1. INTRODUCTION OF TRAIL BRIDGE

1.1 GENERAL

1.1.1 Historical Background of the Trail Bridge

The ropes of creepers, vines and other trailing plants in many countries are the natural sources in originating the idea of a suspension Bridge. The earliest ever recorded forms of suspension bridges are the rope and bamboo supported bridges of the Eastern Himalayan and South America. It is guessed that the origin of suspension bridge lies in the eastern part of the Tibetan massif. Many types of catenaries deck from the simplest to the most advanced forms are found in this area. The first written reference to a suspended type bridge in the Hindukush range was recorded in 90 A.D.

One of the earliest types of a sophisticated river crossing is the Tuin type bridge. Still there are many Tuins in the country. A traditional Tuin is a simple wooden trolley running over the single rope, normally tied in the trees.

Instead of a single rope, crossings with the use of three ropes, hoisted in V shape are in use till to day in Yunan-Burmese border, in many parts of south East Asia and even in the northern part of India.

The bamboos are later used to form a firm bamboo cables. Bamboo strips from the softer inner part of the culms form the core of the rope. Around the core are woven a thick plaiting of bamboo strips. These are taken from the outer silica containing layers. They are extremely resistant to wear.

In the replacement of the Bamboo cable bridges, the iron chain suspension bridges came in light as more advanced technology.

Among the ancient bridges, these were the most permanent structures, as the iron chains were of high quality and lasted for a long period. They were also more convenient for traffic, with platforms protected on either side by a bamboo or other fence.

The oldest known iron chain suspension bridge was built in Yunan China in the sixth century A.D. One of the still existing bridges of this type can be found at Satlaj River at Tholing, in Tibetan territory of China.

In Nepal, such chain bridges were developed at the beginning of the 18^{th} century. Iron chain suspension bridges still exist in Nepal.

Western peoples only became interested in suspension bridges on any appreciable scale with the introduction of wrought iron, first, in China, in the form of chains.

The first linking we have of chain-suspended structures in Europe is in the Schollenen canyon in the Swiss Alps. The bridge, probably built by a Roman Emperor, was built in the year 1218 according to the latest research.

In England, suspension bridges using such chains tended to arise near the early shipyards. It is believed that the first chain bridge in England was erected over the Tees near Middleton in 1741. It was of primitive character, just a footbridge too wide, known as the Winch Bridge.
The credit for the first iron suspension bridge in the USA goes to James Finley, who built his first chain bridges of 70 ft span across Jacob’s Creek, Pennsylvania, in 1796

1.1.2 Development of Modern Theories

Around 1800, the theory of the parabolic cable-supporting load, that was uniform along the span, was developed in Europe. It is remarkable that the parabolic form under such conditions, though previously suspected, was not earlier proved.

During the first quarter of the nineteenth century, more intense work on the behaviour of suspension bridges began to develop. The second quarter of the nineteenth century saw, in England, many experiments directed towards stiffening suspension bridges. The first very well known suspension bridge built on this new theory was the great Brooklyn bridges in 1883. Brooklyn Bridge was a triumph of intuitive engineering and was heralded as the eighth wonder of the world.

With the completion of the Brooklyn Bridge there came also two major steps forward in theory of suspension bridge: the growth of the “elastic” and “defection” theories.

Plenty of research work has been done ever since, leading to the construction of progressively more economical, more slender and more ambitious structures. One type of so called high technology bridges has found the way back from Europe to its place of origin in the Asian Himalayans: the foot trail bridges in Nepal.

1.1.3 The Trail Network and Trail Bridges in Nepal

The kingdom of Nepal is immensely diverse in topography. The hill regions, bounded by plain terrain and Tibetan plateau are extremely complicated geo-physically for an easy communication. The large number of rivulets and rivers crisscross the country’s landscape and definitely create obstacles to a smooth and proper movement in the trails. Loss of life, livestock and property of those who risk through the rivers is quite common. Days of waiting at the riverbank for the river to subside or arduous uphill and downhill detours cause much waste of time and energy. In spite of such condition, the people in the hills are establishing and maintaining a traditional trail network for centuries. There are many ancient trade routes linking India and Tibet through Nepalese hills. There are many regional routes and many minor trails, linking up places of local importance. Footpaths and mule trails are the lifelines for the exchange of goods, the sick going to health posts and the children going to the school. Uneasy accessibility of remote areas is one of major constrains in the delivery of essential services, markets and all aspects of development work by the Government and privates. Despite great efforts in the development work, a large part of the hill population will depend on the traditional trail network for decades to come.

Indigenous bridges are evident since long time all over Nepal. Local people used to span the waterways with rudimentary twine; bamboo, log, wooden and chain trail bridges using traditional skills. These attest to a long tradition of bridge building in Nepal. Their indigenous art of designing and building bridges and their depth of creativity are also seen in the way they utilize the locally available materials such as stones, twine, bamboo, wood etc.

Modern bridge building in Nepal started with the building of the Scottish trail bridges at important locations along the main trade routes at the beginning of 20th century. There were 30 bridges completed started by Chandra Shumshere till the end of Rana Regime in 1950. These bridges were fabricated in Scotland and constructed by a Scottish firm.

Dr. K. I. Sing was a first promoter of trail bridge construction in the 1950’s after the downfall of Ranas in Nepal. A contract was signed between Nepal and USA in 1958 with an objective of constructing 25 bridges. Unfortunately the fund provided by USA was taken back, once the Nepali side rejected to carry out the project using foreign companies advised by USA. The Nepali Government showed a preference for a programme with a bigger participation of Nepali teams.

The Swiss Geologist Mr. Toni Hagen made a report on development problems in Nepal emphasizing the importance of trail bridges to UN in 1959. Then the UN organization UNTAB indicated its interest better coordination between the bridge builders of financing for trail bridges and consequently Helvetas worked out the plan to start the project. But at the critical moment, UN lost their interest in the project, and the project was canceled.

In 1964, at the initiative of U.S Aid the Suspension Bridge Division (SBD) was established under the umbrella of the Public Works Department. Except for the period between 1981 and 1986, when it was under MPLD, SBD has always been a division under DoR within the MoWT. Since 2001, SBD is renamed as Trail Bridge Section and is under Department of Local Infrastructure Development and Agriculture Road of Ministry of Local Development (DOLIDAR, MOL). Up to day this organization's main mission is to build bridges.

On the request of His Majesty's Government of Nepal, in 1972, the Swiss Government started its involvement in the SBD, now named TBS. Since then the Swiss Government, has been assisting SBD in the planning, construction and maintenance of trail bridges with technical as well as financial support through Helvetas. In order to elaborate clear guidelines as to justify and to plan rationally the bridge requests, main trail study was carried out. A computerized database of the status of all main trail bridge called as Central Bridge Register is made for. Partnerships with local government units and private organizations are made for diffusing technical knows how, methods and practices for carrying out maintenance at local level. Capacity Building Activities are made among partners for updating technical knows how.

1.2 BRIDGE PLANNING

Bridge planning is done at two levels, i.e., planning at Center Level and planning at Local Level.

1.2.1 Planning at Center Level

The trail bridge section (TBS) is operating at the central level for the planning and coordination of trail bridge building in national perspective. TBS is under HMGN's Ministry of Local Development, Department of Local Infrastructure Development and Agriculture Roads (DoLIDAR).

The role of TBS, at central level, is to lead to the optimum use of national resources providing policy support to the Local Government (Bodies). This role includes:

- policy making,
- setting norms and standards,
- developing and availing planning tools,
- decentralization of funding by providing sectoral/block grant to the local government for trail bridge building,
- enforce and monitor the application of Nepal Trail Bridge Policy (NTBP),
- coordinating all bridge building agencies in national perspective,
- synchronizing bridge planning of the nation,
- maintaining nation wise trail bridge inventory and planning tools,
- facilitate/provide technical support to the DDCs in planning survey, design, construction and maintenance of trail bridges,

The Planning and Monitoring Section (PMS) within the TBS is responsible for the central level planning of trail bridges in national perspective. Based on geographical studies of the country, it has developed several instruments to plan new construction and maintenance of trail bridges in national perspective.

These instruments are:

- Transport Infrastructure (previously known as Map Main trail map),
- District-wise central cervices maps,
- Region-wise new bridge and maintenance requests files,
- Central bridge record (CBR) and
- Computer database of the central bridge register and planning and monitoring information system (CBR-PMIS),
- Nepal Trail Bridge Record (NTBR)

DDCs plans and implements the new construction as well as maintenance of all trail bridges.

1.2.2 Planning at Local Level

Local Government (DDCs) is to facilitate and coordinate trail bridge program at the district level. The role of local government includes:

- coordinate bridge building agencies and bridge program in the district,
- prepare periodic and yearly trail bridge plan,
- develop institutional capacity (management, technical, SOS) to construct new trail bridges and maintain existing bridges,
- use available resources by applying demarcation convention and appropriate implementation approaches,
- monitor bridge condition / take responsibility for maintenance of all trail bridges mobilizing VDCs and communities,
- provide technical and social organization support to the communities,
- mobilize NGOs and private sector to farm out implementation responsibilities,
- maintain and update District Bridge Record (DBR) and Transport Infrastructure Map of the District.

All bridges are planned and implemented at local level. The DDCs are recording bridge requests and planning their constructions. A very successful BBLL's (Bridge Building at Local Level) approach to construct the bridges with the active participation of local communities, VDCs and DDCs has build good confidence on these local authorities for decentralized way of planning and construction of bridges.

1.2.2.1 Planning of Long Span Trail Bridges (LSTB)

All trail bridge is classified as Long Span Trail Bridges (**LSTB**) or Short Span Trail Bridges (**SSTB**).

LSTB bridges are quite expensive and demands high technical input. In general, these bridges can be constructed through the private sector only. Therefore, these bridges shall satisfy the defined socio-economic criteria. For this purpose, there exist simple socio-economic criteria, i.e., **such bridges shall be built only at the crossings of main trails and at strategic crossings**.

The **Main Trails** are defined as per the following socio-economic factors.

1. Economic factors
   - Traffic: The volume of traffic crossing the bridge during different times of the year and the daily average volume of people and animals
   - Potential growth center: Places of markets, tourism, agricultural and handicrafts industries and other agro products.
2. Social factors

   Social factors influencing the feasibility of a bridge in the locality are:
   - population distribution,
   - location of education facilities such as schools, campuses, technical institutes, etc.,
   - market places, banking, cooperatives and social services facilities,
   - religious sites,
   - industrial plants and handicraft centers,
   - health posts or hospitals,
   - Revenue offices, district administrative headquarters.
3. Trail network

   Main trails are:
   - trails linking regional, zonal and district headquarters,
   - trails linking places of dense population and infrastructures,
   - trails linking important road heads, market places and service centers,
   - trails linking all the above mentioned places with each other

4. River type

The river concerned shall be classified in terms of its size and fordability. The river is:

- Major : perennial and non-fordable throughout year,
- Medium : perennial but fordable with difficult in the dry season,
- Minor : non-fordable during flash floods only.

According to above factors, Main Trail Maps (Transport Infrastructure Maps) were produced by TBS/DoLIDAR. Any bridges on the crossings along the main trail, justifies for LSTB and need not socio-economic study.

The **Strategic Crossings** are defined as per the following socio-economic factors.

- Traffic Volume:

  The daily average volume of people and animals should be minimum 400. The traffic should comprise at least 20% porter or pack animal.

- River Type

  The river type should be Major or Medium.

If the crossing fulfills the above criteria it can be classified as strategic crossing and a LSTB bridge is considered to be socio-economically feasible.

1.2.2.2 Planning of Short Span Trail Bridges (SSTB)

These bridges are significantly cheaper than LSTB bridges. The technology is based on local skill and maximum use of local materials, hence can be built by the community themselves (hence, it is named as community bridges). Therefore, with SSTB high number of bridge request can be fulfilled with the available resources.

Nevertheless, these bridges also have to satisfy the defined socio-economic factors as described bellow.

a. Socio-economic feasibility

The following information is collected for the socio economic feasibility under the decentralized planning.

1. The geography of the prospective bridge, which shall include the location of the site, river name, crossing name, names of DDCs, VDCs, ward numbers and Ilaka numbers on both banks.
2. The information of nearest crossing facility to the proposed site. The purpose of the proposed site in accessing market, health centers, schools, road-heads, public service centers and important objects.
3. Information on previous attempts or initiatives for the construction of a bridge at this site.
4. Information related to estimated bridge span, location of road head and portaging distance from road head to the site.

6. Information on direct benefiting populations by collecting number of households and population.
7. Information on participation of communities; the number of people determined authentically to take interest on the bridge this or that way.
8. Any disputing issues on the proposed bridge site in past or at present.
9. Commitment of financial contribution from different stakeholders.

b. Criteria for prioritizing bridges

The criteria for prioritizing bridges is worked out giving “prioritization-weight” in a scientific way, by simply putting bridges in order of highest to lowest weight. The weight is based on a simulation technique accounting for factors such as benefiting population, access to markets to enhance local economics, dispensaries and schools as well as poverty orientation, gender and marginalized population and geographic condition. The marginalized people include small farmers (food sufficient up to 3 months) and occupational caste/dalits. The weights of different bridges are relative indicators of the importance of the bridge compared to one another. Weight by itself has no significances.

The effective weight to prioritize bridge is based on the following formula:

$$\text{Total weight} = \{(2.041\ P + 2.856\ MP) \times DG\} \times \{(12 - RT) \times (1 + RF/100)\}/12$$

Here,

P	Number of people (population) directly benefiting from the prospective bridge
MP	Number of marginalized people
DG	Distance gained in hours by having a bridge. The difference of distances between the current nearest crossing and the proposed site in multiplication of individual group and division by total sum of population gives the distance gained.
RT	Number of months the river can be crossed without a bridge.
RF	Risk factor: estimated % of benefiting population that succumbed over the last five years.

1.2.3 Social Organization Support

The communities (users) themselves with the support of BBLL have constructed thousands of trail bridges in the country within a decade. On the basis of experience of past support to the communities and local authorities, DoLIDAR with support of BBLL/TBSSP has published a manual on social organization support (SOS manual). This manual provides the communities and local government authorities to process the bridge construction program from its planning to implementation. The manual is in two volumes.

The volume – I contains:
1. Orientation on Community bridge building
2. Planning and Coordination of a trail bridges
3. Local resource mobilization
4. Monitoring and quality control
5. Construction management
6. Record keeping and accountability
7. Post construction measures
8. Reporting system

The volume – II contains:
1. The identification of bridge necessity
2. Pre-feasibility study and prioritization
3. Formation of users committee and social organization support
4. Social assessment and survey of bridge site
5. Community agreement and bridge layout
6. Local resource mobilization
7. Demonstration model bridge training
8. Commencement of bridge construction
9. Final checking, formation of maintenance committee and routine maintenance

1.2.4 Future plan

The bridge sites must not be located in area where ongoing or planned road construction activities.It should be assured that the bridge will not be obsolete in the foreseeable future due to such activities.

Similarly, the presence of other infrastructure development projects in the area, which in future, plans to construct alternatives to the proposed crossings, shall be studied and considered.

1.3 CLASSIFICATION OF THE TRAIL BRIDGE TECHNOLOGY

On the basis of planning procedures, technical aspects, construction technology and economic reasons, there are different kinds of trail bridges in Nepal.

i) Local Traditional Bridges

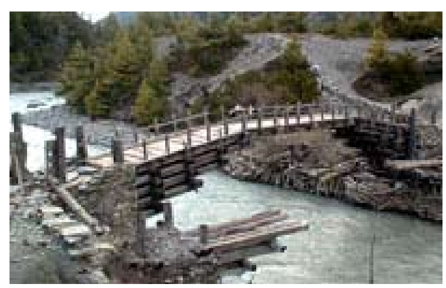
Local Traditional Bridges, built on empirical know-how using people's experiences, are very common in Nepal. Engineering calculations are not done for such bridges and the use of local materials, such as boulder/rock/tree anchors, dry stone masonry or wooden log towers, is a specific feature. The decking is often bamboo and wooden planks.

Local Type Suspension Bridge

The walkway cable and the main cables are both sagging downwards and the sags are different. The towers are usually of small height. They may be wooden pillars or dry masonry or even concrete columns. A typical name, the *Baglung type,* is used for such bridges with towers and foundations made of properly chiseled stones. The elevation of the cable saddles may not be the same on both banks. They extend mostly in the range 25.0 – 75.0 meters. Such bridges are many in Baglung district.

Wooden Cantilever Bridge

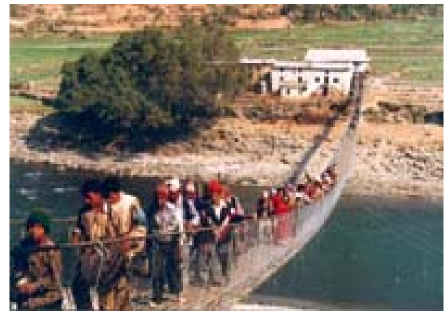
Wooden logs are the main component of the local cantilever bridge. These bridges are quite elaborate and durable. The wooden logs of different lengths are kept fixed to the bank by a counter weight in the form of stone work piers. The cantilevering parts of the logs are arranged one over the other in ascending order of length over the river. The middle gap between the two cantilever arms is decked by a single span log. Such bridges span up to 30 meters. There are many such bridges in the mid-western region of Nepal.



Wooden Log Bridge

The wooden log bridge is the simplest type of river crossing with limited span. The wooden log may be a tree trunk or shaped timber or bamboo.

ii) Modern Trail Bridges



Development of technology for constructing safe, comfortable, durable and economical bridges with sufficient engineering input began with the establishment of the Suspension Bridge Division (SBD). These bridges were designed with detailed engineering calculation as per required norms and specifications. "SBD Bridge Manuals" for the survey, design, standard drawings and execution were prepared in 1983 and are widely used by all bridge builders. These Manuals have been updated and improved continuously as more and more experience is gained. Now, these revised SBD Manuals are newly published as "Long Span Trail Bridge (LSTB) Manuals" (in four volumes).

With the development of the country, the moving-ability of the people has also increased. The demand for trail bridges increased greatly. The realizations of many bridges of local importance were to wait their turn for years in central planning programs. Hence, local communities insisted on constructing these bridges of local importance on their own initiatives.

HELVETAS Nepal (Swiss Association for International Cooperation) undertook a program, popular as the BBLL (Bridge Building at the Local Level), in 1989 to meet the high demand for local trail bridges. The BBLL modeled its design after traditional bridges that used to be built in Baglung. Within a short period of 14 years, more than 1,200 bridges could be completed. The experiences gained in these years led to developing a complementary bridge design of existing SBD standard bridge design. The manuals of this technology are prepared both for suspended and suspension types of trail bridges. The rational behind such types of bridges is its cost effectiveness in compare to SBD standard bridges but limited to the smaller span up to 120m. In the BBLL type of Trail Bridge, the use of local materials and local skills is maximized to make it cost effective and local context friendly.

With the advent of the Local Self-Governance Act 2055, the SBD under the Department of Roads (DoR) has been integrated since July 2000 into the TBS (Trail Bridge Section) of the Department of Local Infrastructure Development and Agricultural Road (DoLIDAR) under the Ministry of Local Development (MoLD).

The bridges developed by the SBD are proven to be suitable and rational only for “long” spans. The SBD standard bridges, therefore, are converted as the "Long Span Trail Bridge (LSTB) standard" for bridges of span more than 120m.

Meanwhile, the design of BBLL type of bridge is further improved and now it is the "Short Span Trail Bridge (SSTB) standard" for bridges of span up to 120m.

1.4 STANDARD BRIDGE TYPES AND DEMARCATION CONVENTION

1.4.1 Short Span Trail Bridge (SSTB)

"Short Span Trail Bridges" are surveyed, designed and constructed on the basis of engineering norms. The use of local materials such as locally available stones is a remarkable feature of the design. The engineering survey, design and construction technology are simplified and can be performed by overseer-level technicians or even by experienced sub-overseers. Many calculations, research work and practical experiences have resulted the simplified calculation methods and development of Standard Designs of SSTB bridges.

Since 2002, after the proven observations, Manuals on Suspended and Suspension types of SSTB Bridge are developed and published. SSTB type of bridge is to be designed for spans of up to 120 meters. The walkway width is 70 cm or 106 cm for suspended and 106 cm for suspension type bridge.

The typical cost of a suspended type bridge of the SSTB standard is NRs. 7,000 per meter span for 70 cm walkway width and NRs. 9,700 (as of Yr.2003/2004) for 106 cm walkway width additional NRs. 600 per man-day porter distance per meter span, The cost of a suspension type bridge is, on the average, 40% higher than the cost of a suspended type bridge.

1.4.2 Long Span Trail Bridge (LSTB)

After some initial support in the first half of the 1960's, "the Swiss" intensified their on-demand involvement with the SBD until 1981. This on-demand support was followed by a more intensive phase-wise support (1981-2001).

"Long Span Trail Bridge Standards" are modified and updated version of the SBD Standard Design. They are now applied only when the span is over 120 meters. The typical cost of a suspended type bridge per meter span is about NRs.20,000 (as of Yr.2003/2004). The cost of a suspension type bridge is, on the average, 40% higher than that of a suspended type bridge.

1.4.3 Demarcation Convention
(As per National Trail Bridge Policy)

The Norms, Standards and Technology shall be applied as follows:

for Spans up to 120 m (120 m inclusive)	Short Span Trail Bridges (SSTB) Norms, Standards and Technology (both Suspended and Suspension Type Bridge) as expressed in the SSTB-Manuals)
for Spans more than 120 m. and less than 350 m ……. less than 275 m …….	Long Span Trail Bridge (LSTB) Norms, Standards and Technology for the Suspended Bridge Type for the Suspension Bridge Type as expressed in the LSTB-Manuals
for Spans up to 32 m (32 m. inclusive)	Steel Truss Bridge