NTNU Department of Architecture and Technology

Future sustainable development of buildings in the high altitude Khumbu region of Nepal

A design for Cafe De Imja Tse Bakery and Guesthouse, Chukhung 4730m

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Supervisor: Tommy Kleiven

Acknowledgements

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Also to Sue Harper Todd and Craigie Levie.

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Tenzing Jangbu Sherpa and his wife Kami Doma Sherpa in Chukhung, for their hospitality and their enthusiasm with the project.

Panuru Sherpa & Passang Riki at Phortse Guesthouse,
Ang Tshering, Psng Sherpa and family at Hilltop view lodge, Khumjung,
Purmina at Everest Lodge in Ghat (best bedrooms in the Khumbu)
Staying with you all was where I experienced the incredible hospitably and kindness I mention!

Dalja, pien, Taktuk chakpu khysa.
(Roughly translated from Sherpa: Look after yourselves our dear friends. We love you all.)

Friends at hilltop lodge, Khumjung February 2020

Abstract

The Khumbu, also known as the Everest Region, is the home of the Sherpa people. Originally from Tibet, they emigrated to this region of Nepal 600 years ago. In Nepal's population of 30 million around 300,000 are Sherpas. They have become accustomed to the harsh conditions of living at high altitude in cold conditions where even the lowest Sherpa settlements are above 3500m. Traditional Sherpa houses are built with local materials and their known construction methods. With much of the Khumbu being a ten-day walk from the nearest road, the availability of modern materials is very limited. These buildings, in local stone, often suffer severe damage in this earthquake prone region. Indoor temperatures commonly fall below freezing whist open yak dung fires, used for cooking and heating, contributes to poor indoor air quality.

Since the middle of the 20th century tourism from trekking and climbing has become increasingly important to the local economy. A shortage of materials following an earthquake in 2015 and demand for inexpensive buildings to accommodate tourists has led to an influx of poorly constructed prefabricated buildings and a loss of traditional techniques. Today accommodation standards are generally regarded as poor by Westerners. Modern and usually expensive Western practices are usually only seen in Western funded developments and are generally not available to the local Sherpa people. Tourist spend per day is low and less than it was ten years ago. Rooms are commonly available for $5 USD. Increasing the standard of tourist services will raise the spend which will benefit local living standards and educational opportunities and consequently slow the rate of indigenous depopulation.

The first part of this thesis looks at historical and current Khumbu building practice. It examines their sustainability and then seeks to identify both simple affordable improvements that can be implemented locally. The second part of the thesis presents a development proposal for an existing high altitude bakery in Chukkung (4730m).

Contents

Motivation

My real interest in the Khumbu began in the spring of 2015 when Nepal was struck by a devastating 7.8-magnitude earthquake. Nearly 9000 people were killed and hundreds of thousands made homeless.

The earthquake triggered many avalanches in the mountains. One of these devastated the central section of Everest Base Camp. In the height of the climbing season, EBC as it is known, is home to approximately three thousand people. Fortunately, most people had left their tents at the time the avalanche struck, however, 21 people were killed and over 70 injured, many seriously.

Among those killed in the avalanche were 3 Nepalese working for ICE8000. They were friends and colleges of our close family friend and Everest summiteer Sue Harper Todd. They were Pasang Temba Sherpa who was the cook at Mount Everest's 21,000 foot Camp Two, Sherpa Tenzing who was a climbing Sherpa and Kumar who ran the base camp cooking operation for the Todd's business. All three of the men left behind families that relied on them for their livelihood. Between them they had 9 children and one grandchild.

Pasang Temba had been a close friend of Sue's since she first visited the Khumbu in 2003. She has spoken movingly about being met by him as she descended from the summit of Everest the following year. Seriously dehydrated and exhausted after an eighteen hour summit day, Sue was met by him above camp two. He insisted she took the last remaining contents of his water bottle. She describes this as one of the kindest things anyone has ever done for her.

Happy Sherpas at Base Camp the day before the earthquake

Pasang Temba's family house after the earthquake in 2015, among many that fell down

Pasang Temba's family living in tents, spring 2015

Pasang Temba's family home is in the village of Pangboche at 398m. This totally collapsed in the earthquake at the same time as he died three days walk away at EBC. His family – his wife Ang Rita, their three children and grandchild lost their home, their income and husband, father and grandfather in an instant. With no alternative they lived in tents. At nearly 4000m, the same height as many Alpine mountains, it was a pretty desperate situation. - (I have included a blog post about this from Sue herself which can be found in Appendix. 1)

Along with Sue, my family, friends and co-workers at Braemar Mountain Sports we immediately decided to launch a fund-raising effort to support the wives and families of those killed in the avalanche. The Sherpa Family Support Fund was set up, and we managed to raise £20 000 in the first 3 weeks. A large portion of these funds came from an evening "Avalanche Auction" in which some amazing lots were very generously donated. These included salmon fishing on the River Dee, a day on the hills with Mountain guide Kenton Cool and lunch with the First Minister of Scotland.

With some of the money raised, the Pasang Temba home was rebuilt in conjunction with New Zealand climber, Mike Allsop. As well as this, the money was used to assist the Kumar family start a chicken business and general living support has been given to the bereaved. The plan is that this will continue as and when support is required.

One of the reasons that the avalanche was so heart-breaking for many friends and family members was because they felt a deep connection to the Sherpa people. The Sherpa people are incredibly humble and have "kindness and generosity that knows no bounds".

"I was privileged enough to stand on the summit of Everest with Sherpa Ang Nuru, a boy with whom I felt so safe and I know I was lucky to be climbing with him as my partner. I have been to Everest Base Camp almost every year since then, sometimes twice a year, either helping out on expeditions or leading treks. During this time the Sherpas who work with us have become my friends. They welcome me into their houses when I pass through their village and willingly share what little they have with me." - Sue Harper Todd

I myself first visited the Khumbu in February this year. This kindness and generosity, that many friends had spoken of I experienced first-hand. I was invited graciously into family homes where nothing was too much trouble for them. I was also shown extreme kindness and care when I became ill in the mountains. I was stuck by how happy they seemed to be whilst having so little in material terms, - many families live in very simple uninsulated homes without running water, electricity, let alone internet connection.

Whilst I was in Nepal, my Dad and myself were staying with a lovely couple, Passang Riki and Panuru Sherpa, in the village of Phortse. Whilst chatting throughout the evening we found out that Passang Riki was in fact the sister of Pasang Temba, the friend of Sue's who was killed in the avalanche.

I think that life in the Khumbu and the Sherpa culture is critical to understand prior to undertaking a building project in this special place. The Khumbu is a unique and challenging place to develop sustainable architecture. As well as cultural traditions and local politics, it is made difficult by its extreme remoteness, lack of infrastructure, roads and technology. This makes the availability of materials challenging. In addition, there is its harsh climate and often a lack of capital.

Friends Sue and Ang Nuru on Everest Summit 2004


Myself, Passang Riki (Pasang Temba's sister) and my Dad in Phortse March 20202


Ang Nuru, his wife Maya, their daughter Xingzang and myself in Kathmandu March 2020

My motivation for beginning the MSc. programme in Sustainable Architecture was to learn more in order to be able to help these people. My desire to do something positive has only increased recently following my recent visit to Nepal. I keep in close contact with several friends there.

This year all of us around the world have been affected in some way by the coronvirus Covid-19. Many of us, including myself, are incredibly fortunate to live in developed countries which provide us with free healthcare and economic support if we are unable to work. In the Khumbu there is no such thing. With this year's spring (and most likely autumn) tourist season cancelled, a large majority of people will have no income.

To build a new building, the way in which it would be done in many western countries, for example Norway, with "super insulation" and triple glazing is not sustainable in this local community, economically or socially. Instead solutions need to focus on low technology principles, which goes right back to building in accordance with the climate and utilising passive strategies - one of the first things I learnt on the Sustainable Architecture programme.

I hope that the concepts in this project will contribute to the future well being of those living high in the Khumbu. The local craftsman, working with timber and stone are very talented and I think combing their traditional skills with some of the ideas in this thesis has the potential to deliver great benefits to the communities. This can contribute to a new phase of development that is both achievable and sustainable - environmentally, socially and economically.

Aims & Objectives

What is “sustainable architecture” in the Khumbu?

- Is this vernacular architecture or something new?

What are sustainable materials and practices?

- What materials are available locally? And how sustainable are they?
- Which materials not available locally are sustainable and how can they be brought to the Khumbu?
- Can some local techniques be adjusted to make them more suited for modern buildings?
- Can some modern concepts be introduced to local craftsman to combine with their current skills?

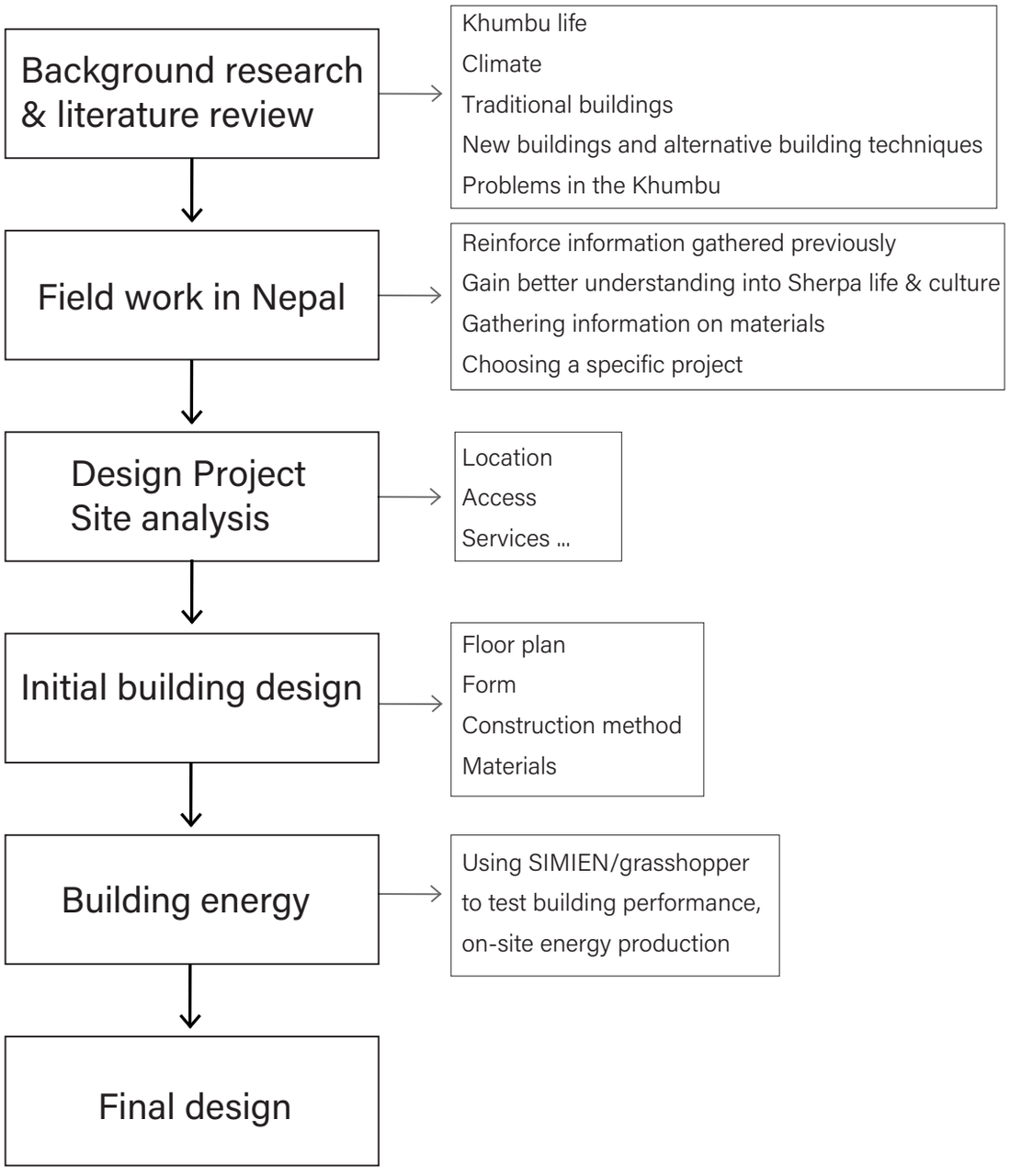
How can the development of buildings improve the lives of people living and working in the Khumbu?

- Considering environmentally, social and economic sustainability

Design a building which implements the findings above which can be used as an example or “lighthouse project” for others in the Khumbu

- Renovation/ extension of an existing building in the small village of Chukhung at 4730m altitude: Cafe De Imja Tse Bakery and Guesthouse

Method



Structure of this thesis:

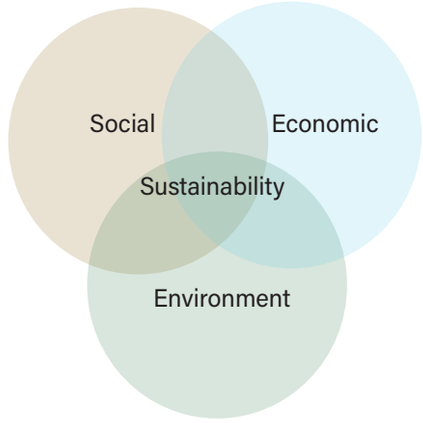
Part 1: The first part of this thesis is an introduction to the Khumbu.

This serves to provide some of the essential background knowledge required to undertake a building project in this region. It describes the lives of Sherpa people and their livelihoods, from traditional life to much more recent change. It also looks at traditional Sherpa architecture and local materials and techniques before moving onto more recently introduced materials and some examples of recent building projects.

Part 2: The second part of this thesis is a design for a renovation and extension to an existing building.

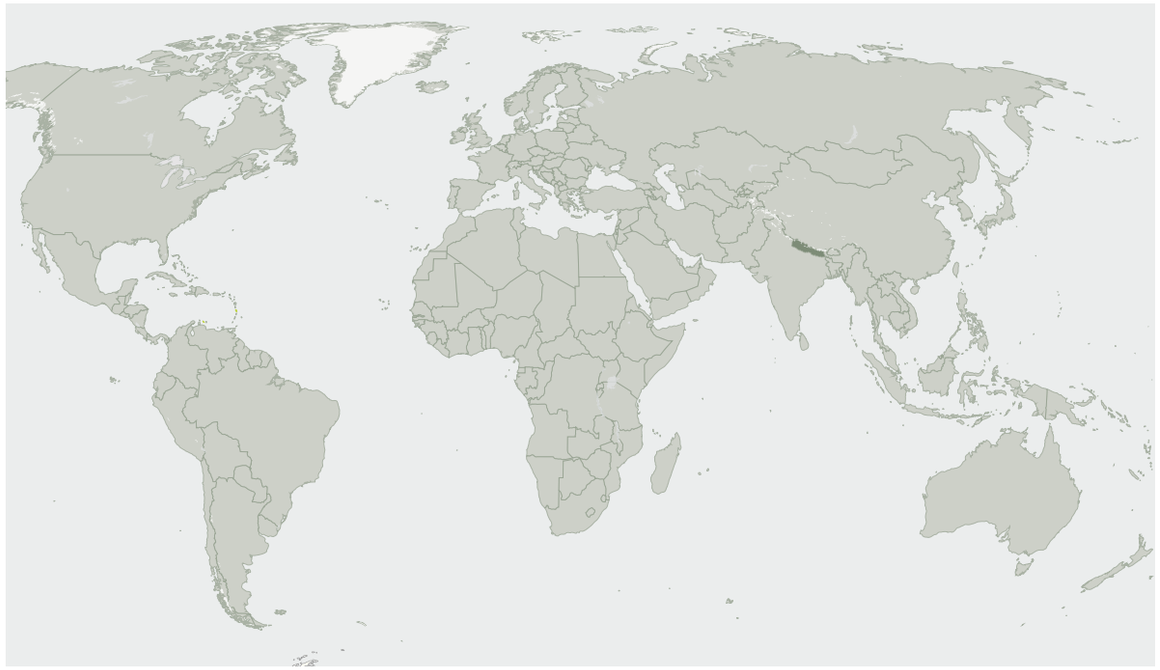
The design is for a site which currently houses a bakery and "snookerhouse" in Chukhung, one of the highest Sherpa villages in which the owner would like to diversify and offer a limited accommodation but at a higher standard than is currently available.

In this part of the thesis both positive and negative observations gained from earlier local research contribute to the development proposal. The design is intended to improve comfort for tourists as well as boosting business for the owners. It does this by implementing a mixture of traditional and new techniques in order to design a sustainable and achievable building. Whilst this project is a specific case, the aim is that many of the concepts in the building design could similarly be applied to other local buildings to bring a larger benefit to the community.



Part 1: Introduction to the Khumbu

Geographical Location



Nepal located in South Asia, mainly in the Himalayas

Solukhumbu District

Nepal, home to 29 million people, is a landlocked country which shares borders on the north with Tibet and the south with India. Kathmandu is the capital and largest city.

Nepal has 7 provinces. The Khumbu region lies within the Solukhumbu district which is in Province No. 1 in the Easter-most part of Nepal.

Elevation in the Khumbu varies from 3300m to 8848m on the summit of Mount Everest, the highest place on earth.

The Khumbu is a place of world importance. Within it lies Sagarmatha National Park and a World Heritage site. The region is diverse in its ecosystems and holds a rich history and culture which needs to protected and preserved.

Reaching the Khumbu

The Khumbu is not easy to reach.
To get there the choice is:
a) 45 min flight to the short, inclined runway at Lukla airport - only possible on clear days,
b) 10-12 hour drive by jeep (with an additional 4 days walking to Lukla)
c) short helicopter flight - (300-600 USD per person)

Lukla: The World's Most Dangerous Airport

David Nikel Senior Contributor ⓘ
Travel
A look at travel and lifestyle in Europe with a focus on Norway & Scandinavia.

Tenzing–Hillary Airport, known as Lukla airport in Nepal. GETTY

More than 300 people have died attempting to reach the summit of Mount Everest, with countless more injured. Yet the dangers begin well before trekkers even reach base camp. The most common way hikers reach the area is to fly to the tiny Himalayan settlement of Lukla, 9,383 feet above sea level.

SOURCE: Forbes, David Nikel

Nepal's Fifteen-Hour Jeep Ride From Hell

Chris Brinlee Jr
12/31/14 12:50PM • Filed to: ADVENTURE

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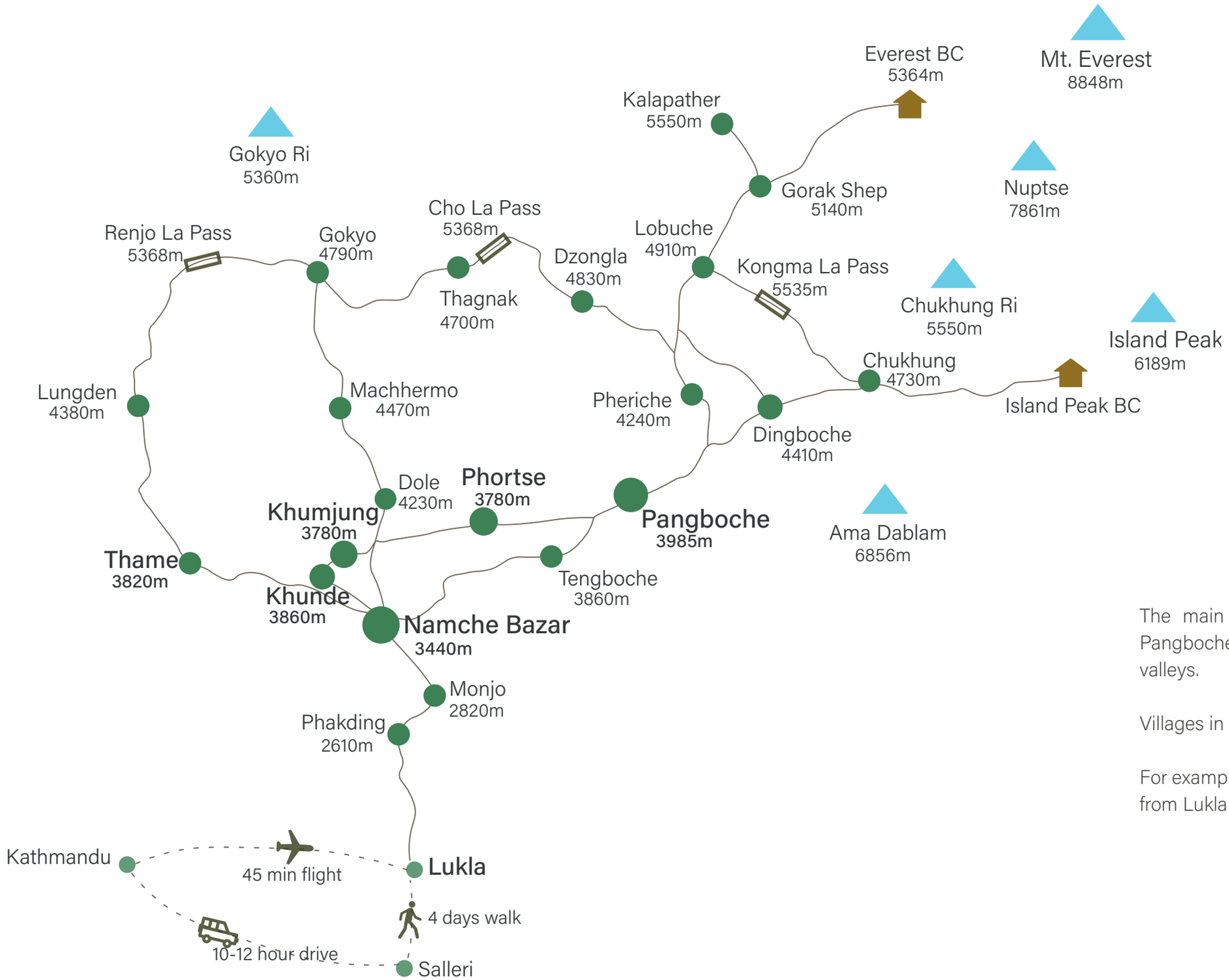
The Jeep Ride From Hell is a 15 hour journey (if you're lucky) from the Nepalese town of Salleri to Kathmandu. There's a reason why it's a "jeep" and not a bus. That reason is that the "roads" are anything but; we often needed four-wheel drive to cross streams, get out of ruts, and make it through mud. All while

SOURCE: Gizmodo, Chris Brinlee Jr

Helicopter, capacity 5 + pilot§§, Kathmandu

Khumbu Map



The main villages (Namche, Khumjung, Khunde, Phortse, Pangboche and Thame) are built in the wide glacial U-shaped valleys.

Villages in the Khumbu are extremely remote.

For example, the village of Pangboche (3985 m), is 3 days walk from Lukla Airport and 10 days walk from the nearest road.

Climate

According to the global Koppen-Geiger Climate classification (Kottek, 2010), the major villages in the Khumbu region have a (Dwc) Snow climate with dry winter and cool summer. Here, the temperature of one to three months is greater or equal to 10 °C but less than 22 °C, and coldest month -3 °C or lower.

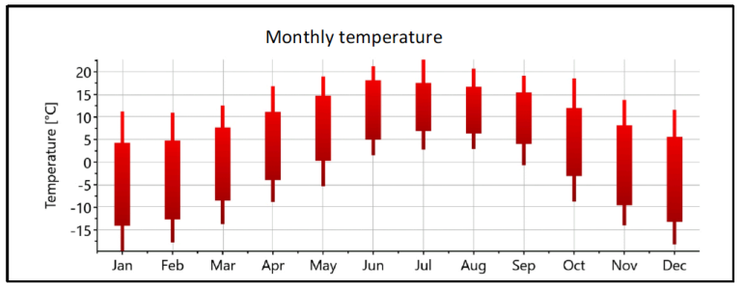
The climate is greatly affected by altitude. The settlements high in the Khumbu, some of which are only part of the year inhabited, have a polar tundra climate (ET) - Where the temperature of warmest month is less than 10 degrees but above 0. Mount Everest itself lies in polar frost (EF) - where the warmest month below 0.

The climate is characterised by 4 seasons:
Cold snowy winter (December -> early March)
Sunny spring season (March -> early June)
Wet summer - monsoon (June -> end of August)
Sunny autumn season (September -> early December)

The spring and the autumn are the two tourist seasons. These are referred to locally as pre and post monsoon seasons.

TEMPERATURE

The village of Pangboche (3985 m) experiences an estimated average daily temperature swing of 14°C. Temperatures drop below -15°C in winter and rise over 20°C in the summer. Average temperatures in the summer are typically around 11°C and dropping to an average of -5°C during winter.

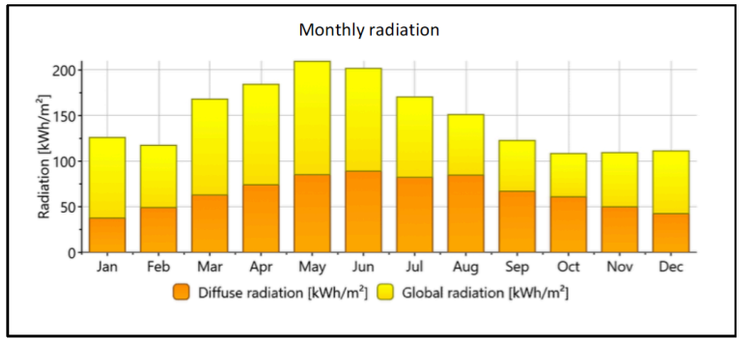


Monthly temperature Dingboche- Meteonorm

SOLAR RADIATION

In village of Dingboche (latitude of 27.9° North), there are over 300 days of sunshine annually.
The daily average global horizontal irradiation is 4.9 kWh/m2.

Solar radiation, is generally high throughout the year, particularly between the months of March and June, with the highest solar radiation in the early summer in May, with hourly averages of horizontal radiation approaching 800 Wh/sqm.



Monthly radiation Dingboche 4400m - Meteonorm

Sherpa Life

The Sherpas in the Khumbu have a unique way of life with a special social and economic structure which is necessary to understand in a sustainability context. Their distinctive way of life is well adapted to their environmental conditions and high altitude.

The majority of households rely on tourism-related activities including mountaineering and trekking leaders, porters and cooks, to generate income. In the Khumbu, the two tourist seasons in the year are; Pre monsoon, the spring during March, April and May and post monsoon in the autumn in the months of September, October and November.

Tourists visiting the Khumbu would take a route staying in various villages. Climbers planning to tackle Everest or other 5000 and 6000m peaks would slowly ascend from the lower villages over several days to acclimatise.

Whilst some local people work in agriculture, (primarily potato cultivation) most of the agricultural tasks are done by migrant workers from further down the valley. These are generally not Sherpa but Rai people. The Rai people also work collecting, drying and stacking the yak dung, the most universally used fuel.

Religion is extremely important and plays a vital part in the daily lives of the Sherpas. They have deep Lamaist beliefs which is evident from inscriptions on stones of "maniwalls" and the prayer flags on their houses. Religion is lived and practiced. The Sherpa people have an attitude in keeping with this and are kind, and humble

Tashi's Bakery, Pangboche

Sherpa long dress and striped apron

Stacked yak dung

Mani wall at the side of the trekking path

Change in the Khumbu

The Khumbu is changing. A study by (Gyan P. Nyaupane, Alan A. Lew & Kevin Tatsugawa) looked at the perceptions of change.

Positives included:

Increased number of children in school and improved education quality

Improved access to health care and education

Gradual spread of electricity

Safer steel bridges

Safer trekking

Better education of guides

Tourism contributed to modernisation

Tourism allowed Sherpas to remain in Khumbu

More modern housing

Access to TV, news & entertainment

Efforts are being made to revitalise Sherpa language

Increased availability of warm clothing

More diverse availability of food

Regeneration of forests and wildlife

Negatives included:

Lack of Sherpa related curriculum

Outmigration of children and young people for education

Lack of transport

No roads

Limited access to electricity

Competition resulting in cheaper quality treks

Trekking increases pollution problems

Trekking only benefits popular trails

Seasonal fluctuations in income

High dependency on tourism

Government officials focusing on quantity not quality

Growth of villages on trails and declining of smaller villages

Older buildings not preserved

New buildings don't reflect Sherpa culture

More hospitality can be expressed to guests than Sherpas

Loss of Sherpa language

Loss of Sherpa culture

Outmigration

Modern economy results in less family time

Large quantities of litter

Changing weather patterns

Increased heat related illnesses

Glacial retreat

Glacial lake expansion

Buildings in the Khumbu

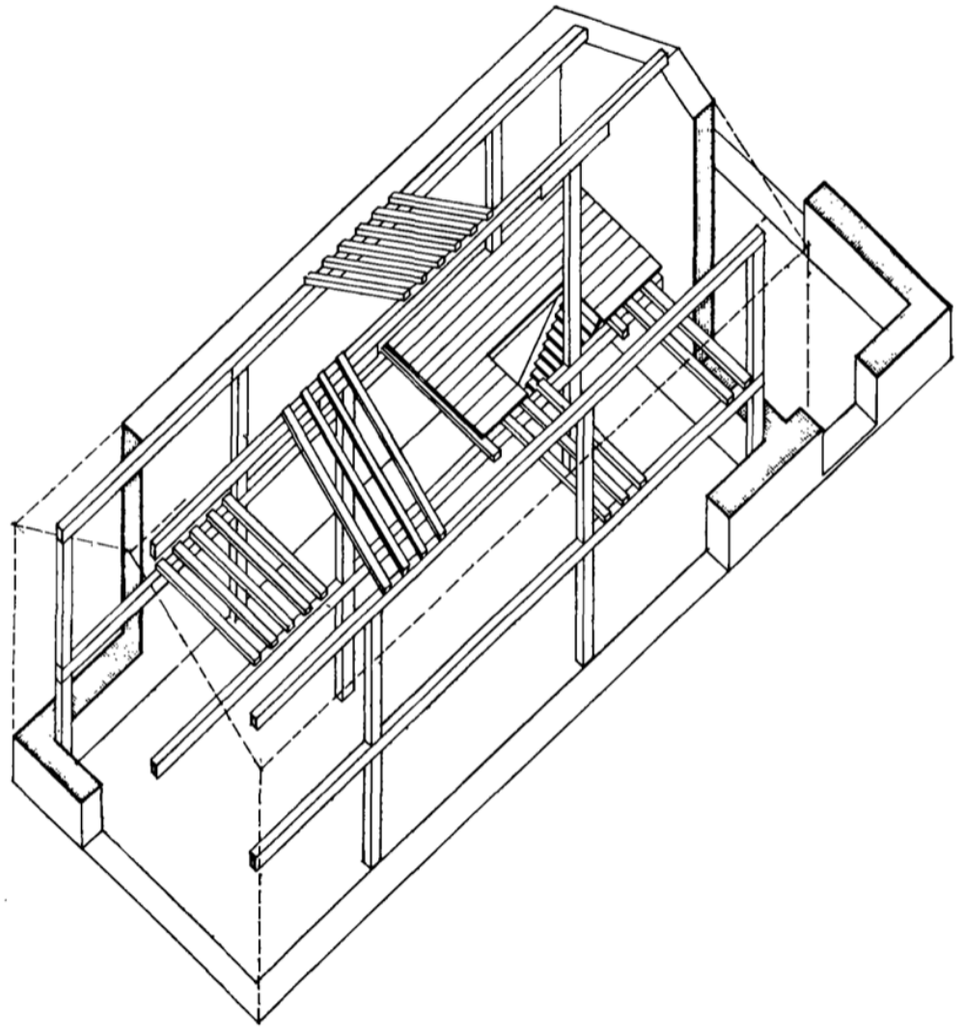
Yak herders house , Pangboche

Traditionally buildings high in the Khumbu were stone built with heavy stone slab roofs. The walls were thick and built usually of rough stone rubble and bonded with mud. Concepts such as vapour barriers and insulation were unheard of and even today this remains the case on many remote building projects. Windows were small; sometimes not even glazed. Externally the rubble walls would be plastered in a mix of yak dung and mud. Buildings would be constructed out of what was available locally.

In the last twenty years there has been a lot of building in the Khumbu as the demand for tourist accommodation has increased from trekkers. Most of the accommodation is poorly built and very cold.

Vernacular Architecture

A Sherpa house



Source: FRAMEWORK OF SHERPA DWELLING-HOUSE (SESTINI, V. & SOMIGLI, E., 1978)

Traditionally in the Sherpa villages, most buildings were built in small groups usually with all windows and doors facing the same direction, south, to gain heat from the sun.

The typical Sherpa house is of an elongated shape and usually parallel to the slope of the hill. The ground floor can be built into the slope of the land behind. The back of the house usually has little to no windows or doors. This is somewhat because it is built into the slope and because there is no sun exposure.

The foundations and floor are built on locally available stone and houses could be both single or two story. In the case of a two story house, the ground floor would often house livestock and be used for storage (such as grain and fuel wood), whilst the living area would be located above and usually be accessed by a wooden staircase.

The building would consist of an outer protective wall which is constructed of locally available stone, that can be up to 1m thick. This would usually be unshaped stone - rubble, plastered with yak dung and mud mixture.

An internal timber frame sits inside the stone and a wooden ceiling is supported by timber beams. Horizontal timber beams can also be built into the outer stone walls in order to increase their earthquake resistance. Whilst this is not so commonly seen in older most simply rubble built houses the traditional technique is apparent in many of the buildings built of dressed stone.

The house would have a pitched roof in order to shed snow and the summer rainfall. They would historically be roofed with slate or fir shakes, although now most have been replaced with corrugated iron. Heavy stones would often be placed on top to prevent lighter roofing material blowing off in strong winds.

A traditional Sherpa house, Dingboche

Traditional Materials

All building materials which are not sourced locally must be carried into the Khumbu to the site, usually by porter. It is vitally important to bear in mind the location and the impact this has on building practice, where often it can be as many as ten days walk from the nearest road. Helicopter lift is prohibitively expensive and very limited in capacity above 4000 metres.
The steep, unstable terrain, and distance from urbanisation promotes the use of local materials in the Khumbu. Labour in the Khumbu is relatively cheap, and the main cost when building in Khumbu is usually the cost of transportation of materials.

STONE
The Khumbu has abundant stone, rocks and mud. Dry stone is used in all building types. This is obtained locally and is shaped manually. The stone work is either dry or held by a soft mix of claylike earth. These walls are not strong. Stone is extensively used for slabs for roofing and paving.

There are two main types of stonework.
Mason rate: 2200 rupees per day (18 USD)

"Normal stone"
2 days per m^2

Normal stonework

"Special stone"
5 days per m^2

Special stonework

Stone shaped by hand

Stone taken from mountain

Transportation of stone

Traditional Materials

TIMBER

Timber is a vitally important but scarce material. Most of the Khumbu is high alpine land, above the tree line. The forests that do exist are in the lower altitude southern border of the region. The main tree species growing in the Khumbu are silver fir and birch. The limited timber available in region means it is generally flown in or carried up from further down the valley, where the land is more fertile.

Traditional Sherpa houses required timber for beams, floors, rafters, window frames, doors and furniture. It is not easy to find and it is expensive to build in timber. The earthquake caused a surge in demand for timber and prices rocketed. As well as economic value, forests are sacred and Sherpas have a long history of local systems to protect them. Today, National Park regulation severely restricts tree cutting. Even outside the park boundary at lower levels a permit from the Forest Department has to be obtained to move timber away from the local area. This often results in lower quality timber being used or that less critical timber elements are used.

There are no power tools - everything is done by hand. The time consuming cutting can explain their use of larger timbers further apart than typical western constructions

Ganga showing the horizontal timber battens built into the dry stone wall

As well as construction, wood is also widely used for decorative aspects, including brightly painted windows and doors. These have a high cultural and religious significance.

Timber delivery by porter

Modern Materials

CEMENT

Cement is transported from Kathmandu and has begun to replace the earth-clay mix to hold stone together. According to (Nripal, 2016), the areas which were most severely affected by the earthquake in 2015 had 90.5% of houses constructed from stone masonry and mud. It is commonly known by the Sherpa people that mud mortar is not strong but the cost of using concrete is prohibitive.

25 kg of cement in Scotland costs about 4 USD delivered to site. The same quantity delivered to the higher Khumbu settlements would be around 65 USD. The use of cement is not widespread and often the mix ratio is very weak. Temperatures can also frequently be too low for using it. Where it has been used cracks in floor slabs are common.

The Yak herders house - patched gable that collapsed in the 2015 earthquake

INSULATION

Most buildings in the Khumbu are not insulated. Some have began to use glass wool and polystyrene for insulation, although this is not that common. Their introduction can be linked with the increase demand for tourist accommodation and warmer, more comfortable buildings.

The understanding of how to use insulation materials is also not widespread. I've seen 100 mm glass wool being pulled apart to increase its coverage. It's easy to see why. Insulating materials are usually imported from China or India and a 5.5 m^2 roll of 100mm Rockwool in Kathmandu costs $85. This cost will be doubled by the time it reaches the high Khumbu, making it prohibitive for most.
Solid insulation like XPS Ravatherm (formerly Styrofoam) is available in Kathmandu but it is very expensive. A 2400 x 1200 50mm thick costs $61 in Kathmandu. In the mountains I have only seen this material on projects funded by Western donors.

MEMBRANES

Membranes are not in common usage in either floors or walls.

Whilst visiting Beehive Lodge in Paiya we removed timber linings from the interior of a dry stone built lodge bedroom (see daylight through stonework.) After stretching a breathable membrane tightly over the timber battons we taped all the joints. Further horizontal timber battens were added to provide an air gap and the wall was reclad. We insulated the ceiling with aluminium foil faced bubble wrap. Manufacturers claim this is equivalent to 55mm of polystyrene, (a thermal resistance of up to 1.5 W/m2K. A 37m2 roll weighs about 6kg. Not yet available in Nepal, materials like this could generate genuine and affordable benefit in ceilings, walls and below suspended floors if properly installed.

Removed timber linings to install a breathable membrane,Beehive Lodge, Paiya

Daylight visible through dry stone wall, Beehive Lodge, Paiya

Taped joints, Beehive Lodge, Paiya

Transportation of materials

The correct choice of “sustainable” building materials varies greatly depending on location.

Their are 3 ways of transporting materials and goods
- By porter (carried on foot)
- Helicopter (cargo or sling load)
- By animal, for example; yak or donkey

Transportation of gas - notice narrow path on mountainside

Cargo helicopter, capacity 3000 kg [Sagarmatha Next]

Porter passing through the weekend market in Namche

Donkey crossing a bridge in the Khumbu

nd modern buildings (Bhochhibhoya, S. et al, 2016)

Energy in buildings

DINING ROOM STOVE

Almost all lodges have a traditional barrel stove in the middle of the dining room. This is fuelled by dried yak dung above the tree line. Even below the tree line National Park regulations restrict the gathering of fallen wood to about twelve days in the year. Yak dung burns like peat, a traditional fuel in the west of Scotland. Stove flues are always single wall and are often perilously close to combustible materials. Most lodge accidental fires are because of this.

Often the heat is concentrated immediately round the stove where porters tend to congregate on plastic garden chairs 'hogging the fire.' With the exception of where bedrooms are directly above the dining room the main stove has no beneficial effect on the bedrooms. Bedrooms are almost always cold and often damp. Condensation on the single glazed windows a constant problem.

Top loading stove (very typical)

Mixture of wood and dried yak dung

Hilltop Lodge Khumjung with central barrel stove

PROPANE GAS

Propane gas room heaters are used in some of the more modern lodges. They lack atmosphere and generate condensation. The traditional stove, whether fuelled with yak dung or timber draws moisture out of the room.

There is a perception burning timber and yak dung is 'bad for the environment.' In one lodge we questioned the advisability of their propane room heater suggesting a wood stove would add atmosphere, cost less to run and reduce condensation. The reply was that 'burning wood is bad for the environment so we are burning gas".

Gas is generally imported from India, driven by truck to the foothills, carried by donkey for a week and then by porter for the final stage to the highest lodges. A 19kg bottle actually weighs over 30kg when full. A porter will carry two bottles, often equal to their body weight. A 19kg bottle will cost around $75 USD at higher locations.

SHOWERS AND PROPANE

Showers are either solar or liquified petroleum gas, lpg. The solar showers are seldom enjoyable and the lpg showers have a very slow delivery rate at a comfortable temperature.

PARABOLIC SOLAR DISH COOKERS

Parabolic solar dish cookers are relatively inexpensive and useful for heating kettles of water. Black kettles are allegedly better but seldom seen. To be effective the dishes have to be constantly adjusted for maximum performance. In locations affected by strong winds they do not survive for long.

LPG shower (left) and parabolic solar dish cooker (right)

Energy in buildings

COOKING
Gas is usually used for cooking. Kerosene stoves are common in tourist lodges at higher elevations. Kerosene is cheaper but has a terrible smell and is painful for the eyes.

Cooking is also done on an open fire or stoves. Sometimes in combination with gas to cook multiple things at once.

Cooking on gas burners (propane) at Hilltop Lodge, Khumjung

ELECTRICITY
Most of the lower villages have a limited mains electricity supply of which is mostly supplied from hydro-power. The higher villages do not have mains electricity.

Photovoltaic systems have become more popular. Now, many lodges have their own small scale systems and there are subsidies available for remote the areas of Nepal.

The abundance of water and natural altitude differences mean that hydro power is a logical choice for the area. Small hydro power plants exist but investment is required in order to improve efficiency and reliability.

Cooking kerosene, Dzongla

Cooking over open stove, Beehive Lodge Paiya

Dzongla Inn 4830m, clear skies and cold temperatures are ideal for PV panels

Some key problems

THERMAL COMFORT

Traditional buildings in the Khumbu have very little or no thermal insulation, but people are well adapted to this. A study on thermal comfort in houses in Solukhumbu at 2600m altitude, (Rijal, 2010), found that dwellings had an average daily mean indoor air temperature of as little as 6.5 during the winter months.

The research showed that residents adjusted to the cold winter climate by wearing thicker clothing and sleeping under thick blankets. Large quantities of butter tea are consumed in winter to keep warm. This is a hot drink made from tea leaves, yak butter, water and salt. It is found that people are satisfied with their indoor thermal conditions even though they are hugely different from the average range of international comfort standards. (Rijal, 2010) Western tourists however have different expectations and sick climbers tend to be even more sensitive to the cold.

INDOOR AIR QUALITY

Burning animal dung produces smoke which is the result of the incomplete combustion, leading to emissions which seriously damage human health. Hundreds of toxic chemicals are produced; small particles, carbon monoxide (CO), formaldehyde, benzene, nitrogen dioxide, hydrocarbons.

Dangerous levels of indoor air pollution caused by traditional stoves lead to a number of serious health issues, including pneumonia and other severe respiratory infections (ARI) among under-fives and chronic obstructive pulmonary disease (COPD) and lung cancer in adults.

The air quality is far worse with open stoves. It is unlikely that the Sherpa people will end using yak dung as fuel. However using "cleaner stoves" such as the Sapana Stove (Pedersen, 2009) , can reduce emissions and provide a safer environment inside the kitchen.

CLIMATE CHANGE

Mountain areas are among those most vulnerable to climate change due to their larger ecological and economic complexity. (Luthe, 2012) In the Khumbu, research has shown climate change effects are suffered particularly severely, with the warming rate between 3 and 5 times that of the global average. (Shrestha U. G., 2012).

The rapid growth of the built environment in the Khumbu can have contributed to increased environmental emissions adding to climate change. Studies have also shown that the burning of yak dung as fuel producing black carbon pollution that increases the melting rate of snow in the Himalayan Mountains. This study by (Li, Bosch, Kang, & et al, 2016) showed that this black carbon produced by the incomplete combustion of fuels for cooking and heating stoves has been seriously undervalued in global climate change models.

Even locals feeling the cold at Khangri Lodge, Chukhung

Visible black smoke on walls inside yak herders house

Glacial retreat

Recent Constructions

In April 2015 a major earthquake devastated Nepal. Over 8790 lives were claimed, more than 22,000 people sustained injuries and half a million houses destroyed. (Nripal, 2016) The housing sector suffered the largest impact. (Government of Nepal, 2015)

Since the earthquake, many of the buildings built have been of basic timber frame construction rather than the traditional stone for fear of another earthquake. The building below, built shortly after the earthquake consists of 75 mm x 45 mm timber framing at 900 mm centres. The timber frame is then lined inside with plywood and clad externally with 0.8 mm flat sheet steel. The only insulation is a 7 mm "concrete frost blanket" - a very thin sheet closed cell polyethylene, which is usually used to temporarily cover freshly poured concrete.

In many new buildings the traditional techniques have been abandoned. It must be considered whether avoiding heavy materials, such as traditional stone, is the best option to make a house earthquake resistant. The resistance to earthquakes could also be improved by buildings to suitable standards.

New build since the earthquake, Pangboche (Ang Nuru's house)

Panel Constructions

Shortly after the earthquake the Nepalese version of kit houses or SIP's began to appear. In the last few years they have become the most popular way of building in the Khumbu.

At a meeting in Kathmandu the owner of the main producer of the panels explained panel make up and gave an indication of cost. Panel size is generally 2400 x 1200. The panel frame is 75mm wide C section steel. On the exterior is a 12mm thick insulated facia panel. Very lightweight foil backed glass wool is in the panel but it has little structure and will inevitably sag. The inside tends to be finished with either cement board or ply. The panels are screwed together with tek screws and the internal joints covered by thin strips.

Make up of most common panel system

Owner of main producer of panel kits at his office in Kathmandu

They have the advantages of being reasonably cheap, light-weight and relatively safe in an earthquake. However, buildings constructed with this system are extremely cold. They lack the thermal mass and "climate conscious design" of the tradition-al stone buildings. They are poorly insulated with significant thermal bridging. There is no vapour barrier and moisture from inside the building would likely build up inside the panel. The insulating effect of glass wool is massively reduced when it becomes wet.

As well as the poor technical performance, the system is crit-icised for its aesthetic appearance. Whether this is adding to the loss of Sherpa culture and traditional techniques. Also as more and more of these buildings appear many have said that small villages in the Khumbu are loosing their charm.

New build house with SIP kit

New build lodge with SIP kit

Traditional dry stone and concrete - New Lodge, Dingboche

Front of new hotel

Perfectly formed stone blocks - carved by hand

Inside the construction, visible sagging of concrete beams

Varying quality of stonework, wooden door and window frames

This is an example of a recent construction from stone and concrete. The building is a new hotel which is under construction in the village of Dingboche at 4400m.

The building is massive, with large rooms which will be most likely not be uninsulated and cold. It will have been expensive and take a long time to complete the building. For a high cost, the building is unlikely to provide a high level of comfort to its hotel quests.

Questions can be raised over the quality of the build. The stone work varies from place to place. A concrete ring beam is visible between the two stories, this is most likely an attempt at earthquake proofing.

Most worryingly, there is visible sagging in the concrete beams which have long spans. The use of concrete in any structure requires a level competence and familiarity with it. Is it safe? Now, let alone when an earthquake strikes?

Sagarmatha Next Project, Namche

The project Sagarmatha Next site is situated above Namche, at an elevation of 3800 m next to the Syangboche airstrip. The project consists of four buildings each planned to have different functions; Interpretation Center, Workshop, Café Gallery and House.

The project states sustainability as an underlying motivation and that the buildings are designed with 80% of the construction local materials.

The main construction is of traditional dry stone and horizontal wood beams for strengthening. It also features the concrete ring beam at the top of the stone wall and steel rebar. This building is the only where I saw the use of solid insulation, XPS, whilst being in the Khumbu

The quality of build is very high and the craftsmanship, particularity of the curved stone walls, beautiful. The stone work is known locally as "Special stone". This is the highest quality and takes one skilled mason 5 days to complete 1 m^2 of stone work. The building will have had a high cost and is funded externally. It has also taken a long time to build.

For more about Sagarmatha Next, see sagarmathanext.com

The Khumbu Climbing Centre (KCC)

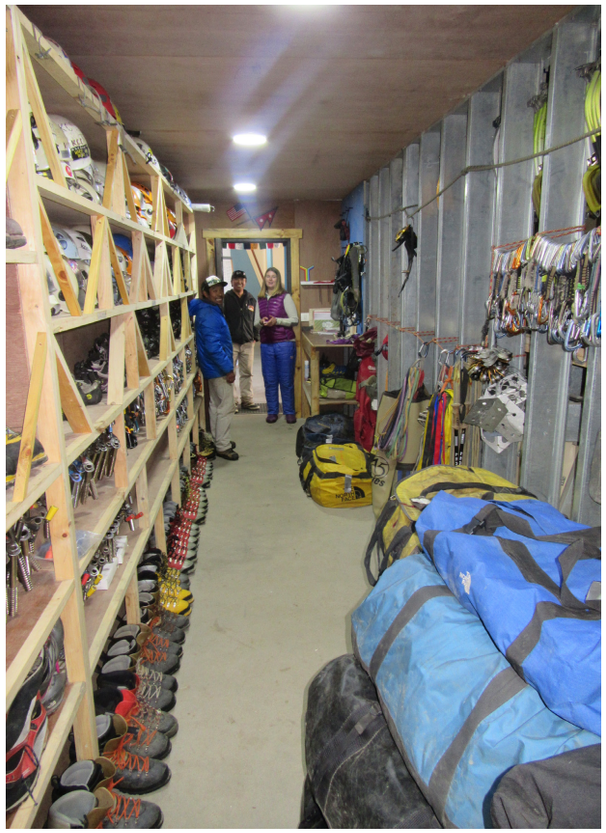
The Khumbu Climbing Centre (KCC) is located in the village of Phortse. It is a project of the Alex Lowe Charitable Foundation and was designed to function as a school to increase safety margins and teach Nepalese climbers best practice. The facility has a Walltopia climbing wall, outdoor training wall. There is also a viewing area which can be used for exhibitions, screen films or presentations and library, available for public use.

The building design began in 2003 and was drawn by a group of students at Montana State University School of Architecture. It was required to be warm, weatherproof and earthquake resistant, makes use of passive solar design and uses its orientation to maximise solar gains.

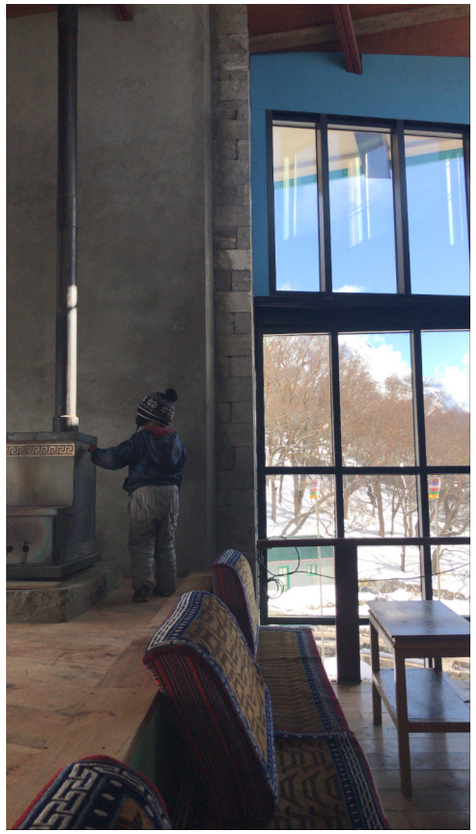
Open viewing area for exhibitions, screening films or presentations

Front of Khumbu Climbing Centre

Library for public use (good collections in mountaineering and children s books



Well stocked equipment store for rental and courses



Social seating area with good natural daylight

Inside bouldering wall

Happy KCC team for spring season 2020 [Facebook]

The KCC building is a two storey stone and glass building which uses similar materials to existing Sherpa houses in the village. The building is well insulated and aims to make use of passive solar design and uses its orientation to maximise solar gains. It was calculated by modelling with Revit and Ecotect that the building could be heated almost solely by passive strategies. Seismic strengthening is incorporated into the building by combining the dry stone walls with gabion baskets and steel frames which are tensioned using steel cables to provide lateral strengthening.

Construction of the building was slow. This was partially due to insufficient funding, difficulty sourcing and transporting materials and more immediate needs which resulted from the April 2015 earthquake. It was not completed until 2018.

Part 1: Findings

Local communities have adapted and developed specific building strategies which are rooted in traditional knowledge. These are essential to understand in order to find the most effective strategies to develop the building sector towards higher efficiency and sustainability. The development should avoid energy intensive, expensive artificial means to provide comfort and instead utilise local materials, knowledge and skills. This is required to ensure efficient use of resources for a sustainable future for the region.

The design of the traditional Sherpa house needs to be adapted to modern living and comfort standards, especially in the situation of tourist lodges, in a way which can be sustained by the local community.

Sustainable development must balance social, economic and environmental needs. A building's entire life cycle needs to be considered not just the operation of the buildings. This includes assessing the environmental impacts related to the extraction, production and transportation phases. The energy and materials consumed and the emissions to the environment must be taken into account. Careful consideration to this will help to reduce emissions and protect the natural environment.

Generally the remote communities are unaware of easily achievable benefits and the effects of some of their existing practices have on health, economy and the environment. As travel and communication opportunities are limited, many of the community have little understanding of modern construction techniques and building science. Currently, there is a lack of successful replicable buildings to set an example.

The Khumbu Climbing Center is an amazing facility and in many ways can be seen as a sustainable building. It aims to combine traditional and modern building practices to provide a warm and safe environment to develop skills. Questions can however be raised over the time it has taken to build and its cost. The building was paid for by sponsors and it is generally thought of by local people as having "cost too much".

Solutions to develop future buildings in the Khumbu must be affordable and practical for the average Sherpa household. The sustainable development of buildings in the Khumbu must balance social, economic and environmental needs. These developed buildings can provide better living conditions for local people. Improved indoor air quality will reduce related health issues and improve general well-being.

Tourist comfort will also increase and local people can charge a fair price for providing improved services. The increase in local revenue will further improve the standard of living and likely also cause a rise in education. In the past 10 years many Sherpas have left Nepal. Some have gone to Dubai to work in rope access or as general labourers where they work 6 months on, 6 months off. In previous years, many Sherpas also left to the United States, initially on a tourist visa which they would overstay, later hoping to become US citizens. It is important that the most talented Sherpas and those with initiative are encouraged to stay as it is those few that can contribute to the development of future buildings, developing the tourism facilities that, in turn, will benefit everyone in the Khumbu.

Building extension to Phortse Guesthouse, neighbouring building of KCC

Part 2:
Chukhung Bakery Project

Cafe De Imja Tse Bakery and Guesthouse

Introduction to Part 2

This part of the thesis consists of a design for a renovation and extension to Cafe De Imja Tsee Bakery in the village of Chukhung, one of the highest Sherpa villages at 4730 m above sea level. The building currently houses a bakery and "snookerhouse" in which the owner would like to expand to a small hotel or guesthouse.

This project acts as a case in which to implement the findings from part one of the thesis. It is hoped that by focusing on what is really sustainable in both traditional and more modern buildings can achieve improved comfort for tourists as well as increased business for the owners.

When I began this thesis I had intended to design a new building but I changed my mind when I visited Nepal. I met the couple who own the bakery whilst I was staying in Chukhung, in the neighbouring building, Khangri Resort, which is owned by his brother. Tenzing, the bakery owner, mentioned that he would like to expand his business and build accommodation for quests. I was immediately drawn to the project. I think that the renovation adds some additional challenges but to me it is also more interesting. The existing building and real demand for this project makes it more personal and also increases the importance of cultural heritage and ensuring a new build can compliment the existing building. Currently the Khumbu doesn't need more buildings, it needs better ones. So for this reason it also makes sense to use a renovation for the design case. While a specific case is used in this part many of the concepts in the building design could be applied to other existing and new buildings.

Kami & Tezing the bakery owners, the chef, porter Tenjing and myself - being invited to eat with the family in the kitchen is a privilege I got to experience!

Project description and goals

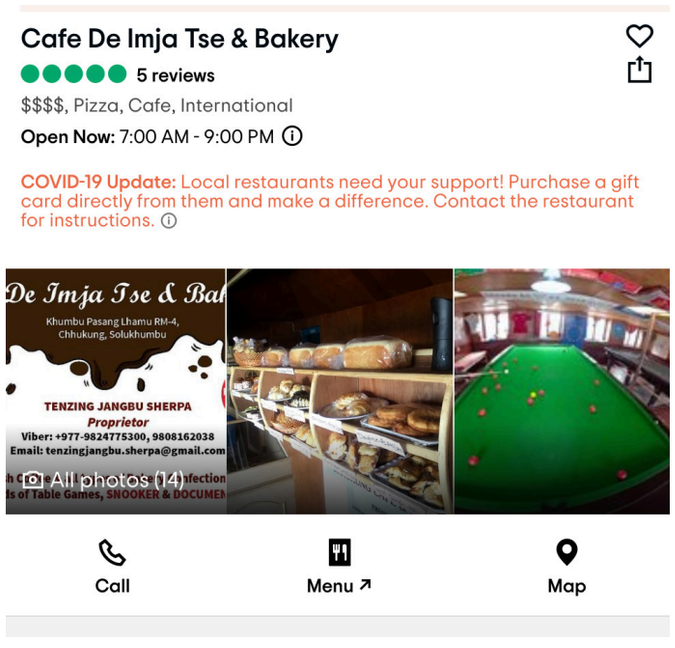
Kami Doma Sherpa & Tenzing Jangbu Sherpa [personal Facebook]

Front of bakery and view north Everest visible with cloud on ridge, source: Woeldroamer, Google photos

Pictured is Kami Doma Sherpa & Tenzing Jangbu Sherpa. This Sherpa family live and work in the village of Chukhung, during the tourist seasons. They own a small business which consists of a bakery and a snooker house.

His wishes for the building were as follows:

- Addition of standard rooms (for 2 people)
- Addition of dormitory rooms (for families or groups of people)
- A sun space to sit in during the day
- Toilets
- Storage space



Cafe De Imja Tse & Bakery

In addition to the requirements provided by Tenzing, a further set of goals were established. These were based on how accommodation standards generally in the Khumbu could be improved to provide a comfort level closer to the standard western tourists are accustomed to, as well as ways in which Tenzing and his wife could increase their income.

Additional goals:

- Create an attractive new building that compliments the existing building and its neighbours
- Achieve a better indoor temperature in bedrooms compared with other tourist lodges
- Review the arrangement of the existing building functions and possibly rearrange
- Look at options retrofit of the existing building
- Generate renewable energy to serve his site
- Provide something special - why would guests specifically choose to stay here?
- Provide the best rooms in the village. Ensure his place can provide a higher standard, which allows a higher charge for quests allowing him to increase his income

Source: Cafe De Imja Tse & Bakery, Tripadvisor

Project description and goals

For a standard room, in a typical Khumbu lodge two people might pay 5 USD a night for a room, 15 USD on food and perhaps between 5-10 on drinks. Unlike most places in the western world the cost of a room is not the main expense. Some lodges will even give away their rooms for free in order that guests will buy food.

Typically in the Khumbu, rooms are of a poor standard. They usually have two single 750 mm beds and very little additional furniture. They are rarely insulated are often of poor quality construction, with sometimes gaps in the wall and windows not properly sealed. They are cold, draughty. There is no soundproofing and rooms can often only be separated by a single layer of plywood. It is not uncommon for indoor temperatures to drop below 0 degrees during the night, and unless tourists have an expensive sleeping bag, a good nights sleep is very unlikely.

Standard basic room in a typical lodge

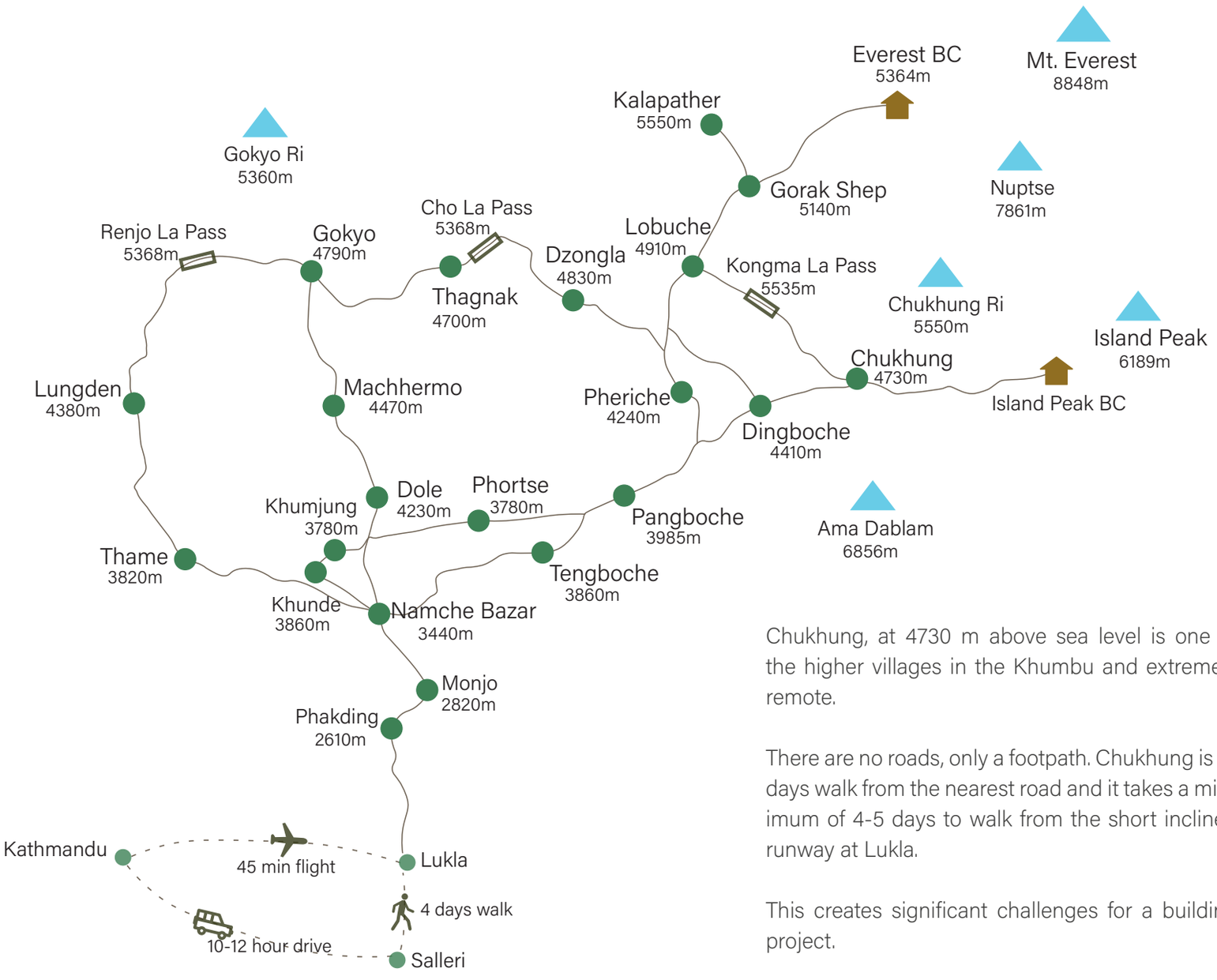
Khangri resort left, bakery right

The neighbouring lodge, Khangri Resort, is owned by Tenzing's brother. It is important that when Tenzing expands his business, the brothers can maintain a good relationship and can collaborate rather than competing against each other. One way they can do this is by providing different services. For that reason the rooms upstairs have been designed as "luxury" by Khumbu standards. There is a market for something between a very basic 5 USD room and the very fancy hotels, extortionately expensive which can be found lower down in the valley. Whilst some tourists will always book the cheapest room, there are many who will pay slightly more to get a better standard - particularly when they have been walking all day at above 3000 m altitude.

What makes a better room? What will some trekkers pay more for? Primarily warmth. A slightly larger than "normal" but not so big it's cold. Windows that aren't draughty. Not to have condensation streaming down the windows. Small additions are nice; not having to get out of your sleeping bag to turn off the light. Hooks on the wall, shelves for your 'stuff', an opportunity to dry your socks, a reading lamp, a phone charging point, a private sit on toilet, toilet paper and wash basin.... All these little things taken for granted usually suddenly become luxuries. Trekkers like coffee and cake but it's got to be high quality. Trekkers like beer and popcorn. These are great additional sources of revenue especially whilst the market rate for rooms remains low.

Khangri Family [personal Facebook]

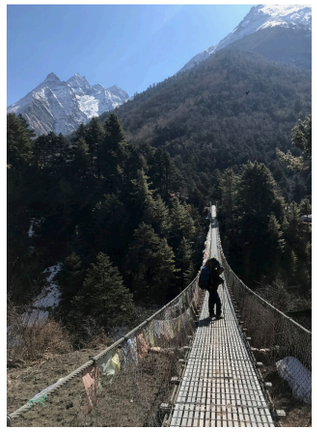
Location



Chukhung, at 4730 m above sea level is one of the higher villages in the Khumbu and extremely remote.

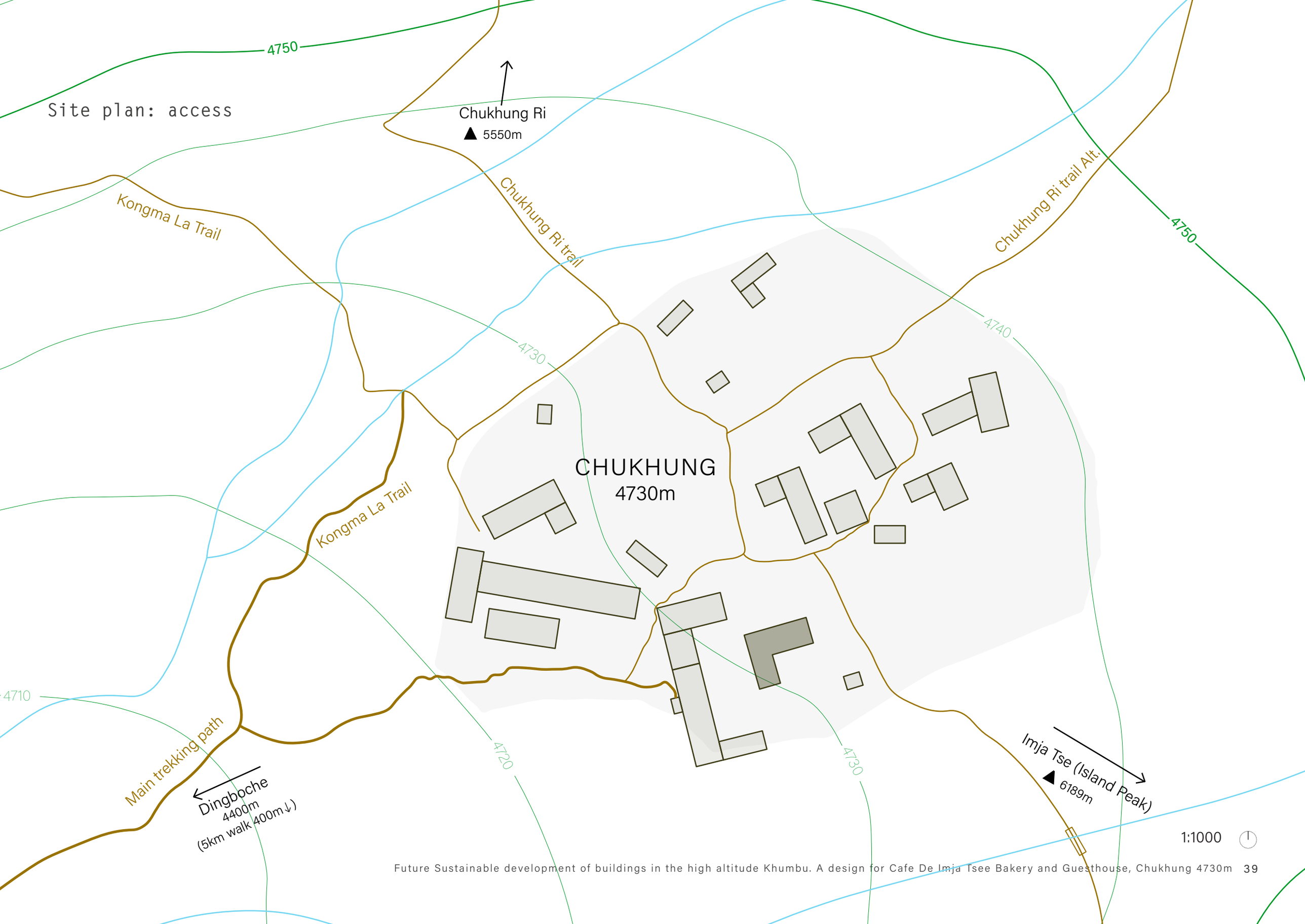
There are no roads, only a footpath. Chukhung is 10 days walk from the nearest road and it takes a minimum of 4-5 days to walk from the short inclined runway at Lukla.

This creates significant challenges for a building project.



Variable conditions on the journey to Chukhung

Site plan: access



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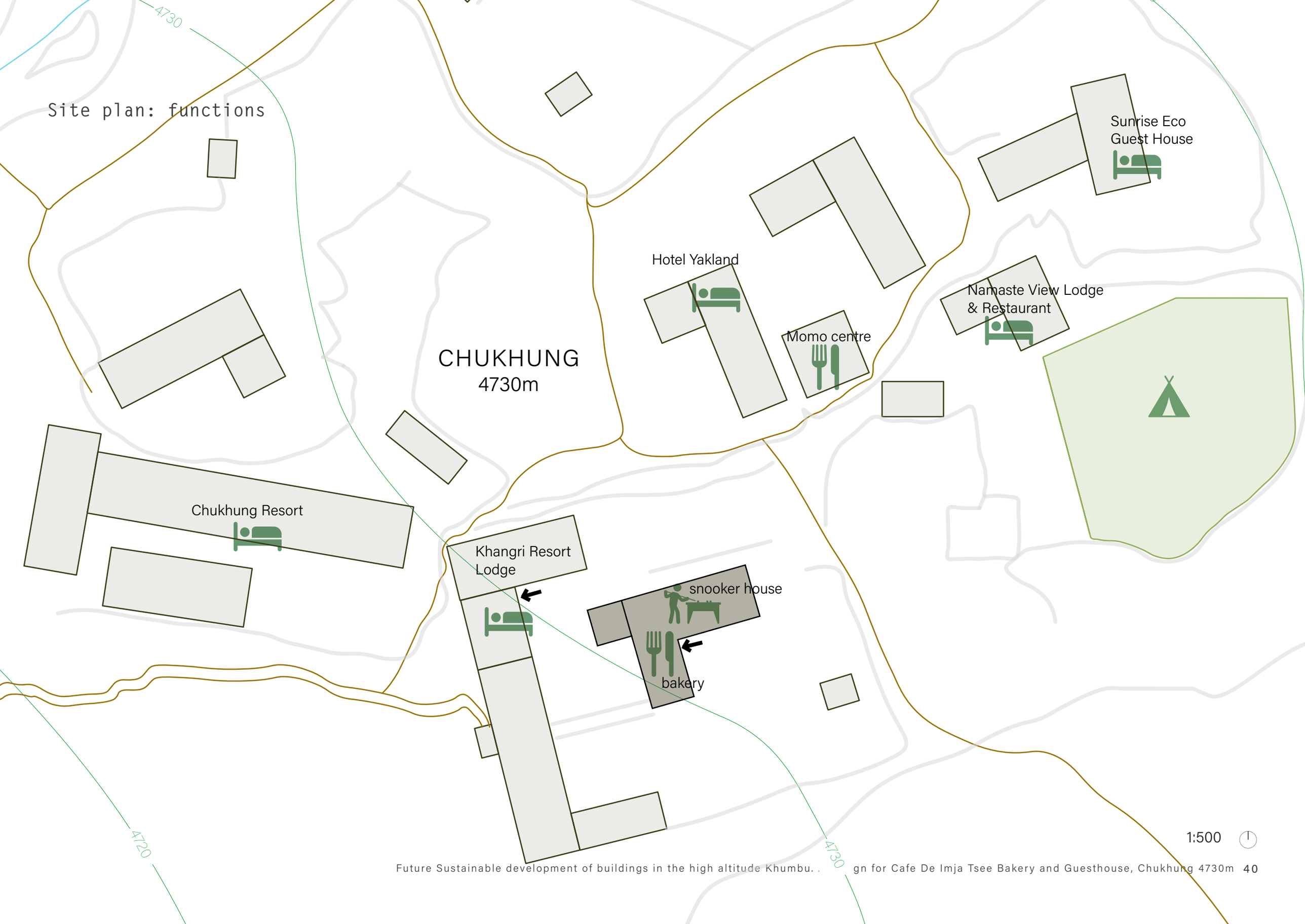
Site plan: functions



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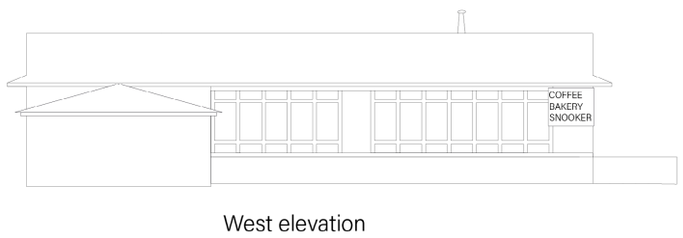
Existing building - photos

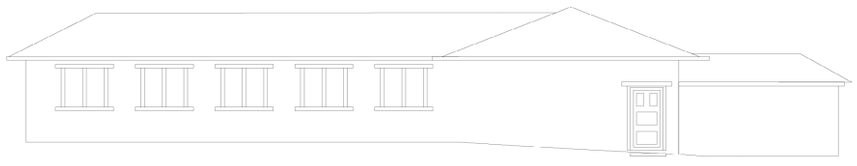
Existing building - elevations



West elevation

South elevation

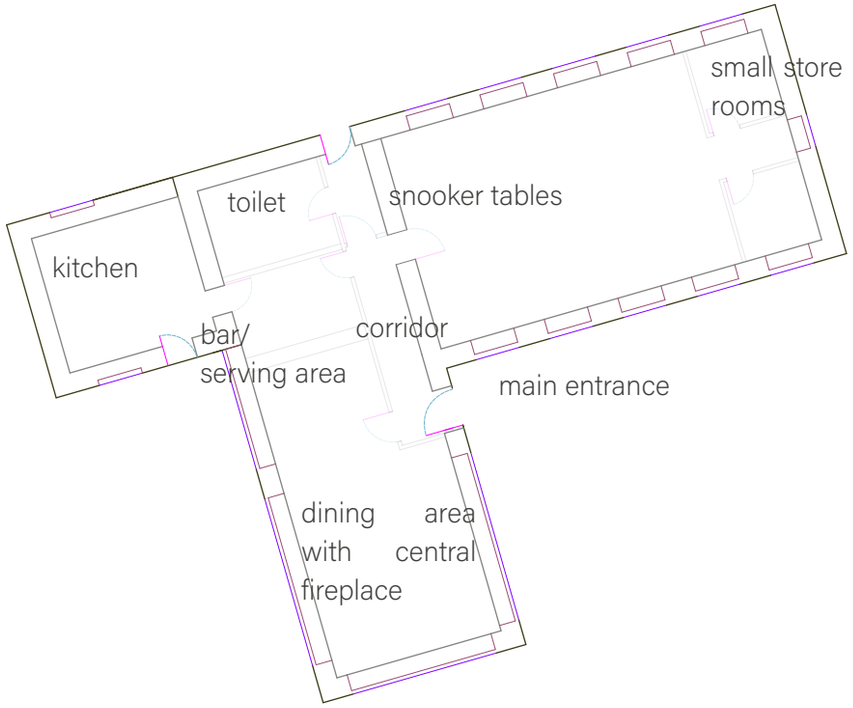
East elevation



North elevation

1:200

Existing building - functions



Source: Cafe de imja Tse and bakery, Facebook

Source: Cafe de imja Tse and bakery, Facebook

Snooker house

Entrance and corridor

Kitchen

Cafe seating area

Existing Site

View of Lhotse wall/ to Mt. Everest

Owned land boundary

Entrance
to Khangri Resort

Entrance
to Bakery

Sunset
(trekking season)
5.33PM - 5.56AM

Sunrise
(trekking season)
6.38AM - 7.43AM

Entrance from
main trekking path
(through archway)

View of Ama Dablam mountain

Sunpath

Site 1:200

Design process

Ask a trekker how their trip to Everest Base Camp was and the first answer will be good. The second answer will be cold. This is why the larger widows are oriented to the daytime sun. The design aims to capture warmth and store it by better insulation. The windows on the opposite North side are tiny. They are for toilet ventilation (and a little natural light) and a glimpse of the view towards Lhotse wall and Everest.

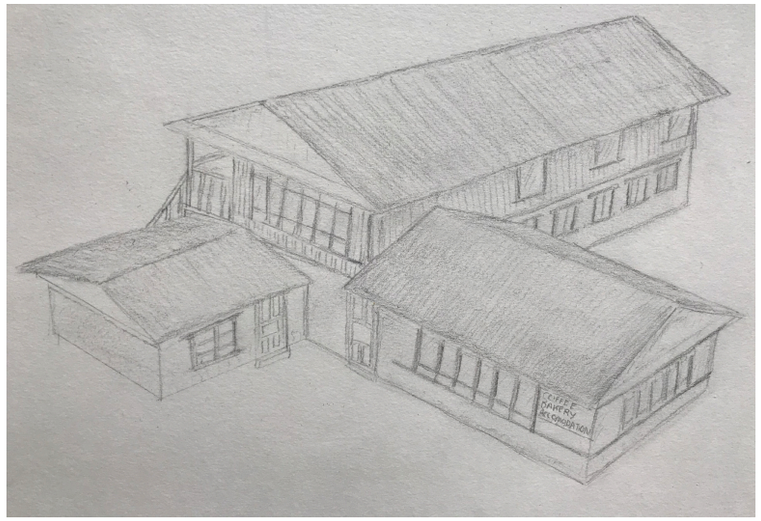
Privacy is not in abundance in a Khumbu Lodges. Rooms are noisy, toilets are usually shared and not always as clean as they could be. The client aspires to have the best rooms in town. In the design the four higher standard bedrooms are separated from the rest of the property by the access stair. The bedrooms all have en-suite toilets and wash basins. They share a private sunroom. Beds will be a low tech version of the 'zip and link' ones becoming in popular in Westerm accommodation providers; flexible, two singles or a double. These are the facilities that many trekkers are looking for. There are many people who would like to go these places but the facilities are too basic for them to endure! Better facilities will undoubtedly attract higher spending guests.

It has been noted that the stone walls of the snooker house appear to be in good condition below the flaking render. This is positive. The stones appear cut to shape. The walls are not rubble built. However as this location is an area prone to earthquakes it is prudent to build in protection where possible. Rather than simply rest the joists on the old wall heads of the snooker house as would be 'normal' I have introduced a "semi spine construction" method after considerable discussion and advice from others. Although this does place some restrictions on the layout downstairs, the method proposed would allow the structure to remain standing even if there was a collapse of the original stone walls.

The existing bakery entrance is hidden from where the Khangri resort guests congregate. The neighbouring Khangri resort will sleep approximately 60 people. Day time services there are not a priority and they regularly recommend the bakery for good coffee. The highly visible proposed new entrance will gain trade.

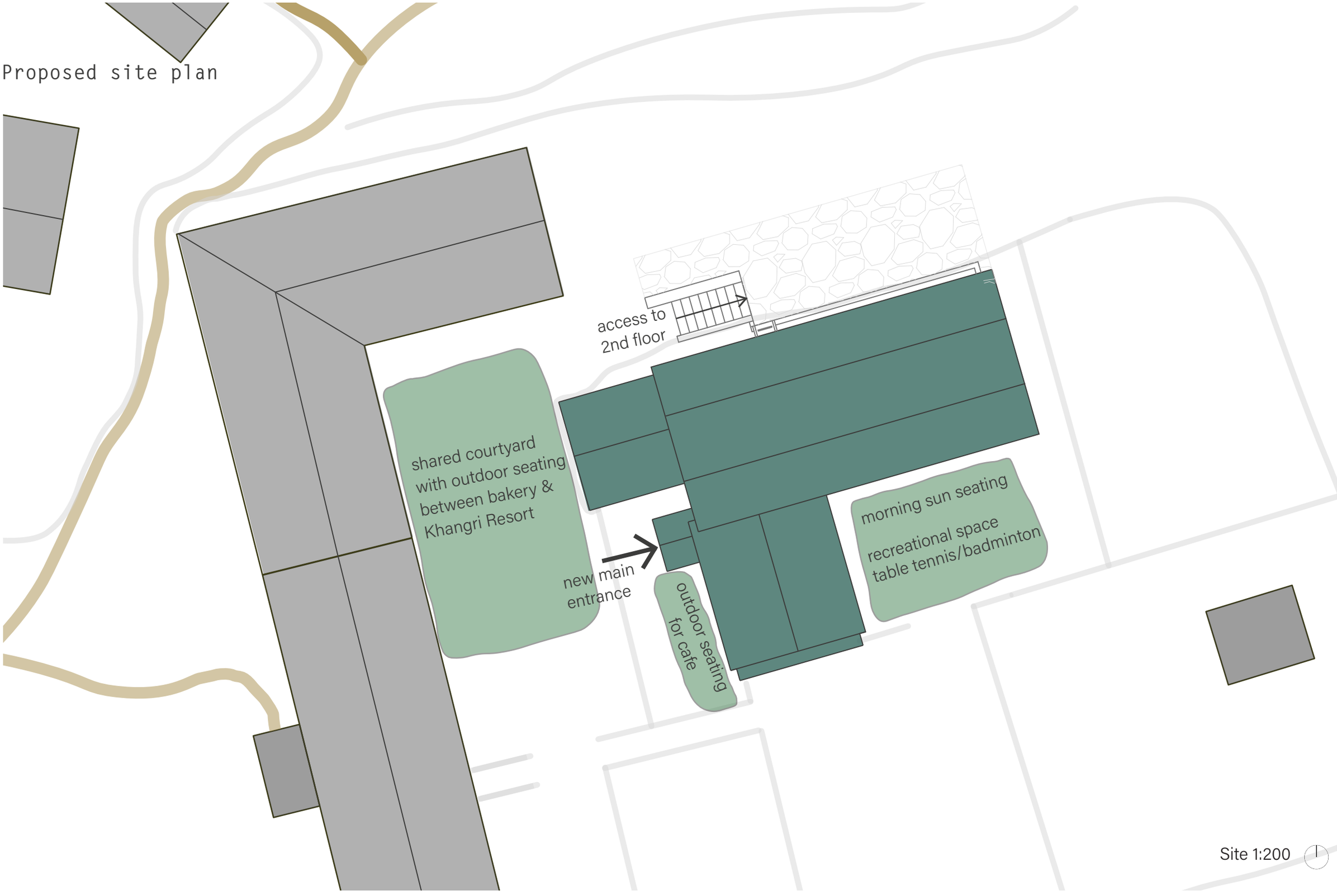
Aesthetically features from other buildings are included in the design. The log purlins will be visible in the upper bedrooms and the exposed ends will be visible on the external gables. The brightly carved window detail seen in the monasteries will be replicated around the large new windows on the southern aspect.

The construction for the building proposed is a "semi spine construction". This will later be explained. The proposed construction method will be a new concept for local tradesman and support will be required during construction. The benefits of earthquake resistance have already been mentioned. In addition the short spans are safer and easier to build. Use of timber is very efficient. The plan is to build in 'crates', with multiple levels of redundancy without having to introduce vast amounts of steel and concrete. What I propose is low tech.



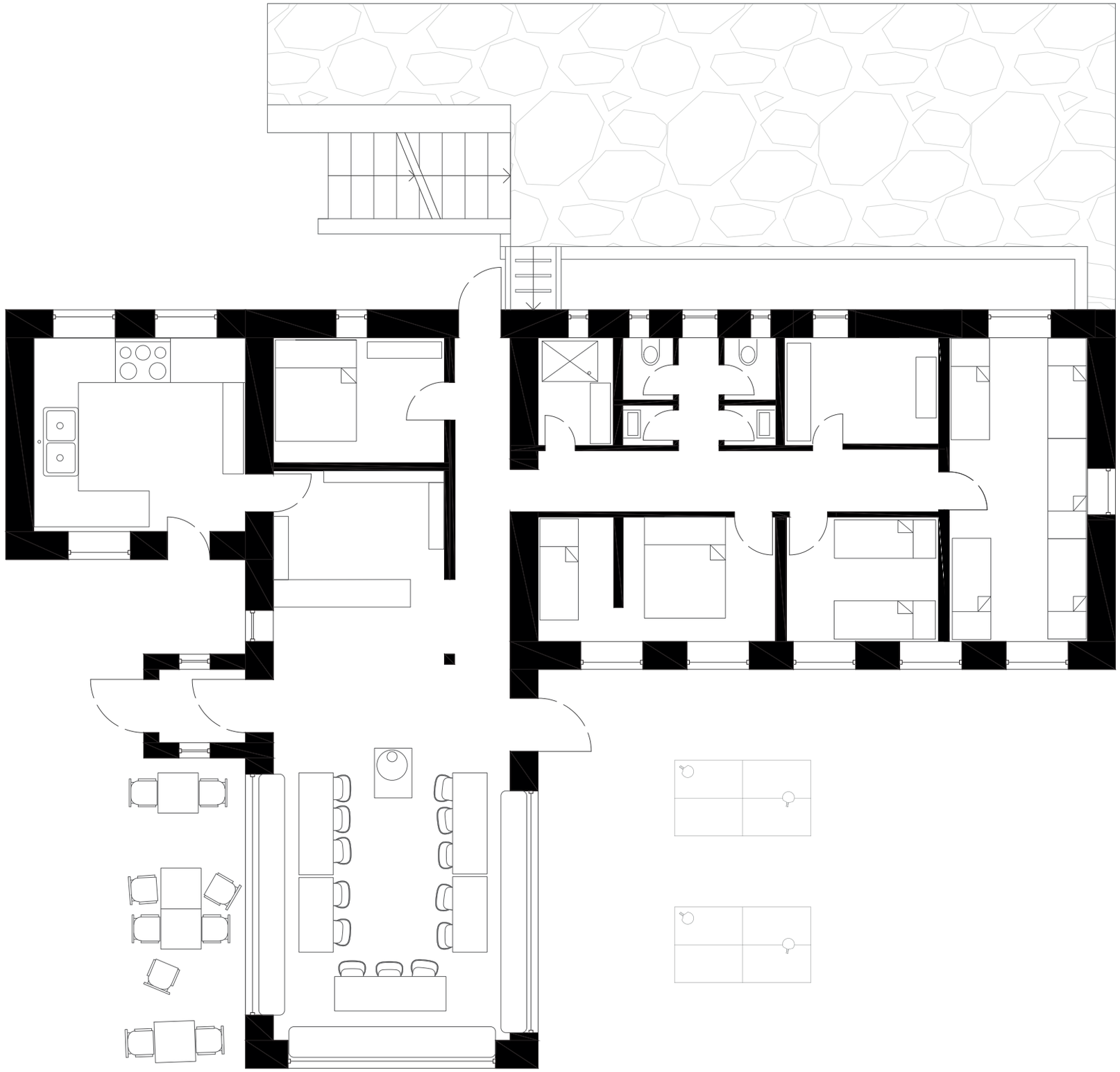
Sketch of idea for building form

Proposed site plan



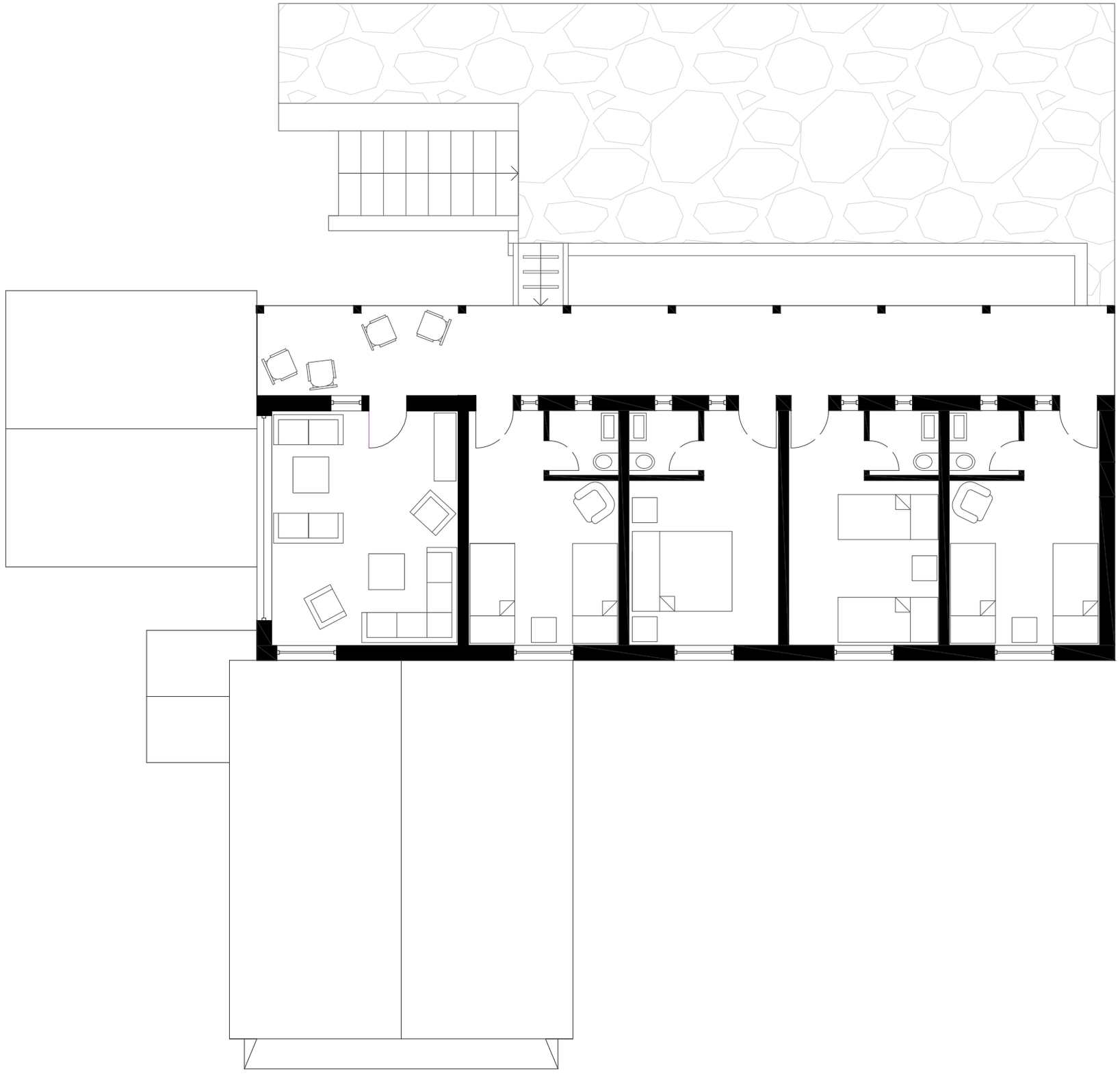
Site 1:200

Floor plans



Ground floor 1:100

Floor plans



Second floor 1:100

Floor plan design

ACCESS & OUTDOOR SPACE

The main access to the building is moved from the east facade to the west. This is a more direct route from the main trekking path. It also means it is much more clearly visible and creates a courtyard between the bakery and the owner's brother's lodge next door. This includes a small porch whereby having one door open at a time can reduce heat losses. The original entrance door is kept and provides access onto a recreational space which could be used for badminton or table tennis.

Outdoor seating in front of the bakery will provide a nice place to sit as well as advertising the function of the building. The outdoor seating could also be made from local stone with some cushions. Usually outdoor seating consists of plastic chairs, and stone could create a much more attractive seating area. The stone would also warm up in the afternoon sun, providing a warm place to sit for guests when they arrive as well as being good for drying shoes and clothing.

Stone wall bench example, https://www.hammerheadstoneworks.com/

BAKERY, KITCHEN AND SERVING

The existing kitchen and dining area is kept close to its original layout. Although small by western standards, the kitchen functions well for the owners and they have established a space efficient layout. The removal of an internal wall in the bakery gives more space at bar which acts as a serving area for cafe customers and as a reception desk for guests staying the night.

BATHROOMS & STORAGE

These are placed on the north where there is little natural daylight due to the close existing retaining wall. Placing these functions here leaves the best spaces free inside the building for rooms where is natural daylight more critical.

VERANDA

Placing a corridor outside uses less space inside the building. It gives a semi private entrance to guests in the upstairs rooms. From the balcony there is an excellent view to the north. Seating in front of the sunroom will have some sun in the evening. The covered deck also provides a place to sit if it rains. Locating this covered veranda on the northern side means that the daylight and any solar heat gains during the day to the bedrooms are not compromised by the overhanging roof.

STAIRS

Access to the second story is provided by a stone staircase and wooden ramp. This is accessible from the outside and also through the back door on the north of the ground floor. The stone staircase makes use of an existing stone wall and difference in ground height. The elevated ground could also be attractively paved with stone. Stone in the Khumbu is naturally occurring and readily available. It is obtained locally, from near Island Peak Base Camp above Chukhung. It would be moved by porters and the blocks would be shaped by hand on site. The transportation of the local stone, is not harmful to the environment and provides an additional benefit of the provision of out of season work for porters. Local stone workers are highly skilled and generally their work is of very high standard.

Steps example, http://archive.nepalitimes.com/article/nepali-times-buzz/

Floor plan design

BEDROOMS

Bedrooms are intended to be just the "right size". It is important not to build more than necessary for several reasons. The first is materials. Their cost for them and their transportation to Chukhung. A bigger building has also more environmental impact as it uses more natural resources, has a higher embodied energy and produces more greenhouse gas emissions. Another very important reason is for thermal comfort. Achieving thermal comfort in a range close to acceptable for tourists is already a huge challenge. A bigger room is more space to heat and more area for heat losses. The rooms are designed to be spacious enough to be comfortable and provide good functionality. They would mostly be used for one, two or three nights (although some may stay longer) and so do not require the same space as a typical bedroom. Tourists would usually have a large rucksack for which they require some space. Some shelves and a small table will also be useful.

The existing downstairs was chosen to accommodate the group rooms whilst the upper floor selected for the "luxury rooms". The group rooms have a more compact but still functional layout. They are designed to be flexible and give multiple options for families. The group rooms can in total sleep 10 people, a usual number of participants in a trekking group.

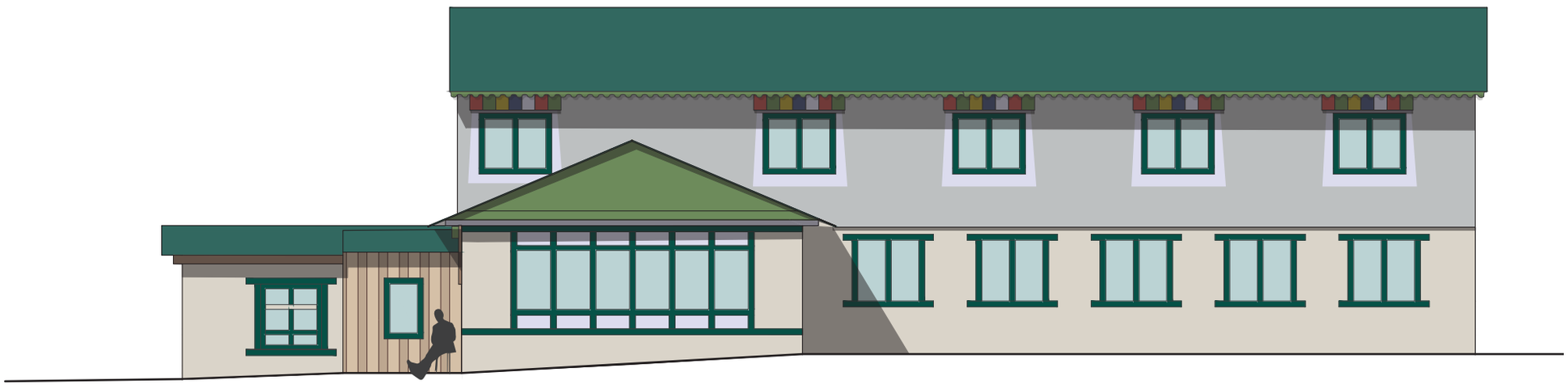
The luxury rooms on second floor are designed to be comfortable and attractive. Large rooms are seen by some as a symbol of wealth but here it was important to differentiate from size and quality and not oversize the rooms. The structural design of the extension, results in an interior sloped roof with exposed traditional round log purlins, creating an attractive and interesting space. There are various layout options for the rooms with twin (900mm) beds or a double. Each room as a small wash hand sink and toilet. It is common in lodges in the Khumbu that one most go to another building to access a toilet. This prevents guests having to venture out at night, particularly in bad or cold weather. It also adds privacy, there will be improved cleanliness and provides an additional number of toilets to satisfy the buildings functions as the cafe during the day as well as the hosting guests. The window on the south facing facade is positioned to provide central daylighting. The "medium size" can offer a compromise between daylighting, solar heat gains and transmission heat losses. It is intended that this southern window would be fixed, whilst smaller openable windows are located inside the bathrooms and bedrooms on the north for ventilation and a view towards Lhotse Wall and Mount Everest.

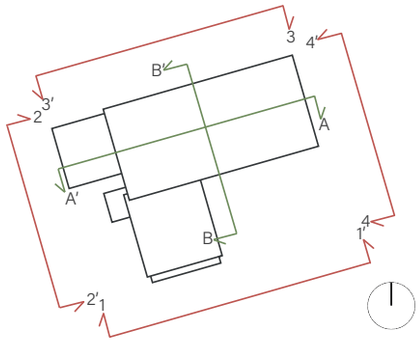
SUNROOM

The sunroom was one of the owners requirements for the building. This could be either a private room for the overnight guests or alternatively as a venue for private party type cafe customers. The large window faces the afternoon sun and looks out down the valley. This would be a nice place for guests to relax when they arrive (typically early afternoon). The large window is an existing window which is removed from the ground floor in order to add the new entrance. As materials are so valuable here, every attempt should be made to either reuse or re-purpose them. A second layer of glass could be added to reduce heat losses.

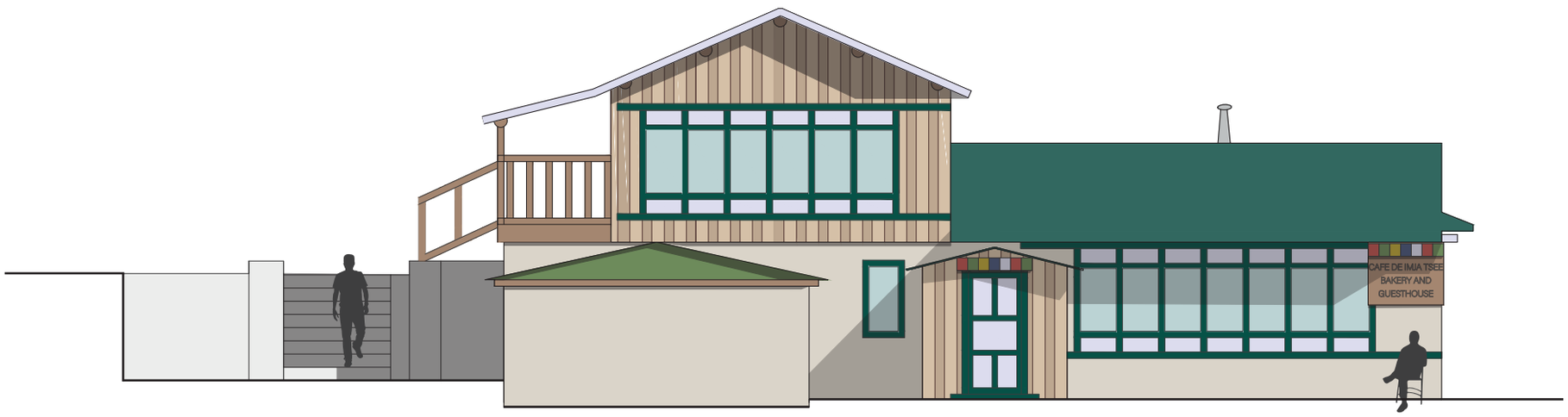
Looking onto Khangri Resort (neighbouring building). Evening sun, view North towards Lhotse Wall and Mount Everest. Source: Khangri Resort, Facebook

Elevations 1:100



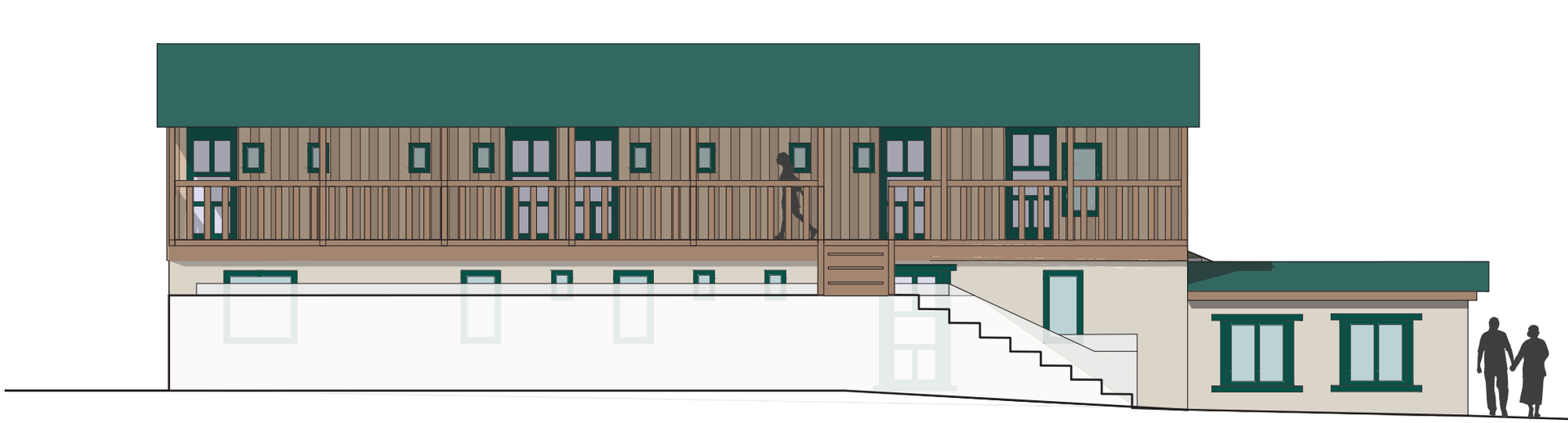


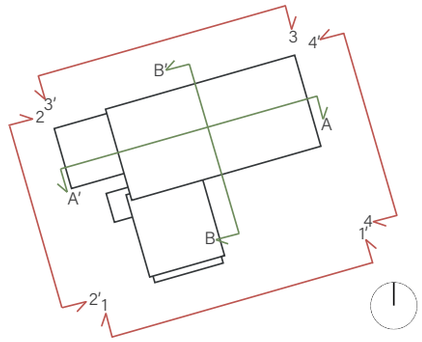
1 - 1'



2 - 2'

Elevations 1:100





3 -3'

4 -4'

Sections 1:100

A - A'

B - B'

Windows and facade

WINDOWS
Windows have several functions. These include supplying daylight, a solar heat supply, and ventilation.

High performance double glazed units are virtually absent in the Khumbu. The combined costs of purchase and transport preclude their use. Almost all windows are single glazed. Traditional frames are timber but UPVC and aluminium are becoming common. The aluminium frames are generally not insulated, unattractive, are a highly effective cold bridge and run with condensation. Locally built windows are often poor fitting. In the Khumbu, any window capable of being opened is usually draughty.

In my design I have maximised the use of fixed glazing whilst maintaining sufficient ventilation by specifying small opening windows where necessary. All new windows should have two single layers of glass. This is because a typical original single-glazed window will have a U value of 5.0W/m2K but adding "secondary glazing" will likely achieve a value of 2.7W/m2K.

Condensation is a major problem in cold high altitude locations. Condensation arises when warm, moisture-laden air meets a cold surface such as the glass in a window. The moisture forming on the glass is unsightly, can encourage the growth of mould, cause window furniture to rust and even penetrate into timber frames giving rise to rot. A second layer of glass will alleviate the problem to some extent. Condensation will still occur on the inner face of the outer pane, but trickle vents can be installed to keep this to a minimum.

There are craftsman capable of making quality timber windows a weeks walk below the site. It is imperative that they are installed correctly and on site supervision is likely to be required.

Below shown is an example of a window made for 2 layers of single glazing at Sagarmatha Next. The water damage evident from being "open to the elements" for several weeks on the close up is concerning, especially if there is a build up of condensation between the panels. This is critical to avoid in this project. Here there was no evidence of drain holes or trickle type vents as was suggested by Ganga, local builder who was accompanying us.

One of the buildings in Sagarmatha Next project

Water damaged window

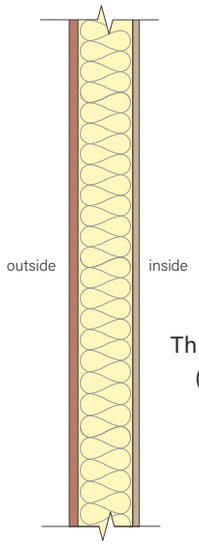
FACADE & ROOF
Timber cladding is used in most visible areas. Placing timber by entrances means it gives a feeling of warmth near the rooms. It is also protected from the elements by the roof overhang.

Flat sheet steel is used in the remaining areas as the cost of wood is high and it is difficult to source. This comes on a roll and easy to transport. To brighten up the facade and improve the appearance of the steel, traditional detailing is used at the windows and along the roof edge.

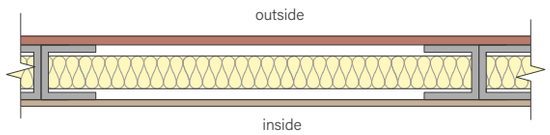
The roof would be clad in corrugated iron, the same colour as the existing and surrounding buildings. "BAKERY" can be painted onto the roof. This is done in some places to advertise. This would be visible by people climbing the closest peak, Chukhung Ri and could improve business in both the bakery and guesthouse.

Example of flat sheet steel at Phortse Guesthoue

Analysis of Kathmandu panel system



KTM panel wall section



KTM panel wall section (plan)

Thickness (mm)	Material
9	Cement board/plywood
75	Steel C-section/lightweight foil backed glass wool
12	Insulated facia panel

When planning the structure for the extension, taking a closer look the popular "Kathmandu panel" system was an obvious place to start.

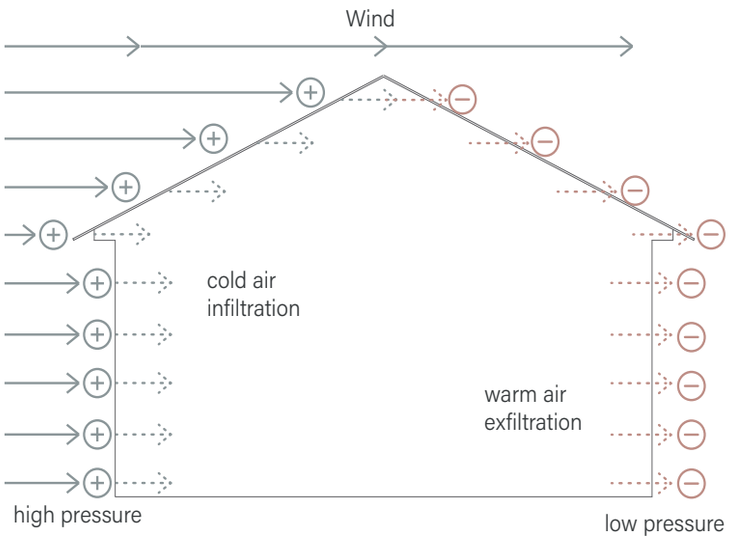
This panel system (see page 28) has become the most popular building method in recent years. It consists of a steel C-section with a thin layer of glass wool, backed with plywood or cement board on one side and an insulated facia panel on the other. They are screwed together with tek screws and internal joints are covered with thin strips. A complete panel measures 2400 x 1200 mm and weighs approx. 25 kg if constructed internally with plywood. Cost of a single panel in Kathmandu is approximately 180 USD.

ADVANTAGES:

- Established, simple and reasonably cheap system which is available
- Relatively lightweight and somewhat safe in an earthquake, at least when compared with some current practices

DISADVANTAGES:

- Extremely cold due to lack of insulation.
- Major thermal bridging
- Foiled backed glass wool has little structure and will inevitably sag very quickly
- Joints on external facia panels (as they come in strips 600 mm high) mean that the insulation is not even close to airtight zone causing cold air to circulate in the insulation. It will also result in poor airtightness of the building causing extensive infiltration.
- Internal finish of panels not visually attractive
- Externally not attractive



Wind induced infiltration, will be large problem with panel system

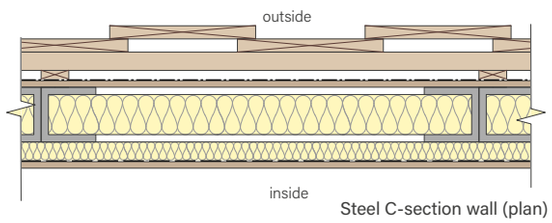
Variations of the panel construction also exist. The building below uses the steel C-section from the panel construction and also the facia panels. The wall is kept in alignment with a "timber head binder", this only does its job if the timber is straight. The facia panels come in thin strips. The high number of joins which are not sealed will result in poor thermal performance. The finishing is also very poor and not visually attractive. Note the join on the corners below.

Whilst the panel construction system as is currently done delivers buildings with very poor performance, there are ways to improve it. Adding a vapour barrier on between the C-section and internal lining would protect the insulation dampness from sources inside the building but however not allow the panels to be ‘finished’ internally prior to delivery to site.

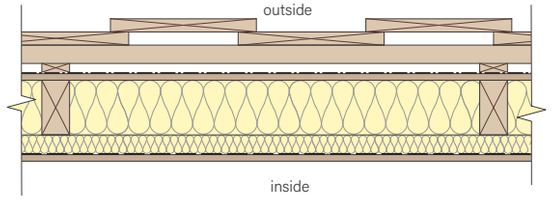
Variation of panel system with "timber head binder"

Frame using Steel C-section or timber studs

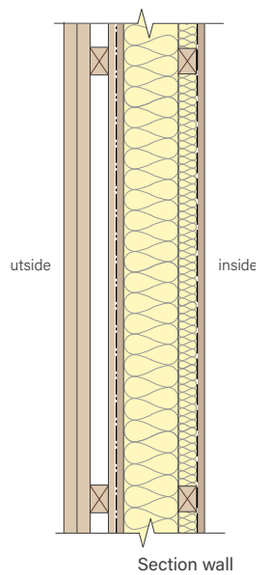
After confirming that the KTM panel system did not perform well and was not well suited for the project, it was further investigated whether the steel C-section from the panel system may be of use. The steel C-section from the panel costs around 3 USD a meter. Alternatively, timber studs could be used in place of the steel section. A comparison of the similar wall build ups is shown here.



Steel C-section wall (plan)



Timber stud wall (plan)



Section wall

Thickness (mm)	Material
9	Plywood/timber lining
2	Polythene membrane
25	Horizontal battens (25mm x 35mm), 600 centres/ infill with XPS
75	Steel C-section or Timber studs (75mm x 38mm), 600 centres/glass wool or alternative insulation
9	Plywood or OSB (6mm alternative)
2	Breathable membrane
12	Vertical timber (12mm x 38mm), 600 centres/ventilation
25	Horizontal timber (25mm x 38mm), 600 centres/ventilation
36	Vertical cladding 2 x 200mm boards, 25mm overlap

This system, in both cases of steel C-section and timber studs, has significantly improved qualities over the two previously discussed panel systems.

A wind barrier on the outside of the main structure prevents against cold air infiltration whilst an airtight vapour barrier on the inside will prevent condensation damage if there is a high moisture load inside the building. Polythene is chosen as it is affordable and readily available. It can be placed directly on to the plywood without the need for and air gap. (Note though that if the insulation was wet it couldn't dry out to inside.) The construction does not have a service void and any cables could be neatly clipped to inside. It would be critical to avoid puncturing the polythene.

Thermal bridging is reduced, particularly in the case with timber studs (due to its lower thermal conductivity compared with steel).

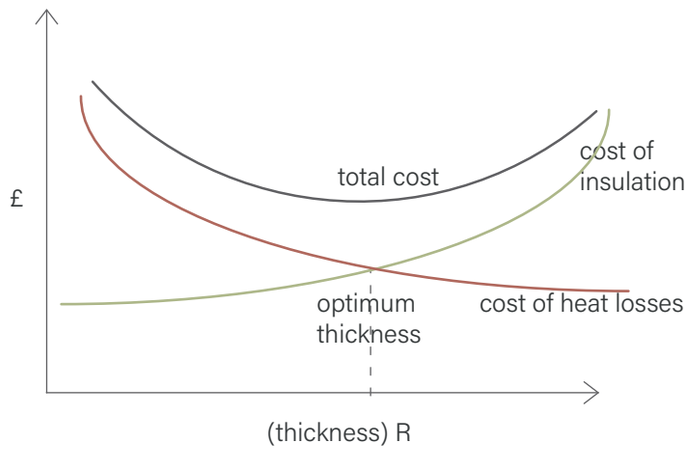
The performance between the ply or timber linings and polythene, is also improved by the additional layer of battens infilled with XPS. This also helps to reduce thermal bridging. This insulation can be sourced easily in Kathmandu.

HOW MUCH INSULATION?
Some quick calculations were done to compare the U-values of the constructs of the KTM panel system with one that included more insulation.

For a simple thermally-bridged wall, using the 75 mm C-studs filled with mineral wool at 600 centres, clad externally with 1 mm flat sheet steel and internally with 6mm plywood. This wall had a U-value of 0.84 w/m^{2}K

Doubling the thickness of insulation and stud depth improved this to 0.49 w/m^{2}K. The same thickness in a timber frame performed better again at 0.28 w/m^{2}K.

Beyond around 250 mm of mineral wool insulation there are not significant reductions in the U-value. This means that the cost of material would not be worth the savings which would be obtained with heating.



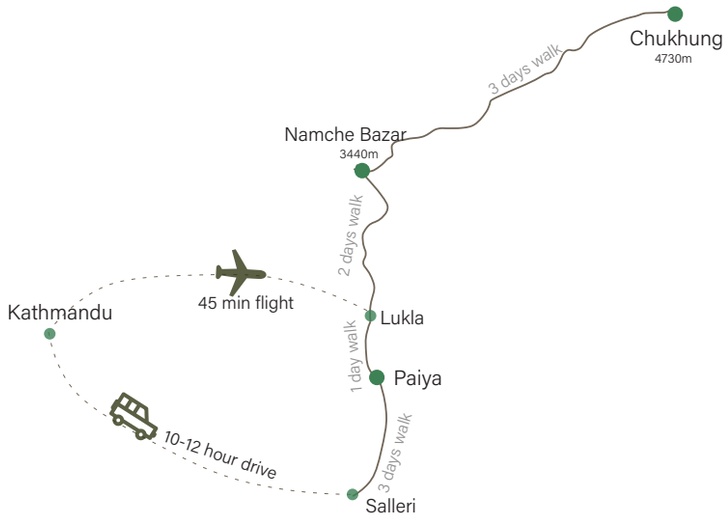
Optimum thickness is a balance between investment and saved costs

Steel or timber? Key Questions

Which is easier to source?

The steel C-section is available in Kathmandu.
Flight KTM to Lukla + approx. 5 days on foot or truck to Salleri (10-12 hours drive) + approx. 10 days on foot.

Timber is available in Paiya
Approx. 6 days walk from Chukhung



Map outlining travel between KTM, Paiya and Chukhung

Which is cheaper?

Material cost:

312 rupees a metre for C-section 75mm wide steel in Kathmandu.
262 rupees a metre for 100 x 50 timber from Paiya.
(Where 100 nepali rupees is approx. 0.8 USD or 8.2 NOK)

Transportation cost:

Weights are similar, both are close to 2.5 kg a metre.
In terms of volume, the steel C-section would be less bulky, however they cannot be stacked tightly, only one C can face another C. So, the volume is approx. 50% of that of timber.
Due to the fact that timber is available in Paiya, which is significantly closer than Kathmandu, it requires less transportation and would therefore be the cheaper option.

* Also note that the weight of both sections could be reduced by replacing the 9mm plywood or OSB with 6mm. In the west 9mm would normally be used, however 6mm might be sufficient. Since 2 sheets of 9mm weigh same as 3 sheets of 6mm, this could significantly reduce weight of materials when considering a whole building.

How do they compare in terms of environmental impact?

Transport

Timber would be carried on foot from Paiya (most likely by porter) had have negligible environmental impact.
From purchase in Kathmandu, the steel C-sections would be flown by plane or driven by diesel truck before being carried on foot. This has significant associated emissions to the environment. It is also most likely the steel C-sections would produced in India so would be further transported before arriving in Kathmandu.

Production

The timber from Paiya is sourced from Gangaram Rai (pictured), who works locally as a builder and owns a tourist lodge along with his wife Ngima. He owns 600 trees he carefully manages.

Steel production has a number of impacts on the environment. This includes emissions (CO, SOx, NOx, PM2), as well as wastewater contaminants, hazardous wastes, and solid wastes. The major environmental impacts from integrated steel mills are from coking and iron-making. Due to the fact the production of steel is energy intensive and significant carbon dioxide emissions are related to its energy consumption. [SOURCE: http://www.greenspec.co.uk/building-design/steel-products-and-environmental-impact/]

Is it feasible to source quantity of timber required?

Whilst it might seem that timber is the obvious choice, a major question is whether there is enough timber available. Forests in the Khumbu are sacred and there are strict restrictions on harvesting timber - a very valuable resources. There may not enough timber for others to build in same method whilst managing forests sustainably, at least not in a short space of time.

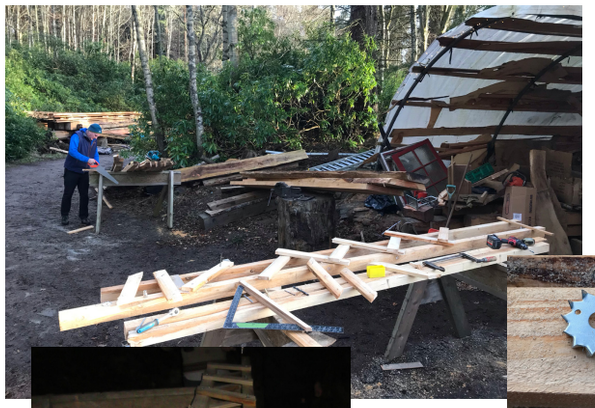
Bee Hive Lodge in Paiya, Gangaram Rai working with hand tools

Looking for more from less

In the Khumbu it is very apparent how scarce and valuable a commodity timber is. Even the smallest pieces of timber are salvaged and reused. It is also noticeable that the dimensions of some of the timber used in construction appear oversized. Floor boards are often 30mm or even thicker. This may be down to the way that the local timber is milled. Planks are generally cut from a tree suspended on a gantry with a big two man saw. One at the top, one underneath.

Chainsaws are appearing in the forests below Lukla (five days walk from site) but these are the exception not the rule. In places like Paiya, also below Lukla there is sufficient power to run a relatively large hand held circular saw. This works fine as long as there has not been a drought, that other people aren't using the power and it's not been too cold to tie up the micro hydro scheme water supply in ice. The thin deep cut blade of a powerful circular saw gives the opportunity to begin looking at ways of getting 'more from less' in terms of structural timber.

Having looked at the commercially available open web type joists in Europe I took the opportunity to see what we could achieve with timber off cuts whilst at home in Scotland. One weekend a Nepalese visitor and an architect met up with myself and my Dad. We experimented using different sizes of timber, threaded rod, bolts, spiked washers, nail plates and the spiked connector plates used on most commercially available roof trusses.



Our first attempt used too much timber and the threaded rod combined with spiked washers wasn't successful. We made different versions dramatically reducing the timber sizes. We eventually found that we could achieve massive strength using very little timber and we tested our efforts to destruction. The main problem we encountered was that as we are short of the spiked connectors, we cut them too small with the grinder in an attempt to make them go further.

The eventual failure was in the connectors ripping out, not surprising as on close inspection critical parts of the timber structure might only have had four or five spikes engaged. We recorded our results and the next step would working with a structural engineer to see what can be safely assembled. Again, compromises have to made in the high mountains. In my design I see the use of these beams as fundamentally important in reducing the reliance on stone walls in such an earthquake prone zone, particularly in the case where an extension is built on top of an existing building.



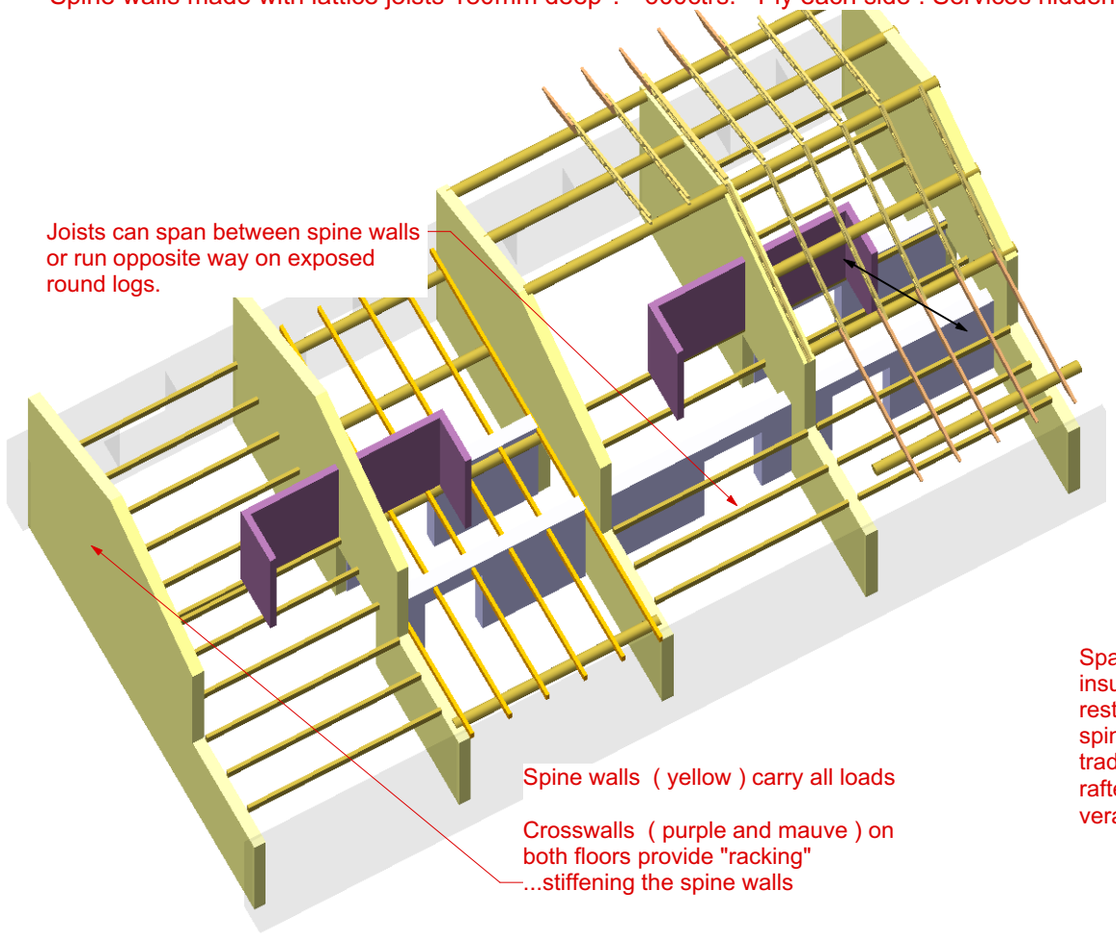






Structure

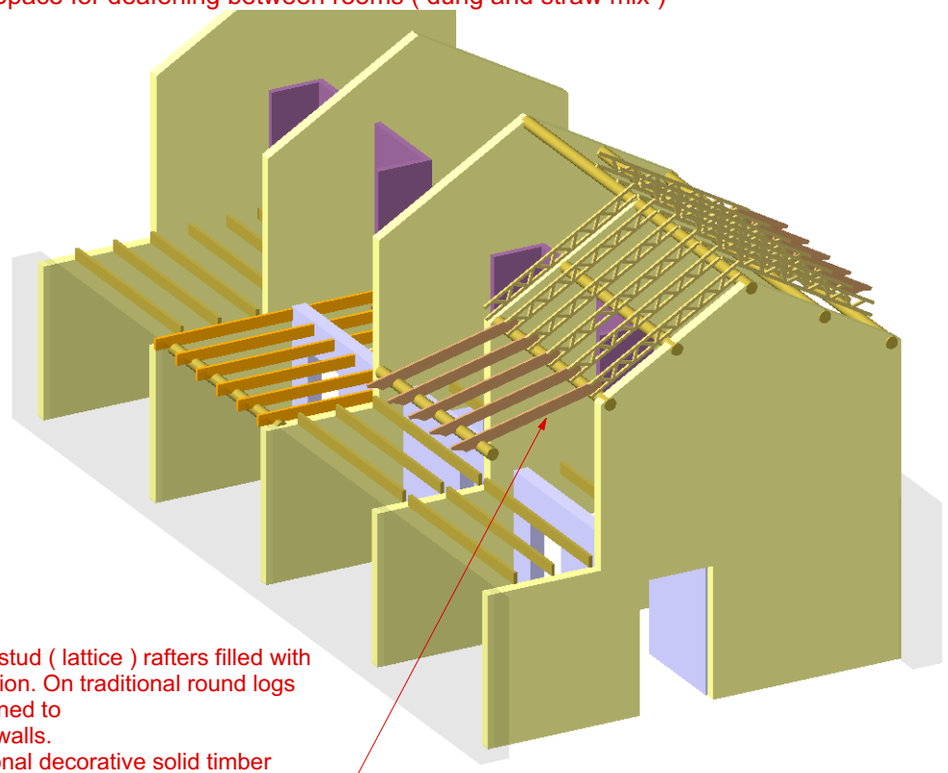
Spine walls made with lattice joists 180mm deep ? 600ctrs. Ply each side . Services hidden . Space for deafening between rooms (dung and straw mix)



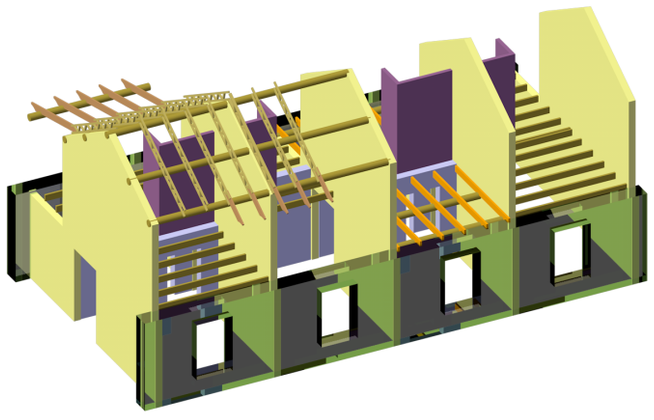
Joists can span between spine walls or run opposite way on exposed round logs.

Spine walls (yellow) carry all loads

Crosswalls (purple and mauve) on both floors provide "racking" ...stiffening the spine walls

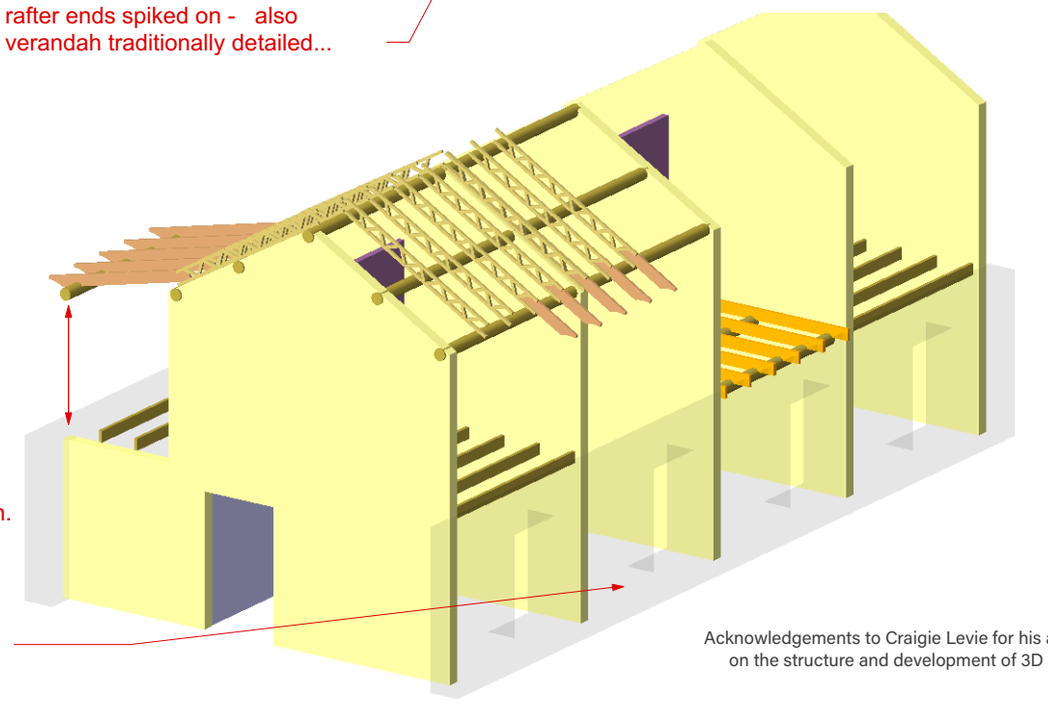


Spacestud (lattice) rafters filled with insulation. On traditional round logs restrained to spine walls.
traditional decorative solid timber rafter ends spiked on - also verandah traditionally detailed...



Ground floor Stone walls (shown ghosted)non-structural infill /screen.

Extenal walls to upper floor not shown- these to be spacestud filled will insulation- providing additional racking strength.



Acknowledgements to Craigie Levie for his advice on the structure and development of 3D model

Retrofit of ground floor

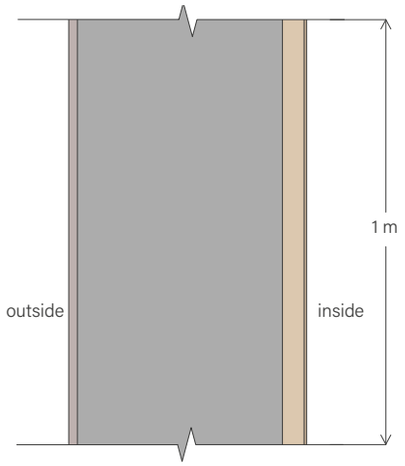
It was considered whether the original building should be retrofitted with insulation or if it should be left as it is.

The walls measure approximately 550 mm thick although vary from point to point. Shown is an estimated wall build up.

Original walls

Thickness (mm)	Material
6	Plywood
50	Timber framing (50mm x 50mm) at 900 centres
≈ 450-500	Stone/rubble
≈ 10	Plaster (yak dung/mud mix)

Total thickness approx. 550 mm



Original walls (approximated)

Old buildings are usually retrofitted with insulation as an energy saving measure. In the case of the first story of the bakery the main priority is to reduce heat losses and raise the internal temperature. Air tightness should be improved, bad windows replaced and properly sealed.

Options for insulation retrofit:
- External
- Internal

External insulation (+ possible refurbishing of facade)
- Provides a continuous wind barrier
- Eliminates thermal bridges
- Would alter the appearance of the original building (window reveal, size of roof etc.)

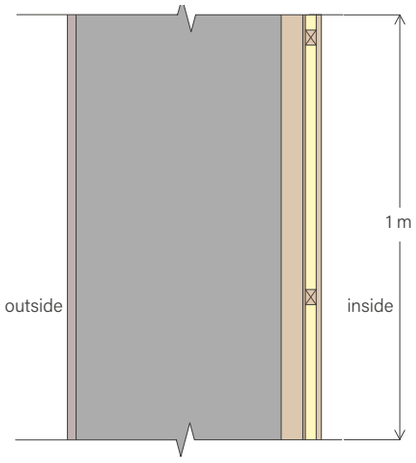
Insulation on the inside
- Keeps the original facade
- Reduces the floor area
- Some thermal bridges can be worsened
- Lowers temperature on the old structures leading to possible frost damages
- Can lead to moisture problems so must ensure vapour barrier on the inside

Some questions to consider included:
- Availability of additional materials required
- Cost of additional materials required (material cost and transport)
- Maximum preservation of existing materials. For example; can the interior plywood be removed without damage?
- How important is it to preserve the outside facade?
- How important is it not to lose internal floor area?

Proposed is to insulate on the inside. This would be less work and cost less. The insulation could be brought all the way to the start of the extension to avoid worsening thermal bridging.

Retrofitted walls

Thickness (mm)	Material
12	Timber boards
25	XPS/ Timber framing (25mm x 38mm) at 600 centre
6	Plywood
50	Timber framing (50mm x 50mm) at 900 centres
≈ 450-500	Stone/rubble
≈ 10	Plaster (yak dung/mud mix)



Proposed retrofitted insulation on interior of walls

The scenario assuming that it would not be possible to remove the interior plywood without significant damage. The interior walls as they are currently could be strapped with 25 x 38 mm battens at 600 centres. A solid board type insulation, for example XPS could be tightly fitted between the battens. This type of insulation could provide significantly more insulation than mineral wool (or other fibre type insulations) in a small space due to its higher R value. The joints should be covered and sealed with a wide tape .

The interior of the bakery currently is darkly varnished plywood. Working on the inside gives the opportunity to introduce a different finish, such as vertical wood boards, which could create a more attractive and visually comfortable indoor environment without changing the character of the place.

Insulation - Plastic Project

In the Khumbu there is an abundance of plastic bottles. Despite the water in the region being mostly safe to drink, the majority of tourists prefer to drink bottled water. PET bottles are brought in by tourists as well as by the local population for sale to tourists. As well as water tourists buy soft drinks such as Sprite, Coca Cola and Fanta.

During the last few years, the average number of trekkers visiting the Khumbu has been about 65,000 a year. The average stay is 12 days and a tourist will probably buy 3 litres of water a day. If 90 % of the tourists are buying water,

0.9 x 65,000 tourists x 12 days x 3 (1 litre bottles) = 2,106,000

This is over 2 million bottles a year in only water.

The plastic is a big problem in the Khumbu. The build-up of non-degradable waste causes the death of numerous animals and is an eye sore for people visiting the mountains. Just as everything must be carried in, it must be carried out. The cost of bringing the plastic bottles back to Kathmandu is prohibitive to recycling. Although now not permitted, previously, bottles have burnt in fires outside along with other waste, causing harmful levels of dioxins to be emitted. (WECF , 2005)

Water bottle left (thin plastic, produced in the region) and Sprite bottle (heavier plastic - imported)

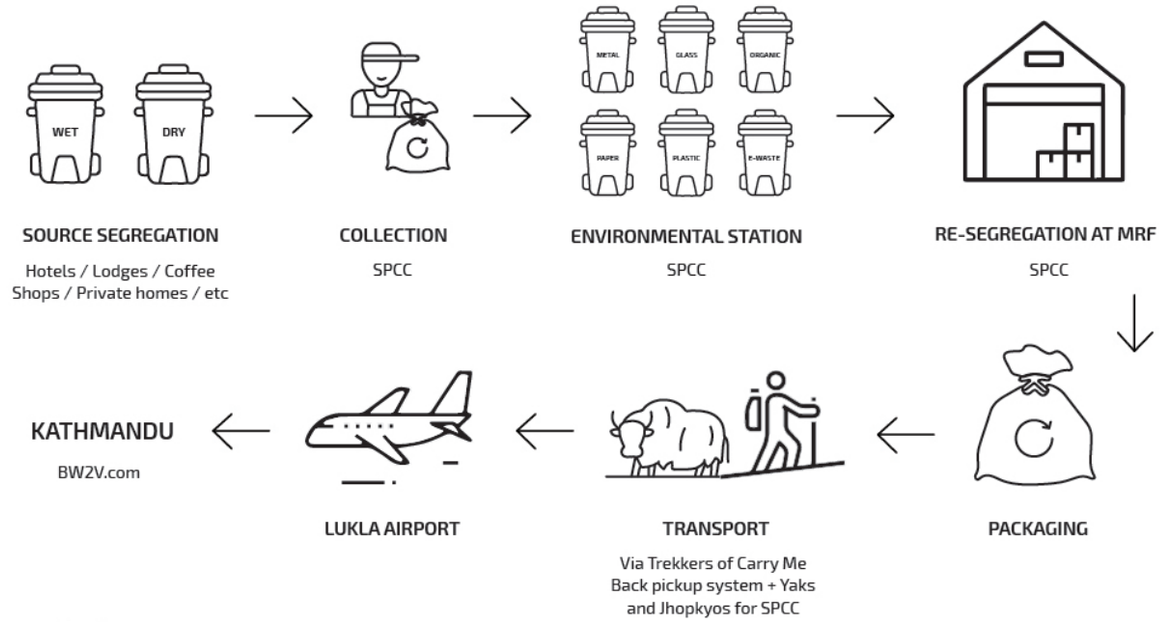
Sale of plastic bottles is an important source of income for many in the Khumbu

Insulation - Plastic Project

The Sagarmatha pollution control committee (SPCC), is a NGO which works to manage waste in the Khumbu. This includes on all the trekking trails and settlements in the national park and its "Buffer zone". They also check climbing permits, monitor illegal climbing, and implement waste management strategies at the base camps of the Khumbu area's mountains and peaks including Mt. Everest.

"Carry Me Back" is a project run by the SPCC, in which bottles are collected in Namche Bazzar, shredded and packed in 1 kg bags. Tourists are asked to carry them to Lukla and the flight operators give a preferential rate to fly the plastic to Kathmandu. From there they are transported to Pokhara by road for recycling.

Whilst the "Carry Me Home" project has had some success; preventing the burning of bottles and keeping the Khumbu clean, it is not without problems. The cost for the SPCC is high and questions can be raised over the environmental cost of transportation. Speaking to local people whilst in the Khumbu, they also told me that there had been some issues with tourists discarding their 1kg of plastic or "forgetting" it whilst eating lunch at one of the lodges on the way between Namche and Lukla. Then whose responsibility does this plastic become?



Sagarmatha next

Solid Waste Management solution for Khumbu Valley [Sagarmatha Next]

Meeting with Yangji Doma Sherpa, Public Relations Officer SPCC, Kathmandu

Meeting with Ang Dorjee Sherpa, Chairman on Executive Board SPCC, Kathmandu

From 1st January 2020 the local parliament has introduced a ban on the import of 500ml bottles of soft drinks like Coca-Cola, Sprite and Fanta to the Sagarmatha National Park. Typically these drinks sell for 300 to 400 rupees. (3 to 4 USD). With the low room cost of around 5 USD, (sometimes nothing) the sale of these drinks make up a significant portion of the income particularly for small businesses. Whilst visiting the Khumbu in February we found it was in fact a big concern to locals with smaller lodges and shops.

For example, friends Ang Nuru and his wife Maya have a Lodge at Dzongla (16,000 feet and ten days walk from the nearest road). They have 22 rooms and generally charge 6 USD. For ten weeks in the post monsoon season they are often full as long as ground conditions for crossing the high Cho La pass are okay. At this time of year they will sell an average of 25 500ml bottles of soft drinks a day. Over the season this will generate a profit of 3,300 USD. This can be seen as vital income to the many small businesses like theirs.

Insulation - Plastic Project

There is high demand for building insulation from many of the lodges but it is very expensive in Kathmandu. Generally it is imported from India. The duty and transport costs are high making it unaffordable for most people. A possible solution to the plastic problem is to use the bottles for something useful - producing building insulation.

With two machines it is possible to turn PET plastic bottles into polyester wool. The bottles must first be shredded into 3 to 4mm PET chips. A second machine then pulls the PET fibres to create polyester wool. The SPCC already have a shredder which they use for the "Carry Me Back" project. A company in Bulgaria manufactures the machine that will turn the chips from plastic drinks bottles into polyester wool.

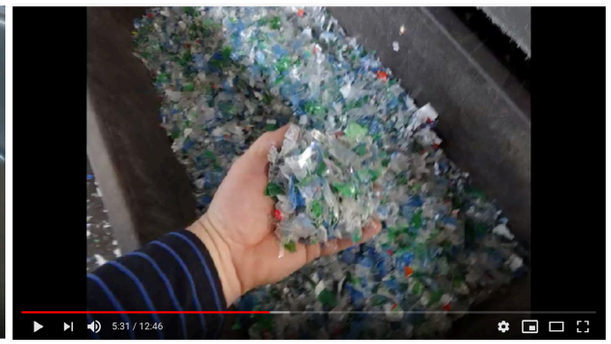
This machine, the Eco Wool 3, requires a 10kw power supply to start up and once warm 3kw to run. It can produce up to 50kg of polyester wool an hour. The village Namche Bazzar has a reliable hydro scheme with sufficient capacity. The machine weighs about 350 kg and costs 12,000 Euros.

Whilst in Kathmandu, my dad and I met with the SPCC Chairman, Ang Dorje Sherpa as well as Yangji Doma Sherpa the Public Relations Officer. They both were enthusiastic and keen to identify potential problems with the idea and for ways to overcome them. We discussed a budget including the costs of maintenance, training and the purchase of likely spare parts. As the SPCC is a not for profit NGO they only pay 1% import duty to Nepal. They are also confident that the local parliament would reverse the recent ban on the sale of 500ml plastic bottles if it could be demonstrated that the 'problem plastic' could be put to a very good use. This belief is backed up by friend (and elected Parliament member) Ganga Ram Rai.

The plastic bottle project, would have numerous advantages for local communities. It could further reduce litter on the trails. Currently litter is collected within the national park but trails outside have a lot of litter. The project could provide some employment for local people and reduce the costs of waste management for the SPCC.

The insulation produced could be sold at an affordable price providing a locally available and obtainable source of building insulation. This could be implemented in the project at Chukhung and others businesses in the Khumbu.

Stage 1: PET plastic bottles



Stage 2: Bottles shredded into chips

Stage 3: Bottles shredded into smaller chips

Stage 4: Machine pulls PET fibres to create polyester wool

EASY WOOL 3 (youtube)

Heating, electricity and Hot water

SPACE HEATING

In addition to being a heat sources, the traditional central stove has a strong cultural importance and provides character. Although most traditional stoves are barrel shaped, recently squarer looking stoves are being imported 'flat pack' from India. Whether imported or made locally (as the one shown) these square stoves give the opportunity to introduce glass stove windows. Whilst this won't effect the temperature it will dramatically improve the atmosphere and help to create a perceived feeling of warmth. An electro magnetic fan on top of the stove could help distribute heat around the room.

An option for heating the bedrooms is to use a 12 volt underfloor heating mat. Manufacturers such as SALMERK Innovative Underfloor are the market leaders. This can be used to heat below a small area (around a square metre) of slate in the otherwise timber floor, primarily during the day. The stone will absorb heat whilst the PV panel is in the sun and then release it during the evening. A small warm area is of particular benefit for drying footwear.

HOT WATER - SHOWERS

Assuming for the time being an LPG shower is installed, there is definitely the opportunity to reduce the load by introducing some warm water storage facility so that the gas is not heating water from around freezing temperature.

Simple low tech solutions are preferable here. Systems need to be easy to operate and maintain. Long lengths of black water pipe laid out in the sun is a simple, effective and affordable means to warm water during the day. During the trekking seasons the weather is generally good, high pressure with lots of solar radiation. It is imperative that a simple token operated solenoid valve timer is fitted to the showers. Many trekkers abuse the trust in being asked to limit shower time.

Photovoltaic Panels

Currently the bakery and snooker house uses around 1.5kW. Solar PV panels on the southern facing section of the roof integrated into the roofing material.] In the following stage of this building design, studies would be undertaken into the requirements for electricity and simulations would be carried out order to size a PV system. This should be developed in conjunction with the owners and it should be investigated methods of storage and whether any surplus can be sold to others in the village.

Locally made square stove (cost was 640 USD), Phortse Guesthouse

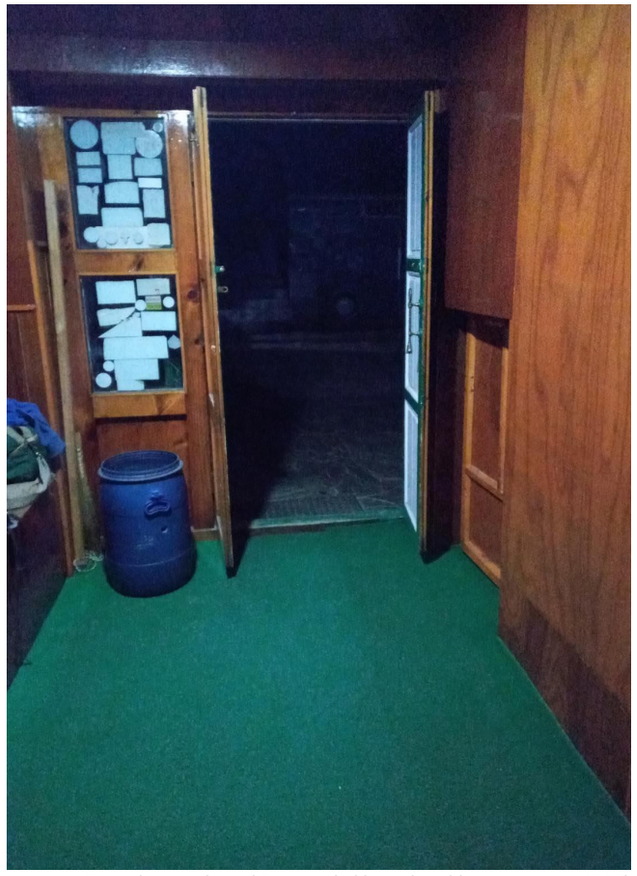
Premises Presentation

Sherpa's are not good at closing doors! Obviously this a harsh generalisation but there's a lot of truth in it. It's not uncommon to be sat in a lodge dining room in the evening. It's finally warmed up inside to 10°c once the stove has been lit and the large number of guests sat there. It's 20 degrees colder outside. The outside door swings open, someone walk in and sits down without closing it.

Most of the locals are accustomed to a cold living environment. Western tourists aren't. I've discussed this with Sherpa friends. They agree, they don't notice the cold like tourists. There is more to it than that though. They do want their premises to look open. That's a major reason for the exterior door being open. Their doors are lovely but they're solid doors with no glazed panels. A closed door is a closed lodge is how many of them think. One evening I was walking up the lower Khumbu as it was getting dark. The path runs only a metre or so from the front doors of the older houses and lodges. Many had very inviting open fires burning as there is a supply of 'shing' (firewood) below the village of Namche. The doors were generally open. The fire was primarily for cooking, not to warm the house.

Having been involved in our family tourist business for as long as I can remember, I'm well aware of the importance of presentation. I do think there are simple things that can be done. Close the door but light a couple of small candles in the window. Introduce a small glazed panel. Introduce simple welcoming signage. There are ways to look open without loosing all the building heat.

Door closers. I'd estimate about 5% of lodges are aware of the open door issue. They've made simple self closing door devices, usually constructed from light climbing cord, a small pulley and a half litre coke bottle...the amount of water in the bottle determining the strength of the system.



Open door at Khangri Resort, Chukhung (outside temperature -15 °C)

Lighting is also important. Nepalis tend to use cool white bulbs. Whilst these cool white bulbs appear brighter to the eye than warm white they do not look attractive. (The cool light can be seen in the picture with the open door.) Choosing warm white bulbs for the rooms in will add to a feeling of cosiness in the evenings.

Whilst in the Khumbu, we took some LED solar powered fairy lights to a friends lodge as a gift. We didn't manage to raise the temperature of the dining room but we transformed the atmosphere. Candles on tables make a huge difference. Many lodges have cool white naked bulbs as the only source of lighting. Subtle changes here cost little but will have an effect on their businesses.

Transformed atmosphere thanks to candles and fairy lights (also a power shortage)

Conclusions

Sustainability extends far beyond the actual building construction. A sustainable building project needs to contribute to the region and to its people having a better existence there in the long term.

The benefits of having an understanding of local labour skills, availability and cost cannot be over stated. The same applies to materials. Face to face interaction with the Sherpa “client” was crucial as understanding the expectation of the prospective Western customers has been built in to the proposal.

The design will improve comfort for tourists. Turnover and profit will increase for the owners. It does this by combining the existing traditional skills and materials with new techniques and surprisingly few new materials to deliver a sustainable and achievable building. Whilst being case specific many of the concepts in the design can be applied to other Khumbu projects.

This can support and preserve Sherpa livelihoods. The increase in income gives Sherpas more opportunities. It allows them to send their children to school, perhaps go on a holiday, travel as well as continuing to live, work and thrive in the Khumbu.

Friends Ang Nuru, Maya and their daugher XingZang

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Avalanche at Everest Base Camp. Sherpa Family Support

Posted Mon, 18/05/2015 - 22:02 by Sue

Newsletter: susanharpertodd.com newsletter

Apologies for sending this again, but the photos and links didn't work in the first one.

Three weeks ago (although it seems like much longer) the earth moved below Nepal. It destroyed countless homes, killed thousands of people, and caused a huge avalanche to sweep through Everest Base Camp, killing and injuring many of those in its path. For those who know and love the beautiful country of Nepal and its people, and even for those who don't, the devastation caused by the earthquake has been heartbreaking. We all want to help these people, whose kindness and generosity know no bounds, and who have now lost everything.

I have spent a lot of time at Everest Base Camp. Months of my life have been spent living in a tent in this beautiful but barren desert of rock and ice surrounded by some of the highest
mountains in the world. I first went out there in 2003 and the following year I was privileged enough to stand on the summit of Everest with Sherpa Ang Nuru, a boy with whom I felt so safe and I know I was lucky to be climbing with him as my partner. I have been to Everest Base Camp almost every year since then, sometimes twice a year, either helping out on expeditions or leading treks. During this time the Sherpas who work with us have become my friends. They welcome me into their houses when I pass through their village and willingly share what little they have with me. Many of them come from the village of Pangboche, which for us mere mortals is 2 or 3 days walk from Base Camp, but they will do the same walk in a day!

On that terrible day when the earthquake struck, three of our Sherpas died. Our base camp took the full force of the avalanche and was completely destroyed. The avalanche came off the mountain of Pumori which is directly behind our camp. No one in their tents had any chance. It was just a stroke of luck that most people had gone up to Camp 1 only that morning, very early. Terrifying as it was being at Camp 1 in thick mist with avalanches thundering down all around from the faces of Nuptse and Everest, it was as nothing to the death and destruction that had just occurred at base camp. Unfortunately Pasang Temba, who had been our Camp 2 cook for nearly 20 years, was killed, as was Kumar our cheerful, always smiling kitchen assistant, together with Tenzing, a climbing Sherpa for whom nothing was ever too much trouble. All these men leave families. Between them they had 9 children and 1 grandchild. And to make matters worse, Pasang Temba's house was destroyed in the earthquake, as was Ang Nuru's. They are now living in tents. The village of Pangboche where they live is at almost 4,000 metres (13,000 feet), which is the summit height of many alpine mountains and it is cold up there! We need to help them... Well I, at least, am determined to help them and I am hoping that some of you may help too.

A few days ago Ang Nuru rang me from Namche Bazaar and said "we don't know what to do.." I said to him "don't worry we will help you," not knowing quite how but just knowing that somehow we WILL help them. I know that anything is possible... I learnt that when I climbed Everest. So I then gave Ang Nuru a list of questions which I needed answers to with regard to the rebuilding costs, what materials are needed etc, which he himself could not answer, but which he knew our Sirdar (head climbing Sherpa) Kame, could. Ang Nuru said he would go immediately to Pangboche to see Kame, which entails a 6 hour walk! So Ang Nuru walked to Pangboche that afternoon, got the answers from Kame and walked all the way back to Namche the next day so he could ring me back with the answers! How can we NOT help these people???!!! Ang Nuru was SO grateful for the promise of our help, he couldn't stop saying thank you. I know this boy so well. We have shared so much together and I can tell from his voice that we are a ray of hope in a seemingly desperate situation. After that call I sat down and cried. Feeling helpless, wanting to reach out and hug him. Wanting to make it alright. I trusted this boy with my life on the mountain and he looked after me so well. It is now time to do something for him, and for the other Sherpas who lost their lives working for us.

Many of you reading this will have been to the Khumbu, either climbing or trekking, perhaps even with me, and some of you will personally know the Sherpas I am talking about. I know you will agree when I say that the Sherpas are such lovely people. They are so kind, so generous, so willing and glad to share what little they have that I, who have so much more in material terms, feel humbled and inadequate, knowing that in reality they are the ones that can teach me. They live from their heart. Something that we here in the west have forgotten how to do. These people are such a great example to us of the true meaning of humanity. We can learn much from them. We can learn how to replace that side of our humanity that many in the west have lost. And in return we can now help them.

If you would like to donate you can do so through this link https://crowdfunding.justgiving.com/Sherpafamilysupport . The money is going to go directly to the Sherpas.

Every little helps no matter how small. It was lots of small steps that got me to the summit of Everest and we can now help these people to climb their Everest. Thank you.

With Love

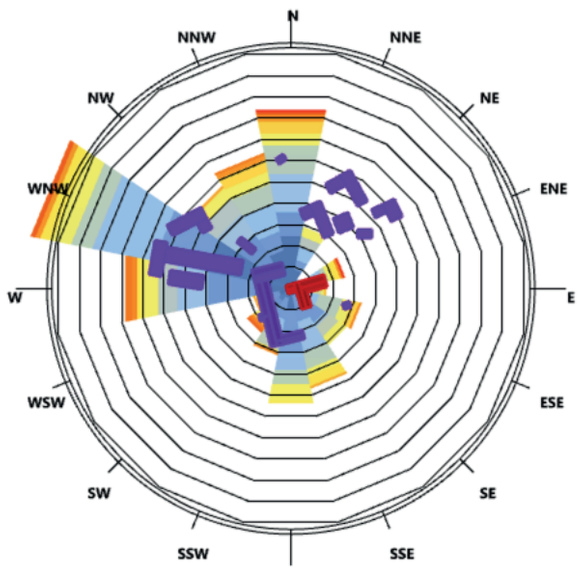
Sue

Source: Sue Harper Todd, available at: http://www.susanharpertodd.com/content/avalanche-everest-base-camp-sherpa-family-support

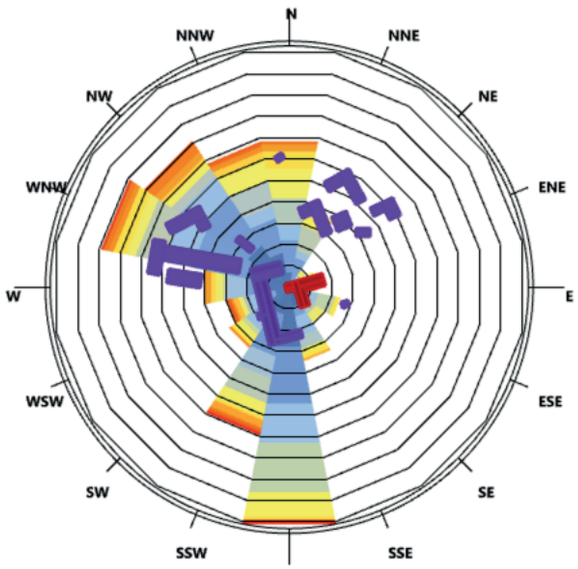
Appendix 2

Wind-Roses spring and autumn tourist seasons

Hourly data for windspeeds > 1 m/s. Each closed polyline shows frequency of 1.2% = 8 hours



March



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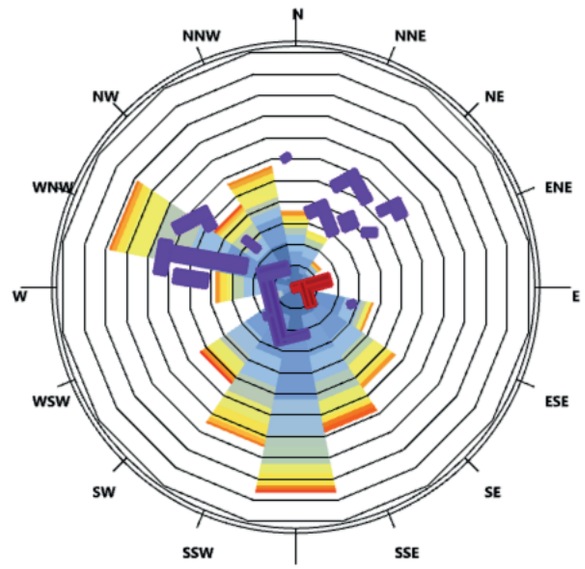
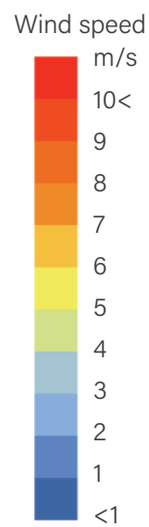
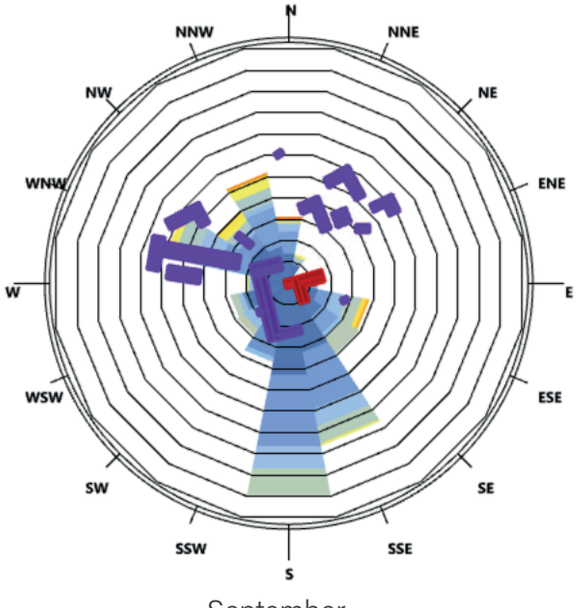


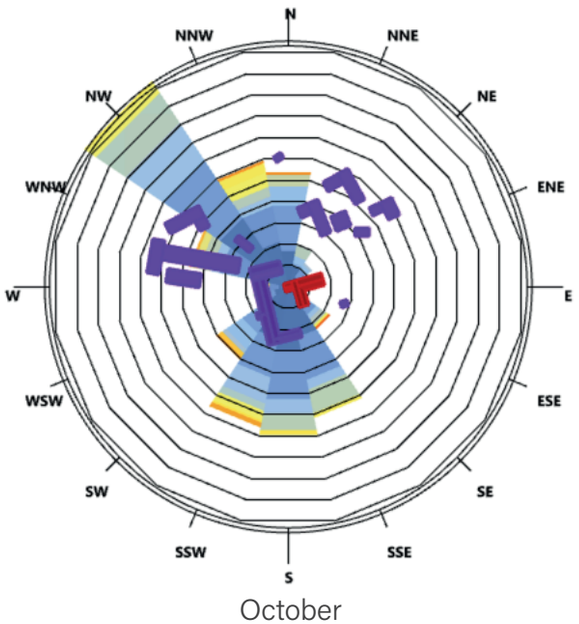
May



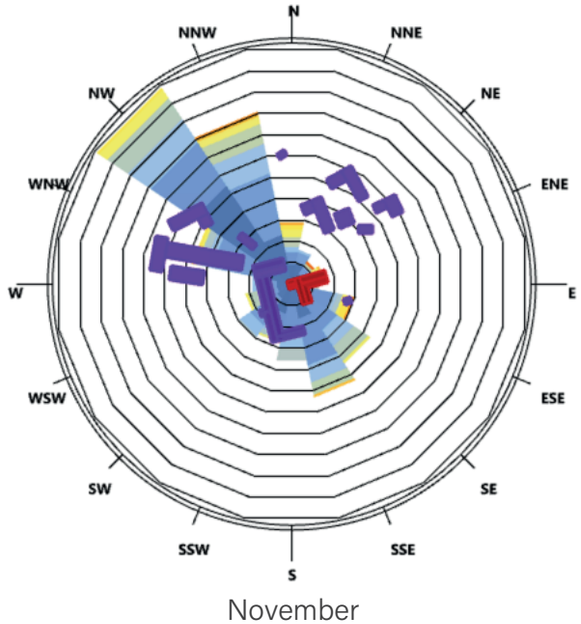
The wind changes throughout the year. Here is shown the main months of the tourist season. In March the prevailing wind is from the north west. This shifts to a more southernly wind



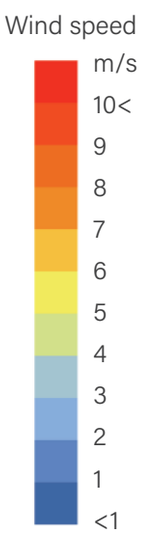
September



October



November



Appendix 3

Radiation Analysis during spring and autumn trekking seasons

Shading from Khangri Resort (grey) included in analysis