its implementation, and investment in cybersecurity can be cited as two of the major lessons to be learnt. Like in the UK, special task force needs to be formed in order to monitor cyber activities so that cybercrimes can be stopped from happening, thereby saving resources and creating safer societies.

Keywords: cybercrime, cyber threat, data protection, data security, cyber law, cyber security

1. History of Cyber Criminology

Data storage, duplication and retrieval form the basis of the digital world which comes with its own challenge of data security. Data security deals with protection of data through consideration of privacy of the authorised owner or handler, and compliance of applicable protocol and requirements (O'Toole et al, 2018). Cyber security on the other hand has many definitions including 'strategy, policy and standards regarding security of and operations in cyberspace' (CNSSI, 2018). When data is geographically distributed in servers located worldwide, and advances in cloud computing is making data and services accessible to all over the Internet, the importance of cyber security cannot be undermined.

The earliest known reports of computer manipulation, computer sabotage, computer espionage and the illegal use of computer systems was in the 1960s (Seiber, 1998). While the 1970s saw the first serious treatments of 'computer crime' (McKnight, 1973), the relatively limited role of computers in daily life meant that such offence typically related to theft of telecommunication services and fraudulent transfer of electronic funds.

By the late 70s, it was warned of what would happen if law enforcement did not evolve at the same rate as technology and its illicit exploitation (Bequai, 1978). Cybercrime is defined as a broad term that describes everything from electronic hacking to denial of service attacks that cause e-business websites to lose money (Kratchman, 2008*).* While interpreting "access" and "authorization" in further detail has helped secure the privacy of computer users in legal debates (Kerr, 2003), studies have also helped sketch some typologies of cybercrime, listing twelve major risk factors of the Internet that in combination provide a unique opportunity structure for crime (Koops, 2010). As the world prepares with various legal measures against cybercrime, there is no denying that the study of criminal behaviour prevalent in the digital platform is an important area to consider.

Broadhurst et al demonstrate that cybercrime appears to require leadership, structure, and specialisation (Broadhurst, 2014). In the UK, research has also been carried out on tools used by cybercriminals to breach information system security, the impact of cybercrime and the legal responses of the UK, European Union and Council of Europe (Brown, 2009). It has been argued that

a comprehensive policy on cybercrime has to consider the allocation of resources, the relative seriousness of the crimes, the investigative and prosecutorial procedures and the nature of the actual victimization that occurs (Moitra, 2005).

2. Cybercrime in Nepal

2.1 Comparative study of cybercrime in Nepal

It is said that crime follows opportunity and the increasing penetration of information technology and communication (ITC) in Nepali population means preparedness against cybercrime is the need of the hour. By 2019, 67.23% of the population of Nepal is already using broadband and 52.71% are using it on mobile devices (NTA/GoN, 2019).

In the fiscal year 2018/2019, 180 cases of cybercrime were registered in Nepal until 13th June 2019. Among them, 125 cases were from the Kathmandu Valley alone and 55 cases from outside the valley. Compared to the previous fiscal year 2017/2018 when 132 cases were registered throughout the year, a sharp rise could be easily traced. Earlier in the fiscal year 2016/017, Nepal Police had registered only 53 cases in total (IFEX, 2019).

A comparative study of the types of cybercrimes reported in Nepal over a period of five years until 2014 listed social network as the one topping the list, which itself is six times more than the next highest figure for email threats. Web SMS threat, hacking, SMS lottery fraud, illegal data access and phishing were cited as other lesser reported cybercrimes. Among all cybercrimes, copyright infringement was least reported according to Nepal Police in 2015 (Dahal, 2017).

According to same report, the charge sheet was dominated by Section 47 of Electronic Transaction Act 2008 which is regarding the publication of unlawful content (MoICS/GoN, 2006). While Section 47 was referred mostly on its own, rest of the application of the act was also by combining Section 47 with other sections like Section 44, 45, and 46.

2.2 Case Studies of Cybercrime in Nepal

2019 was the darkest year of cybercrime for Nepal as it faced two of the biggest digital heists in the history. Within a period of only three weeks from August 31 to September 26, 2019, hackers from neighbouring countries created menace by organised and sophisticated hacking.

ATM Fraud 2019
Nepal Electronic Payment System that incorporates 11 banks of Nepal was hacked using Malware by a group of hackers (Satyal, 2019). They could withdraw enormous amounts of money from ATM vaults injecting a malware which helped bypass authorization by the banks. NRs 12.6 million was confiscated along with 132 forged Visa debit cards and 17 authentic Visa cards from four Chinese nationals who used their bank cards in ATM vaults of different banks in Kathmandu (Dhungana, 2019).

Online Banking Fraud
NRs 48.5 million was stolen from the Lahan branch of the state-run Agriculture Development Bank and Panas Remittance in Baneshwor, Kathmandu, by a group operated by a man from India. Living in Mumbai, the man deployed as many as 12 Nepali current account holders in various banks of Nepal. The hackers who used malware variants in order to gather information and steal credentials before transferring amount to their bank accounts, were able to send NRs 3 million using hundi to their Mumbai operator (Dhungana, 2019).

3. Data Protection and Cyber Law in Nepal

In 2004, Telecommunications Policy by Nepal Telecommunications Authority mentioned the plans to enter the information society with necessary arrangements including cyber law (NTA/GoN, 2004). In 2010, the renewed IT Policy drafted by IT High Commission overruled its predecessor, IT

Policy 2000 (ITHC/GoN, 2010). Also notable is the fact that there are directives in place for anyone who wants to access information in Nepal (NTA/GoN, 2018).

In the last two decades, Nepal has made some important advancements in data and cyber security through legal measures. Although laws and regulations were drafted in Nepal to strengthen its cybersecurity, it progressed rather slowly through debates in the parliament and was eventually passed amidst various concerns on 29th December 2019. Some of the relevant acts for information technology and communications in Nepal are as below:

- Electronic Transaction Act 2006,
- National Cybersecurity Policy 2016 (draft),
- Information Technology Management Bill 2019 (approved on 29th December 2019)

In a 2018 field survey with a sample of 140 employees of the government of Nepal, 85.7% expressed their awareness of the threats of cybercrime (Giri, 2019). Majority of them considered taking or giving information by unauthentic use of other person's computer as the major cause of cybercrime, besides the leakage of personal as well as official information. Offence against the nation using information technology was also a popular idea of cybercrime in their opinion.

3.1 Electronic Transaction Act 2008

Nepal's foray into data security started with 'The Electronic Transactions Act (ETA)' which was first proposed in 2006. The act legalizes all electronic transactions and digital signatures. It defines and sets penalties for computer and cybercrimes, such as hacking, piracy, and computer fraud (MoICS/GoN, 2006). While the act focusses on authenticity of electronic record, public/private keys and digital signature, it also tightens the grip on various common security issues. The act elaborates on the technicalities and related penalties for cases that include piracy, destruction or alteration of computer source code, unauthorized access in computer materials, damaging any computer and information system, and the publication of illegal materials in electronic form. Various special cases are tactfully addressed in the act e.g., Computer fraud.

The first case that was advocated after the implementation of ETA was the Maina Dhital vs Bikash Thapa case in 2013. The government had filed the case based on first information report of Bikash Thapa's female colleague Maina Dhital, stating that journalist Thapa had sent a number of vulgar emails and defamed her character. The apex court overturned the order of Patan Appellate Court that had upheld the Kathmandu District Court bail rejection order to proceed with the case as per Section 118(2) of the Court Procedure Chapter of Civil Code (Joshi, 2013).

3.2 National Cybersecurity Policy 2016

While still in its draft stage, the National Cybersecurity Policy (NCB) 2016 promised to answer most of the questions that are crucial for the well-being of a cyber-secure nation. The Policy was developed by Nepal Telecommunication Authority (NTA) with technical assistance from International Telecommunication Union (ITU). Discussions were initiated with national, regional and international experts to ensure a broad participation including governmental, non-governmental and open stakeholders' consultations (NTA/GoN, 2016).

The policy rightly warns that while ICT can support the operation of critical infrastructure such essential services can in future also be attacked remotely through networks that connect them, and today, cyber-attacks are largely transnational and offenders act with a great degree of sophistication. It emphasizes on the need to monitor developments in the risk landscape, provide services for government, citizens and businesses, prevent attacks and investigate those that could not be prevented.

One of the important proposals it makes is of an independent national body called Nepal Computer Emergency Response Team (NepCERT), supervised and monitored by the Ministry of

Ministry of Information and Communications, Ministry of Science and Technology and Nepal Telecommunications Authority. Responsible for providing services related to Cybersecurity to the government, government institutions, law enforcement, businesses and the people, it should focus on promoting Cybersecurity and raising awareness, supporting institutions and businesses in prevention, detection and response to Cyber-attacks upon request; maintaining 24/7 points of contact; carrying out digital forensic investigations; receiving and distributing reports about incidents and auditing and providing special support to critical infrastructure provider.

3.3 Information Technology Bill 2019

Following its approval on 29th December 2019, Nepal's Information Technology Bill (ITB) 2019 superseded ETA 2006 and is highly aligned with NCB 2016. After being drafted in 2018, ITB was presented to the Parliament on February 14, 2019 and debated on February 28, 2019. This bill clearly holds high importance for a number of sectors including legal, policing, information technology, banking and finance, economic and social health.

As ITB supersedes ETA, many improvements can be brought through necessary amendment in existing articles within the prevailing act. One of the major criticism of ETA 2006 has been its criminalising freedom of speech on Internet (Dahal, 2017) and human right watchdogs have recommended to annul Section 47 dealing with publication of unlawful content, which the Nepal Police has been criticised to have extensively used as a weapon to suppress the voice of journalists, writers and comedians (IFEX, 2019).

The jurisdiction of the IT bill is quite clear in its being applicable to anyone within or outside the borders of Nepal given the person's conduct would constitute an offence against it. It has provisions for managing crimes related to illegal Interception, illegal data interference, illegal acquisition of data, illegal system interference and illegal devices. The bill also enlists sophisticated cybercrimes like forgery, electronic fraud and identity related crime. While ITB succeeds in many ways with provisions and preparedness to fight cybercrime, it is widely criticised by the human rights activists for its fundamental flaw with criminalising any criticism of government over the social media (Rai, 2019), perhaps more so than its predecessor ETA 2008.

4. Nepal in the Global Cyber Security Index

In terms of Global Cybersecurity Index (GCI) score, Nepal is classified in Initiating stage while India, China, Pakistan, Bangladesh and Sri Lanka are in Maturing stage (ITU, 2017). In the contrary, United Kingdom is in Leading stage. Nepal's poor performance in GCI can be analysed with regards to its score in various areas that need improvement. In the Asia and Pacific Region Scoreboard, Nepal has fulfilled the requirements of international participation, multilateral agreements and professional training courses but these measures have not been instrumental in bringing concrete results. As a result, Nepal is still ranked poor in all five core areas of in Cybersecurity including legal measure, technical measure, organisational measure, capacity building and cooperation.

Nepal hasn't been able to exploit the available expertise from both the technical as well as financial industry to achieve the required level of cybersecurity index. Formulating such an intersectional intelligence can be a robust protective layer around the banking sector whereby attracting global investment and boosting the tourism sector. In this regard, one of the best examples that Nepal can learn from is its neighbouring state of Sri Lanka that created the Financial Sector Computer Security Incident Response Team (FINCSIRT) in 2014. FINCSIRT is a joint initiative of the Central Bank of Sri Lanka and the Sri Lanka computer emergency response team with responsibility for receiving, reviewing, processing and responding to computer security alerts and incidents affecting banks and other licensed financial institutions in the country (FINCSIRT, 2019).

In neighbouring country India, when the National Crime Reports Bureau reported an increase of 45% in cybercrime in 2009 over that of 2008, the trade association of Indian IT industry NASSCOM

and Data Security Council of India (DSCI) came together to take serious initiatives to fight the rising crime situation (DSCI, 2011). In the absence of such in-country collaborations, Nepal is bound to face further challenges in facilitating industries with potential to contribute to GDP as well as attracting foreign investment.

In 2011, the UK government funded a £860 million *National Cyber Security Strategy* as its first five-yearly plan for 2011-2016. The vision was to deliver a vibrant, resilient and secure cyberspace with an aim to make the UK one of the most secure places in the world to do business in cyberspace and act towards building UK's cyber security knowledge, skills and capability (Cabinet, 2016). In 2016, the Cabinet Office issued UK's second five years *National Cyber Security Strategy* doubling its investment to £1.8 billion. This was not only a timely response from the national level to a fast-moving digital world but also an unprecedented exercise of transparency by preparing everyone in the society in the fight against cybercrime (HMG, 2016).

With a vision that the UK is secure and resilient to cyber threats, prosperous and confident in the digital world, the 2016-2021 strategy aims to defend against cyber threats, deter hostile actions taken against the UK and develop an innovative cyber security industry. Global Cybersecurity Agenda (GCA) developed by International Telecommunication Union (ITU) has clearly emphasised on the capacity building of any nation for cybersecurity (Schjølberg, 2008) and it is high time that Nepal responds with a technical plan in place. The UK's preparedness to detect, understand, investigate and disrupt hostile action taken against it is something that is sorely missing in Nepal's approach towards cyber security. It is in the absence of such a plan that, in 2019, Nepal faced two of the biggest heists in history, leaving it further behind from winning the global trust in cybersecurity.

5. Comparisons with the UK Context

5.1 General Data Protection Regulation

General Data Protection Regulation (GDPR) is the European data protection regulation application as of May 25th, 2018. It is to be followed by all member states thus harmonising data protection laws across Europe (Intersoft, 2018). It lays down rules relating to the processing and free movement of personal data, and thereby protects the fundamental rights of natural persons. It emphasizes on the principles that are related to processing of personal data and conditions for consent (European, 2016). According to GDPR, the principle for processing data according should be lawful, fair and transparent. It limits the purpose of data collection within what is adequate and relevant. It also emphasizes on accuracy and up-to-date status of data which is kept for no longer than is necessary *(Article 5-11, Chapter 2, GDPR).*

One of the areas where EU's GDPR excels over Nepal's data protection act, ETA, is in the limited elaboration on compensation. The ETA document enlists penalties in almost all areas it touches upon. In fact, the term □□□□ (punishment) appears 28 times but □□□□□□□□□□□□ (compensation) gets mentioned only once in the entire document of 40 pages (with no simultaneous occurrences of synonyms for punishment like □□□□□, □□□□□□□ or □□□□□□). In comparison, the GDPR document mentions penalty/penalties 23 times but also lists out compensation for a total of 16 times. The data protection law in Nepal clearly underestimates the value of compensation as a means of discouraging potential defaulters and safeguarding the fundamental rights of the victims. On the contrary, GDPR elaborates on the right to compensation and liability *(Article 82, Chapter 8).*

5.2 Consent

As the deadline for GDPR compliance approached, all organisations including businesses in the UK were made to collect consent from those whose data were held. In 2018, the months of March and April were when all UK-residents' inboxes were swamped with requests for consent to allow the

storage of personal data. This one-off exercise was a legal requirement which did not only cost businesses days or even weeks of additional work, but also clearly pushed aside all of the non-respondents from many existing databases.

In the context of Nepal, the legal requirement to collect consent from data providers is enforced in practice which limits the usefulness of the legal provision. If the collection of consent in electronic form could be made mandatory to all which strict regulation in place for defaulters, it can hugely safeguard the fundamental rights of those who are expected to hand over personal data.

It is also advisable that a regional cyber security standard be formulated for SAARC countries which would mean learning opportunity from neighbouring countries which have relatively higher GCI compared to Nepal. Such international ventures would mean higher levels of commitment by various governments which will always lie in the interest of the wider population of the region.

5.3 Data Protection as a part of Work culture

There is a role of every individual and organisation in helping to implement a law and it should be more of a common agenda when it comes to cyber security. Implementation of security measures in the digital world should be a joint effort by both the private and public sectors. Some of the ways in which UK organisations helped enforce data protection regulation are as below:

- Introductory workshop at the workplace by experts,
- Compulsory online courses and interactive tests for all employees,
- Regular email reminders until courses are completed and tests are passed,
- Surprise emails to test the employee response,
- GDPR champions in every department and smaller teams,
- Authorized certification for employees passing the GDPR courses, and
- Regular update of software so that any security breach is not compromised.

None of the above are taken as priorities by organisations in Nepal which needs rectifying. For a start, such requirements related to data protection could be streamlined more easily if linked with the company act itself.

5.4 Investment in Cyber Security

Unlike the UK which is able to invest billions of pounds over five-year projects dedicated to its national cyber security, the issues that Nepal has yet to face as a developing country are manifold. With a more recently achieved political stability, infrastructure development still remains one of the prime objectives for Nepal. Besides its other priorities like accessible healthcare and education for all, economic development has never been less important.

In a fast-moving digital world where computer systems are vital to almost all areas of development, Nepal cannot close its eyes to the emerging global as well as local cyberthreat. According to Cyber Security Awareness Report 2015, web defacement and advanced persistent threats aimed towards the websites of government and companies have been reported in the past. Global cybersecurity communities have also identified these incidences even when they have been unreported. For the identification, management and mitigation of these risks, adoption of proactive and reactive measures is vital (NTA/GoN, 2015).

Nepal cannot wait to make a start in the direction of creating a safer digital market for its investors and customers and one such program is National Cybersecurity Awareness Programme (NCAP). NCAP was proposed as a project to formulate, administer, manage and implement the cyber security awareness training for Nepal. As a team working with ITU experts, its mission objectives included sharing best practices and experience from other countries. Like all awareness projects, and as the focus is on raising cybersecurity awareness among identified target groups, it was understood that NCAP was not a profitable project. Nepal's fight against Cyberthreat cannot

be a fixed-term project and it has to be a continuous process. Moreover, awareness alone should be the fulfilling criteria for cyber security. Proactive monitoring, intelligent detection and timely prevention are other major considerations that Nepal needs to make. How will Nepal fund similar and bigger cyber security programs need to be worked out, and whether the private sector should also invest as a major stakeholder is open to debate.

6. Proactive Monitoring for Fraud Detection

Nepal's biggest hacking case till date, ATM Fraud 2019 (2.2.i) would not have been stopped in time, had a member of staff not noted an unusual incident of ATM vault emptying sooner than expected. We cannot rely on human detection and reporting of activities that are outside their direct roles. When these activities are several and overlapping, situations can be more complex than what is comprehensible to us. Detection of irregularities as well as matching the known patterns in bigger and dynamic networks can be processed in real-time with powerful servers and intelligent algorithms.

Data from transaction registering in an ATM can be coded and visualised to improve our understanding of the system. Data visualisation and pattern detection has been used in various other fields including software re-engineering and the study of programming languages (Shrestha, 2003) (Shrestha et al, 2004). Such known methods can be implemented in real-time data from ATM vaults to build automatic alert systems. Not only in ATM transactions, such a system capable of monitoring constantly and processing in real-time can also be implemented over the account transactions of a bank, or a group of banks. This adaptation can be a solution for cybercrimes like the one listed under 2.2.ii. Additional modules like keywords detection from chat data and telephonic conversations can also complement the detection process. Below are some of the images from the visualisation of artificially created data for ATM vaults (Fig 2).

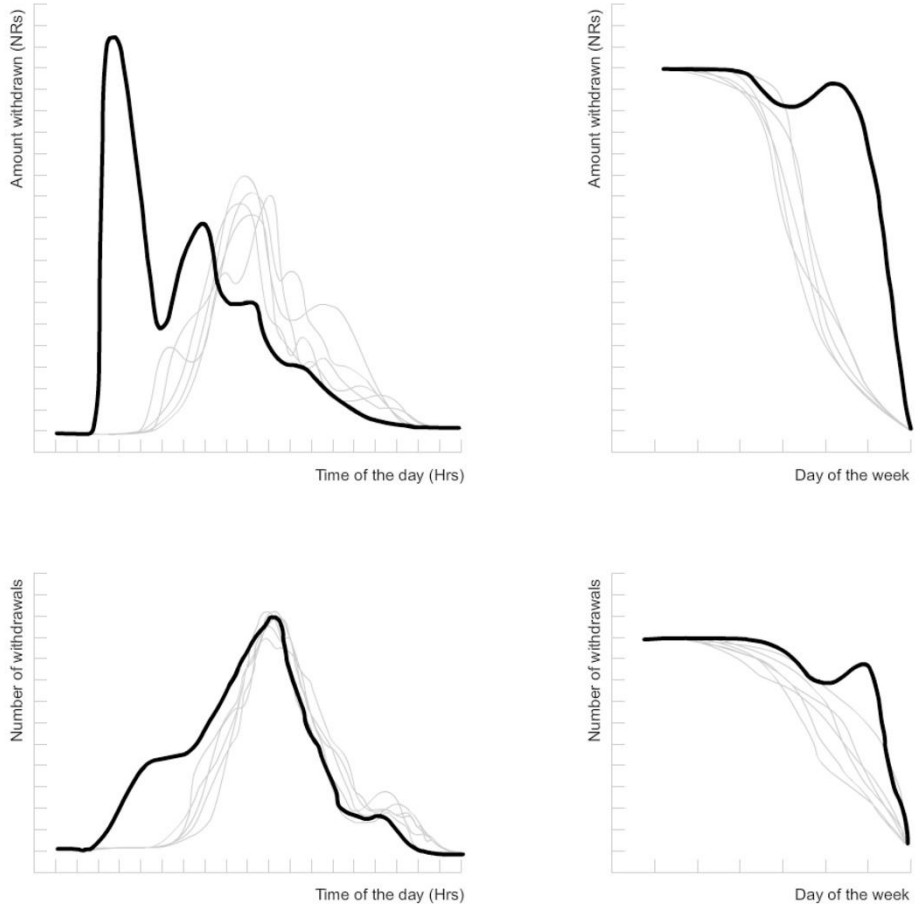

Figure 2: Visualisation of ATM cash withdrawals using artificially created data

They demonstrate the detection of predefined patterns that can attempt to prevent frauds without relying on manual processes and drawing inferences automatically. Such monitoring systems need to be scalable to accommodate bigger real-life graphs, which are constituted by a large number of nodes. Proactive monitoring can be one of the major roles of the proposed National Computer Emergency Response Team, which can work closely with Nepal Police.

7. Conclusion

Although there has been fairly some progress in formulating legal framework for handling data and cyber security, Nepal still has a number of lessons to be learnt from those countries with higher Global Cybersecurity Index. Besides the grave concerns raised by the advocates of human rights, cybercrime policies alone are not going to be enough for Nepal in order to create a reliable and secure platform for domestic and international businesses to flourish. The discrepancies in policies as well as practice as highlighted in this paper need to be addressed. One way to fill those gaps is to compare with the UK counterparts before coming up with effective and local solutions. This paper enlists potential solutions like further elaborating of general data protection regulations, considering the importance of consent, developing data protection as a part of the work culture, investment in cyber security and proactive monitoring of fraud detection.

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Transport Modelling Application in Kathmandu: New Baneshwor Junction Example

Dr Birendra Shrestha
Principal Transport Modeller, Transport for London, United Kingdom
b.p.shrestha@hotmail.com

Abstract

Transport modelling is a technique that can assist to assess the outcome of a transport scheme before implementing in the field. Depending of the type and the extent of the scheme, different modelling approaches may be used on its own or a in a combination of different approaches. Three distinct transport modelling approaches widely used are: macroscopic, mesoscopic and microscopic. Among these, microscopic modelling approach provides an excellent experimental base for the design of control strategies which enables the visual and statistical evaluation of the achieved results. Such a tool was used to assess the effectiveness of manual traffic control versus optimised automatic traffic control taking New Baneshwor junction in Kathmandu as an example. This paper describes various transport modelling approaches, compares the effectiveness of traffic signal option using a selected approach and demonstrates how a transport modelling tool could be used to assess the effectiveness of a traffic scheme.

1. Introduction

Apart from being the capital city, Kathmandu is the most populated city in Nepal. Being a main hub for businesses, education, health and foreign travel, the population of Kathmandu is ever increasing. This has led Kathmandu Valley through a phase of massive urbanization, with the population going up by a million within few years. Along with the growing population, the vehicle ownership is also increasing. As a result, there is a considerable increase in traffic in Kathmandu's roads. Serious traffic congestion with frequent standstill of traffic for extended periods in Kathmandu Valley's roads is a daily routine (Figure 1).

Figure 1: Queuing traffic at Maharajgunj junction in Kathmandu

Attempts have been made to address the increased traffic demand by expanding some part of the road network and signalising some of the junctions. However, the traffic signals seem to be switched off during the peak hours and handled by manual control by the traffic police. The reason given for switching to the manual control instead of automatic traffic signal control is effectiveness of the timing. To compare the effectiveness of manual traffic control versus

optimised automatic traffic control, this comparative study was carried out using a transport modelling tool. For this purpose, different traffic signal timings at New Baneshwor junction were modelled to compare junction performance. This paper describes various transport modelling approaches, compares the effectiveness of traffic signal option using a selected approach and demonstrates how a transport modelling tool could be used to assess the effectiveness of a traffic scheme.

2. Modelling approach

Modelling of a transport scheme is carried out to assess the outcome of the scheme before implementing in the field. Depending of the type and the extent of the scheme, different modelling approaches may be used on its own or a in a combination of different approaches. Three distinct transport modelling approaches widely used are: macroscopic, mesoscopic and microscopic. Figure 2 shows the hierarchy of these approaches.

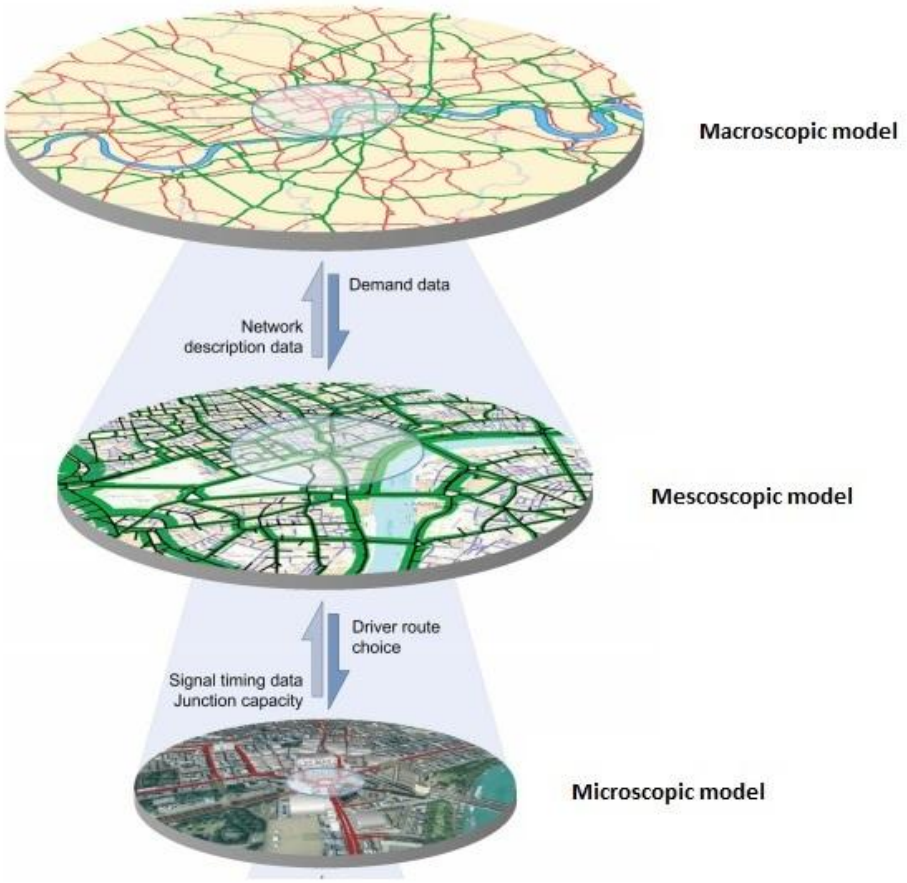


Figure 2: Transport Modelling Hierarchy (Adapted from TfL, 2010)

Macroscopic approach is a high level modelling which is focussed at assigning traffic in a large area i.e. estimating the routes and flows of traffic in a network. In this approach, traffic models use formulae with average values of the parameters such as vehicle flow and capacity over a period of time. CONTRAM, SATURN and Visum (PTV, 2019) are the examples of the models based on this approach. These models can be used in the evaluation and assessment of big traffic management schemes (e.g. pedestrianisation of a road, constructing a cycle route)..

At mesoscopic level, the model deals with more detailed information than macroscopic modelling and takes count of individual vehicles. However, they are not individually identifiable and controlled. The most detailed level of modelling is microscopic modelling in which individual vehicle is modelled. See Aimsun Chapter

Microscopic simulation, an attempt is made to model the behaviour of each vehicle/driver as it moves through the road network, based on the characteristics of the vehicle and driver behaviour. Microscopic simulation environment provides an excellent experimental base for the design of control strategies which enables the visual and statistical evaluation of the achieved results. There are a number of commercially available microscopic simulation modelling softwares including Vissim (PTV, 2019) and Aimsun (Aimsun, 2019) as a market leaders.

A microscopic model road links, roundabouts, priority junctions, signalised intersections and traffic management measures at a high level of details. Such a model use car following and lane changing models to mimic the driver behaviour in the field. Its signal control program can use detectors to measure traffic characterises of individual vehicles (i.e. speeds, volumes, travel times) to alter the signal timings accordingly. Such a model is very useful in understanding the detailed traffic behaviour in the modelled network. These models provide detailed insight of a scheme with visual representation of individual vehicles showing use of the traffic lanes, queuing vehicles, any blocking back. Hence, such tool is very effective in the detailed modelling of a congested traffic signalised junction. As such model allows to model traffic signal operation based on the vehicle detection, manual traffic control could be simulated by changing the detection parameters. Hence this approach is used in this study for detailed exploration and effective visualisation of the junction working.

3. New Baneshwor Junction

New Baneshwor junction is a major junction at the heart of Kathmandu. The junction is at the middle of the main link joining the centre of the city with eastern parts including the international airport. The junction is next to the international conference hall where the country's parliament is sitting at present. Due to the importance of the junction, this junction had gone under major improvement project under the assistance of Japan Government in ... (Source). In addition to the improvement of the layout, traffic signals were also installed at the junction to control the traffic automatically. However, at present, the traffic signal control is not operational during the peak periods and manual method of control is used instead. The reason for using manual control instead of automatic traffic signal control is said to be ineffectiveness of the automatic signal timing. Current layout of the junction manually controlled (traffic police at the centre of the junction) in the morning peak is shown in Figure 3.

Figure 3: New Baneshwor Junction under manual traffic control

As the current traffic signal control is fixed time, the signal timings are based on the traffic flows counted during the design. If there is a change in traffic demand from the survey, the traffic signal control is not effective. In such case, either the traffic signal needs to be adaptive so that traffic

signal timing changes according to the traffic demand in the field or there should be options to choose an appropriate signal timing plan for a specific time period. In both cases, however, signal timing plans must be clearly thought and properly designed to maximise the efficiency of the junction. Transport modelling tool helps producing the output based on the traffic demand and various options that are considered. For example, two signal timing options are compared in this paper.

The modelling of the junction is based on the site visit by the author in November 2019. The traffic data used in the model is based on the JICA report (JICA, 2018). The traffic count data provides hourly flow at the junction presented in terms of the Passenger Car Unit (PCU). It is to be noted that there are service lanes running parallel on the both sides of the main road (Madan Bhandari Road). These service lanes are used by public transport and left turning traffic only. So, the volume of left turning traffic using parallel service road is removed from both East and West approach. Figure 4 shows the layout of the junction modelled and Table 1 shows the traffic flows in terms of PCU modelled in the model.

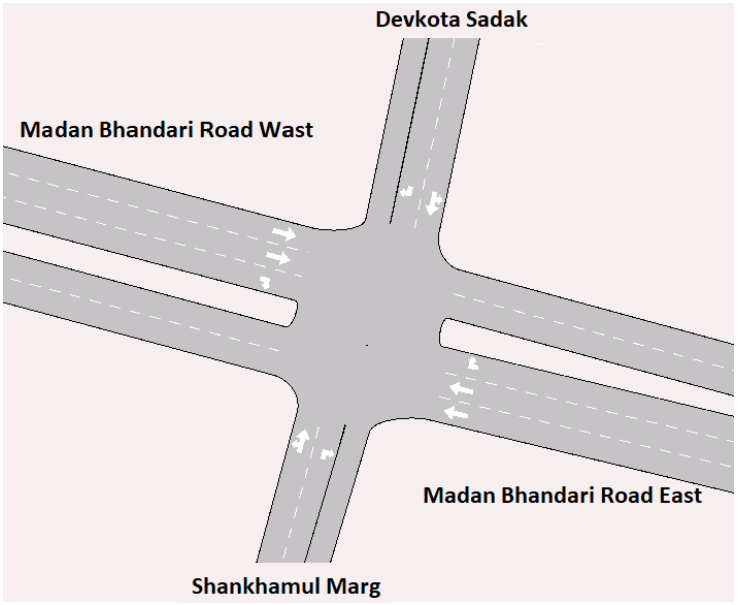


Figure 4: Junction layout of New Baneshwor Junction

Table 1: Traffic flow modelled (PCU/hour)

	Madan Bhandari Road East	Devkota Sadak	Madan Bhandari Road West	Shankhamul Marg	Total
Madan Bhandari Road East	0	0	1089	109	1198
Devkota Sadak	267	0	155	499	921
Madan Bhandari Road West	2062	257	0	0	2319
Shankhamul Marg	131	362	106	0	599
Total	2460	619	1350	608	5037

Using the traffic flows, two signalling options modelled are shown in Figure 5 (a) and (b):

a. Existing : Similar to the manual method of control
b. Proposed: Devised on the basis of the traffic flows

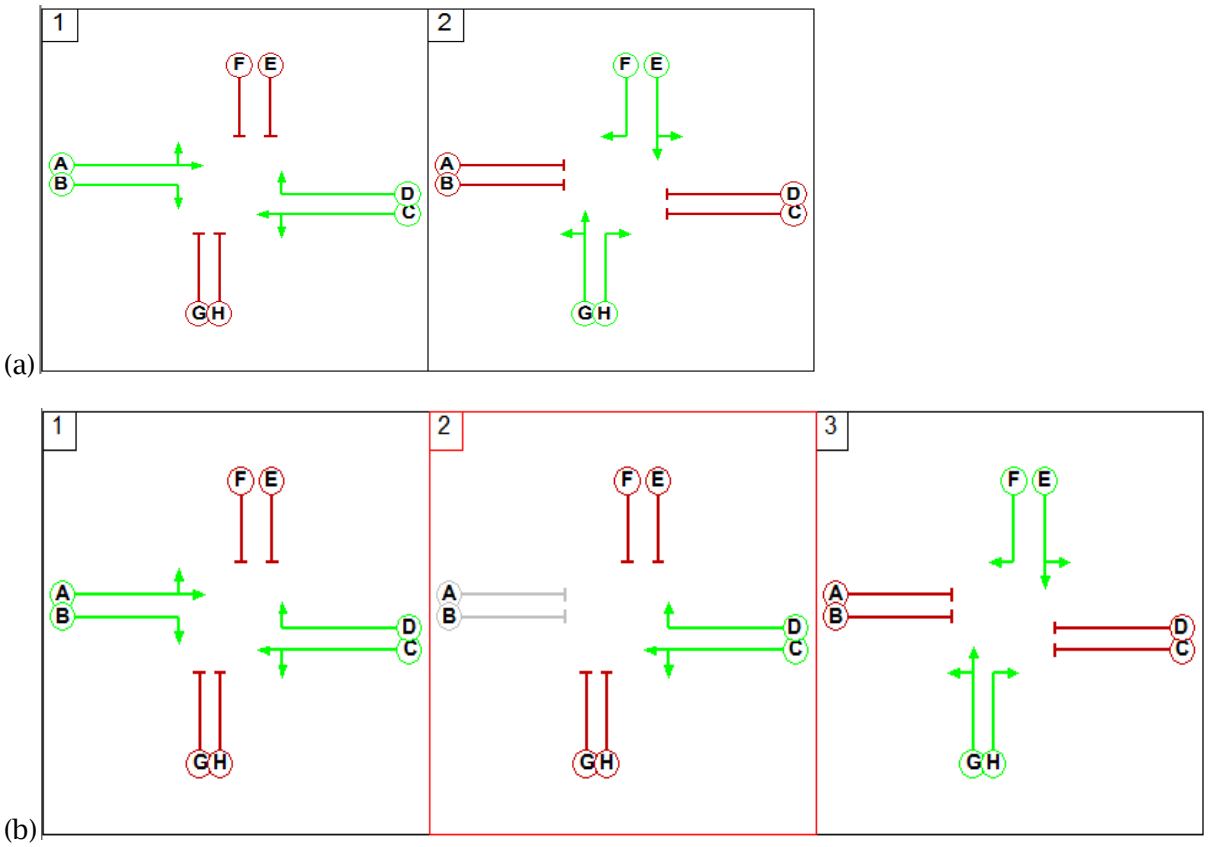


Figure 5: (a) existing method (b) proposed method of signal control

In exiting option (option a) only 2-stage control is adopted. To emulate the way of manual control detectors were placed on the approaches and the signal timings were extended till there is a big gap between vehicles in an approach. The option (b) proposed method has 3 stages with a stage in the middle for traffic turning right to Devkota Sadak from Madan Bhadari Road. The expectation was that the dedicated right turn will cater the need of heavy right turning traffic a improve the efficiency of the junction.

4. Results

The visual output of the end of simulation is given in Figure 6 and the main output parameters of the simulation result are given in Table 2.

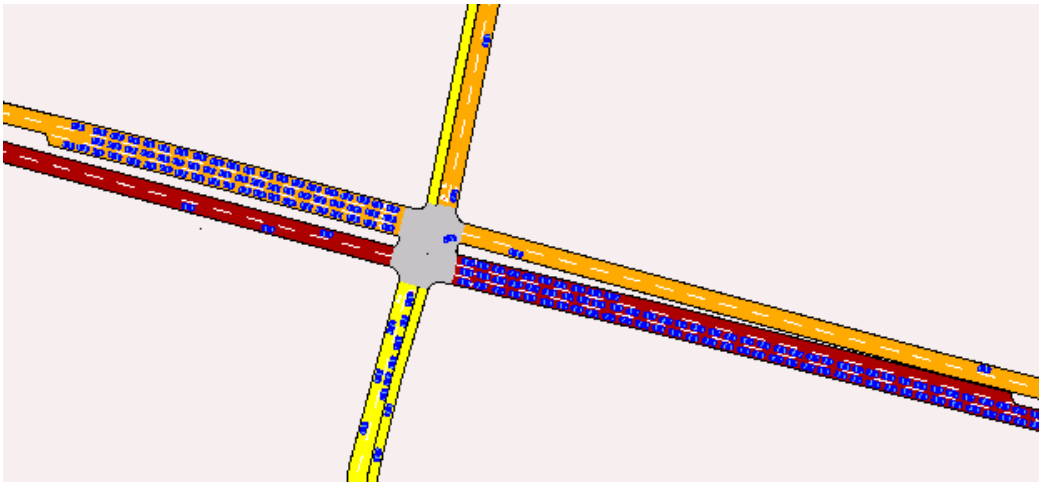
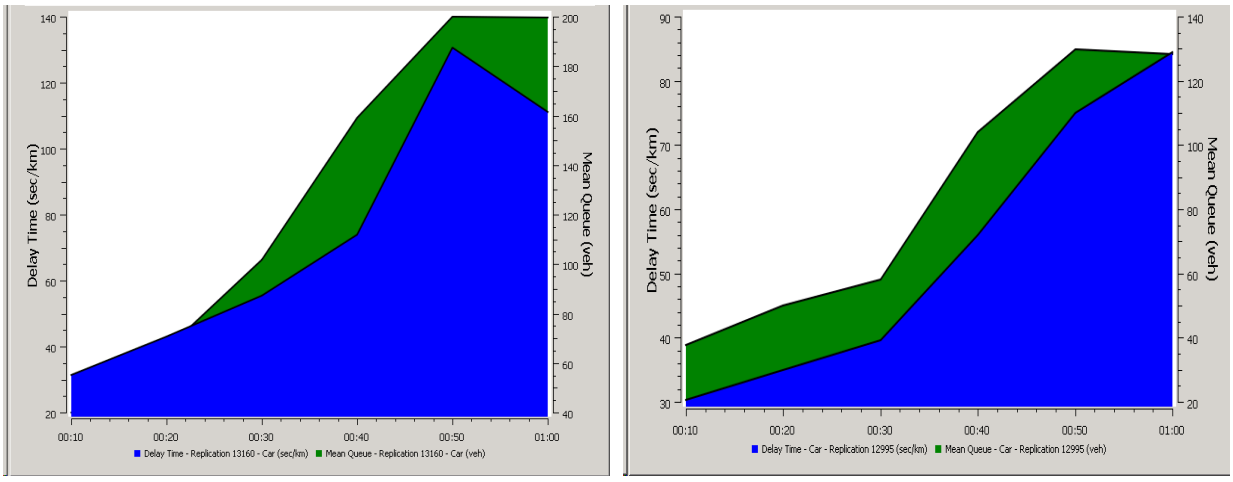


Figure 6: Vehicle queuing at the junction at the end of the simulation

Table 2: Model output

Output parameters	Existing	Proposed	Change
Mean Queue (veh)	127.8	84.6	34%
Delay Time (sec/km)	76.1	54.4	29%
Total Number of Stops (number)	3856.9	4325.1	-12%
Speed (km/h)	28.7	27.9	3%

It is evident from Table 1 that the proposed signalling option (option b) performs better than the existing method of control (option a). The proposed method reduces the mean queue by 34% in comparison to the existing method. This has resulted in the reduction of total delay time at the junction by 29%. Shorter queue and lower delay is found to be the case for every 15 minute time slices as shown in Figure 7.



(a) *(b)*

Figure 7: Delay and queue results for 15-minute time period for (a) existing method (b) proposed method of signal control

The bigger delay in the existing option is due to the method of signal control opting to clear queue of an approach rather than balancing the green time within a limit. This type of balancing is a tricky when controlling manually as in the case of New Baneshwor Junction. However, this type of control reduces the number of stops due to the less number of signal changes happening in an hour. There is also a slight increase in the average speed of the vehicles as result of less number of stops. Overall, results show that the proposed option is more efficient than the existing method of control.

5. Limitations and Discussion

The results of this study provided promising output in favour of properly designed fixed time traffic signal control. However, before generalising the results, some of the known limitations and the justifications for the validity of the results are discussed below.

The simulation modelling carried out in this study based on the default parameters in Aimsun. The model being the product of a European country, default parameters may not entirely true for the driver behaviour in Kathmandu. It would have been better if the parameters were based on the data from Kathmandu, which is an expensive and time consuming exercise. However, as the attempt in the paper has been to compare the effectiveness of two different signalling options

rather than the estimation of the absolute value, the use of the model with default parameters is acceptable.

As the data in the JICA report is given in terms of the PCU (Passenger Car Unit) instead of the vehicles (car, bus motorcycle, etc.), the model has only cars in it. The model has not included other types of vehicles including motorcycles which are dominant type of traffic. Even if the motorcycle count data was available, motorcycle drivers' behaviours is not well defined in the models and hence would be difficult to use. Again, this being comparative study, the relative results are valid.

In the model, exiting option (option a) is modelled as a vehicle actuated junction to emulate the way of manual control. In such operation, signal timings are changed according to the detection of the vehicles at the detectors placed on the approaches. The signal timings were extended till there is a big gap between vehicles in an approach. The different gap values produce different results for the same model. However, in the field, this gap depends on the personnel controlling the traffic and hence not possible to model accurately for all situations.

Even though the results presented in the paper are related to the efficiency of the junction operation, benefits could be compared in terms of the environmental and health benefits too. Especially, the implementation of the automatic signalling system removes the need of the traffic police resources at the junction. This reduces the cost of man power controlling a junction operation as well removes the health hazard caused by roadside pollution to the personnel standing at the middle of the junction during the busiest period of a day.

6. Conclusion

This paper has described various transport modelling approaches that could be used to assess a transport scheme. The appropriateness of these approaches depends on the scope of the scheme defining the extent of the scheme and the details of the analysis needed.

This paper showed that traffic signal operation could be improved by testing various options using a transport modelling tool to find the most efficient one. The results demonstrated that the properly designed traffic signal option could improve efficiency of a junction in comparison to the manual traffic control operation. However, in some cases where junctions are very close to each other, optimum solution at a junction may not be sufficient. In such situation, coordination of traffic signals may be needed to find the optimum solution to the whole network of these signals (rather than only one). This will much more complex traffic signal controller also known as Urban Traffic Control (UTC) which control several traffic signals under a single platform.

There are many variants of UTC system currently implemented around the world. London's UTC system is known as SCOOT (Split Cycle and Offset Optimisation Technique) (Department for Transport, 1995). In addition to the optimum solution to the whole network of signals, such system also provide other advanced traffic management applications such as gating and bus priority at traffic signals (Shrestha, 2003). These applications allow authorities to implement more environment friendly transport to encourage public transport such as buses (Shrestha, 2019)

Practice of carrying out transport modelling before implementing a transport scheme is a standard practice in the developed countries where it needs to go through rigorous scrutiny of the stakeholders involved (road users, neighbourhood, pressure groups, etc.). Adopting such practices save wasted resources and unnecessary investment. This is especially important in the mega urban transport project including tunnel approach at Thankot-Sisne Khola project.

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Formulating sustainability policies for middle-and low-income countries: A case study of Nepal

Parakram Pyakurel and Ramesh Marasini
Postdoctoral Researcher, Solent University, UK
Associate Professor, Buckinghamshire New University, UK

Abstract

Countries with different income levels need different policies for sustainability and therefore sustainability policies cannot be generalized. The sustainable development policies used by the developed countries require adaptation and contextualisation whilst developing the sustainability policies and priorities on middle- and low-income countries. This paper through, the literature review, introduces a sustainability framework for developing countries, which embeds United Nations Sustainable Development Goals (SDG) and proposes a policy formulation strategy by categorising policies into manageable sub-divisions. A sustainable framework as has been presented using a case study of a low-income country, Nepal.

Keywords: Sustainable development, Policy formulation, Governance strategy, Low-income countries.

1. Introduction

The processes towards achieving sustainable development goals are different for the middle- and low-income countries because of their differing backgrounds and development priorities (Couret, 2008). This paper adopts country categories of middle (including upper middle and lower middle) and low-income as classified by the United Nations (UN) (WESP, 2018). Figure 1 shows the data from world bank on carbon footprint per capita for high income countries like USA, UK, middle income countries like China (upper middle income) and India (lower middle income) as well as a low-income country like Nepal.

- US 16.5
- China 7.5
- UK 6.5
- India 1.7
- Nepal 0.2

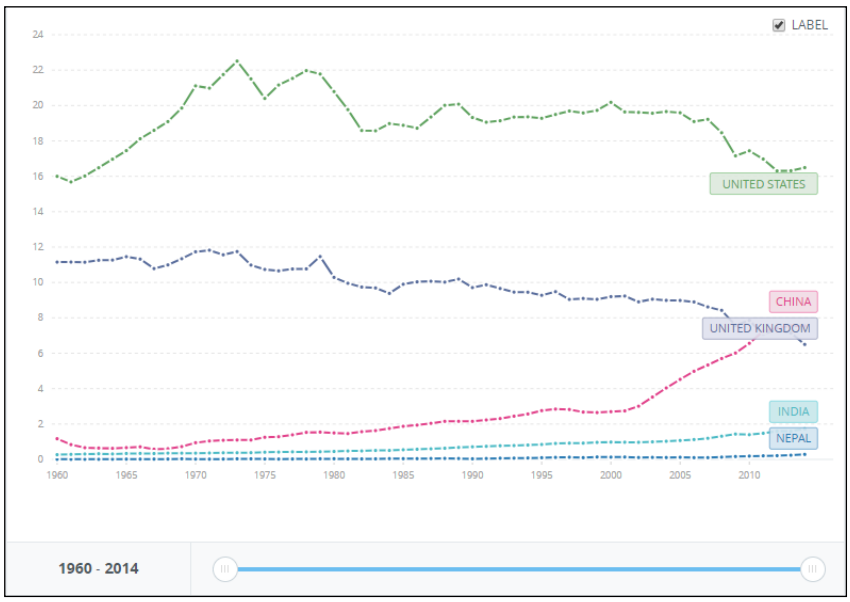

Figure 1: CO_2 emissions metric tonnes/capita (source: World Bank, 2019)

It is obvious that the priorities for sustainable development would be different, the developing countries require strategies for carbon footprint reduction whilst maintaining quality of life and social equity. For the middle-income countries, the strategy for sustainable development is mainly focused on maximising energy efficiencies through innovative technologies and processes and improve quality of life through social equity, infrastructure, health and comfort. For the low-income countries, the sustainability is driven by the requirements such as elimination of poverty, job creation, training of unskilled workforce, providing safe shelter and drinking water amongst other issues. The main factors that could either enable or cripple sustainable development in low-income countries have been identified as complex interactions among poverty, climate change, rapid urbanisation and food insecurity (Cobbinah et al., 2015). Likewise, Asongu (2015) from the prospective of donor agencies to low-income countries suggest that the factors to achieve sustainability should include: mitigate short-term poverty, address concerns of burgeoning population growth, train recipient governments on inclusive development, and fight corruption and mismanagement. Although the factors affecting the implementation of sustainability in the low-income countries have been identified and basic recommendations proposed, Couret (2008) suggests that differing approaches have been suggested or implemented in the low-income countries and there is a lack of clear policy formulation strategies for sustainability specifically focused for middle-and low-income countries.

This paper proposes a framework that comprises strategies to formulate policies for sustainability in middle and low-income countries by creating policy categories encompassing key factors that affect sustainability. The framework can be utilised as a planning tool for policy formulation by governments and other concerned regulating bodies. A case of Nepal is considered to illustrate the policy formulation strategies. The term sustainability is used in this paper in a broad sense to account for all the Sustainable Development Goals (SDGs) (UN, 2015) declared by the UN.

2. Sustainable development goals

Focus on economic growth and consumption as a means for development has been noted as major inconsistency that challenges the sustainable development paradigm (Spaiser et al., 2017). Given the broadness and openness to interpretation of the term “sustainable development”, several attempts have been made to clarify and improve the definition of this term (Bolis et al., 2014; Imran et al., 2011). In this paper, terms like “sustainability” and “sustainable development” exclusively focuses on the UN’s SDG (UN, 2015). The UN’s SDG comprises of 17 goals that are strongly directed at middle and low-income countries. These goals include no poverty, zero hunger, affordable and clean energy, sustainable cities and communities, and climate action. In subsequent section, a strategy to formulate sustainability policy framework that encompasses SDG is presented.

3. Policy framework

Sustainability policy framework applicable to middle and low-income countries is presented in Figure 2. Critical earth-system processes such as climate change, rate of biodiversity loss, nutrient cycles and environmental pollutions (Griggs et al., 2013) are considered to prepare the framework. To facilitate effective sustainability policy planning, this paper divides the policy making process for sustainability into three categories, namely, governance policy, livelihood policy and control policy (Figure 2). These policies are briefly discussed below:

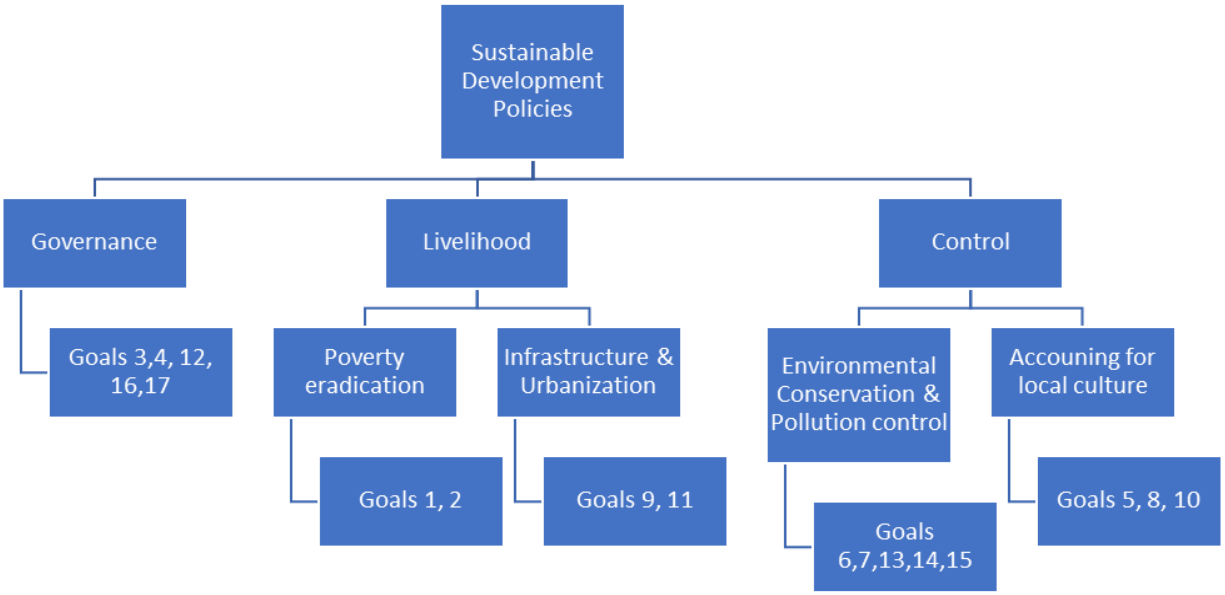

Figure 2: Sustainable Development Framework

3.1 Governance policy

This category of sustainability policy guides the management of top-level government operations. Meadowcroft et al., (2005) point out that governance for sustainability is a future driven continuous process where governments need to address issues such as environmental limits, sustainable resource management, human population and so on. They also emphasise that multilevel governance and co-ordination at local, regional, national, international and global scales is crucial where decision-makers remain responsible to citizens, communities and stakeholders.

The lack of accountability of decision-makers in developing countries is a key factor leading to corruption and malpractices in the implementation of sustainable development. Peace, justice and strong institution is Goal 16 (UN, 2015) of SDG and Transparency International (TI, 2017) has highlighted that SDG cannot be achieved without tackling corruption. The developing countries rely on aid from donor agencies for various development initiatives. Although finding exact data is hard and maybe not even possible, corruption on aid money is one of the biggest challenges in poor nations (Kenny, 2017). Donor agencies need to work with government and robust aid flow monitoring mechanisms need to be developed to understand how and where corruption happens. Approach to combat health sector corruption by leveraging SDG has been proposed by Mackey et al., 2018 this approach can be extended in all sectors. Adapting from Mackey et al. (2018), it can be argued that coordination among all stakeholders, better advocacy and stronger institutions, and focused political will to combat corruption in all levels are required.

For sustainability, the decisions should be taken at appropriate levels closest to the citizens, which emphasises the importance of decentralisation. The degree of decentralisation is found to be much less in poor nations compared with developed nation (Olowu, 2003) which implies that the levels of autonomy of local governments are low in poor nations. Sustainability oriented governance policy should ensure and promote decentralization so that local governments can effectively execute local level development projects and programs. The importance of hastening decentralization for sustainable development for Cameroon has been highlighted by Kimengsi & Gwan (2017). Since decentralization empowers local communities, it should be a crucial component of governance policy. Table 1 summarises the essential requirements for sustainable governance.

Table 1: Key requirements for sustainable governance (Meadowcroft et al. 2005)

Requirements	*Examples*
Appropriate political frameworks	Goal identification, monitoring, evaluation and continuous improvement at all levels of governance
A long-term focus	Strategies for next 20-30 years, not a reactive response
Understanding of ecological processes and of social/ ecological interactions	Bio-diversity, importance of preserving natural habitats, ecosystem services
Knowledge integration from natural and social sciences into decision making process	Circular economy, climate change, sustainable production and consumption patterns
Use learning processes	Learning from failures

In the context of Nepal, accountability strategies as highlighted in Table 1 should be some important factors to be considered while devising governance policy on sustainability. Stronger community level engagements in local governance policies can help utilise local resources and knowledge for development in Nepal. This is particularly important as lack of understanding and application of indigenous resources has been identified as one of the constraints for better public accountability (Kim, 2009).

3.2 Livelihood policy

A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base (Krantz, 2001). This category includes policies that tackle major livelihood challenges of middle and low-income nations such as poverty and economic growth. The Livelihood policy can be further divided into poverty eradication policy and infrastructure and urbanization policy as discussed below:

Poverty eradication policy
This policy aims at achieving Goals 1 (No poverty) and 2 (Zero hunger) of the SDG. Approaches to poverty eradication have to be identified on a case by case basis for every nation and be built into the poverty eradication policy. Nevertheless, some key guiding principles that generally applies to majority of middle and low-income nations are: improving agricultural yields, improving non-farm economy and expanding income-earning opportunities (Yanagihara, 2003) in general.

Nepal targets to reduce population living under extreme poverty to below 5% by 2030 (NPC, 2017). Nepal has made a remarkable progress in poverty reduction over the past few decades, mainly due to labour migration abroad (Uematsu et al, 2016). However, poverty eradication should not just rely on remittance money sent by migrant workers back to Nepal and poverty eradication strategies that generates local employment need to be explored. Some lessons learned from World Bank supported poverty alleviation project (WBG, 2017) have been need of coordination among different government ministries, training needs for local communities, and robust data collection. In this regard, policy to support robust database creation on poverty situation of Nepal is needed. Likewise, policies that enable socio-economic surveys at granular levels are needed to identify potential poverty alleviation projects, training needs of poor communities and types of support most effective for poor communities.

Infrastructure and urbanisation policy
This policy combines two major Sustainable Development Goals of the United Nations, i.e. Industry, Innovation and Infrastructure (Goal 9) and Sustainable Cities and Communities (Goal 11) (UN, 2015). Two main purposes of this policy are to: a) guide infrastructural buildout and expansion and b) direct the urbanization process. As opposed to high income nations nations,

infrastructure based on consumption of depleting natural resources do not already exist in low-income nations, which provides an opportunity for utilizing sustainable materials, techniques, and technologies for construction and management of sustainable infrastructure. Therefore, utilization of energy sources and materials that are regenerative and sustainable has to be built into infrastructure planning and policy. In the context of landlocked country like Nepal, transportation, energy infrastructure and information and communication technologies have been identified as crucial infrastructural constructions that have to be given priorities (Jaimurzina & Sanchez, 2017). In the context of Nepal, major national pride projects (NPC, 2019) include irrigation, road, dam and hydropower (energy infrastructure) projects. It is suggested that large scale information and communication technologies project also be considered for national pride projects.

Since the populations of middle and low-income nations are expected to move to urban areas, the United Nations Development Programme (UNDP) has identified inclusiveness and resilience as important factors to promote sustainable urbanization (UNDP, 2016). Therefore, urbanization policy should help improve equality and inclusiveness in cities so that equal opportunities are accessible to all the population. Likewise, a resilient city is able to adapt to changes without compromising its stability and measures that improve city resilience should be a part of urbanization policy. Other important factors that should be considered in urbanization policy are approaches to tackle urban poverty and sustainable transportation.

In the context of Nepal, rail connection from India (Kolkata Port) (UNCRD, 2018) and China to Nepal is essential to enable effective flow of goods for both import and export. Likewise, the target to increase the paved road density by 2030 by 25 times the density level of 2015 (NPC, 2017) is important to be met as this promotes equitable road access to rural population (SDG Goal 9, target 9.1). Furthermore, Kathmandu is an overcrowded metropolitan city where urban area expanded up to 412% in last three decades and the most of this expansion occurred with the conversions of 31% agricultural land (Ishtiaque et al, 2017). The dramatic population growth has caused major sustainability issues such as air pollution, waste management problem and water scarcity (Mohanty, 2011). Therefore, it is necessary formulate urbanization policies that enables urbanization of other cities so that the population pressure from Kathmandu can be eased. Sustainability indicators need to be developed for cities to plan and monitor sustainability of Kathmandu and other cities.

3.3 Control policy

This policy category provides regulatory framework to ensure that development and construction works carried out under infrastructure and urbanization policy (see Section 3.2.2) ensure sustainability. The Control policy can be further divided into two divisions as discussed below:

Policy for environmental conservation and pollution control
This policy aims at achieving Goals 6 (clean water and sanitation) 7 (affordable and clean energy), 13 (climate action),14 (life in water) and 15 (life in land). Infrastructural development and expansion demand massive consumption of natural resources and energy, which can eventually to lead to severe environmental degradation. Therefore, policy and guidelines need to be developed for natural resources consumption pattern for building new infrastructure as well as expanding existing infrastructure. The policy framework for sustainable urbanization as well as sustainable infrastructure development and expansion should have at least following three requirements:

- Application of objective and possibly quantifiable metrics to measure sustainability of infrastructure to be constructed or expanded;
- Economic Cost benefit analysis;
- Environmental effects analysis.

Issues of waste management and pollution control are likely to be critical with the construction and expansion of infrastructure as well as urbanization. Therefore, policies for the optimal management of waste and pollution are required. Adoption of circular economy can be explored to minimize waste, pollution and natural resources consumption. Prospects of circular economy in ensuring sustainable development has been stated by Korhonen et al. (2018) which defines circular economy as economy constructed from societal production-consumption systems that maximizes the service produced from the linear nature-society-nature material and energy throughput flow. This is done by using cyclical materials flows, renewable energy sources and cascading-type energy flow.

In the context of Nepal, conservation and maintenance of forest and plant diversity resources should be a part of policy formulation as forests with relatively high plant diversity values have been found to be important for providing critical forest products (fuelwood and fodder) to local communities (Rana et al, 2016). However, population and pollution management should be given major priorities in the policy formulation for Kathmandu.

Policy of accounting for local culture
This policy indirectly supports achieving Goals 5 (Gender equality), 8 (Decent work and economic growth) and 10 (Reduced inequalities) of the SDG. Culture-led development programmes promote greater social inclusiveness and rootedness, resilience, innovation, creativity and entrepreneurship for individuals and communities, and the use of local resources, skills, and knowledge (UNESCO, 2012). One the other hand, ignoring culture can lead to bad policy (Small et al., 2010). Furthermore, culture has been identified as one of the pillars of sustainable development by United Cities and Local Governments (UCLG, 2018). Therefore, cultural beliefs and sensitivities of a community has to be carefully taken into account before formulating any policy on community development. A case study of Akash Bhairav Temple in Kathmandu, Nepal has been presented as an example of the importance of culture in community development by Singh & Keitsch (2018). They argue that development project in Indrachowk (community surrounding the Akash Bhairav Temple) that disregards the cultural values and aesthetic perceptions of local people will not last long because the locals will lose interest in the project and development project in which the locals do not feel the ownership is bound to be unsustainable.

4. Conclusions

This article proposes a sustainability policy formulation framework by classifying complex policy strategies into manageable sub-divisions for middle-and low-income countries. The framework covers three main groups of policies: governance, livelihood and control, which encapsulates Sustainable Development Goals providing a holistic and joined-up approach. Several examples have been included in the paper using Nepal as a case study of low-income countries. The examples overwhelmingly suggest that several political and economic factors determine the sustainable development priorities. For the policy formulation, management of natural resources should be given a high priority.

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Evaluation of Low Rise Building Systems in Hilly Regions of Nepal

Jagat Kumar Shrestha, PhD

Associate Professor, Institute of Engineering, Tribhuvan University, Lalitpur, Nepal
Email: jagatshrestha@ioe.edu.np

Abstract

This paper assesses total energy consumption and CO_2 emission of different structural systems of buildings used for the reconstruction of earthquake-resistant houses in Nepal after the Gorkha Earthquake. The Ecoinvent dataset version 3.5 and software tool OpenLCA version 1.8 has been used to assess the total energy consumption and CO_2 emission due to construction of brick masonry, compressed earth block, interlocking block, reinforced cement concrete and stone masonry buildings after the earthquake considering the climate change category in the context of hilly regions of Nepal. The study considers four stages of lifecycle assessment: , material production and transportation stage; the construction of the building stage; operation of the building and demolition stage of the 5 low rise residential buildings with bricks, stone and concrete construction materials. The study concludes that the selection of building structural system and the materials of construction contributes by more than 60%in total lifecycle energy consumption and CO_2 emission that responsible for a high impact on the environment. The findings of this study would be useful to the policy makers to select the right structural system of the building with appropriate construction materials for the construction of houses minimising the impact to the environment.

Key Words: Life Cycle Assessment, construction materials, low rise building system, energy consumption, CO_2 emission

7. Introduction

The construction and operation of buildings pose a massive impact on the environment because it consumes huge natural resources and releases emission which are giving rise to Global Warming. According to Roodman et al. (1995), buildings are responsible for 17% world's freshwater withdrawals, 25 % wood harvest and 40% material and energy flow causing the significant effect to the environment. United Nations Environment Program (UNEP) Global Status Report 2017 reported that building and construction (including manufacturing of materials and products) together contribute around 36% of global energy use and 39%of energy-related carbon dioxide (CO_2) emission (Abergel et al, 2017). The impact of buildings to the environment has become a pertinent issue and a number of studies have been conducted devising different analysis tools to assess the impacts as well as explored the ways to reduce the energy consumption and its environmental impact (Singh et al, 2011).

Among the assessment tools developed by the researchers to model the realistic situation, Life Cycle Assessment (LCA) tool is considered as a reliable tool to evaluate the environmental impact of a product throughout its life cycle (Fava et al, 2009) , (Oyarzo et al, 2014). The life cycle of a product consists of the pre-use which includes extraction and acquisition of raw materials, material production, and manufacturing process and the end-of-life. The study of the life cycle of a product helps to identify the potential impact on the environment and adopt counteractive measures to avoid the negative impacts ISO, 2006). The LCA concept has also been extended to the LCA analysis of the buildings (Adalberth, 1997). The LCA tools are being used in life cycle studies of buildings all over the world using ISO 14040 series as a basis. However, researchers have adopted different methodologies for different studies (Rashid and Yusoff, 2015).

The LCA tool has been widely used in the impact assessment of different materials of the buildings. Fujita et al. (2008) used the tool to estimate CO_2 emission for concrete and timber houses for the pre-use and operational phase. Omar et al. (2014) compared a conventional concrete house and an industrial building system house with a precast wall panel for concrete and steel reinforcement using the LCA for the pre-use phase. However, a full building life cycle or 'cradle-to-grave' analysis is required for the evaluation of the full environmental impact of residential buildings on the global warming impact. The LCA of any particular building involves evaluating its whole life-cycle (the construction stage, operation stage, maintenance stage, and demolition of buildings stage).

In the context of Nepal, after the country was hit by 7.8 magnitudes Gorkha Earthquake in 25th April 2015 and its subsequent aftershocks, more than half a million houses were destroyed (NPC, 2015). After the earthquake, the country has been going through major rehabilitation and reconstruction activities. The reconstruction of durable and earthquake resistant houses with local skill and feasible materials is the foremost challenge. Meanwhile, new technologies have emerged for fast reconstruction activities. Compressed Stabilized Earth block (CSEB) is one of those new innovations for Nepal. The basic materials used for CSEB are soil, cement and water which are ultimately compressed to a block (Waziri and Lawan, 2013). The CSEB block has been widely used in reconstruction of the earthquake damaged houses in remote villages since it only requires simple machines and materials are locally available except cement. Besides that, other structural systems used for houses construction since prior to the earthquake reconstruction are Reinforced Cement Concrete (RCC) frames basically in urban areas, cement mortar or mud mortar masonry in burnt bricks and stones.

The most common structural system used in buildings in Nepal is load bearing system and framed system with reinforced concrete and the major construction material used are stone, burnt bricks, concrete, steel, timber, Interlocking Bricks (IB) and the CSEB. However, the environmental impact of materials used in the structures has not been sought in these constructions which is an important issue that engineers often should have balanced in their design choice against the environment. A significant anthropocentric environmental impact is derived from civil construction (Akan et al, 2017). Assessment of present level of impact of construction works should be known for lessening environmental consequences as it has been estimated that 40 to 50 percent of greenhouse gases are produced by the construction industry. In this respect, the sustainability issue and energy consumption which poses less impact to the environment from these construction activities with different options of the structural system to be studied. At present, many researchers are seeking for building construction materials that are less harmful to the environment. For example, the energy consumption and pollution emission in the production of some brick construction materials are shown in Table 1 (Maini, 2005). The data in Table 1 shows that the CSEB consumes significantly low energy and produces less CO_2 emissions. However, these materials should have sufficient strength for the required structural performance at the severed loading conditions.

Table 1: Energy Consumption and Pollution emissions of some brick materials

	Energy Consumption [MJ/m^2]	CO_2-emission [kg/m^2]
CSEB	110	16
Kiln Fired Bricks	539	39
Country Fired Bricks	1657	126
Plain Concrete Blocks	235	26

The assessment of the buildings is essential for sustainable material and low impact alternatives selection for the construction (Tarabieh and Khorshed, 2019). The total lifecycle energy of a building contains two components namely embodied energy (EE) and operational energy (OE) (Dixit

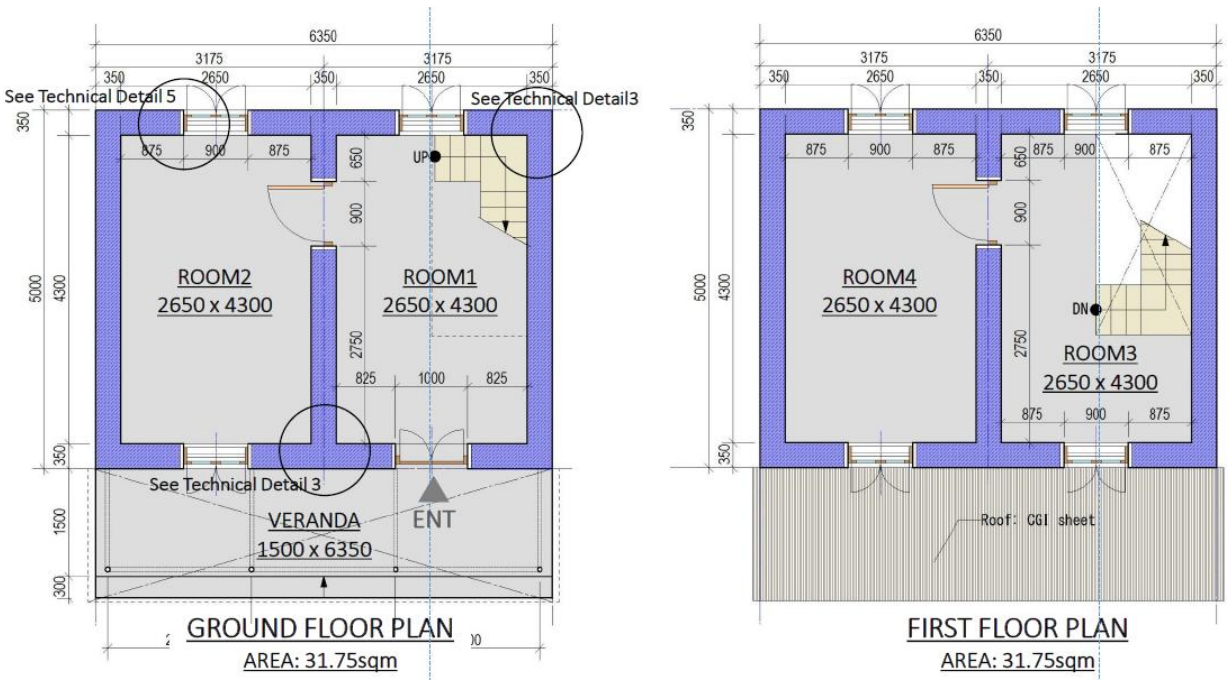
et al, 2012), (Hasan and Langrish, (2015). The importance of LCA in the construction sector is being increased because it helps in assessing the impact at each stage of the lifecycle of a product and identifies sustainable materials and improvement in the construction process that produces less harmful impacts to the environment (Bribián at al, 2011). In line with this, the environmental impact of the building of different structural system with different materials used in the constructions after the Gorkha Earthquake is assessed in this paper. This research aims to evaluate the low rise buildings considering environmental impacts through the entire life cycle of the buildings that provide good structural performance at the critical loading ensuring the safety and strength, which is being constructed under reconstruction and new constructions after the Gorkha Earthquake in Nepal.

8. Methods

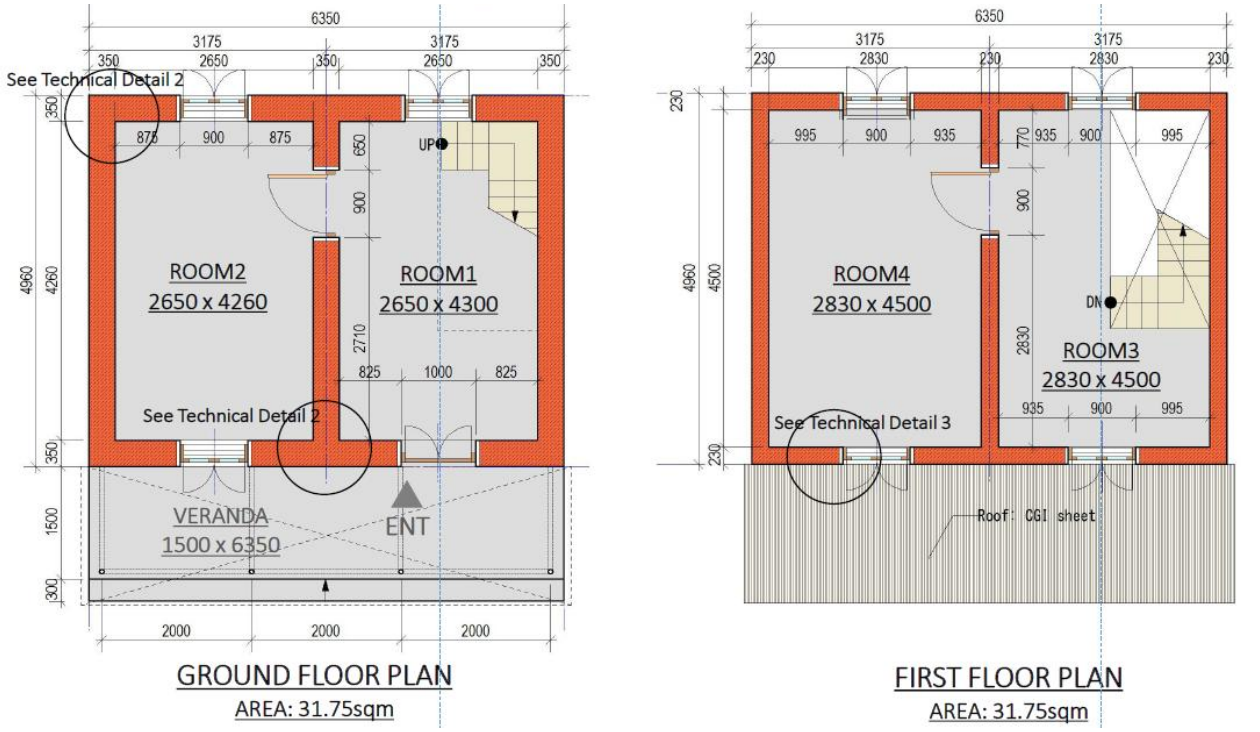
This study is carried out based on the principles and framework of Environment management: life cycle assessment prescribed by ISO 14040:2006 (ISO, 2006) which considers four phases of life cycle assessment: goal and scope definition, Life cycle inventory (LCI) analysis, Life cycle impact assessment (LCIA) and Interpretation or improvement assessment. All the buildings with different structural systems and materials considered in this study have been analyzed to ensure safety and strength.

2.1 Goal and Scope Definition

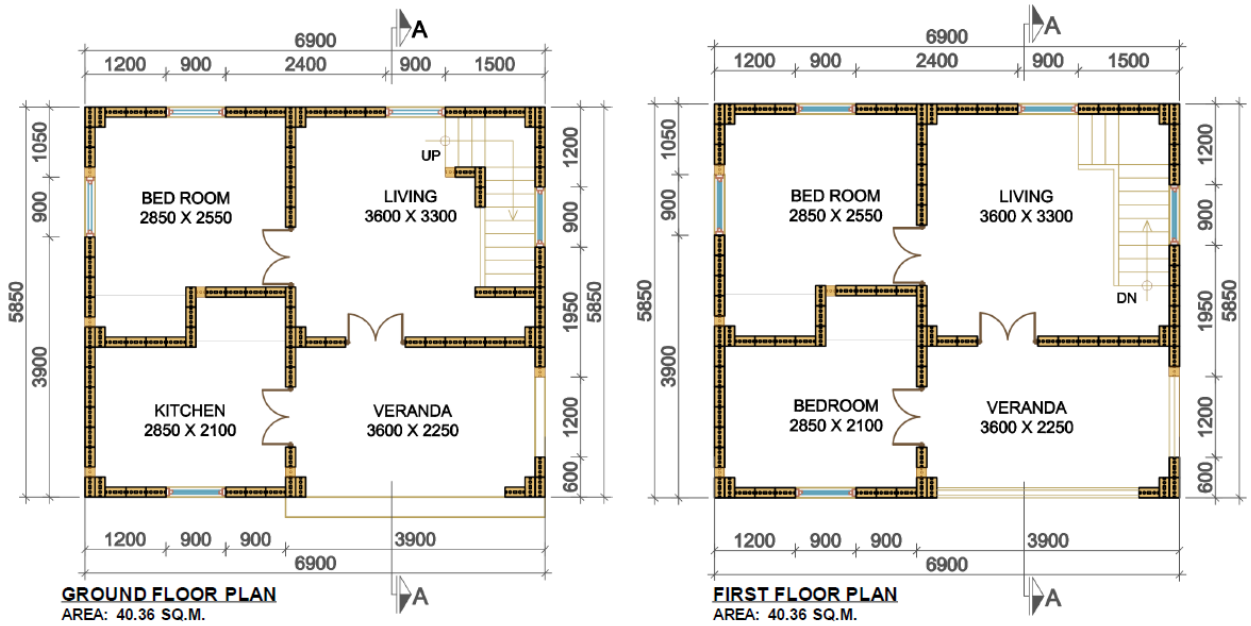
The reconstruction of buildings after the Gorkha Earthquake is being implemented guided by the Design Catalogue for Reconstruction of Earthquake Resistant Houses (DUDBC, 2015), (DUDBC, 2017) [21, 22]. The life spans of the buildings are assumed to be 50 years based on the recommendations of the previous researches (Rashid and Yusoff, 2012). The buildings are detached houses and can accommodate 4 family members. The structural systems of the buildings are generally the load bearing wall system constructed using bricks, blocks and stones. There are some framed system houses using construction materials like reinforced concrete, steel and woods. This study considers 5 low rise residential houses from the catalogue of different construction materials and the structural systems as these buildings were the most commonly constructed buildings after the Gorkha Earthquake. The floor plans of the houses are shown in Figure 1.



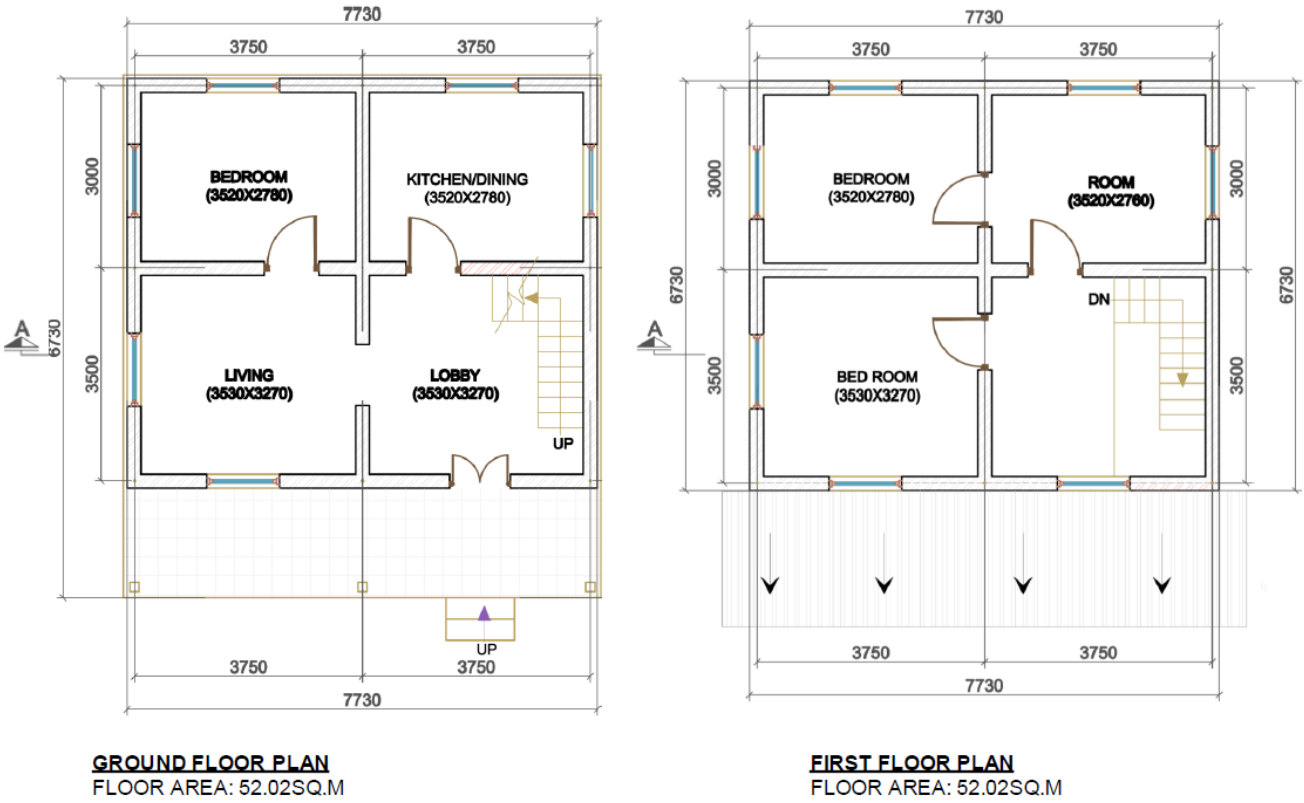
(a) SMC2.1 (Stone Masonry)



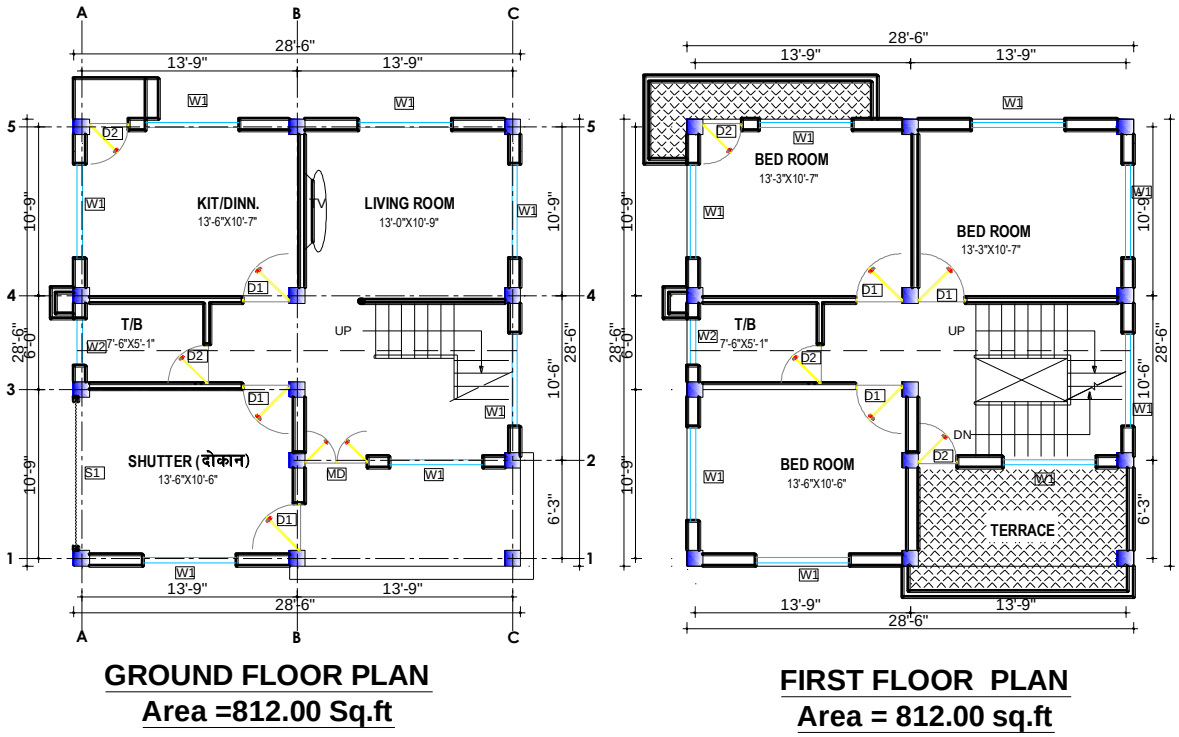
(b) BMC2.1 (Brick Masonry)



(c) IB1.2 (Interlocking Brick Masonry)



(d) CSEB 4.2 (Compressed Stabilized Earth Block Masonry)



(e) RCC (RCC Frame building)

Figure 1: Floor plans of the building systems [21,22]

In general, life cycle analysis of a product includes the production of construction materials, transport of those materials to a construction site, on site building construction, operational and maintenance energy use, demolition, transportation of demolished materials to landfills or for recycling. The study considers four stages of lifecycle assessment of 5 low rise residential buildings with different structural system and construction materials starting from firstly, material production and transportation stage; secondly, construction of the building stage; thirdly, operation of the building stage to finally, demolition stage.

The LCA modelling has been carried out in Open LCA version 1.8 to calculate energy consumption and CO_2 emission. Due to data limitations, the Ecoinvent dataset version 3.5 was used in the analysis of the buildings. Households were considered of 4 member small families with annual per capita electric energy consumption of 161 kWh (CBS, 2013). For the calculation of Energy consumption of the sample buildings throughout their life cycle, the Cumulative Energy Demand (CED) Life Cycle Impact Assessment (LCIA) method was used. Similarly, for the calculation of CO_2 emission, ReCiPe Midpoint (H) LCIA method was applied. The CED method has 8 which are given in Table 2 and ReCiPe Midpoint (H) has 11 impact categories (Acidification, Climate change, Depletion of abiotic resources, Ecotoxicity, Eutrophication, Human toxicity, Ionizing Radiation, Land use, Ozone layer depletion, Particulate matter and Photochemical oxidation). However, only climate change impact category was studied from the ReCiPe Midpoint (H) method because most of the buildings are being constructed in rural hilly areas of Nepal and the impact of other categories to the CO_2 emission have been neglected.

Table 2: Cumulative Energy Demand

Impact category group	Name of the impact category in the method
Non-renewable resources	Fossil
	Nuclear
	Primary forest
Renewable resources	Biomass
	Geothermal
	Solar
	Wind
	Water

The size of the houses in this study is varied and comparison of the energy consumption building wise wouldn't be realistic. Hence, total energy consumption and CO_2 emission were compared based on per square meter of the floor area of the buildings to consider the effect of size of the building.

2.2 Material Inventory

The data used for LCI were taken from Design Catalogue for Reconstruction of Earthquake Resistant Houses (DUDBC, 2015), (DUDBC, 2017). The materials used in the buildings are obtained from the bill of quantities (DUDBC, 2015), (DUDBC, 2017) as given in Table 3.

2.3 LCIA and Interpretation

Khasreen et al. (2009) have suggested four common impact categories for the LCIA global warming potential (GWP), acidification, ozone depletion (ODP), and eutrophication. However, this study is limited to the first category i.e. GWP. LCIA is interpreted in line with the goal and scope of the study that includes an assessment basically the total energy demand and CO2 emission.

Table 3: Materials inventory of the buildings

S.No.	Materials/Descriptions	Unit	Building System				
			SMC 2.1	BMC 2.1	IB 1.2	CSEB 4.2	RCC
	Floor area	sq.m.	63.5	63.5	80.72	104	167
1	Brick	No.		36936			35735
2	Cement	Bags	187	196.87	138	158	577
3	Sand	Cu.m.	29	23.07	13.9	10	43.52
4	Aggregate	Cu.m.	10	10.91	12.2	19.8	52.6
5	Reinforcing Bar	Kg.	777	776.35	671.1	1410.1	5622
6	CGI Sheet	Bundle	4.71	4.71	4.2	8.2	
7	GI Plain Sheet	sq.m.			8.7	9.8	
8	Aluminium Door	Sq.m.					36.05
9	Aluminium Window	Sq.m.					40.68
10	Wood	Cu.m.	4.35	4.43	2.8	1.7	0.5
11	CSEB Blocks	No.				10691	
12	MS Black Pipe	Kg.		1408.3		1408.3	
13	Stone	Cu.m.	48		18.1		
14	Interlocking Blocks	No.			6447		

9. Results and discussion

9.1 Overview of the results

The energy demand by category, of the buildings is shown in Figure 2. Going through individual energy categories, it is found that the IB building system consumes the highest portion of solar energy which comes from nature. For all the buildings, energy consumption is highly dominated by fossil fuels (more than 55%) which are the source of greenhouse gas emissions. The total consumption of other energy (wind, water, solar, nuclear and geothermal) is less than 20%. The analysis shows the consumption of nuclear energy as well, this is due to the use of dataset of Europe as such data is not available for Nepal. Table 4 shows that fossil fuel consumption is the least in stone masonry system SMC2.1 which is around 55% of the total energy consumption by the building. The RCC system consumes the highest energy which is around 69% of the total energy consumption.

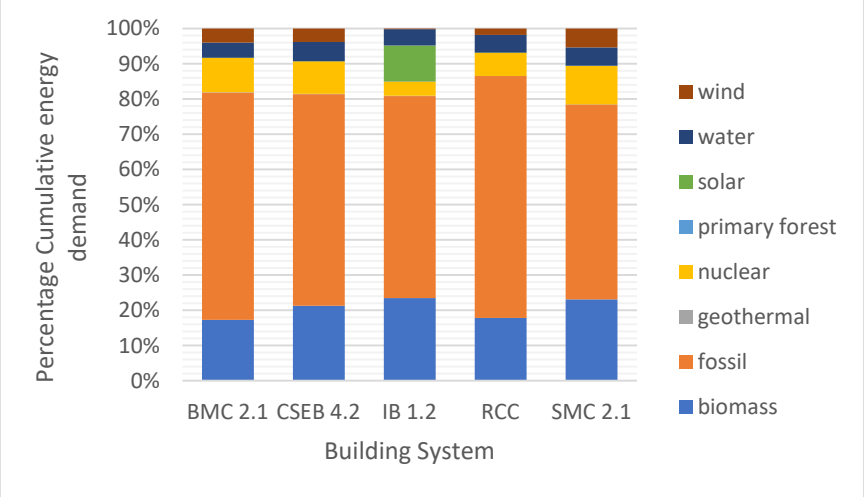


Figure 2: Proportion of different energy consumptions by the building system

Table 4: Fossil Energy Consumption

Building System	Fossil energy (per m2)	Total Energy (per m2)	% of the total
BMC 2.1	16,058.27	24,877.05	65%
CSEB	9,427.23	15,697.33	60%
IB	8,694.19	15,149.50	57%
RCC	15,509.22	22,599.20	69%
SMC 2.1	10,101.26	18,247.75	55%

The total energy demand of the buildings throughout their life cycle is calculated by summing the values of the renewable and the non-renewable impact categories of energy. The consumption of energy is mainly in material production as no heating and cooling system in the context of rural buildings in Nepal, however, no breakdowns were done for the stages of the lifecycle of the buildings. The energy demand of the burnt brick masonry building during its lifecycle is 24877 MJ-eq per m^2, which is the highest among the 5 building systems. The RCC system consumes 22600 MJ-eq per m^2 which the second highest. The IB1.2 system consumes the lowest 1550 MJ-eq per m^2. The stone masonry SMC2.1, building has 18245 MJ-eq per m^2 energy demand. The comparative chart of life cycle energy demand of the building systems is shown in Figure 3.

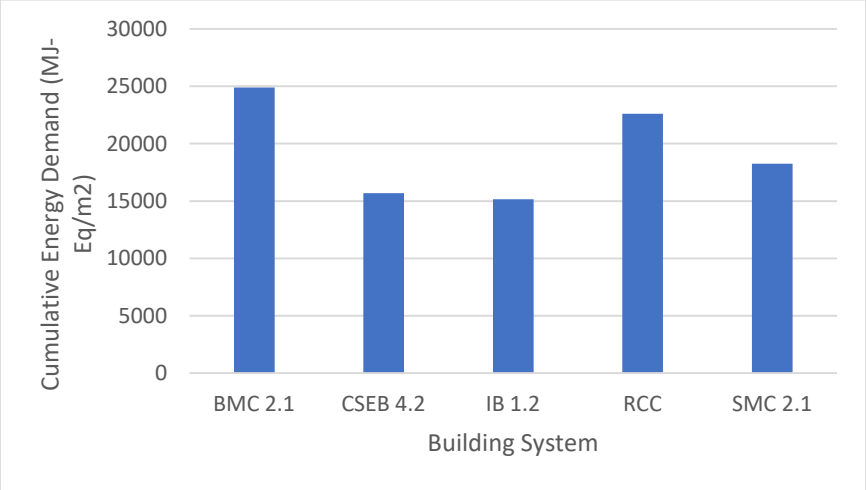


Figure 3: Life cycle energy demand of the building systems

Figure 4 shows the climate change impact of the building systems which corresponds to the CO_2 emissions. CO_2 emission is the highest for the burnt brick building system (1560 kg CO_2 equivalent per m^2) followed by RCC system (1500 kg CO_2 equivalent per m^2), Stone masonry building system SMC2.1 (1000 kg CO_2 equivalent per m^2), IB1.2 system (931 kg CO_2 equivalent per m^2) and the least for the CSEB4.2 system (923 kg CO_2 equivalent per m^2). The buildings which use the natural building materials such as IB1.2 and stone contribute less CO_2 emission throughout their life cycle than the buildings which uses the processed materials like concrete, metals and burnt bricks. This finding of the research is in line with the finding of Rodrigues *et al.*, (2018) in the evaluation of the embodied carbon and energy of industrial building construction.

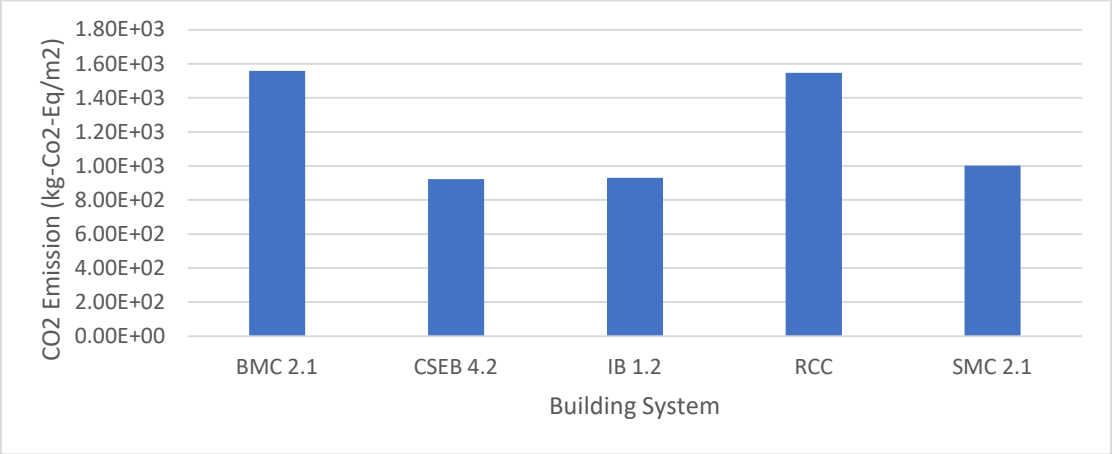


Figure 4: CO_2 emissions by the building systems

9.2 Impact of materials

The selection of materials in the structural system contributes a huge impact on the mass scale to the negative impact on the environment. The result of this study shows that CSEB4.2 and IB1.2 building systems emit the lesser CO_2 emission (923 kg and 931 kg CO_2 equivalents per m^2) throughout its lifecycle. The burnt brick and RCC building systems emit the higher CO_2 emission (1560 kg and 1550 kg CO_2 equivalents per m^2). This shows the burnt brick and RCC system emits 1.69 times higher than the emissions of the CSEB4.2 and IB1.2 system. Similar results were obtained in terms of energy consumptions. IB building system demands 1550 MJ-eq per m^2 energy whereas burnt brick building system demands the highest 24877 MJ-eq per m^2 energy which is 1.64 times the demand of the IB1.2 system throughout its lifecycle. The higher energy and the higher greenhouse gas emissions have been largely contributed due to the use of a substantial quantity of cement and use of fossil fuel in burning bricks in burnt brick and concrete-based building elements in the structural system.

Construction materials and the structural system have a significant impact on the environment. The use of environment friendly local construction materials and structural system has significantly less impact on the environment. The impact of the construction of simple low rise residential buildings can have a higher negative impact to the environment which uses mostly the imported materials from outside the construction areas such as burnt brick, steel, reinforcements and cement. Use of locally available materials and the traditionally practicing structural system has less negative impacts on the environment as shown by stone masonry system SMC2.1 in Figure 4. However, the selection of the building type depends on the location of the house. For an example, for higher himalyan region, bricks, blocks and RCC frame buildings wouldn't be suitable.

10. Conclusions

Based on the climate change aspect, the study has evaluated the low rise residential buildings with brick masonry, compressed earth block, interlocking block, reinforced cement concrete and stone masonry in terms of energy consumption and CO_2 emissions. The results of the study show that IB building system emits the least CO_2 emission throughout its lifecycle and burnt brick and RCC building system emits the highest CO_2 emission which is 1.64 times higher than the least emitting system. In terms of energy consumptions, CSEB and IB demands lesser energy whereas burnt brick and RCC system demands the higher energy which is 1.69 times the demand of the CSEB system throughout its lifecycle. IB, CSEB and stone masonry building system consumes less energy and contributes less CO_2 emissions giving less impact on the global environment.

It can be concluded that the selection of building structural system and the materials of construction contributes a lot in total lifecycle energy consumption and CO_2 emission and

responsible for a significant impact to the environment. This outcome of the paper would be useful to the policy makers to implement the right building system with appropriate construction materials for the construction of houses which will give the less impact to the environment in the huge reconstruction of houses as in post-earthquake reconstructions.

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How to Build the Underground Metro Rail in Kathmandu

Dr. Binod L. Amatya
Consulting Civil Engineer, ARCADIS, London, UK
blamatya@gmail.com

Abstract

This paper presents a proposal for an underground metro-rail network for the densely populated central part of the Kathmandu Valley in Nepal. Four underground metro rail routes are proposed for the urban core area to facilitate urban mobility. The ground conditions within the valley are complex due to the nature of its deep lacustrine deposits comprising water-bearing ?sands and soft clays. This paper discusses and demonstrates the feasibility of underground metro-rail construction in the ground conditions extant and investigates the appropriate sizes, depths, methods of construction and the construction costs of the relevant underground assets such as tunnels, cross-passages and station boxes.

Key Words: Kathmandu Valley, Underground Metro-Rail, Lacustrine Deposits, Tunnelling, Station Construction

1. Background

The Kathmandu valley is the cultural, political and economic hub of Nepal and Kathmandu is the capital and largest city in the country. It is anticipated that the valley has population of between 5 to 6 million. Due to the lack of adequate urban infrastructure, the city is facing problems of transport chaos and environmental blight, particularly air pollution such as that caused by vehicular traffic.

Figure 1 Proposed Kathmandu Underground Metro Map

Kathmandu needs a 21st century rail infrastructure to resolve these problems and to make the capital an organized, connected and vibrant city. To achieve these aims, a new mode of transport, the underground metro-railway system, is necessary at the core part of the capital city to maintain its historic value at the same time offering an efficient transport system in the densely populated area. This would provide a mass transit capability for the city, which could allow an improved quality of life, enhance economic prosperity and promote sustainable development in the region.

2. Underground Metro Routes

As shown in the map (Figure 1), a network of four underground metro lines are proposed, namely Kathmandu Line (green), Patan Line (blue), Bishnumati Line (black) and Chakrapath Line (red) for the central part of the Kathmandu Valley. For the whole valley, about 200km long, a network of rail (overground and underground) is proposed (see Amatya 2017).

This paper will examine and elaborate upon the tunnel route for the Patan line (Satdobato-Bhrikuti-Mandap-Basbari section) and the Kathmandu Line (Kalanki-Bhrikuti-Mandap-Koteshwor section) in particular. These two lines could be regarded as the *Cross Rail* of the city and therefore should be the lines to be prioritised. In addition, construction of metro-rail stations at two core locations in the city at New Baneshwor and Thamel will also be discussed.

3. Ground Condition of Kathmandu Valley

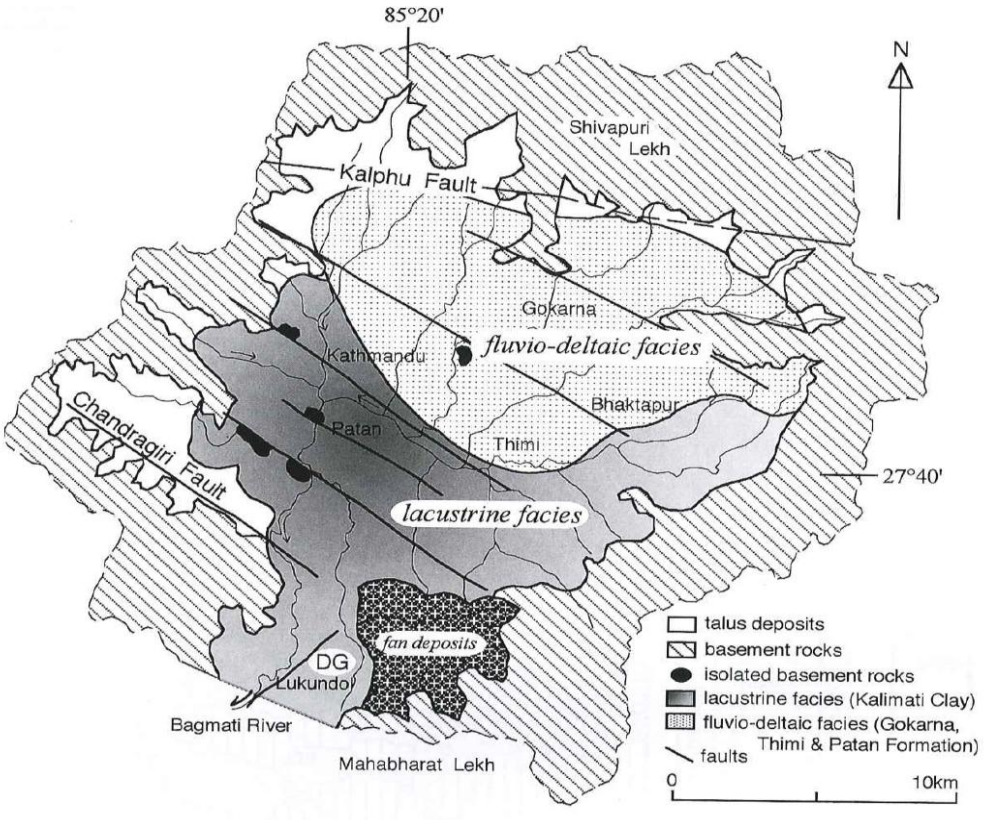

Figure 2 Outline geological map of the Kathmandu Valley (Sakai, 2001)

An outline geological map of the Kathmandu Valley is shown in Figure 2. The figure shows that fluvial deposits (silty sand) are prevalent in the northern part of the valley while at the southern part lacustrine deposits occur indicating silty clay and clayey silt. Such deposits are further verified by examination of various archive records of boreholes constructed at locations along the Patan Line. Refer Figure 3. 'Dump' in the legend to Figure 3 means Made Ground.

Along the Kathmandu Line (Koteshwor-Bhrikuti Mandap-Kalanki) route, silty clay or clayey silt is prevalent within 5 to 10m below ground level?(bgl) overlain by sandy superficial deposits or a discontinuous strata of sand and clay. A typical soil profile of the ?ground subsurface along the Kathmandu line is shown by a representative borehole at 'Rabibhawan' in Figure 4. There is a significant variation in the recorded groundwater level data. In general, it is anticipated that the underground water level will be encountered at very shallow depth at sites close to the river and within 4 to 5m below ground level?(bgl) remote from any watercourses.

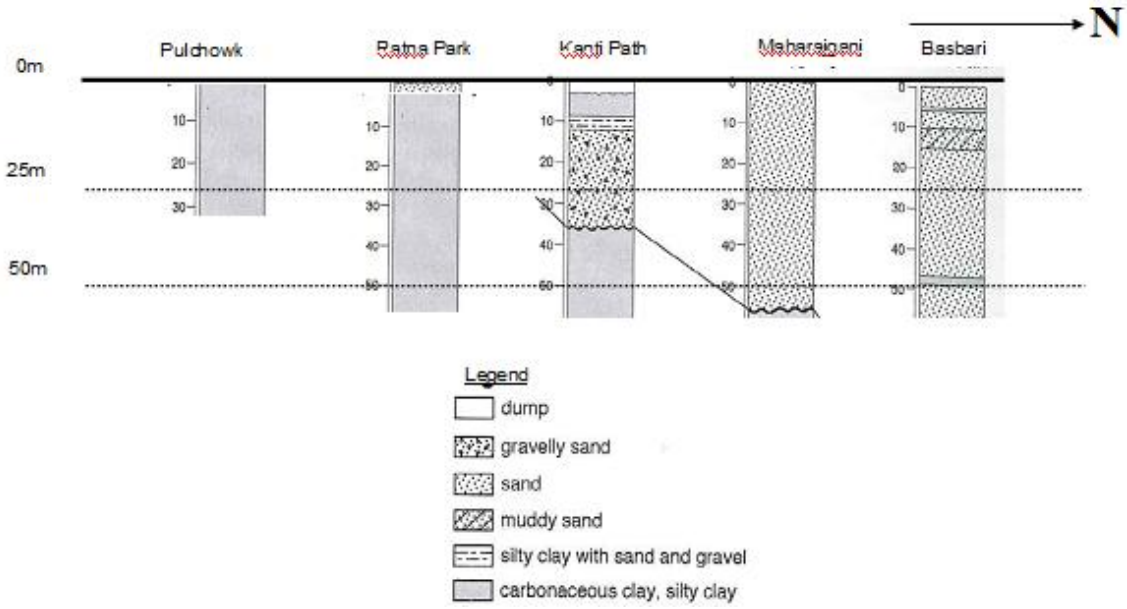

Figure 3 Typical soil profile along the Patan line (N-S direction)

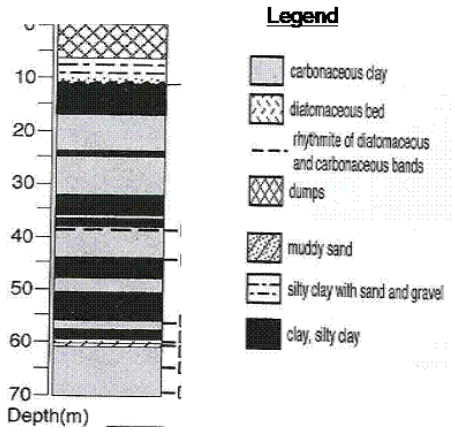

Figure 4 Typical soil profile along the Kathmandu line (E-W direction) (Sakai et. al, 2001)

4. Tunnelling in Kathmandu Soil

Tunnelling in the Kathmandu soils is mainly discussed herein for the Patan Line and the Kathmandu Line.

4.1 Main tunnel

The alignment is selected to follow major roads where possible to limit the effects of tunnelling on surface structures i.e. buildings and other infrastructure. For the metro-railway, twin tunnels of internal diameter ranging between 5.4m to 5.8m is proposed. The vertical alignment is chosen based on the overall geology along the route and the maximum allowable gradient for passenger train tunnels as per STRASYA specification. Up to 3% gradient is adopted in some sections of the route. The tunnel level (top of rail) varies along the route but in general it is proposed to be at a depth not exceeding 25 to 30m bgl. In some locations due to a ?deep river valley such as that at Bishnumati river site near Tankesor station, Bagmati river site near Thapathali/Tripureshwor, the tunnels could be at a more shallow depth at approximately 20m bgl at these locations.

Vertical alignment was selected to be deep to reduce the stresses due to seismic activity and hence reduce the thickness of the lining and avoid mitigation measures for liquefaction that might have been required otherwise within the fluvial deposit prevalent within top 5-10m of the ground.

Generally,? the tunnels are expected to be located in the Kalimati Formation (comprising clayey silt/silty clay) except for the northern section of the Patan Line. The ground along the route from Jamal station to Maharajganj consists mainly of up to 20-35m thickness of silty sand/sandy strata and the tunnels will pass through this stratum. The twin tunnels will be spaced to be a minimum of one tunnel diameter apart.

Tunnel construction and tunnel boring machine? (TBM) launch portals will be located out of the city core area. This would allow for an easier access, the removal of spoil, and transport and storage of tunnel segments.

4.2 TBM selection

Ground conditions play an important role in the selection of a TBM. Due to safety requirements for tunnelling personnel, settlement restrictions and the recorded success of tunnelling projects around the world, a shielded earth pressure balance? (EPB) tunnelling machine is the likely preferred option when compared to an open face method. From a study of the ground conditions undertaken along the routes (except the northern section), geological information (See Figure 5) is fed into the graph, illustrated in Figure 7. As a result, an EPB machine is judged appropriate given the soil nature being predominantly clayey silt and silty clay with some fine sand lenses.

EPB machines are less effective in coarse materials, such as sands, due to the difficulty of ?applying an effective face support pressure in a cohesionless sand medium. However, modern techniques where the use of soil conditioning agents, appropriate TBM management and driving, EPB TBMs can be adapted to deal with sands relatively well.

Due to the mixed ground conditions associated with the northern section of the Patan Line (see Figure 6), there is not a straightforward choice of tunnelling methodology. The area around Jamal-Maharajganj section is best suited to a slurry TBM (see Figure 8(b), whilst the southern sections of the line would be better served by an earth pressure balanced TBM (see Figure 8(a). As a result of the high costs associated with the manufacture and operation of a mix-shield machine, they are considered too expensive for this section of the project and EPB is recommended for both the Patan line and Kathmandu Line.

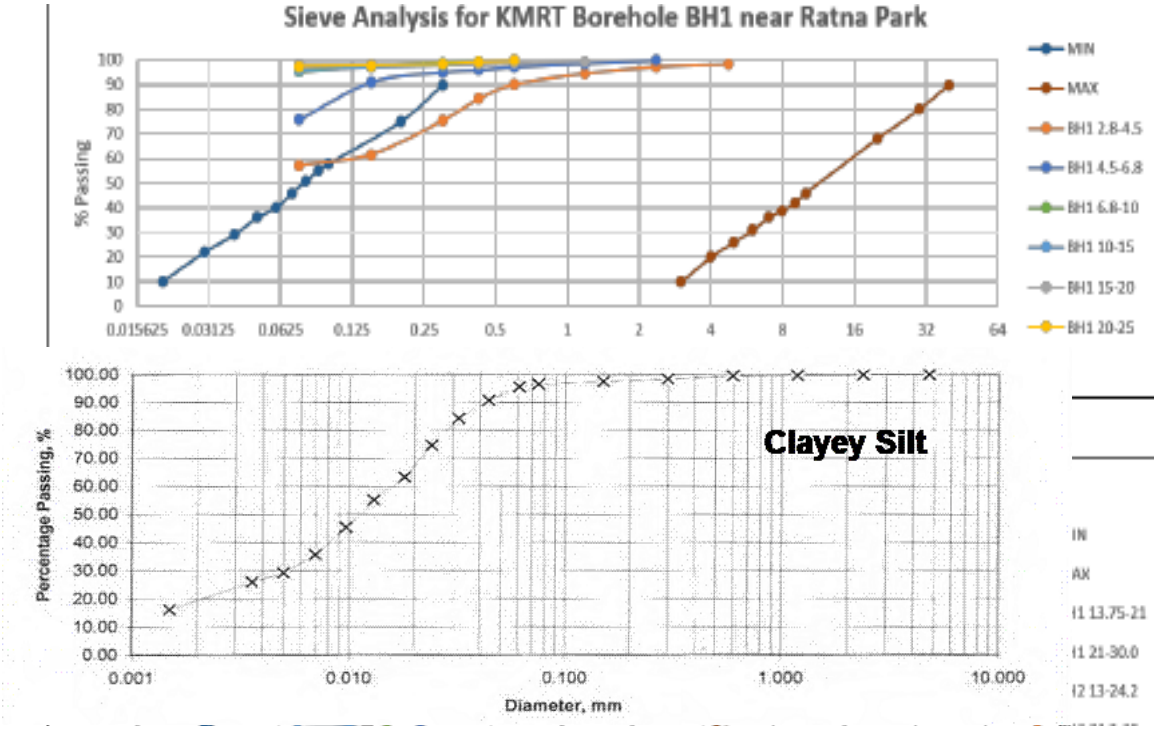

Figure 5 Particle size distribution of Kathmandu soil at central, south, east and west site

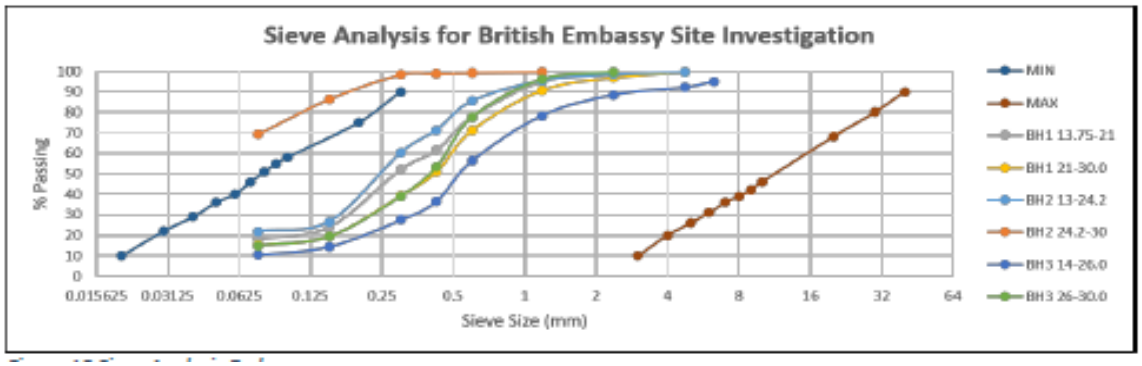

Figure 6 Particle size distribution of Kathmandu soil (Northern sites)

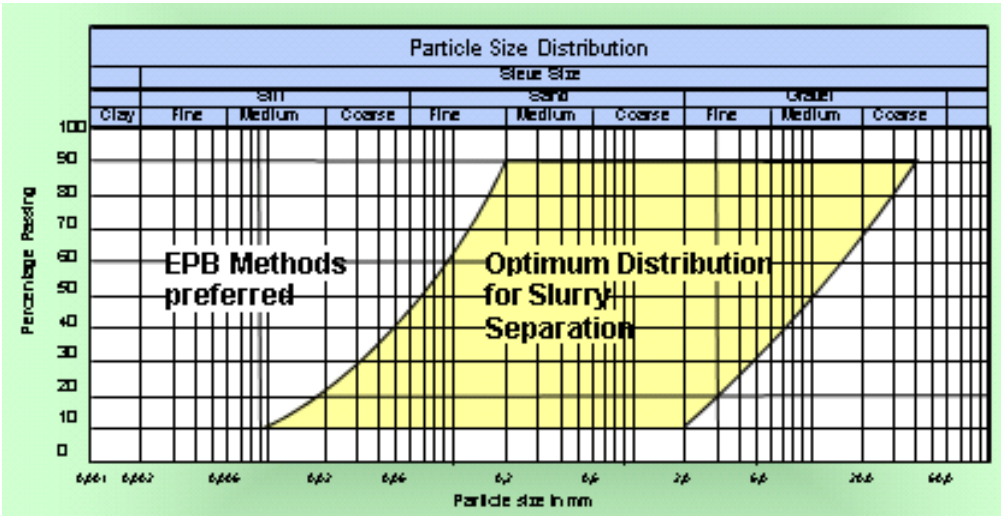

Figure 7 Tunnelling machine selection method based on Particle Size Distribution (Slocombe, 2017)

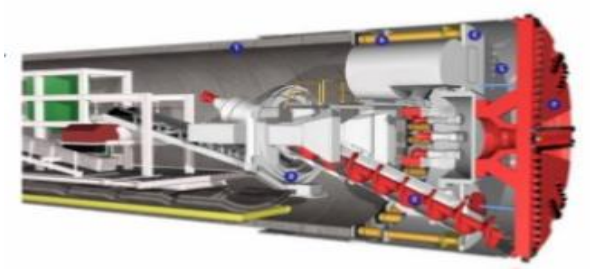

Figure 8(a) EPB TBM

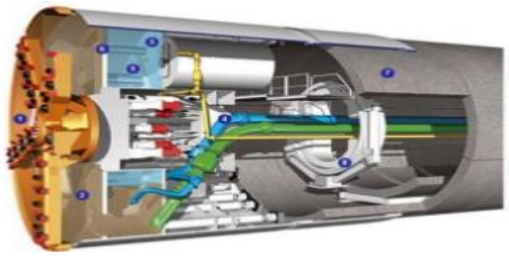

Figure 8(b) Slurry TBM

The TBM method of excavation will aim to achieve a consistent production rate of about 130 to 150m of excavation per week with (three shifts/day of 8hrs each) 12hr shift per week for any unplanned maintenance time. For each line, two TBMs will be driven (in closed mode) separately with a lag of 30 days. This is to allow the ground around the first tunnel to stabilize before influencing it again when the second tunnel is constructed, potentially reducing overall settlement at the surface.

Once each TBM completes its drive and has made its break-through into the station box, there will be a period of maintenance for the TBM machine before pushing it through the completed station box to commence the next section of tunnel drive.

4.3 Tunnel lining

Reinforced precast concrete segmental lining as shown in Figure 9 will be designed to withstand the dead loads, live loads, the static load of the ground as well as seismic (earthquake) forces. A 300mm thick lining is considered adequate for the proposed alignment of the Patan and Kathmandu Lines. The percentage of steel reinforcement varies with the number of segments designed for each ring. Six to eight segments for each ring could be appropriate. This number is partly controlled by the seismic aspect of the design and partly by ease of constructability. When the tunnel was designed with six segments, there were significantly higher strains induced in the segments during a seismic event than compared with an eight-segment design.

The rings of segments will be erected and bolted together in both the radial and circumferential directions to aid buildability. Waterproof gaskets will be provided; due to the high ?water table the lining will be subjected to high porewater pressures. Compression gaskets of one or two complete circuits between the segments will be used to give the best chance of maintaining a reasonably watertight seal. Hydrophilic gaskets may be used together with the normal compression gaskets.

Figure 9(a) Segmental lining tunnel

Figure 9(b) Precast concrete segment lining

4.4 Cross passage tunnels

Three metre diameter cross-passages built at 500m intervals are proposed for the running tunnels. The cross-passages will be constructed following the completion of the construction of running tunnels. A typical figure of a cross passage is shown in Figure 10.

Given the ground conditions of consisting of weak soils, comprising clayey silt or silty sand, at the tunnel axis level, the excavation of cross-passages poses a stability risk, which might lead to ground collapse. Therefore, it will be necessary to implement ground improvement prior to excavation of the cross-passages. The most appropriate technique to use is jet grouting with cement-based suspensions of at least 4.5m ground thickness above and below the cross-passage tunnel axis (i.e. 9m thick). The aim is to improve the shear strength of the ground provide a long enough stand-up time to use the Sprayed Concrete Lining (SCL) method for the primary support of the cross-passages followed by a cast in-situ concrete as the permanent lining. The thickness of the primary and secondary lining would vary based on its location. In general, SCL of at least 150mm thickness and permanent lining of the similar magnitude are may be considered adequate.

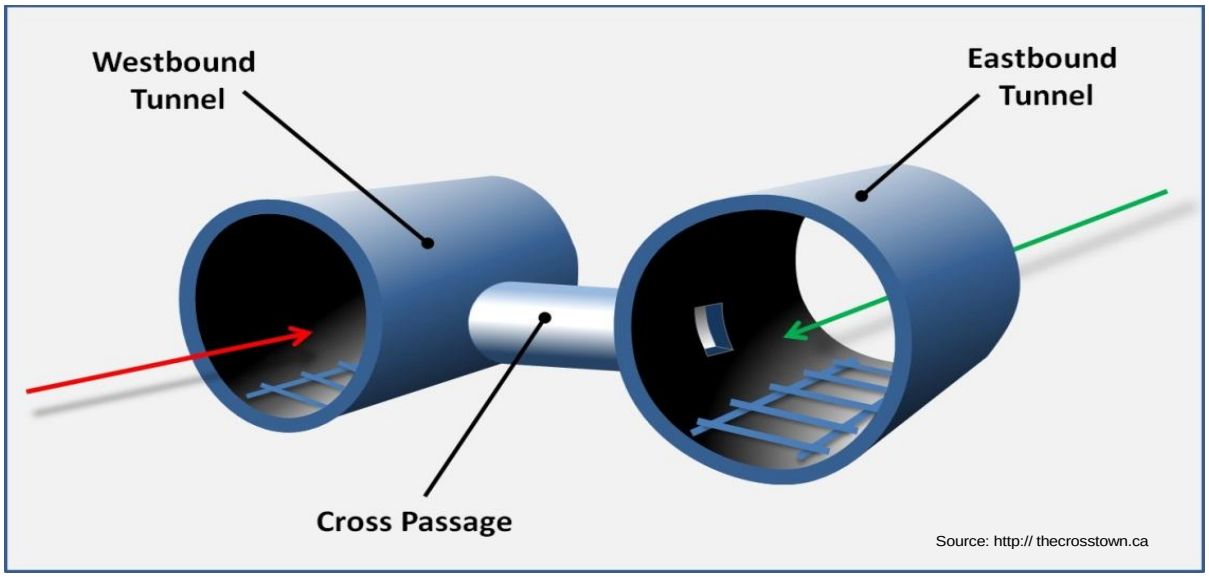

Figure 10 Cross passage tunnel

5. Underground Stations in Kathmandu Soil

Several local(intermediate) stations and major stations as shown in Figure 1 will be required to keep the underground metro system functional. In this chapter, construction of station box at Thamel/Lainchaur (of the Patan Line) and New Baneshwor (of the Kathmandu Line) will be discussed. These two stations are chosen because the ground conditions at the proposed sites of these two stations are distinctly different from each other and these could represent the northern area and rest of the core part of the valley respectively.

A typical box structure of between 100m and 150m length, 28m to 35m width, and 25m to 30m depth is proposed for a local station.

5.1 Thamel Station

The Thamel station is proposed to be located at Lainchaur in the existing gardens to the north of the Social Welfare Council (SWC). The site is within/near Leknath Marg at the north and Kantipath on the east side.

The ground conditions at the site are predominantly silty sand with layers of sand to a depth of greater than 30m, with the station base slab and tunnels sitting well within the sandy layer.

Groundwater is anticipated to be encountered between 5 and 8 m below ground level. A schematic view of a station is shown in Figure 11.

The proposed station building comprises an excavation of the following approximate dimensions:

- Length = 120 m
- Width = 35 m
- Depth = 25 m.

Due to the high water table and porous sandy ground conditions at the Thamel Station site, the multi-storey station box will need to be fully waterproof in both the temporary and permanent condition. For temporary waterproofing during construction, treatment of the ground around the station box is recommended by jet grouting columns of about 2m diameter for up to about 5m width before commencement of the excavation of the box structure. This will allow for easier drilling of the bored pile wall as well as an increased resistance to ground movements.

For permanent waterproofing, the station retaining walls must be continuous, forming a complete structure. The sandy soil of the Thamel station site makes diaphragm walls an expensive option due to the high concentration of bentonite in the mud suspension required to maintain the excavated ground stability. A more appropriate option is the construction of a bored pile wall. A bored pile wall can be used to form a strong, impermeable barrier in both the temporary and permanent situation.

The most common way to achieve a continuous piled wall is to use a series of hard-soft piles. A secant bored pile of 1000mm diameter (hard pile) at 1.5m centres alternating with 900mm diameter soft piles; both piles 35m long are proposed. An example of such piled wall is shown in Figure 12. A top-down construction method is recommended to reduce settlements around the station box due to deflection of the retaining wall during excavation.

Figure 11 Proposed station box for Thamel Station

Additional ground treatment is also preferable for the Thamel Station box. Further to the outer perimeter of jet grouted columns, there is also a requirement for a 'grout curtain' where the TBMs will pass into and out of the station box. This curtain can be formed by a series of jet grout columns at a specified depth below ground. This will make an efficient use of resources (i.e. grout) as well as providing the necessary soil strength and permeability for the TBM to enter or leave the station and to minimise loss of ground.

5.2 New Baneshwor Station

The New Baneshwor station is proposed within the existing compound of the International Convention Centre (ICC). The site is bounded to the south by the Madan Bhandari Road and to the east by the Devkota Sadak.

The ground conditions at the proposed site are defined by the thick Kalimati Formation (consisting of silty clay, clayey silt) overlain by approximately 5 to 10m of mixed and intermittent sandy and clayey/silty strata. Groundwater is anticipated at 3 to 4m below ground level. A schematic cross sectional view of the proposed station is shown in Figure 13.

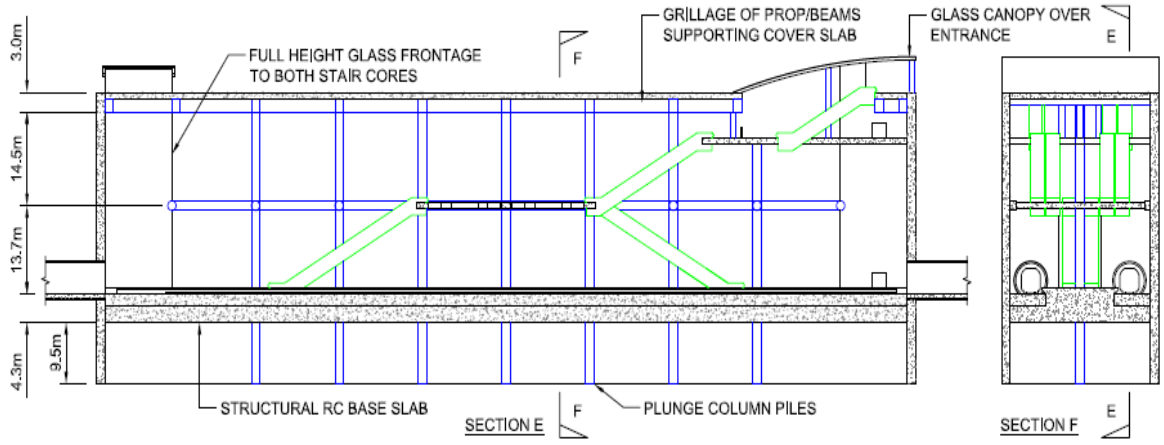

Figure 13 Typical box type local underground station for New Baneshwor station

The proposed station building comprises an approximate excavation of the following dimensions:

- Length = 144 m
- Width = 28 m
- Depth = 33 m.

Due to the probably of high-water table at this site and intermittent sandy/silty/clayey strata within top 5 to10m, ground treatment of the mixed ground around the station box is recommended by jet grouting to aid diaphragm wall build and limit groundwater leakage into the station box.

A reinforced concrete box structure using diaphragm walls is proposed. For the proposed 33m deep station box, diaphragm wall comprising 5m wide panels of 1.5m thickness and 45m depth is anticipated. Two water stops of full station wall height are recommended at each joint of the D-wall panel during construction for post construction waterproofing. Top down construction is proposed for the box excavation and construction. Figure 14 above shows typical details of such wall construction.

6. Cost of Underground Construction

The recent studies indicate the cost of construction (including Civil Engineering and Mechanical & Electrical engineering) of twin tunnels in the ground conditions of Kathmandu in accordance with details mentioned above should be expected in the range of US$80 to 120million/km. A review of the published estimated cost of Mumbai Metro, Line 11 (Source: Wikipedia) which is predominantly underground indicated costs of about US$106 million/km. In consideration of these cost data, US$100million/km has been assumed for an estimation of cost of underground metro construction in the context of Nepalese economy. Table 1 shows an anticipated cost for the individual metro-rail routes.

Table 1 Cost of various proposed metro routes

Line	Underground section (km)	Construction cost (Million US $)
Patan Line	12.0	1200
Kathmandu Line (Kalanki-Bhrikuti Mandap-Koteshwor)	9.5	950
Kathmandu Line (Bhrikuti Mandap-Bauda)	5.5	550
Bishnumati Line	7.0	700
Chakrapath Line	30.5	3050

Studies also indicate that construction of an underground metro station as discussed above could cost in the range of US$ 40 to 50 million to complete for the civil and M&E works in the context of the present Nepalese economy.

Additionally, the studies show that for the construction of 5km long eastern section of the Kathmandu line (from Koteshwor to Bhrikuti Mandap) plus a local station, approximately 2.5years would be required to complete the civil works and a further approximately 1.5 years for finishing works, being fit-out, final inspections and handover. In order to achieve this time frame, all the proposed local and main stations of the route are to be built almost concurrently so that these station structures would be ready to receive the TBMs to commence tunnel drives or upon their completion.

Therefore, in order to build about 22km of E-W and N-S lines in 5 years, a very robust construction programme would be required and introduction of at least 4 TBMs would be necessary.

7. Conclusions and Recommendations

Underground metro-rail is feasible in the ground conditions beneath Kathmandu. Twin rail tunnels of internal diameters ranging 5.4m to 5.8m are proposed. The tunnel rail depth from the ground surface varies along the route but in general is proposed to be in the range 25 to 30m bgl. An earth pressure balance (EPB) TBM is recommended for mechanical tunnelling. 300mm thick precast concrete segmental lining is considered adequate. For cross-passage tunnels, 3m internal diameter tunnels at 500m spacing using sprayed concrete lining (SCL) for primary support and cast-in-situ concrete for the secondary/permanent is recommended.

Depending on the ground conditions, construction of station boxes may need temporary (during construction) and permanent water proofing. For a station box located within silty sandy strata with shallow water table, ground improvement measures such as jet grouting will be required for temporary water proofing and continuous hard-soft secant piles are recommended to keep the station box watertight. Where ground conditions are predominantly silty clay or clayey silt, the station box could be built by reinforced concrete diaphragm wall panels. Top down construction is recommended.

The study also found that the cost of metro construction in the current Nepalese economy could be approximately US$100 million per kilometre. Therefore, in order to build cross rail of Kathmandu such as Patan line of 12km and Kathmandu Line of 9.5km, the total cost of construction including civil and M&E works could be approximately US$2150 million.

8. Acknowledgement

The findings presented in this paper, particularly those related to the underground assets, are based on the design research project carried out by the 2017/18 cohort of MSc students on the

Tunnelling and Underground Space programme of the University of Warwick, UK. The author greatly appreciates the contribution of the students, Prof. Alan G. Bloodworth and the staff of the programme. The author also acknowledges the assistance of the project partners such as ARCADIS UK, MULTI Disciplinary Consultants (P) Ltd (Nepal), ITECO Consultants (Nepal), Institute of Engineering of Tribhuvan University (Nepal).

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Modelling and Simulation of Solar Photovoltaic Rooftop: Case of Kathmandu

Ramhari Poudyal[1], Ranjan Parajuli and Pavel Loskot

[1]PhD Candidate, Swansea University, Swansea, UK

rhpoudyal@gmail.com

Abstract

Solar energy is present in abundant quantities in Nepal, although it is not widely exploited to improve the energy situation of households. In order to promote utilization of solar energy, this paper assesses the energy potential of a typical photovoltaic rooftop module installation in Kathmandu. In particular, the current-voltage and power-voltage characteristics of the PV module are obtained, assuming a simplified equivalent electrical circuit with a single diode. The model is implemented and simulated in Matlab/Simulink. Simulation results are compared with different types of PV modules and the corresponding datasheets. The comparison verifies that the developed PV model can provide accurate predictions for deploying the actual PV modules. Furthermore, using the real weather data for Kathmandu, our results indicate that solar radiation is a viable source of energy which can be promoted on a large scale in households across the city. This would mitigate the present deficiency in electricity supply leading to frequent power outages and enhance the energy security of the country.

Keywords: photovoltaic module, radiation, temperature, energy crisis, Matlab/Simulink

1. Introduction

The burning of fossil fuels for electricity generation is being questioned due to its contributions to different negative environment impact such as acid rain, ozone depletion, and global warming (Balta, 2012). This is leading to issues about the sustainability of our environment, renewable resources and technologies being promoted globally as sustainable alternatives to these fossil fuel-based resources [3], . Among all the renewable energy alternatives, solar stands out as a promising and valuable source for future electricity generation in both rural and urban areas.

The principal objective of this study is to address the acute shortage of energy and wasteful consumption of electricity, which has caused considerable worry in everyday life of the Nepalese people. In conjunction, it also aims to motivate Renewable Energy Technologies (RETs) that will allow the homeowners to produce their energy on the roof and make less dependent on electricity provided by NEA. This will then help to reduce the load on the national grid, which ultimately reducing load shedding period. This being the case, Nepal is surrounded with an enormous source of high irradiance solar power throughout the year. However, Nepal's power system is mostly dominated by large hydropower only and the solar power is still neglected. There is a necessity of energy mix through solar PV rooftop system in Nepal as the fastest solution of energy crisis in comparison with the long-delayed hydropower project. This has led to the origin of this research.

The sum of energy which can be produced from solar power depends entirely on the location available, solar resources and the conversion efficiency of the adopted system. Therefore, case studies involving solar resource assessment and the associated energy conversion technologies become very important for favourable approval and deployment.

Strong policy support and the increasing cost-competitiveness of solar photovoltaic and wind technologies are projected to bolster the deployment of renewable electricity across all regions. Yet, according to long-term scenarios developed by both International Renewable Energy Agency(IRENA) and International Energy Agency(IEA), global renewable energy consumption needs to accelerate substantially to ensure access to affordable, reliable, sustainable and modern energy for all (World Bank, 2019). Despite being abundant with enormous energy resources, Nepal has

experienced relatively low energy consumption in general, and so is true for electricity consumption. Nepal is experiencing a remarkable paradox -the abundance of energy resources and widespread energy scarcity.

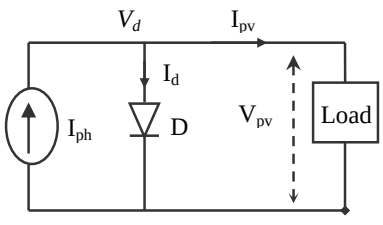
As a developing country, Nepal is one of the least developed countries in the world with 28.09 million populations and relies extensively on foreign aid. The primary sector of the economy is agriculture which employs over 70% of the people and accounts for 33 % of GDP. As Nepal is home to the tallest mountains in the world, tourism has been steadily growing in importance and is an essential source of revenue. Also, the country has been working on exploiting hydroelectric power. Although, most of the hydropower projects in Nepal have been delayed from 6 months to 10 years (Poudyal et al, 2019). Notwithstanding, the Nepalese economy has been steadily growing in recent years, lack of government institutions, growing energy demand, population and remnants of social instability are sources of concern.

Nepal is roughly trapezoidal shape, about 800 km long and 200 km wide, with an area of 147,181 square kilometres. It lays between latitude 260 and 310 north, and longitude 800 and 890 east. It borders China in the north and India in the south, east and west. In 2018, Nepal's gross domestic product (GDP) per capita was 812.20 USD, with an estimated annual growth of 7.1% and Nepal become the top 20 countries with higher rates of electricity access to off-grid solar supply (World Bank, 2019). Recently, The Government of Nepal purposed the plan to reach 100 % electrification within 3 years. Additionally, energy intensity is very low in Nepal where 8,00000 customers use only less than 10 unit of electricity and 11- 20 units use by 17,00000 according to the new tariff fixation committee's analysis. In that case, off-grid solar PV would be the game changer.

Nepal features characteristics of a tropical climate, which resulting in suffering from a severe energy crisis. Poudyal et al (2017), mentioned that energy as an essential stimulant for social and economic growth. The energy crisis affects both rural and urban populations. In addition, the inspiration for this study is to identify original strategies to reduce Nepal's energy crisis in order to sustainably enhance social and economic growth by focusing on renewable energy sources. An overview of Nepal's current energy is given, and a review of the mathematical model based on Matlab/Simulink and algorithms for meteorological data models is presented. This review identifies a clear gap in the literature related to not only energy scarcity in the capital city of Nepal, Kathmandu but also on the use of hourly meteorological data in the assessment of the available solar energy resources which can be utilised by any known solar technology. In the remaining sections of this paper, the gap is addressed through resource assessment, and the design and economic analysis of photovoltaic systems considering available rooftop areas of residential buildings in Kathmandu.

2. Mathematical Modelling

A solar cell is the building block of a solar panel. A PV module is designed by connecting many solar cells in parallel and series. Considering only a single solar cell; it can be modelled by utilising a diode, current source, and two resistors (Zainal et al, 2016). This model is known as a single diode model of the solar cell. Two diode models are also available, but only the unique single diode model is considered here in Figure 1. The PV cell is usually represented by the single diode model. The single diode equivalent circuit of a solar cell is presented in figure 1. The *I–V* characteristics equation of solar cell is given as following (Salmi et al, 2012), (Lagorse et al, 2008):



$$I_{PV} = I_{Ph} - I_d$$

$$I_{PV} = N_P I_{Ph} - N_p I_d \quad (1)$$

$$I_d = I_0 \left[\left(e^{\frac{V_d}{nN_S V_T}} \right) - 1 \right] \quad (2)$$

$$\boldsymbol{I_d = I_0 \left[\left(e^{\frac{qV_d}{nkN_S T_c}} \right) - 1 \right]} \quad (3)$$

$$\boldsymbol{I_d = I_0 I_{ph} = \left(I_{sc} + C_t (T_c - T_{ref}) \right) . \frac{S}{S_{ref}}} \quad (4)$$

$$\boldsymbol{I_0 = I_{RS} (\frac{T_c}{T_{ref}})^3 . exp \left[\frac{qE_G}{nk} (\frac{1}{T_{ref}} - \frac{1}{T_c}) \right]} \quad (5)$$

Cell reverse saturation current,

$$\boldsymbol{I_{RS} = \frac{1}{exp \left(\frac{qV_{oc}}{N_s nkT_c} \right) - 1} I_{sc}}$$

Ignore the effect of $\boldsymbol{R_s}$and $\boldsymbol{R_{sh}}$, i.e $\boldsymbol{R_s = 0}$and $\boldsymbol{R_{sh} = 0}$

$\boldsymbol{E_g}$= Band Gap energy of semiconductor = 1.103;
$\boldsymbol{V_{oc}}$= *23V*

$$\boldsymbol{I_0 = I_{RS} (\frac{T_c}{T_{ref}})^3 . exp \left[\frac{qE_G}{nk} (\frac{1}{T_{ref}} - \frac{1}{T_c}) \right]}$$

Creating the PV module (i.e. ***a controlled current source***) using the following parameters:

k =Boltzmann constant = *1.38 x 10^{-23}(J/K)*
q =Electron charge = *1.62 x 10^{-19}(C)*
$\boldsymbol{I_0}$ =Saturation current at reference temperature/cell = *1.2x10^{-7}(A)*
n = Ideality factor = 1.47
$\boldsymbol{C_t}$ = Temperature coefficient of photon current = *1.7x10^{-3}(A/K)*
$\boldsymbol{T_{ref}}$ = Reference cell temperature = *25 ^{0}C*
$\boldsymbol{S_{ref}}$ = Reference Irradiance = *1000 (W/m^2)*
$\boldsymbol{I_{sc}}$ = Short circuit current at reference conditions/ cell = *2(A)*
Tc =*actual* cell temperature
No. of cells in series/module ***NS*** = 36 (Industrial standard)
No. of cells in parallel/module ***NP*** = 1

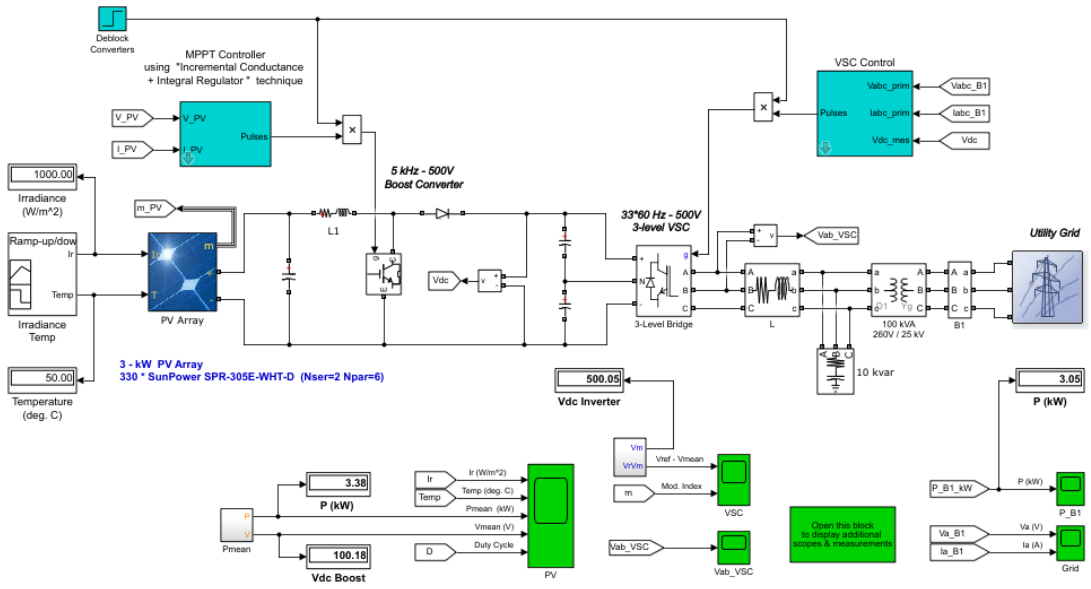


Figure 2 *purposed PV module by Matlab/Simulink*

A modelling system is conducted using SimElectronics advanced component library, which contains a block called Solar cell. The solar cell from MATLAB 8.5.0.(R2015a) is a solar current source, which contains solar-induced current and temperature dependence (Simulink, 2017). All the above equations in 1-5 are inbuilt equations in Matlab/Simulink. It, therefore, customized together to create a module which is presented in Figure **2**. Mathematical description of *I–V and P-V* characteristics for a PV cell is shown in figures 3, 4,5,6, respectively.

2.1 Temperature Effects on Photovoltaic Module

The operating temperature of a PV module determines by the following states: Ambient temperature, the intensity of sunlight falling on the PV module, characteristics of the solar module in which it is conceptualised and wind velocity (Fesharaki et al, 2011), (Dubey et al, 2013)**.** The temperature of the PV solar cell increases due to three reasons: (1) own heat during PV action,(2) the energy radiated at the infrared wavelength which has a heating effect on the cell and (3) increase in solar insolation (Bhatnagar and Nema , 2013). Simulation plots using Matlab/Simulink would be used for demonstrating the impact of varying temperature on a PV module's performance.

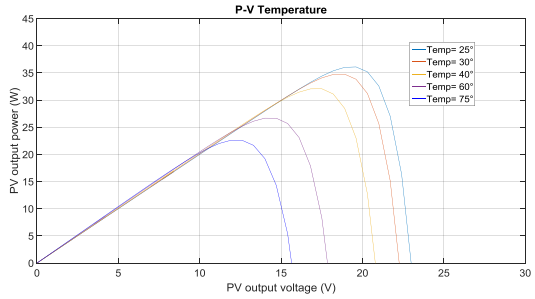


Figure 3 Photovoltaic output current versus output voltage (*I-V*) as a function of temperature

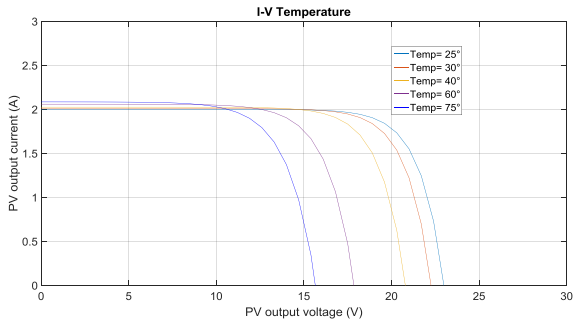


Figure 4 PV output power versus output voltage (*P-V*) as a function of temperature

It is observed that the main effect of increasing temperature of the PV module from Table 1 that as the level of temperature increases the output power generated by the module is substantially reduced. When solar panels are given a wattage rating, they are tested at 25^{0}C against a 1,000 W/m^{2}light source. At a cooler temperature, the solar panel will generate more electricity, while at a warmer temperature; the same solar panel will produce less.

Table 1 *Module temperature with constant irradiance*

Temperature (^{0}C)	I_{sc} (A)	V_{oc} (V)	V_{max} (V)	I_{max} (A)	P_{max} (W)	Efficiency (%)
75	2.0	15.7	12.6	1.7	22.6	9.0
60	2.0	17.9	14.0	1.9	26.6	10.7
40	2.0	20.8	17.5	1.8	32.0	12.9
30	2.0	22.3	18.9	1.8	34.7	13.9
25	2.0	22.9	19.6	1.8	36.1	14.5

2.2 Irradiation Effects

The increase in the value of irradiance indicates an increase in the intensity of solar energy. As the irradiance increases, the current and voltage also increase. This can be illustrated in Figures 5, 6 shows the simulation results of *I-V* and *P-V* characteristics of the varying solar irradiance from 200 W/m^2 in a step of 200 W/m^2 with constant temperature of 25^{0}C. The curve illustrates the solar cell is highly dependent on the solar irradiation values as it shown in the figures. The current generated increases with increasing solar irradiation and maximum output power P_{max} also, increase, as shown in Table 2.

Table 2 Varying irradiation with constant temperature

Irradiation (W/m^2)	I_{sc} (A)	V_{oc} (V)	V_{max} (V)	I_{max} (A)	P_{max} (W)	Efficiency (%)
1000	2	23	19.6	1.8	36.1	14.5
800	1.6	22.7	18.9	1.5	28.4	14.3
600	1.2	22.3	18.9	1.1	20.9	14.0
400	0.8	21.7	18.2	0.7	13.5	13.6
200	0.4	20.9	17.5	0.3	6.4	12.9

Figure 5 output current at various irradiance as a function of module current and output voltage.

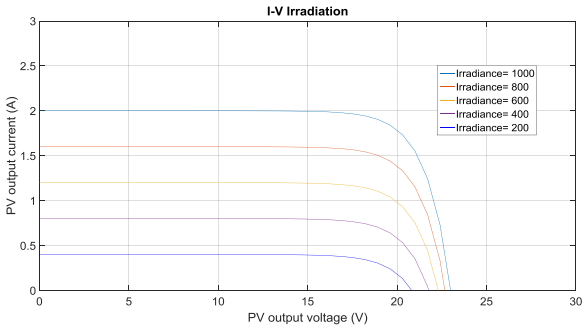
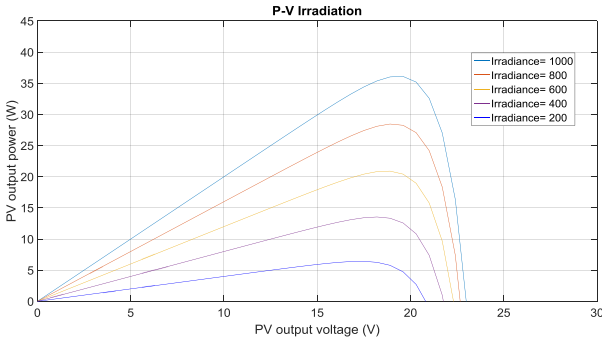


Figure 6 output power at various irradiance as a function of module power and voltage.



3. Suitability in Kathmandu's rooftop model

Technical feasibility considers issues such as the local climatic conditions, temperature, the potential energy production of the system (through simulation); level of smog and dust in urban and rural areas (in order to foresee necessary instruction for maintenance and cleaning of the modules surface; Wind conditions (necessary to construct appropriate structural supports.

Kathmandu covers 595 Km^2 which constitutes about 36 per cent of the total urban household (CBS, 2011) and consumes 29.2 per cent of total electricity distributed by the NEA (NRB 2012). The valley has a moderate temperature throughout the year, having the average maximum temperature of 24.98 ^{0}C and the average minimum of 13.66 ^{0}C. It has daily 5.0 kWh/ kWp and yearly 1826 kWh/kWp according to the World Bank estimation illustrated in figure 7. Nepal has 300 days of

sunny weather with the average solar radiation of Nepal varying from 3.6 – 6.2 KWh/m^2/day (Gayar and Anthony, 2020). The average insolation intensity of Nepal is about 4.7 kWh/m^{2}per day.

Renewable Energy Road map of IEA 2014 assumes that the cost of electricity from PV in different parts of the world will converge as markets develop, with an average cost reduction of 25% by 2020, 45% by 2030, and 65% by 2050, leading to a range of US$ 40 – 160 /MWh, assuming a cost capia of 8% (IEA, 2014). However, Chinese Tier 1 module players were selling at US$ 0.59 – 0.60 /W in China and US$ 0.67 – 0.79/W in other countries whereas German modules were selling at EUR 0.69 (US$ 0.95/W) (IEA, 2014). The cost of solar PV panels is now half of what they used to be only seven years ago, and their prices are likely to fall by another 60 per cent over the next decade (Panos et al, 2016). Recently, India has the lowest bid, comprised at least 3 GWh of energy storage capacity – pumped hydro or battery storage – plus associated clean energy generation assets (Gupta, 2020).

The simulation result shows that the Kathmandu is very suitable for solar energy; monthly average production is higher with the solar cell. Solar power is viable without financial support even in the regions with abundant fossil fuel resources (IRENA, 2017). At the same time, the prices of batteries and other electricity storage technologies have fallen as much as 80 per cent since 2010 (Fu et al, 2017). Considering this economic encouragement of declining price trend, Nepal should immediately follow to adapt solar rooftop in their residential building in a business scale. To our knowledge, an extensive evaluation of rooftop PV solar potential has not been undertaken in Kathmandu on a broader range. This article would help to fill that gap.

Table 3 Financial Analysis of a rooftop solar panel model for a typical household in Kathmandu

Size of feasible solar plant	**3 kW**
Annual values of units generated	4077 KWh
Annual values of solar radiation	5 KWh/m^2/day
Capacity utilisation factor	16%
Total cost	330,000 NPR
Cost of electricity saved	4,080 NPR/month
Total payback period of	6 years
Total loan	231,000 NPR @ 10% over 9 years
Calculated returns	5,043 NPR/month

Kathmandu Household = 254764 [36] ; Kathmandu population = 1,003,285

Kathmandu area = 49.45 Km^2 ; Average household = 3.94 ; Average roofing area = 100 m^2

Kathmandu population density = 20288.88; Assumed usable roofing area = 20 m^2

Solar radiation of Nepal varies 3.6 – 6.2 KWh/m^2/day.

Latitude 27.7224degree N; Longitude 85.3418degree E; Altitude 1295m

Assumed usable roofing area = 20 m^2 for 3KW PV system.

Therefore, total generation = 3 KW x 100000 households = 300 MW.

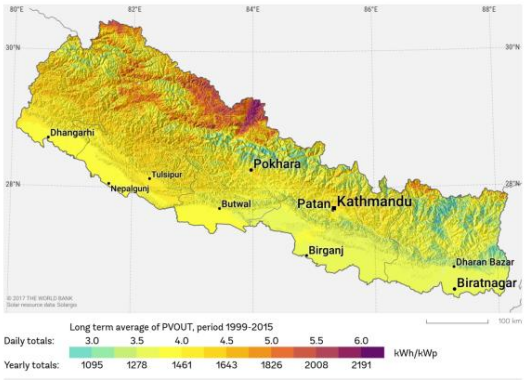


Figure 7 Solar Map of Nepal

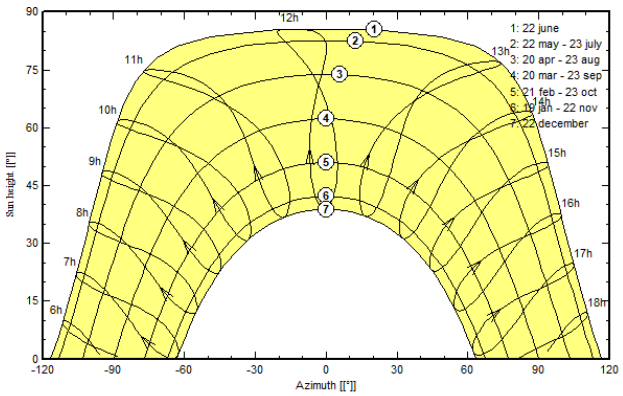


Figure 8 Solar path of Bishalnagar, Kathmandu

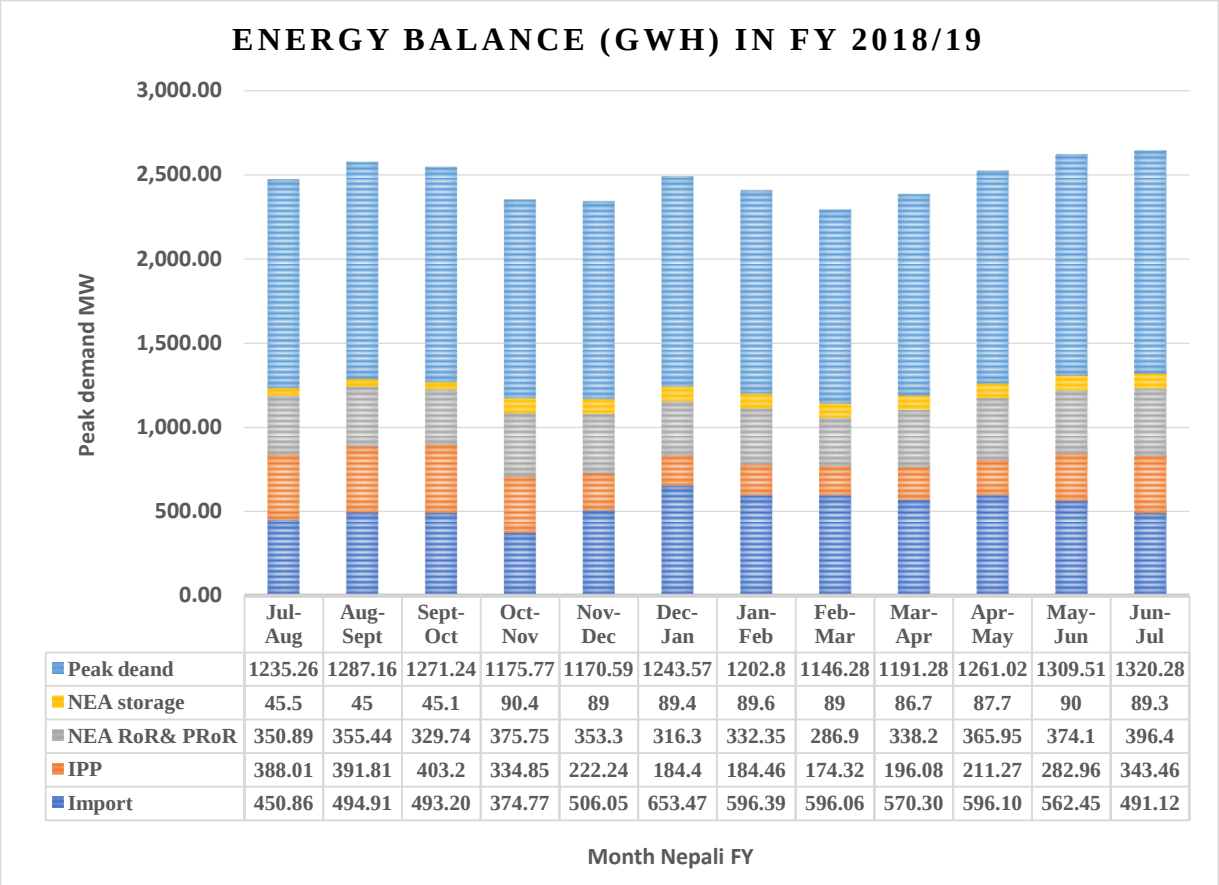
Withal, the simulation result shows that the Kathmandu (located between 27.70169^{0}C latitude and 85.3206^{0}C with the altitude of 1289 m is very suitable for solar energy, monthly average production is higher with the solar cell.

Table 6 *Monthly Data table of the purposed site*

Month	Gh kWh/m²	Dh kWh/m²	Bn kWh/m²	Ta 0c	Td 0c	FF m/s
January	139	24	241	8.9	3.1	0.6
February	141	34	190	13.3	5.5	1
March	170	58	174	18.7	6.5	1.2
April	184	68	169	23.9	8.7	1.3
May	193	84	150	25	13.9	1.5
June	175	92	115	24.6	17.4	1.3
July	156	82	103	23.2	19	1.1
August	159	75	123	23.2	19.1	1
September	141	73	104	22.6	18.2	0.9
October	151	48	175	20.3	14.4	0.4
November	132	33	185	15.7	9.1	0.3
December	139	26	232	10.9	4.9	0.3
Year Avg.	1881	697	1962	19.2	11.7	0.9

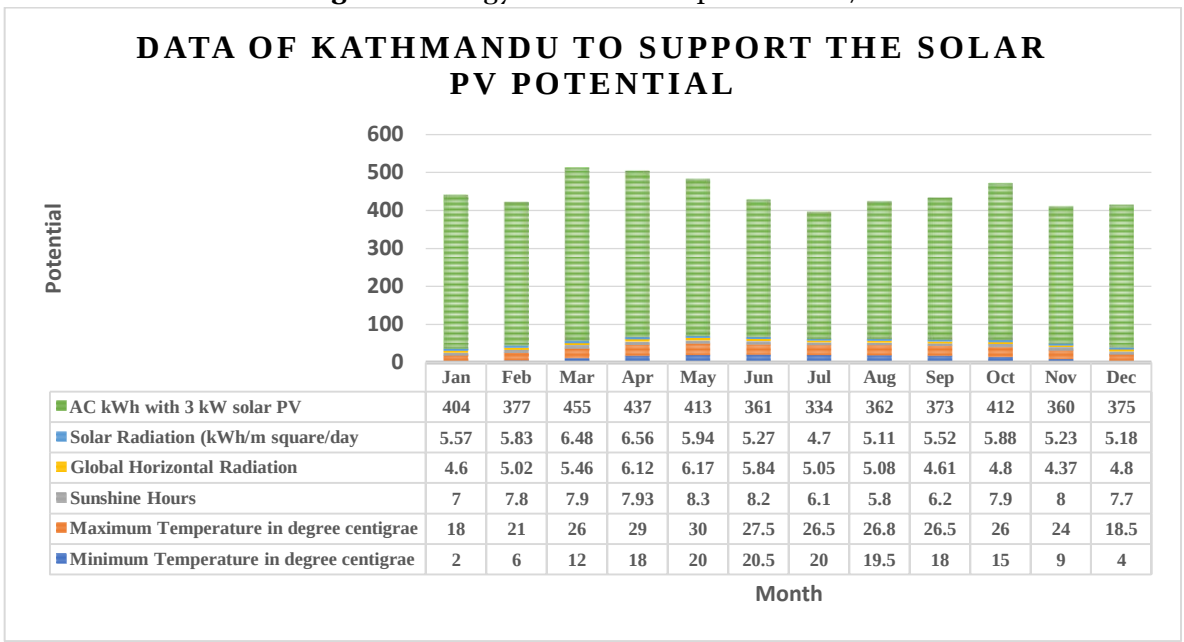
Table 7 *Final Results of AC Energy generation in 3 kW PV rooftop module*

Month	Solar Radiation (kWh/m²/day	AC Energy (kWh)	Value ($)
January	5.57	404	30
February	5.83	377	28
March	6.48	455	34
April	6.56	437	33
May	5.94	413	31
June	5.27	361	27
July	4.70	334	25
August	5.11	362	27
September	5.52	373	28
October	5.88	412	31
November	5.23	360	27
December	5.18	375	28
Annual	5.61	4,663	349



	Jul-Aug	Aug-Sept	Sept-Oct	Oct-Nov	Nov-Dec	Dec-Jan	Jan-Feb	Feb-Mar	Mar-Apr	Apr-May	May-Jun	Jun-Jul
Peak deand	1235.26	1287.16	1271.24	1175.77	1170.59	1243.57	1202.8	1146.28	1191.28	1261.02	1309.51	1320.28
NEA storage	45.5	45	45.1	90.4	89	89.4	89.6	89	86.7	87.7	90	89.3
NEA RoR& PRoR	350.89	355.44	329.74	375.75	353.3	316.3	332.35	286.9	338.2	365.95	374.1	396.4
IPP	388.01	391.81	403.2	334.85	222.24	184.4	184.46	174.32	196.08	211.27	282.96	343.46
Import	450.86	494.91	493.20	374.77	506.05	653.47	596.39	596.06	570.30	596.10	562.45	491.12

Figure 9 Energy Balance of Nepal FY 2018/19



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AC kWh with 3 kW solar PV	404	377	455	437	413	361	334	362	373	412	360	375
Solar Radiation (kWh/m square/day	5.57	5.83	6.48	6.56	5.94	5.27	4.7	5.11	5.52	5.88	5.23	5.18
Global Horizontal Radiation	4.6	5.02	5.46	6.12	6.17	5.84	5.05	5.08	4.61	4.8	4.37	4.8
Sunshine Hours	7	7.8	7.9	7.93	8.3	8.2	6.1	5.8	6.2	7.9	8	7.7
Maximum Temperature in degree centigrae	18	21	26	29	30	27.5	26.5	26.8	26.5	26	24	18.5
Minimum Temperature in degree centigrae	2	6	12	18	20	20.5	20	19.5	18	15	9	4

Figure 10 *Data of Kathmandu to support the solar PV potential*

4. Results, analysis and Discussion

Effects of temperature and irradiation on the PV's output has been examined in detail by mathematical model presented in Matlab Simulink. After analysing the PV/IV characteristics, researchers have compared those relation with the feasibility to install the residential building in

Kathmandu. For this purpose, PVsyst, Meteonorm softwares were used to examine its techno-economic feasibility. The study has demonstrated that there is very encouraging potential for 3kW rooftop solar PV systems to be considered for Kathmandu. The analysis indicates that the PV system would benefit from the excellent climatic conditions, something which would provide additional value to solar energy technology both in terms of production capacity as well as cost effectiveness. They can be implemented in a matter of months rather than the years needs to implement delayed hydropower plants. Moreover, it will provide local employment opportunity and enhance the national energy security. Being clean energy, it is the best alternative energy for dealing with frequent power outages and more economically competitive compared to present alternatives used to deal with the rooted load shedding.

Further, 3 kW rooftop system seems feasible as the payback period is just 6 years, as illustrated in Table 3. Table 6 and Table 7 enumerated the monthly generation potential of electricity in Kathmandu. These results show that if utilises on a business scale, solar PV would be the model energy mix in Nepalese power system. Average 220 MW of electricity could generate in Kathmandu valley alone. Similarly, Solar PV would be game changer to make balance in Nepalese power system during the dry season, as shown in figures 9 and 10. Dry season solar PV could generate the highest electricity once the flow of rivers is plummeted.

"To make an energy fix, we need an energy mix." Nepal should follow this BP's slogan as a mantra in its energy system (Poudyal, 2019). Therefore, in conclusions, suggested to use the authors presented module can be instrumental to know the techno-economic feasibility of solar PV rooftop module in the residential building of Kathmandu. The authors further recommend that present module can help researchers, engineers, energy planners and policy makers with better understanding of the PV system in the context of Nepal.

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Geopolymer Sand as a Construction Material for Sustainable Development

Indra Pd Acharya
Assistant Professor, Tribhuvan University, Nepal
indrapd@ioe.edu.np

Abstract

Geopolymers are an alternative binder to Portland cement used in the manufacture of mortars and concrete, as its three-dimensional aluminosilicate network imparts excellent mechanical properties. Use of geopolymers in place of ordinary Portland cement is favoured owing to the energy and carbon dioxide savings. River sand is another construction material that needs development of a sustainable alternative in the world. Geopolymerisation of fly ash amorphous silica mixtures is employed to produce fine aggregates as a possible replacement to river sand. Geopolymerisation of fly ash amorphous silica mixtures in 10M NaOH solution at 100^{0}C for 7 days produces fine aggregates [termed fly ash geopolymer sand (FAPS)] that have comparable grain size distribution, specific gravity, and improved frictional resistance as compared to river sand. The FAPS particles exhibited more alkaline pH(12.5) and higher total dissolved solids (TDS) concentration (TDS =747mg/L) in comparison to the river sand specimen (pH = 7.9 and TDS = 32.5mg/L). However, when used as fine aggregate in mortar, FAPS-mortar specimens develop similar pH, lower TDS, similar compressive strength, and modulus in relation to river sand-mortar specimens. The experimental result suggests that FAPS particles have a potential to replace river sand in the manufacture of mortar and concrete.

Keywords: Fly ash; Geopolymer; Sands; Sustainable

1. Introduction

Geopolymers are three-dimensional(3D) network of aluminosilicate molecules that are formed by the dissolution of materials containing reactive alumina and silica and possibly an additional silica source (sodium silicate or amorphous silica) in alkaline-activating solutions(sodium or potassium hydroxide) at temperatures of less than 100^{0}C (Davidovits 1979, 1989, 1991; Fernandez-Jimenez and Palomo 2003; Hardjito and Rangan 2005; Hardjito et al.2004).The properties of geopolymers are varied by altering the Si/Al ratio, Na/Al ratio, and water content of the mixture (Palomo et al.1999; Van Jaarsveld et al. 2002; Hardjito et al.2004; Fernandez-Jimenez and palomo 2005; Steveson and Crentsil 2005; Duxson et al.2007).The 3D network that binds the geopolymer imparts excellent mechanical properties such as high rate of strength gain; large compressive and flexural strengths; low shrinkage; and superior fire, sulfate and acid resistance. These properties make geopolymers an alternative binder to Portland cement in the manufacture of mortar and concrete (Palomo et al.1992; Hardjito et al.2004).

Along with ordinary Portland cement (OPC), another widely used material in the construction industry is river sand, which is used as fine aggregate in mortar and concrete. The rapid growth of the construction and infrastructure industry in developing country is quickly depleting this natural source. To meet the burgeoning need, sand is being produced in an unsustainable manner involving washing surface soils (termed filter sands) and crushing of rocks to appropriate sizes (termed manufactured sand) (Reddy 2012). This study examines the feasibility of using fly ash-geopolymerisation reactions to produce fine aggregates [fly ash-geopolymer sand (FAPS)] as an alternative to river sand.

2. Materials and methods

Fly ash from Raichur thermal power plant in the Raichur District, Karnataka state, India, was used in this study. The physical and chemical properties of Raichur fly ash are provided in Table 1.

Table 1: Physicochemical properties of Fly Ash

Parameter	**Value**
Physical properties:	
Specific gravity	2.15
BET surface area (m^2 /g)	1.1
Particle size distribution (%) Sand fraction (4.75 mm to 0.075 mm) Silt fraction (0.075 mm to 0.002 mm) Clay fraction (< 0.002 mm)	 24 % 74 % 2.0 %
Chemical properties:	
pH	8.4
EC (µS/cm)	225
TDS (mg/L)	144
SiO_2 (%)	57
Al_2O_3 (%)	26
CaO (%)	0.97
MgO (%)	0.486
K_2O (%)	1.83
Fe_2O_3 (%)	8.7
TiO_2 (%)	1.55
Loss on ignition (%)	5.39

On the basis of SiO_2 (57%), Al_2O_3(26%) and CaO(0.97%) contents, Raichur fly ash is categorised as class F(ASTM 2008). Nearly 60% of the fly ash particles are finer than 45µm (Fig.1). Laboratory regent grade sodium hydroxide and silica gel (with a particle size range of 0.12 to 0.25mm) were used in the synthesis of FAPS. Commercially available river sand was obtained locally from Bangalore and was used as reference for comparing properties of FAPS particles.

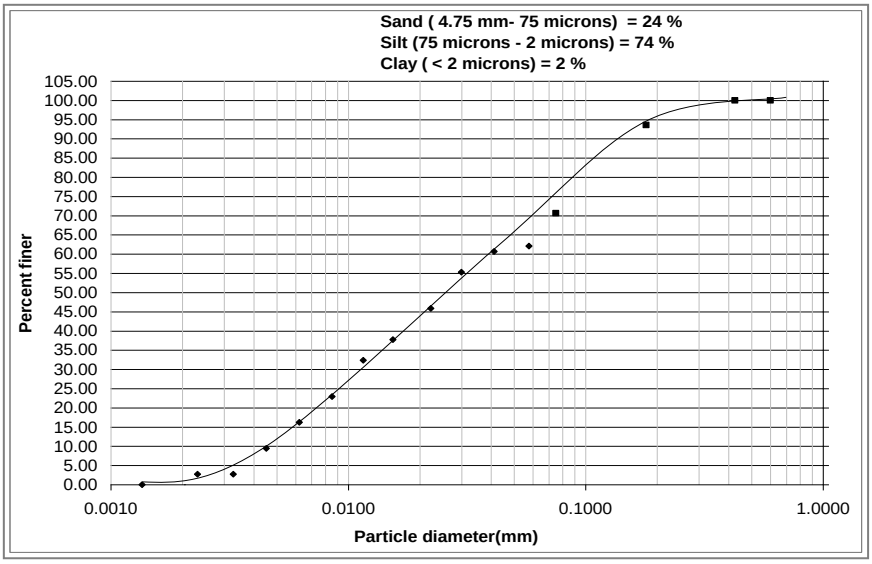

Figure 1: Particle size distribution of fly ash

3. Synthesis of Geopolymer Sand

A mixture containing 336.5g of fly ash and 23.5g of amorphous silica (corresponding to 6.5% silica gel of total mixture mass) was remoulded with 90 ml of 10 M NaOH solution (solids: solution ratio = 4:1; gravimetric water content = 25%). The slurry was dried in an oven for 4 h at 50^{0}C to allow the material to develop adequate cohesion to produce fine aggregates (with a particle size of 4.75 to 0.075 mm) on sieving as the first step. Fine aggregates were obtained by sieving the 4-h dried cohesive mass through 4-mm mesh. The fine aggregates were further heated at 100^{0}C for 7 days in a temperature-controlled oven (±2^{0}C accuracy) to complete the geopolymerisation reactions. After 7 days, the aggregates were removed from the oven and repeatedly washed with distilled water (solids: solution = 1:10) until the electrical conductivity (EC) of the washing was reduced to less than 1 millisiemens/cm. The washed aggregates were oven-dried at 100^{0}C for 2 h producing the Geopolymer Sand (FAPS).

4. Tests with FAPS and River Sand

The pH of the FAPS and river sand specimens was determined as per India standard (IS) 2720 [Bureau of India standard (BIS) 1987].The pH of the specimens was determined by agitating the specimens with distilled water (solid: water ratio = 1:2.5 on a mass basis) for 1 h; after the equilibration period, the suspensions were centrifuged and the pH of the supernatant solutions was determined using an Elico L I20 pH meter. The EC of the FAPS and river sand specimens was determined by agitating the specimens with distilled water (solid: water ratio = 1:2 on a mass basis) for 0.5 h; after the equilibration period, the suspension were centrifuged and the EC of the supernatant solutions was measured using a control Dynamics conductivity meter. The EC values were converted to total dissolved solids (TDS) using the equation (Todd 1980)

$$1 \text{ mg/L} = 1.54 \text{ µS/cm} \qquad \text{(Equation 1)}$$

The specific gravity of the FAPS and river sand specimens was determined as per the IS 2720(BIS 1980) procedure. The grain size distribution of these specimens was determined as per the IS 2720 (BIS 1985) procedure. The XRD pattern of silica gel, fly ash and FAPS specimens were obtained using a JEOL JDX-8030 power X-ray diffractometer (Tokyo, Japan), and the results were analysed using Philips Xpert software. The surface morphology of the FAPS specimens was examined using a Quanta 200 ESEM scanning electron microscope (Steyregasse, Austria).

To determine the frictional properties, direct shear tests were performed on the FAPS and river sand specimens as per IS 2720 (BIS 1986). A strain rate of 0.25mm/min was used in the tests. The specimens (dry density = 1.4 Mg/m^3) were sheared under vertical stresses of 50, 100, and 150, kPa, respectively.

5. Preparation and Testing of Mortar Specimens

The mortar was prepared by mixing one part ordinary Portland cement and three parts river sand/FAPS(on a mass basis) based on IS 2250 (BIS 1981) guidelines. A water-cement (w/c) ratio of 0.45 was used to prepare the river sand-mortar (RS-M) specimens. As this water content was found adequate to prepare a workable mixture. A higher w/c ratio of 0.9 was found necessary to provide a workable FAPS- cement mixture. The moist mixtures were statically compacted to a constant volume of 86.65 cm^3. Static compaction of the moist river sand cement mixture yielded specimens having a dry density of 2.08Mg/m^3.Static compaction of the moist FAPS-cement mixture yielded specimens having a lower dry density of 1.94mg/m^3. Three compacted specimens were each prepared from the river sand cement and the FAPS cement mixture. The six compacted specimens were cured under ambient laboratory conditions (temperature = 25^{0}C) for 24h and then immersed in a tap- water bath (TDS of tap water = 247 mg/L) for 28 days. After 28 days of soaking, the specimens were tested for compression strength at a strain rate of 1.2mm/min. Triplicate measurement of the RS-M and FAPS-mortar (FAPS-M) specimens indicated that the percent variation from the average strength for both types of mortar specimens was less than 5%. The

failed RS-M and FAPS-M specimens were subjects to pH and TDS measurements using the previously described procedures. Water leach tests were conducted with the failed RS-M and FAPS-M specimens in accordance with ASTM D3987(ASTM 1985).The water leach test was performed by agitating 5 g of the failed RS-M and FAPS-M specimens (passing a 425µm sieve) with 100ml of distilled water for 18 h (solids: solution ratio = 1:20). After 18 h, the slurries were filtered and the filtrates were analysed for dissolved sodium ion concentrations using an atomic absorption spectrometer.

6. Results and Discussion

Figure2 presents the grain size distribution of the FAPS and river sand specimens. The FAPS specimen is characterized by coarse (4.75 to 2mm), medium (2 to 0.425mm), and fine (0.425 to 0.075mm) sand fractions of 7.6, 81.4, and 11.0%, respectively. The river sand specimen also dominates in medium(64.5%) and fine (34.15%) sand fractions with traces of coarse sand content (1.4%).The FAPS particles are characterised by uniformity coefficient (C_u) values of 3.25 and 1.55,respectively,classifying them as poorly graded sand (SP) according to IS 1498 (BIS 1970). The uniformity coefficient (C_u) and coefficient of curvature (C_c) are defined as follows (BIS 1970):

$$Cu = D60 / D10 \qquad \text{Equation 2}$$

$$Cc = D^2 30 / D60 * D10 \qquad \text{Equation 3}$$

In Eqs. (2) and (3),$D_{60,}$ $D_{30,}$ and D_{10} refer to particle diameters in the particle size distribution curves at 60, 30, and 10% finer, respectively. Well-graded sands (SW) possess a uniformity coefficient greater than 6 a coefficient of curvature between 1 and 3 [IS 1498(BIS 1970)]. The river sand also classifies as SP based on its C_u value (3.5). The specific gravity of the FAPS and River sand specimens correspond to 2.59 and 2.61, respectively (Table 1). The specific gravity of fly ash corresponds to 2.15 (Table 1).The dense packing of the Si-O-Ai-O- units is considered responsible for imparting higher specific gravity to the FAPS particle in comparison to the fly ash particles.

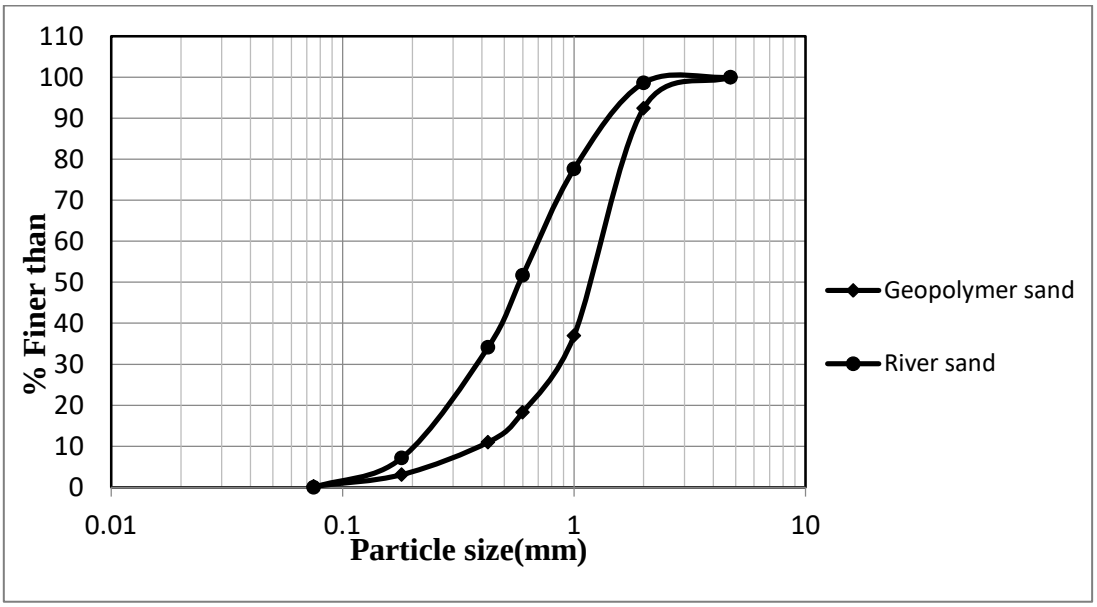

Figure 2: Grain size distribution of river-sand and FAPS specimens

The pH of the FAPS particles corresponds to 12.5 (Table 2). Blending the strongly alkaline FAPS particles with cement to prepare mortar or concrete should not impede their mechanical properties, as strong alkaline pH (12.8 – 13.7) is induced on cement hydration (Fraay et al. 1989).The EC of the FAPS specimens corresponds to 1.15 mS/cm, which translates to a TDS concentration of 747mg/L using Eq.(1).Based on the TDS value, the FAPS particles are classified as

fairly good soil material (BIS 1977). The river sand particles are characterised by a pH of 7.9 and a TDS of 32.5mg/L.

Table 2: Properties of river sand and FAPS particles

Parameter	FAPS	River sand
Physical properties		
Specific gravity	2.59	2.61
Friction angle (degrees)	35.5	28.9
Particle size distribution (%)		
Coarse Sand fraction (4.75 to 2 mm)	7.6	1.4
Medium sand fraction (2 to 0.425 mm)	81.4	64.5
Fine sand fraction (0.425 to 0.075 mm)	11.0	34.2
Chemical properties		
pH	12.5	7.9
TDS (mg/L)	747	32.5

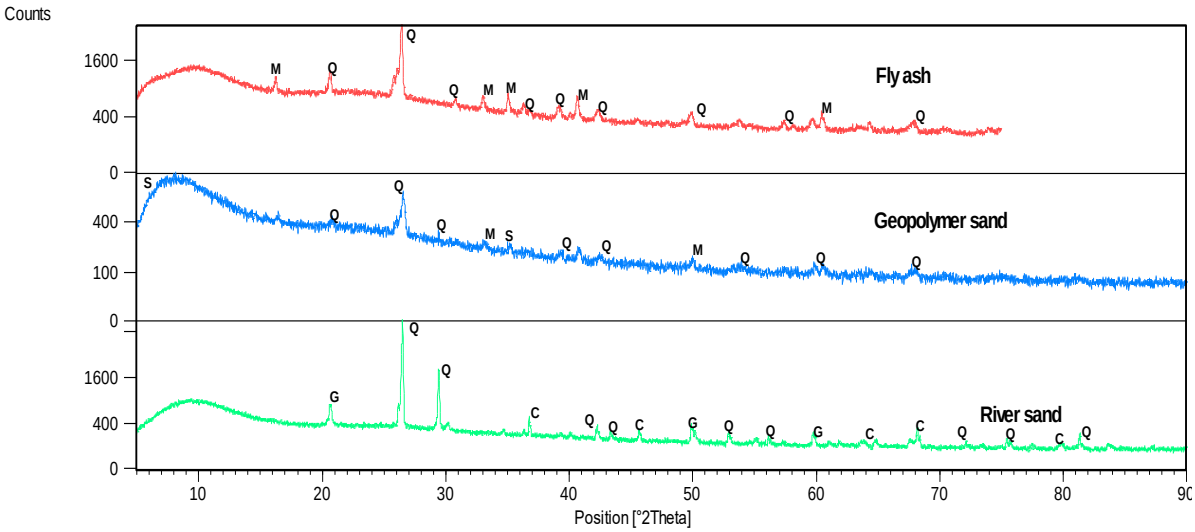

Figure3: XRD pattern of fly ash, FAPS and river sand M = Mullite (Aluminum silicate) and Q = Quartz, G=Gibbsite, C=Calcite

Figure 3 compares the XRD patterns of the fly ash and FAPS particles. The XRD pattern of fly ash shows a broad hump between 2 Theta values of 6 to 15 degree, which is attributed to the presence of glassy matter (Ward and French 2006) .peaks of quartz (SiO2), were found at 20.8, 26.4, and 49.8 degrees. Mullite peaks occurred at 16.3, 32.1, 35.5, and 40.9 degrees. According to Palomo et al. (1992), alkali activation reaction of fly ashes occurs through dissolution of the glassy phase with the reease of silicon and aluminum ions into the solution that subsequently polymerize into aluminosilicate network to create the hardened binder. The XRD pattern of the FAPS specimen shows sharpening of glassy phase as a consequence of geopolymerisation reactions.

Figure 4 plots the failure envelopes (shear stress- normal stress plots) of the FAPS and river sand particles (dry density = 1.4Mg/m^3). The FAPS particles are characterized by a friction angle (Ø) of 35.5 degree, while the river sand developed a smaller Ø of 28.9 degree. Depending on the particle shape and density of packing in the direct shear test, sand particles develop friction angles ranging from 27 (loose packing; rounded grains) to 45 degrees (dense packing; angular grains) (Das 1998). The scanning electron micrograph (SEM) of the FAPS particles in Figure 5 reveals them to be composed of rounded grains.

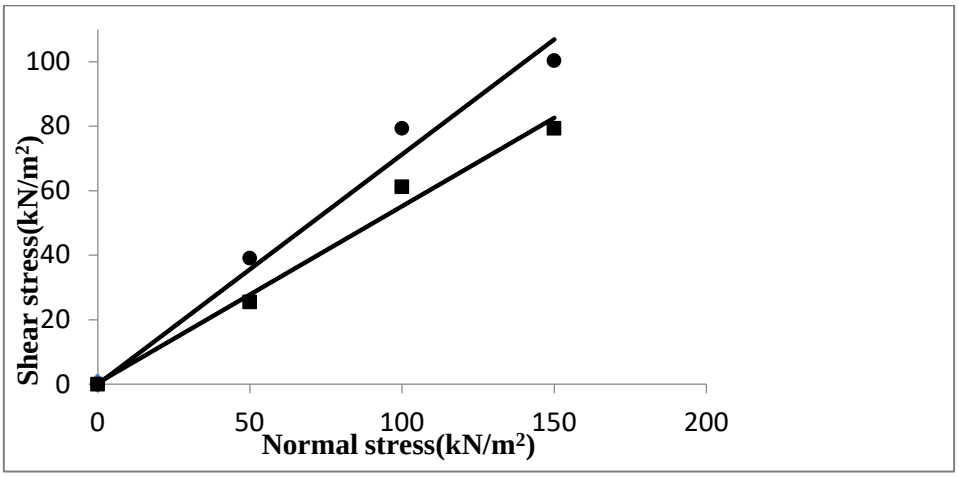

Figure 4: Failure envelopes of river sand and FAPS specimens

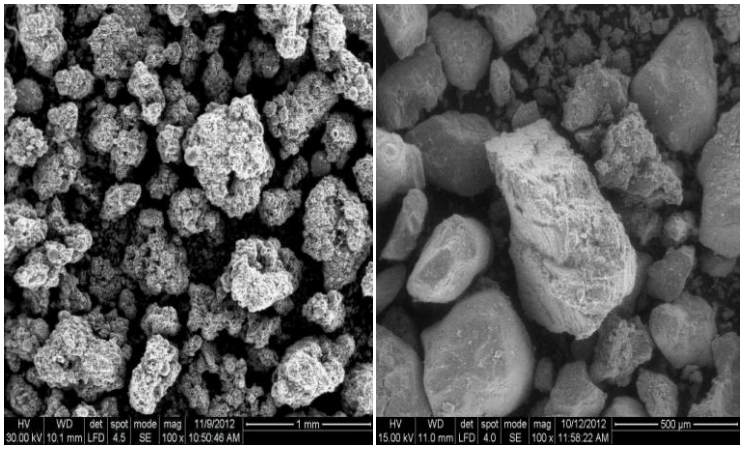

Figure 5: SEM images of FAPS and river sand

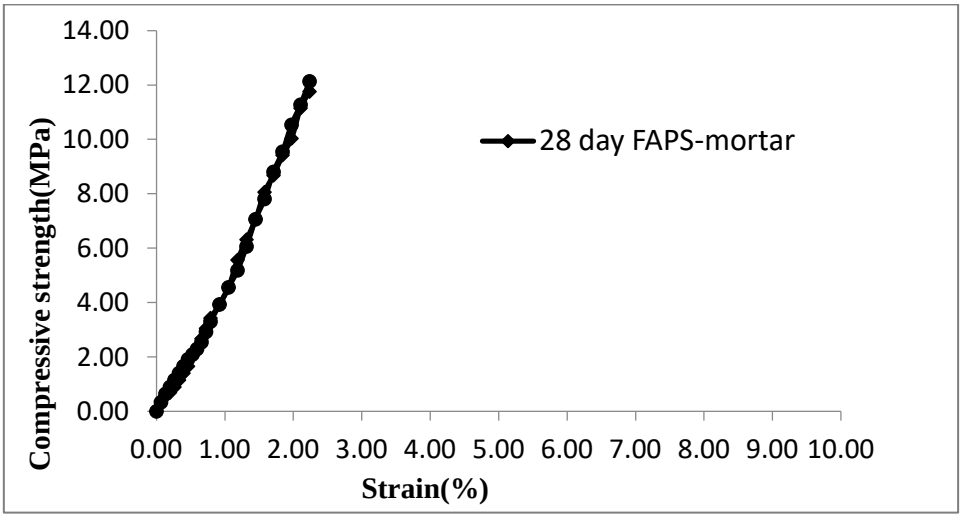

Figure 6: Stress-strain curves of mortar specimens

Figure 6 plots the stress-strain curves from compression tests conducted with RS-M and FAPS-M specimens. The RS-M and FAPS-M specimens developed similar 28 days compressive strengths of 12.2 and 11.6 MPa, respectively. The initial tangent modulus (ITM) of the RS-M and FAPS-M specimens was also similar and corresponds to 0.5 and 0.495 Gpa, respectively. The compressive

strength and ITM values indicate that the lower density (1.94Mg/m^3) and higher water content (w/c ratio = 0.9) did not hinder strength and modulus development in the FAPS-M specimens. Fly ash is used to partially replace cement in the manufacture of high–volume concrete (Fraay et al. 1989). The cenospheres in fly ash react with lime released from cement hydration to form C-S-H compounds. In a similar manner, it is expected that unreacted cenospheres in FAPS-M will react with lime released from cement hydration and contribute to strength to counterbalance the influence of a higher w/c ratio and slightly lower dry density.

7. Conclusions

Gopolymerisation of a fly ash amorphous silica mixture in a 10m NaOH solution at 100^{0}C for 7 days produced fine aggregates (termed FAPS). The FAPS particles predominated in medium-sized (2 to 0.425mm) sand-sized particles. Their particle size distribution characteristics (uniformity coefficient and coefficient of curvature) caused them to be classified as SP. Dissolution followed by poly-condensation of reaction product led to dense packing of the Si-O-AI-O-units that imparted a specific gravity of 2.59 to the FAPS particles, which is comparable with that of river sand (2.61).Dissolution in a strongly alkaline medium imparted a strongly alkaline pH (12) to the FAPS particles. As cement hydration reactions also induce a similar pH, range, the use of FAPS particles in the manufacture of mortar and concrete should be feasible. The FAPS particles are characterised by a TDS of 747 mg/L, classifying them as fairly good soil material. In the direct shear test, despite being characterised by rounded grains, the FAPS particles mobilised a relatively high friction angle of 35.5 degree.

Comparing the properties of the river sand with FAPS particles, both the fine aggregates had similar grain size distribution and specific gravity values. The river sand is characterised by a much lower pH (7.9) and TDS (32.5 mg/L) than the FAPS particles. The FAPS particles exhibited a larger friction angle than river sand (Ø = 28.9 degrees). Despite requiring higher water content, the FAPS – M specimens developed similar compressive strength and ITM values as the RS-M specimens. Mortar specimens prepared with FAPS-M specimens prepared with FAPS and river sand have a similar pH of 12.36 and 12.4,respectively.FAPS-M specimens have a lower TDS(1.545 mg/L) than RS-M specimens (TDS = 1.889 mg/L),implying that they are less vulnerable to developing efflorescence. The larger leachable sodium of the FAPS-M specimens is attributed to residual sodium hydroxide persisting in the FAPS even after washing. The physicochemical and mechanical properties of FAPS and FAPS-M specimens indicate that FAPS particles have the potential to be used as fine aggregates in the manufactures of mortar and concrete.

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Kanhaiya Bhagat Koiri

It is my great pleasure to welcome you to the SONEUK conference 2020. SONEUK is bringing together scholars and practitioners to share and exchange engineering ideas and technologies can be useful for the development of Nepal. This is an exciting opportunity to investigate the positive side of the current globalization.

I am very happy to support this event and wish to express my gratitude to the organisation committee and all participants.

Professor Keshav Dahal

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(Currently in Dublin, Ireland)

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Tara Lamsal

Wishing all the best

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It is a privilege to support the activities of SONE (UK) towards an innovative and flourishing Nepal.

Congratulations and best wishes for their future endeavours

Hari Krishna Neupane

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I am very proud of **SONEUK** for its contribution on friend's networking and for being a change agent to engineering practices in Nepal via various activities.

Krishna Kishor Shrestha

Chartered Highway Engineer

Jacobs, UK

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Vijay Gurung

I am proud to be a member of the team publishing conference proceedings dedicated to improving engineering practices in Nepal.

Best wishes for SONEUK's future endeavours.

Dr Birendra Shrestha

Vice-Chairperson, SONEUK and Coordinator, SONEUK Conference Organising Committee

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Ojesh Singh

Mayaju

Specialists in nail & beauty treatments

29 Church Street, Romsey, SO51 8BT
Tel: 01794 523354
Web: www.mayaju.co.uk

Mayaju is honoured to be affiliated with SONE UK. We wish the organisation continued success in all their endeavours.

Owner Reena Rajbhandari has been working in the beauty trade for the past 22 years and in 2009 fulfilled her dream of opening her own salon when she launched Mayaju.

Reena chose Romsey as the location for the salon for its cosy environment and strong community feel and hasn't looked back since.

The salon has been supported by the local MP Caroline Nokes who in her recent visits said:
'Mayaju provides fabulous welcoming atmosphere which really helps you relax! What a great look for the salon and a real pleasure to support local business.

Now in their 11th year of business Mayaju, Romsey's boutique beauty salon, is the perfect place for all your beauty needs.

With a wide range of treatments from nail care, waxing, tanning, and high-end dermabrasion facials to semi-permanent makeups and HD brows the salon offers everything to help you look and feel great.

Open from 8am to 6PM on weekdays and 8am to 4pm on Saturday this modern salon over two floors uses high quality brand such as Elemis, Dermalogica, Crystal Clear, OPI and CND products which complement their ever-growing list of treatments.

So whether you are looking to pamper yourself, in need of a helping hand getting ready for a special occasion or would like to treat a loved one head to Mayaju.

We would like to thank all our clients who have been so supporting and have embraced up whole heartedly and made u a success. 'Coming from Nepal, and being loved by all has driven us to provide even better service along with charity events to support good causes here and in Nepal'