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RESEARCH ARTICLE

Revolutionizing Mountainous Countries' Transportation: CASWAT-G Surface Ropeway for Multifaced Application

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Highlights

- CASWAT-G surface ropeway (CSR) is the first system developed in Nepal
- Application of green energies to CSR makes it independent running system
- Operation of CSR by GPE and leg muscle efforted energy is a special feature
- The CSR is simple, low cost, sustainable, and environment friendly and safe and hence suitable to use in mountainous countries and
- Nation can get benefits in public transport and in tourism by applying CSR system

Abstract

Mountainous regions often present formidable barrier to traditional transportation system, limiting access and impending economic growth. In this regard, a new technology called CASWAT-G (Circulating Cable Supported Up-down Walking Technology by Using Gravity) surface ropeway (CSR) is one that uses simple parts and eases up-down walking because of the harvested gravitational potential energy (GPE) from the descending user. Different prototype test result showed the efficiency of the CSR's machine is above 80%. Technically verified CSR is very much useful to use for transportation to support people living in the hilly region and for the tourism trade. This technology is very simple, low cost, eco-friendly, sustainable and can be set up quickly with minimum environment impact. Its multi faced application can be in the different fields like: public transport, tree climbing, fun and learning for children, carrying goods, and tourism. Based on the Ph.D. thesis and previous papers of mine, the possible application of the work is described in this paper and it contains graphs, calculations, etc. of previous work.

Keywords: *complex terrain, surface ropeway, leg muscle efforted energy (LMEE), gravitational potential energy (GPE), sustainability of CASWAT-G*

Introduction

According to Hoffmann, a ropeway is a system for the transportation of passengers or goods whereby the passengers or goods are conveyed in different types of cars for which the runway is made of ropes (one or two) or rails and concrete carriageways respectively. Out of ropes used in the ropeways' hauling function is carried out by means of one or more ropes [6,7,8].

Among natural green energies, use of non-conventional energy gravitational potential energy (GPE) to produce electricity is mentioned in the paper of Saran and Ghosh [1]. More than 80 % of the total land of Nepal are mountains and are potential areas to

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use GPE for transportation using suitable technology. In applying railways, road, airways, etc. needs high tech and large amount of investment and so the poor situation of connectivity in the area are mentioned in the papers [2, 3]. Limited means of ropeways like tuin, gravity ropeways, aerial cable cars are in operation [4, 5] for the Accessibility. International and national histories are mentioned by Hoffmann [6,7,8] and USAID report [9]. The concept development and prototype tests were started in Nepal and Master thesises were written at Vienna University of Technology (Austria) by Astigarraga and Fartaria [10, 11]. Michailidou and Papakosta also wrote thesis on this technology at AUTH, Greece [12]. Similar to this technology are the transport means mentioned by Harley Trochimczyk, Hill Hiker and Barthelson [13, 14, 15] papers. Paper of Naniopoulos, et al, [18] mentions about the importance of accessible tourism business in Greece and Turkey.

CTS is a surface ropeway to facilitate the overcoming of strong slope's gravity in complex terrain mountainous countries like Nepal. This system is somehow similar to gravity ropeway, funicular, rock climbing securing system, etc. The first concept developed in Nepal by making different prototypes is the first system of this kind [10] in the world which is operated by the harvested gravitational potential energy (HGPE) and leg muscle efforted energy (LMEE. The system is useful for the hilly countries' sites for walking upwards and downwards and to transport goods.

Theory and working principle of CSR

The fundamental theory and working principle of the system is given as follows:

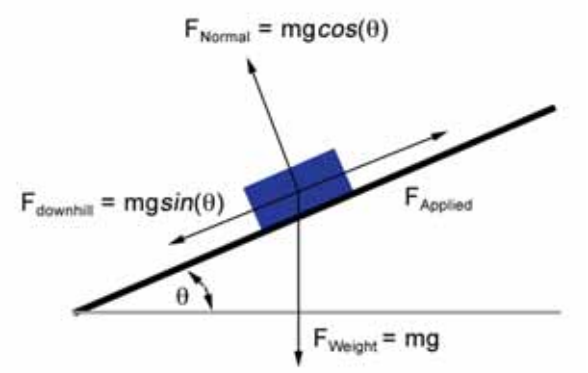

Fig 1. Gravity and its component forces on a body lying on a slope [19]

In fig.1, the cosine component force represents the leg muscle force (LMF) = of both ascending person (AP) and descending person (DP). Similarly, the sine component force represents the harvested gravity force (HGF) = which is used by AP while walking. There is balance of the sum of these forces with the total force = given by equations 1 and 2 where m is the mass of descending user or ascending user (DP/AP) standing on a surface with a slope angle = θ and g is the acceleration due to gravity.

$$(mg)^2 = (mg\ sin\ \theta)^2 + (mg\ cos\ \theta)^2 \qquad (1)$$

This in the form of total energy (= mgh), leg muscle efforted energy (LMEE= $mgh\cos\theta$) and harvested gravitational potential energy (HGPE=) [i.e., multiplying each term by 'h'] is given by the following equation [17]:

$$(mgh)^2 = (mgh\sin\theta)^2 + (mgh\cos\theta)^2 \qquad (2)$$

where h is the vertical height from m to the horizontal line of the triangle in Fig 1.

HGF from both users AP and DP have special uses i.e., HGF from DP is utilized to pull AU upward while HGF from AP is utilized to balance DP's weight. In such a gravity balance, DP and AP use very comfortable LMF to walk up and down. However, the system fails to give its service in the absence of either AP or DP. In such case small engine in comparison to the engine used in aerial ropeways can give its reliable service to the users**.**

Material and Method

The required materials are very simple for its construction since the system is setup on the surface and need not to be so sophisticated to maintain high safety like in aerial ropeways. The material required for the simplest form of CASWAT-G Transportation System

(CTS) is one that uses simple parts like: two bull wheels (BW), two BW supporting structures, one circulating cable (CC), two body connecting cable (BCC), special belt for the users, and two shades for the protection of the up and down stations. By using these materials, the system's set up is as shown in fig 2 and Fig.3 and it ready to use by the users. In above equations 1 and 2, HGPE helps to pull AP that is harvested from DP. The use of LMEE is to push both AP and DP forward. Harvest and use of GPE and LMEE are simultaneous process which mean that HGPE cannot be stored. mg, h, and θ are measured by using digital weighing scale, slope measuring scale developed by the researcher, and h by supplying the value of θ and walking slope distance measured by measuring tape [17] as mentioned in the previous papers and data are used for calculation, drawing graphs, etc.

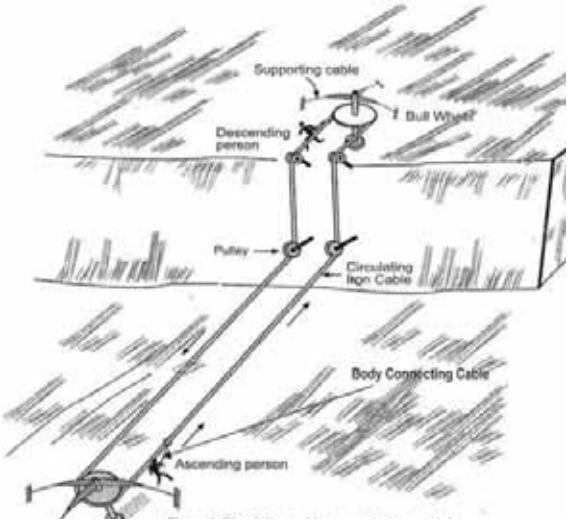

Fig 2. Schematic diagram of CASWAT-G system [22]

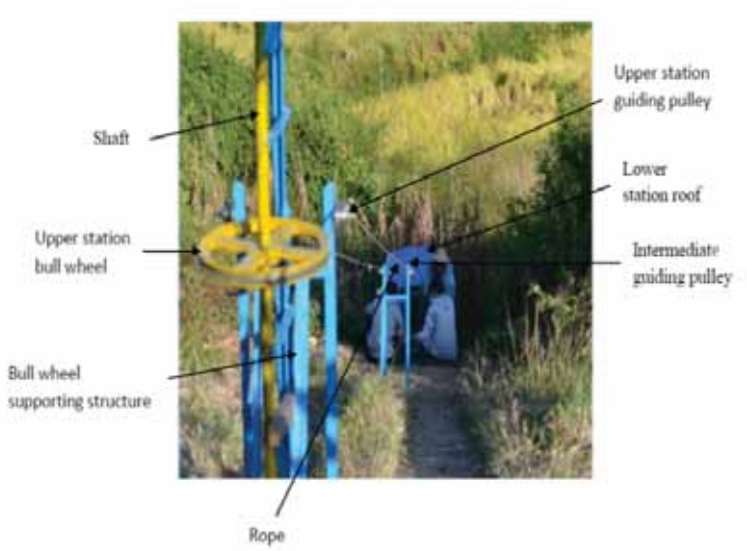

Fig 3. CASWAT-G Surface Ropeway System (length=18m) setup at CEDA of TU, Kirtipur, Nepal (2014)

Results and Discussion

The result shown in graphs are discussed in brief as follows:

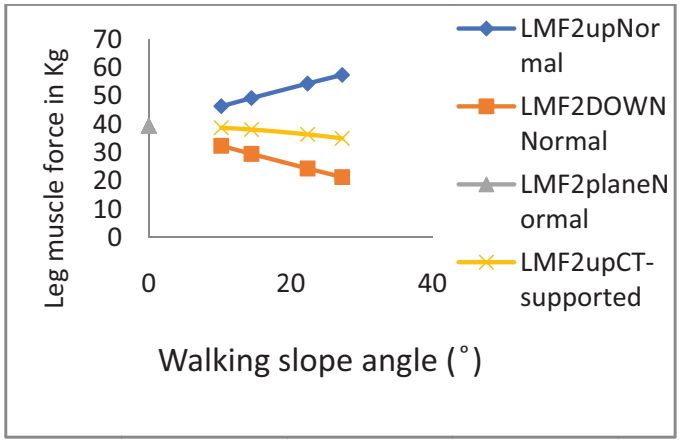

Fig 4. Variation of leg muscle force with walking slope (M_2 =64.5 kg is balanced by M_1=55.5 kg) [22]

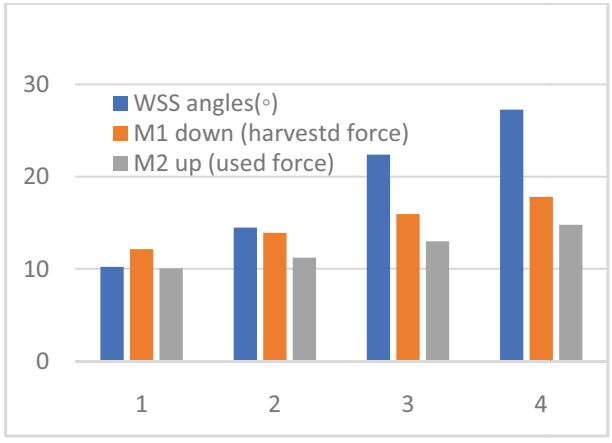

Fig 5. Walking surface slope (wss) vs harvested and used forces.

Fig.5 shows the four cases i.e., 1,2,3 and 4 in which harvested and used forces rise with the rise of walking surface slope (wss) and also in each cases harved forces are larger than used force indicates the loss on the harvested force due to frictional force on the pulleys. This indicates that force can be harvested from the user using CSR which can be used for pulling the AP.

The line for leg muscle force using CASWAT-G supported upward walking (LMF2up CT-supported) in Fig.4 shows below the line of normal leg muscle force walking on the plain surface (LMF2plain Normal) which means walking upwards on a slope land using CSR is even easier than walking on the plain land surface.

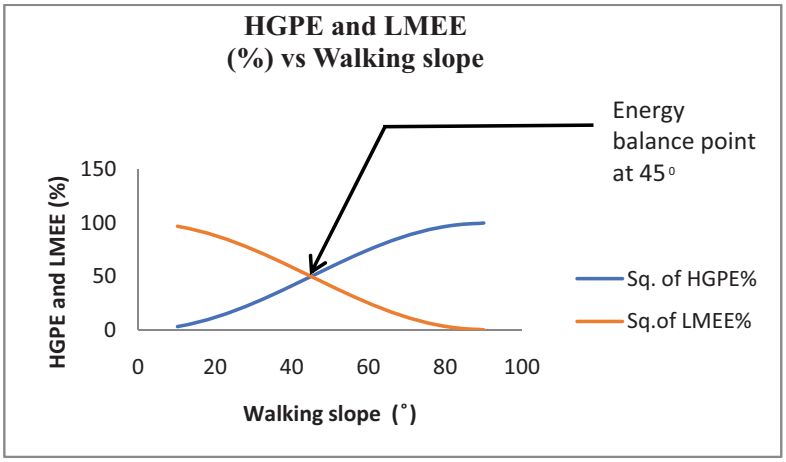

Fig 6. Energy balance between harvested GPE (HGPE) and leg muscle efforted energy (LMEE) [22]

Fig 6 shows the plot between harvested GPE (HGPE) and leg muscle efforted energy (LMEE). In this figure at zero walking slope no HGPE i.e., HGPE= 0 and the user has to apply cent percent LMEE to walk. As walking slope increases, HGPE increases and LMEE decreases which means leaser amount of LMEE has to apply for walking. At 90-degree slope, HGPE becomes 100 percent and LMEE decreases to zero. For ideal case, ascending person can climb without applying LMEE which is the case of tree climbing. Hence this graph is useful in explaining plain land walking to tree climbing or in other words CSR can give its service for slope land walking to tree climbing with lesser LMEE.

Application

While using the system, HGPE is the case from DP which is used by AP for comfortable upward walking. Similarly, GPE harvested from AP is used for controlled walking of AP and DP. Results shows that CSR can be applied for different purposes with its suitable mechanical structural design explained (i.e., CSR for slope land is one type shown in fig 2 and 3, for tree climbing vertical CSR is suitable and for carrying goods, railway track with trolley is necessary) as follows:

1. **Public Transportation:** By setting up CSR in the hill or mountains, general public can use it for walking upwards and downwards in a comfortable way because of the use of harvested GPE. One of the systems developed as shown in Fig. 3, having length=18m was setup at CEDA of TU, Kirtipur, Nepal (2014). The system used to pull AP by harvesting GPE using DP's body weight for comfort ascending of AP and harvested GPE from body's weight of AP was used for controlled walking of DP.
2. **Transporting Goods and Disable People:** By laying a simple rail to run trolleys on it to both sides of the track, the system can be used for carrying goods and disable people in the hilly land. While doing so, a part of the descending load's harvested GPE is used to pull goods to upward destination and there will be energy saving in the fitted machine in one of the stations of the system. Fig.7 shows a model rail line structure which was used to carry good at one of the Pashupati jungle premises temples. However, the rail line for the CSR differs from the one shown in fig.7. This is because the walking surface for the users and goods carrying rail line must be on the same surface level.

Fig 7. shows a rail structure which was used to carry construction materials in one of the temples of Pashupati jungle.

Fig 8. Tree climber at the top of the tree seeing view of the nature [16].

3. **Personal Use:** The CSR system is simple, cheap, eco-friendly, and covering small walking trail of about 1.25m and hence is affordable for personal use. So even individuals can also implement the system for their personal use for short distance within their farm or to make access for themselves to the nearest main stream of transportation system of the nation.

4. **Tree Climbing:** By setting CSR on a tree, tree climbing (TC) can be for public use which means here as a sport in a public place. It can be used to run TC business in a public place by choosing a suitable tree to fit system. Farmers can use the system for picking fruit in their fruit farms, cutting grass on a tree, make tree hive, tree top café (Fig.8), etc.

   McDermott mentions TC as the sport and if it grows, ecologists and climbers grapple with the implications [16].

5. **Fun and Learning for Children:** Fun here means, while using CSR for up-down walking or tree climbing is so easy that children will feel the activities as fun and can be considered as a sport. While using this system, school children can get enough fun and they will learn the practical role of gravity to the transport mode like CSR.

6. **Tourism:** Above mentioned uses of CSR, it can be applied to tourism for various adventurous purposes which can enhance the business in this field. Extra use in this field is that it can be used for climbing, canyoning, conducting businesses like tree top café, tree hive, etc. as follows:

   i. **Trekking and goods supply:** Like public transport mode mentioned above, it can be applied to the trekking routes having difficult high slopes to be overcome without such technology or other means of transport modes. Similarly, goods needed to tourists to these routes can be transported as mentioned above.

   ii. **Climbing:** By setting up the CSR, it can be used to climb snowy mountains or to climb rocks. This system can be used by a single user by using a counter weight (or a small engine) to support DP's or AP's descending or ascending respectively.

   iii. **Canyoning:** Canyoning is a type sport to explore canyon by rappelling, rafting and jumping into fast flowing mountain streams or waterfall. Such sport is very popular in the European Alps in the summer time (fig 7). This type of canyoning is possible in Nepal and are in practice in some site of the nation (Fig.6). The use of CRS in this field can give extra service, fun or adventure in canyoning business [20,21].

Fig 9. canyoning in Nepalese waterfalls, Jalbire, Chitwan [20].

Fig 10. Group of canyoners with necessary canyoning gears wearing on their bodies (Photo: Pureelements) [21]

   iv. **Tree Climbing:** TC can be made of a great importance in tourism too by making tree top café like shown in above Fig.8, tree hive, develop see-saw type fun by DS and AS. For single use, TC can be made possible using counter load.

By applying the system in different field mentioned above, following result can be expected which are discussed below:

Public Transportation: Practical use of the system in the public places in the mountainous countries has high potentiality to make it as a sustainable alternative transportation mean and to make access to the main stream of transportation system of the nation. **Transporting Goods:** By fitting the suitable and simple almost similar to rail explained in the fig.4, the system can be used for carrying goods in the hilly land. Thus, the system can provide facility for transporting goods (like agriculture products in the villages and the necessary product available in the market) from and to the settlement up and down. **Personal use:** Simple CSR system is affordable for even individuals so they can also implement the system for their personal use for short distance up-

down walking purpose within their farm or to make access for themselves to the nearest main stream of transportation system of the nation. **Tree climbing (TC):** Can be for public use as a sport in a public place and to run TC business like tree hive, tree top cafe, viewing surrounding nice views, etc. Farmers can use the system for picking fruit in their fruit farms, cutting grass on a tree of even high enough height. **Fun and Learning for Children:** While using this system, school children can get enough fun and they will learn what is gravity and its function to the transport mode practically and how GPE can be harvested by using CSR.

Tourism: Above mentioned uses of CSR can be applied in tourism sector too for various adventurous purposes which can enhance the business in this field. Extra use in this field is that it can be used for climbing, canyoning, conducting tree top café, tree hive, etc. businesses can give different benefits discussed as follows: **Trekking and goods supply:** By setting up the CSR in trekking routes, it can provide easy up-down walking to tourists as well as transporting goods necessary to these areas. There can be high flow of tourists due to easy access to high mountainous areas which means tourism business can grow drastically and economy in these areas will go high. **Climbing:** By applying CSR to climb snowy mountains or to climb rocks, tourists can experience extra adventure. This type of use in this field can grow business in a different way giving extra economic benefit. **Canyoning:** Traditional canyoning is a sport to explore canyon through activities like rappelling, rafting and jumping into fast flowing mountain streams or waterfall water in a downward direction but on applying CSR, canyoning can be made possible in upward direction which give extra adventure and fun to canyoners. Even physically weak people can involve themselves in such sport and there will be extra more numbers of canyoners in this field giving rise to extra grow of canyoning business i.e., more earning.

Tree Climbing: TC is a very popular sport and can be made of a great importance by applying CSR in tourism for fun like: making tree top café, tree hive, develop see-saw type fun by DP and AP. Even physically weak people can involve themselves in such sport and there will be extra more numbers of tree climbers in this field giving rise to extra grow of TC business i.e., more earning.

Conclusions

From above result and discussion, we can draw three conclusions as follows:

i. **Conclusion to CSR System**

   From above results and discussion, CSR can harvest enough HGPE from DP/or descending load which can be used to pull AP or ascending load and this helps to develop different mechanical structural design and construction of CSR for multipurpose use.

ii. **Conclusion of CSR System's Application**

   This paper and already verified (practically and theoretically) simple, cheap and environment friendly CSR system can have uses for multipurpose and nation can get enough benefit by applying it for public, personal and tourism sector use. The system can provide its alternative service to rural hilly people who are out of reach to the main stream of the nation's transportation system. Goods and even disable people can be transported by developing and laying railway tracks on the same walking trail of the CSR system. Children can learn the practical use of gravity i.e., GPE and can enjoy the up-down walking fun.

   The system can be used in the mountain tourism like: transporting goods and tourists (including bungy jumpers and gliders), canyoning, climbing rocks and mountain, tree climbing, etc.

iii. **Benefit for Mountainous Countries**

   These potential areas that use CSR system will have economy growth through mobility of mountain people which gives rise to enhance their quality of life i.e., good health service, good education, empowerment, employment, etc.

Thus, the system could have multifaced application which can revolutionize mountainous countries' transportation system.

Recommendation

Surface ropeway technology like CSR should be promoted by stockholders of mountainous countries of the world as follows:

- Government who can implement CSR in large scale everywhere in hilly land of the country,
- Community, NGO and INGO who work for the society and
- Even individuals can also implement the system for their personal use for short distance within their farm or to make access for themselves to the nearest main stream of the nation's transportation system.

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