ENVIRONMENT-FRIENDLY CASWAT-G SURFACE ROPEWAY TRANSPORTATION SYSTEM: A PROSPECTIVE APPLICATION IN ENHANCING THE MOUNTAIN PROSPERITY

L. B. Baral[1,2] *, J. J. Nakarmi[1], K. N. Poudyal[3,+], N. R. Karki[3], D. Nalmpantis[2], H. B. Dura[3], V. Amatya[3]

[1]Central Department of Physics, Tribhuvan University, Kathmandu, Nepal

[2]School of Civil Engineering, Faculty of Engineering, Aristotle University of Thessaloniki, PO Box 452, 541 24 Thessaloniki, Greece

[3]Institute of Engineering, Tribhuvan University, Pulchok, Lalitpur, Nepal

(lokbaral@gmail.com)

ABSTRACT

Circulating Cable Supported up down Walking Technology by Using Gravity (CASWAT-G) is a surface ropeway that harvests gravity and uses it along with the use of leg muscle force to operate the system. When both sides' users are connected to a Circulating Cable (CC) and take the support of it, gravity balance is created by the harvested gravity of each user. At such a balance condition, users apply gentle leg muscle force for easy upwards and downwards walking, encouraging users to climb even difficult mountains. This type of ropeway's principle is somehow similar to funicular and ski lift systems and has an efficiency of more than 80%. The measurements carried out showed that the normal upwards or plane surface walking force is larger than the Circulating Rope (CR) supported upwards walking force. This means that CR supported walking under gravity balance is easier than normal upwards or plain surface walking. CASWAT-G system is fast, simple, cheap, efficient and environmentally friendly and it is useful in providing transportation facilities to people living in hilly areas as well as a recreational facility to tourists climbing to these areas.

KEYWORDS

CASWAT-G; Circulating rope supported walking; Environment-friendly surface ropeway; Gravity harvester; Leg muscle force

1. INTRODUCTION

Green and renewable forms of energy like solar, hydro, wind, tidal, geothermal, gravitational, etc. are available in nature. Enormous amounts of non-conventional energy, like geothermal and gravitational, are freely available all around the year, day, and night. Saran and Ghosh (2018) [1] mentioned the use of non-conventional gravitational energy to produce electricity to solve the energy crisis and to protect the environment. Our work focuses on using Gravitational Potential Energy (GPE) for providing alternative sustainable transportation facilities to people living in mountainous areas.

The geographical condition of Nepal has diversity, with slightly over 80% of the land being covered by rugged hills and a series of mountains. Due to high elevation ranges, i.e., 60.0 m to 8,848.0 m, modern transportation techniques like railways, ropeways, airways, etc. are not easy to implement [2]. The paper of

Bhandari and Nalmpantis (2018)[3] has mentioned the poor situation of the hilly and mountain life of people of Nepal due to inaccessibility in the rugged mountain terrain. Such areas face many problems in providing basic needs like sufficient food, healthcare, education, and transportation service. Limited service is provided by alternative means like ropeways (surface and gravity) and the river crossing Tuin technology[4,5] Hoffmann (2006, 2009, 2012) [6-8] has mentioned in his papers the history of ropeway from the beginning of the invention of rope and ropeway as a transportation mode that can be found as early as 250 BC in China. Likewise, the "history of ropeways in Nepal began in 1922 by building a 22 km long cargo ropeway with the financial and technical assistance of the United States Agency for International Development (USAID)" [9,10]. Nowadays, Nepal has three passenger aerial ropeways and more than 21 gravity ropeways [2].

The main innovation work of the system started in Nepal, and later on, the development of the system design work was carried by two students from the Vienna University of Technology, Austria, wrote their theses on the engineering part of the system, and their contribution is very high[11,12]. Likewise, there are two other students from the Aristotle University Thessaloniki, Greece, who experimented on this system, testing its reliability and wrote an extended essay[13]. The system is similar to the funicular cableway system that works in combination with wheeled cars attached to the ends of a cable that run on the railway tracks laid on steep inclines[14,15]and ski lift which is a class of ropeway driven by a motor, which is a conveyor system used to safely and reliably transport skiers and sightseers to the upper point of the mountain on the line [16]. The transportation system resembles the funicular in harvesting the GPE of descending load and its pulling action is similar to the surface ski lift.

2. METHODOLOGY

2.1 Theory and working principle

Considering Fig. 1, we know that the gravitational force of a body lying on a slope angle 'θ' has two components: "the sine component, mg(sinθ), parallel with the slope and the cosine component, mg(cosθ), which is equal to the normal component, as shown in Fig. 1" [9].

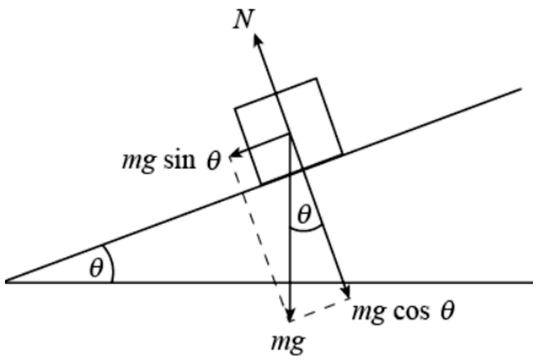

Figure 1. The two components of weight.

With vector addition of forces follows (Eq.1):

$$mg\cos\theta = mg - m(+g)\sin\theta \quad (1)$$

F_d, i.e., the downward force (Eq. 2), including 'μ', i.e., the coefficient of friction between the block and the slope surface,

$$F_d = \mu mg\cos\theta = \mu mg(1-\sin\theta) \quad (2)$$

and for upwards motion (with -g) of the block, the upward force F_u can be written as (Eq. 3):

$$F_u = \mu mg\cos\theta = \mu mg(1+\sin\theta) \quad (3)$$

The force F_p, for plane surface motion can

be written as (Eq. 4):

$$F_p = \mu mg \quad (4)$$

where:

m: the mass of the descending or ascending person,

g: acceleration due to gravity,

θ: the slope of the land, and

the terms in the above equations, i.e., F_d, F_p, and F_u, represent the Leg Muscle Forces (LMF) for downward, plane, and upward directions, respectively.

The efficiency (η) of the system is given as follows (Eq. 5) [9]:

$$\eta = \frac{output\ force}{input\ force} X\,100 = \frac{F_{AP}}{F_{DP}} x\,100 \quad (5)$$

Where F_{AP} is the force applied by the Ascending Person (AP), and F_{DP} is the force applied by the Descending Person (DP) while walking.

These equations can be used to calculate the required LMF in normal upwards and downwards walking in an inclined and in- plane surface.

2.2 CASWAT-G and its working principle

The CASWAT-G surface ropeway transport system is operated by LMF and gravitational force. Like in funicular or gravity ropeways [17,18] part of gravity harvested by the DP is used to pull the AP upwards, which eases each other's upwards and downwards walking. CASWAT-G system, as shown in Fig. 2, resembles the funicular and ski lift system.

The Circulating Cable (CC) acts as a hauling rope which circulates one meter above the ground between two bull wheels. These bull wheels are fixed on the supporting structures on the top and the base of a sloped walking surface. The width of the walking surface is 1 m (Fig. 2 and Fig. 3). In the case of two users who are connected to the CC by a Body Connecting Cable (BCC) and are taking support by it while one is walking upwards and the other downwards, there will be a balance of gravity, due to the harvested force, which will keep them at rest. They will feel light, partly due to their body's weight that is given to the CC. Part of the gravity is transferred to the CC, and while in operation, gravity balance is created among the users on both sides. At this condition, the users feel like walking in- plane surface, which eases the upwards and downwards walking, as shown in Fig. 2 & Fig. 3.

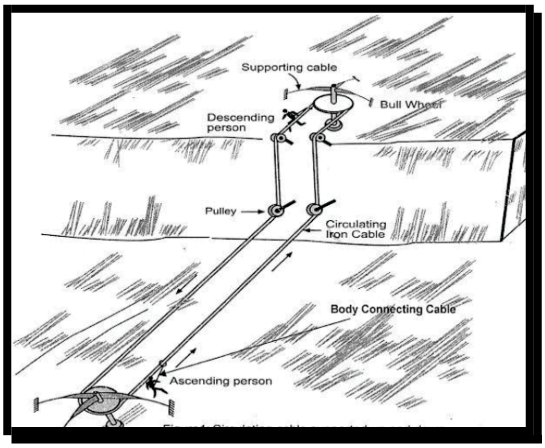

Figure 2. CASWAT-G schematic diagram [13].

Figure 3. CASWAT-G experimental prototype [13].

This study uses two users weighing 64.5 kg and 55.5 kg, while μ=0.61. A Main Digital Weighing Scale (MDWS) and an Individual Digital Weighing Scale (IDWS) were used to measure the total and individual tension of the users, respectively, and the observed data for four slopes were used to draw and graphs and to calculate the efficiency of the system. Graphs of normal LMF versus different walking slopes were plotted for upwards, plane, downwards, and circulating rope supported walking. As shown in Fig. 2 & Fig. 3, the system requires a track width of 1 m, two (2) pulleys of diameter 120 mm, one (1) CC of 6 m length and 6 mm diameter, two (2) plastic BCC of 1.5 m, supporting structure (even a tree stem). Users are connected to both ends on both sides of the cable (that circulates between the upper and lower pulleys) by the BCC. When they start walking, gravity from the DP is harvested which is simultaneously used by the AP to be pulled up. Such harvested gravity in the form of GPE along with the applied Leg Muscle Efforted Energy (LMEE), is utilized to operate the system. Measurement of gravity, land slope, track length (6m) and width of 1 m is used for the study.

3. RESULTS

Variations of the LMF with walking slopes are shown in Fig. 4 and Fig. 5. In Fig. 4, variations of the LMF with walking slopes for the AP=64.5 kg and the DP=55.5 kg are shown. In this figure, harvested force by the DP is found to be larger than the force used by the AP and the lines are almost parallel.

This fact applies for any pair of users regardless of the weight differences [9], which means that larger harvested force by the DP can pull an AP of any weight as long as the system can be run by these forces. The harvested force of any magnitude can contribute to pull an ascending user of any weight ensuring the easy ascension which also means that the same amount of force is applied by the AP to control the DP's accelerated motion ensuring the easy descend. So, both the ascender and the descender have easy walking.

In Fig. 5, the situation of the LMF for a normal walker as well for a CASWAT-G supported (CT supported) walker with AP=55.5 kg is shown for which DP=64.5kg, i.e., the situation of normal downward, plane, and upward walking forces, including CASWAT-G supported walking force, are shown.

At the condition of gravity balance (CT supported), walking by applying LMF is easier than the in-plane surface, as shown in Fig. 5. In Fig. 5, the CT supported line (LMF1up CT-supported) lies between the plane and downwards of the normal walking line. This implies that the LMF for CASWAT-G supported walking is even less than the LMF for normal plane surface walking. This is due to the different gravity (i.e., less gravity) balance under the CT supported system. This result is very important regarding the implications of such a system in providing easy walking as sustainable alternative transportation means to people living in the mountains. In Fig. 5, the LMF line in CT supported walking is slightly less than plane surface normal LMF. It is significant for a higher walking slope angle. In this case, "no external force is required to operate the system, provided there is sufficient weight of the DP available to pull the AP" [9].

From the results and discussion, it is obvious that this technology can be used in the daily life of inhabitants and tourism for climbers. This system "is simple, cheap, eco-friendly, and requires very mild LMF to walk upwards and downwards" [9].

The materials used are simple with fewer parts means cheaper, efficient, emission- less (operated by gravity and LMF only), environment friendly, i.e., small track of 1 m and can be fitted inside the jungle without cutting of trees, safe (since it is a surface ropeway system), quick in installation, and can be made door to door for household purposes, and peak to peak for mountain tourism. The efficiency of the system is above 80% [19].

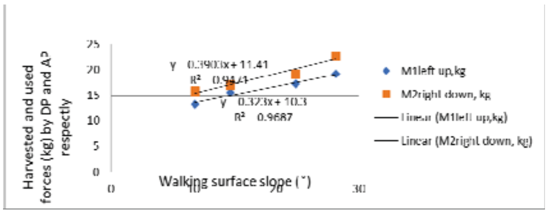

Figure 4. Walking surface slope vs. harvested and used forces by DP=55.5 kg and AP=64.5 kg respectively.

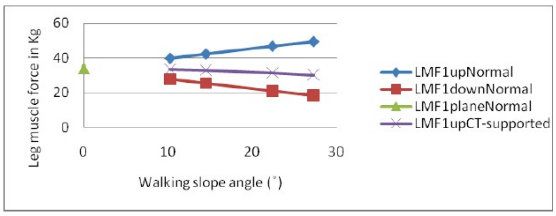

Figure 5. Variation of LMF with a walking slope for the AP and normal walker=55.5 kg for which DP=64.5 kg.

4. DISCUSSION

The system can be used as an alternative transportation system in hilly lands. The advantage of using the CASWAT-G system is that it uses gravity as energy for its operation. By installing the system in a public track route, it can be used as an alternative transportation mode for ordinary people. Since the system is very simple with low installation costs, every household can set up the system in order to be able to move upwards and downwards at their agriculture farm and to connect their houses with the primary mode of transport for short-distance use.

The CASWAT-G system is similar to ski lifts in towing action: particular with rope tows, T-bars, J-bars, and disc-bars.

Likewise, harvesting GPE from his/her own body's weight by the DP and using it to pull the AP upwards, the CASWAT-G system is similar to harvesting GPE from the descending load of the carrier and using it to lift the ascending load in the funicular. Since the lifting action is similar to the ski lift, the recreational use of the system like ski lift in skiing, snowboard, hiking, climbing, etc. Some more recreational uses of the system can be tree climbing (verified already by experiment), rock climbing, canyoning, trekking, etc., should not be doubted.

The CASWAT-G system can attract more tourists who love hiking, climbing, and trekking in a mountainous country like Nepal. Moreover, the use of the system could help the tourism industry in these areas. It can also be installed in rock climbing sites by developing suitable gears. Tree climbing, in the case of vertical climbing, is another possible application of the CT system. Especially children will be delighted to use the system. So, the children at school age can have better chances to learn about gravity and its function. This can give a scientific and experiential dimension in teaching and learning about gravity.

Apart from children, CASWAT-G could be used in tourism, assisting the elderly and People with Disability (PwD) in particular areas of accessible tourism sites[20]. Moreover, it could be incorporated in the general economic growth and resiliency plans of regions of interest [21]. So if the system is applied to mountainous settlement and every peak, there will be the accessibility of government facility of food, health, education, employment, etc. and there will be economic activities (by tourism trade, selling agriculture products, etc.) giving rise to the growth of mountain economy. This means there is a possibility for the prosperity of mountainous areas.

5. CONCLUSIONS

CT supported surface ropeway walking is like normal plane surface walking but with much less LMF effort than in-plane surface walking. This is due to gravity balance rope support with a sufficient supply of harvested GPE from the DP. So, people interested in mountain tourism can enjoy using it. It is obvious from the results that this system is very useful in mountain areas to provide transportation facilities in a simple, cheap, and efficient way with negligible environmental impact. For the inhabitants, it can serve as an alternative sustainable transportation means. At the same time, for tourists, it can be a recreational means for climbing, trekking, lifting, etc. which can enhance the tourism industry of mountainous countries. So, the CASWAT-G system, if applied, can raise the livelihood of the mountainous people through the growth of tourism and agricultural economic activities.

REFERENCES

[1] Saran, S. S., Ghosh, A., 2018, Production of electricity by using gravitational and magnetic energy. In *Proceedings of the 2018 International Symposium on Devices, Circuits and Systems (ISDCS2018)*, Howrah, India. pp. 1–5. https://doi.org/10.1109/ISDCS.2018.8379 669

[2] Karkee, R., Khadka, S., Gautam, S., 2015, Introducing a modified water powered funicular technology and its perspective in Nepal. *International Journal of Science and Technology, 4* (8), 412–419.

[3] Bhandari, S. B., Nalmpantis, D., 2018, Application of various multiple criteria analysis methods for the evaluation of rural road projects. *The Open Transportation Journal, 12,* 57–76. https://doi.org/10.2174/18744478018120 10057

[4] United Nations Environment Programme, 2001, *Nepal: state of the environment 2001.* Khlong

Luang, Thailand: United Nations Environment Programme. http://www.rrcap.ait.asia/Publications/nepal%20soe.pdf

[5] Practical Action Nepal Office, 2010, *Technical guidelines for gravity goods ropeway.* Kathmandu, Nepal: Department of Local Infrastructure Development and Agricultural Roads (DoLIDAR). https://infohub.practicalaction.org/bitstream/11283/314531/1/4de576a7-9534-4e43-8522-1a942e33baf9.pdf

[6] Hoffmann, K., 2006, Recent developments in cable-drawn urban transport systems. *FME Transactions, 34* (4), 205–212. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.970.5258&rep=rep1&type= pdf

[7] Hoffmann, K., 2009, Oscillation effects of ropeways caused by cross-wind and other influences. *FME Transactions, 37* (4), 175– 184. https://www.mas.bg.ac.rs/_media/istrazivanje/fme/vol37/4/03_khoffmann.pdf

[8] Hoffmann, K., 2012, Ropeways from their origins up to the 3rd millennium. In S. Bošnjak, G. Kartnig, N. Zrnić (Eds.), *Proceedings of the 20th Conference on Material Handling, Constructions, and Logistics (MHCL'12)*, Belgrade, Serbia: University of Belgrade. pp. 13–24.

[9] Baral, L. B., Nakarmi, J. J., Poudyal, K. M., Karki, N. R., Nalmpantis, D., 2019, Gravity and muscle force operated surface ropeway: an efficient, cheap, and eco- friendly transport mode for mountainous countries. *The European Physical Journal Plus, 134* (2), 55. https://doi.org/10.1140/epjp/i2019- 12438-0

[10]Cableways Development Consortium, n.d., *Past history of ropeway in Nepal.* http://www.ropewaycablecar.com/about-_us/past-history-of-ropeway-in-nepal

[11]Astigarraga, D., 2011, *Personal transportation system for underdeveloped hilly countries*. BSc thesis, Vienna University of Technology (TU Wien), Vienna, Austria.

[12]Fartaria, L. A. J., 2011, *Energy systems for transportation technologies*. MSc thesis, Vienna University of Technology (TU Wien), Vienna, Austria. https://ria.ua.pt/bitstream/10773/8726/1/5901.pdf

[13]Michailidou, E., Papakosta, N., 2015, *CASWAT-G the individual transportation system in areas with large slopes*. Undergraduate course essay, Aristotle University of Thessaloniki (AUTh), Thessaloniki, Greece.

[14]Harley-Trochimczyk, A., 2009, The fun of funiculars. *Illumin, 10* (4). https://illumin.usc.edu/the-fun-of- funiculars/

[15]Hill Hiker., n.d., *Best funicular systems.* https://hillhiker.com/funicular/

[16]Barthelson, K., Darhele, S., Mitra, M., Sondhi, P., 2018, *Design of a ski lift inspection & maintenance system* (INSPEX final report). Fairfax, VA: George Mason University. https://catsr.vse.gmu.edu/SYST490/495_2018_SkiLift/SkiLift_Final_Report.pdf

[17]Hada., 2009, *Gravity goods ropeways of Nepal: a case study.* Kathmandu, Nepal: n.p.

[18]Parikh, P., Lamb, A., 2015, *Trade and mobility on the rooftop of the world: Gravity ropeways in Nepal.* Barcelona, Spain: Global Dimension in Engineering Education. http://hdl.handle.net/2117/89136

[19]Baral, L. B., Nakarmi, J. J., Poudyal, K. N., 2017, Harvested gravitational potential energy for mountain transportation and for calculating the efficiency of CASWAT-G machine. *Research Journal of Physical Sciences, 5* (4), 1–6. http://www.isca.in/PHY_SCI/Archive/v5/i4/1.ISCA-RJPS-2017-005.pdf

[20]Naniopoulos, A., Tsalis, P., Nalmpantis, D., 2016, An effort to develop accessible tourism in Greece and Turkey: the MEDRA project approach. *Journal of Tourism Futures, 2* (1), 56–70. https://doi.org/10.1108/JTF-03-2015-0009

[21]Angelidou, M., Balla, C., Manousaridou, A., Marmeloudis, S., Nalmpantis, D., 2018, Spatial planning for urban resilience. Assessing current prospects through a multilevel approach and a use case in northern Greece. *Regional Science Inquiry, 10* (3), 33–45. http://www.rsijournal.eu/ARTICLES/December_2018/2.pdf