Simple and Low Cost Environmentally Friendly CASWAT-G Surface Ropeway Transportation System for Mountainous Countries

Lok B. Baral¹, ², ³*, Jeevan J. Nakarmi², Khem N. Poudyal⁴, Nava R. Karki⁴, Dimitrios Nalmpantis³, V. P. Amatya⁴, Hari B. Dura⁴, Chandan Sah⁴

¹ Department of Physics, Amrit Campus, Tribhuvan University, Kathmandu, Nepal
² Central Department of Physics, Tribhuvan University, Kathmandu, Nepal
³ School of Civil Engineering, Faculty of Engineering, Aristotle University of Thessaloniki, PO Box 452, 541 24 Thessaloniki, Greece
⁴ Institute of Engineering, Tribhuvan University, Pulchok, Lalitpur, Nepal

*E-mail: lokbaral@gmail.com

(Received: August 18, 2022, Received in revised form: November 15, Accepted: December, 2 2022, Available Online)

Highlights

- CASWAT-G (Circulating Cable Supported up down Walking Technology by Using Gravity) is a surface ropeway transportation system (SRT system).
- SRT system is operated by harvested gravitational potential energy (GPE) from the users and the leg muscle energy applied by the users.
- Presented technology is useful to apply in the mountainous countries that have high possibilities potential slope places it requires.
- The system is simple, lowest cost over other transportation systems, and environmental friendly.
- The system having efficiency above 80% can provide transportation facilities to hilly areas people as well as to tourists for recreational purposes.

Abstract

CASWAT-G (Circulating Cable Supported up down Walking Technology by Using Gravity) is a surface ropeway transportation system. There is enormous source of gravitational potential energy (GPE) in the nature which needs particular technology to use it for daily life need. Presented technology is useful to apply in the mountainous countries that have high possibilities potential slope places it requires. The system uses simple material and low number of parts which makes the technology simple and low cost. The driving forces are: harvested force from the users and leg muscle force from them. It is a pollutionless and very less destructive to natural environment technology. The simple form of prototype has the efficiency above 80% which is best even among different ropeways and is useful to apply.

Keywords: gravitational potential energy (GPE) harvesting, CASWAT-G supported walking, environment friendly surface ropeway, leg muscle force

Introduction

Green energies like hydro, tidal, gravitational, wind, geothermal, and solar etc. are the form of naturally found renewal energies
sources. Among them gravitational and geothermal are non-conventional and are found day and night all the year. Saran and Ghosh [1] showed the use of GPE to produce electricity which can solve the global energy crisis as well as to protect the worst environment. In this paper we have presented the model to use GPE for providing alternative sustainable transport mean to facilitate people living in hilly countries.

About 80% of the total land covered ranging from 60m to 8848.86m are rugged hills and series of mountains which is potential place to use GPE for mountain transportation. Difficulty to apply railways, road, airways, etc. and poor situation are mentioned in the papers [2, 3] which are challenges for quality of life in those regions. Only limited ropeways like tuin technology, gravity ropeway or modern cable cars are in operation [4, 5]. The international history of ropeway are mentioned in the papers of Hoffman [6, 7, 8] while the Nepalese ropeway history is mentioned in the USAID report [9].

The CASWAT-G transportation system was started in Nepal and the system designed work was carried by two students Astigarraga and Sartari at Vienna University of Technology [10, 11] to complete their master's theses. While two students: Michailidou and Papakosta from AUTH, Greece wrote thesis [12] by experimenting on this system. Similarity of the system with funicular cableway system as a surface ropeway can be compared with the Harley- Trochimczyk, Hill Hiker and Barthelson [13, 14, 15] papers.

Harvesting GPE and using of CTS is similar with funicular system while pulling action is similar to the ski lift. Use of gravity in gravity ropeways are mentioned in the papers Hada and Parikh & Lamb [16, 17]. Naniopoulos, Angelidou, et al mentioned the use of ropeway in tourism and urban transportation system [18, 19, 20]. Sources for pollutant: traffic, industry, power generation and CASWAT-G due to different emission system is show in table 1.

### Table 1. sources of pollutant and their parts in the atmosphere [22]

<table>
<thead>
<tr>
<th>Sources of pollutant emission</th>
<th>PM$_{10}$</th>
<th>NOX$_2$</th>
<th>SO$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic</td>
<td>60</td>
<td>41</td>
<td>14</td>
</tr>
<tr>
<td>Industry</td>
<td>6</td>
<td>8</td>
<td>21</td>
</tr>
<tr>
<td>Power generation</td>
<td>33</td>
<td>45</td>
<td>65</td>
</tr>
<tr>
<td>CASWAT-G</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Theory and Working Principle**

Situation of the component forces of a body lying on a slope angle ‘θ’ are $mg\sin\theta$, and $mg\cos\theta$ (equal to the normal component N) and f the frictional force are shown in Fig. 1 [9].

Vector addition of forces shown in fig. 1 can be given as follows

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

Also the $F_d$, the downward force (µ- the coefficient of friction between the block and the surface) give

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

Similarly the upward force $F_u$

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

The force for plane surface $F_p$ is given
\[ F_p = \mu mg \]  \hspace{1cm} (4)

where:
- \( m \): the mass of the descending or ascending person (DP or AP),
- \( g \): acceleration due to gravity,
- \( \theta \): the slope of the land, while using the system for walking the forces \( F_d \), \( F_p \), and \( F_u \) represent the leg muscle forces (LMF) applied for downward, plane, and upward walking respectively. The efficiency (\( \eta \)) of the system can be given as follows [9]

\[
\eta = \frac{\text{output force}}{\text{input force}} \times 100 = \frac{F_{AP}}{F_{DP}} \times 100 \hspace{1cm} (5)
\]

where \( F_{AP} \) - the force used by AP, \( F_{DP} \) - the force harvested by DP

**Materials and Methods**

**CASWAT-G and Its Working Principle**

The system harvests gravity from users and along with this force and the leg muscle force, system is able to provide its transportation service to the users. The simplest form of this type of surface transportation as shown in Fig. 2 and 3 includes the following parts:

1. Two bull wheels
2. Supporting structure (SS)
3. Intermediate pulleys
4. Circulating cable (CC)
5. Body connecting cable (BCC) and
6. Users’ special belt

![Fig 2. Schematic diagram of CASWAT-G system [9]](image-url)
On connecting the users by BCC to CC and taking support of it, the system harvests gravity from descending person (DP) and it is utilized to pull the ascending person (AP). While taking support, gravity balance is created among users' body weight i.e. harvested gravity of each user. For such balance condition, AP and DP with mild leg muscle force can ascend or descend very easily. Harvested and used forces by DP and AP respectively were measured by using HDWS (hanging digital weighing scale). These data were used to plot fig. 4 and fig. 5 and can be used to calculate the efficiency of the CASWAT-G machine using equation 5 (not calculated here for this paper).

**Results and Discussion**

**Fig 4.** Harvested and used forces (Kg) by DP=45.5 kg and AP=40 kg respectively

**Fig 5.** Harvested and used forces (Kg) for reverse case i.e. AP=45.5 kg and DP=40 kg respectively
In fig.4 and fig.5 harvested and used forces trend line are seen parallel and also seen that the harvested force line lies above the used force line i.e. harvested force is always larger than the used force which is irrespective of the magnitude of the weight of the user (i.e. weight of DP or AP).

Using data of table 1, a comparative pollution level is shown in fig. 4 in which CASWAT-G system has zero level pollution level.

Simple and low number of parts are included in constructing system. This means that constructing cost of the system as tabulated in Table 1 shows its cheapness. Likewise installing cost also cheap since it can be installed to routes having 1m wide or by simple repairing the route. This saves money in constructing route, etc. Setting pulleys lower and supporting structure is very low in comparison to other transportation means since its foundation work does not require more load to resist between two pulleys. The system can be set by using hard rock or trees' stem (wherever possible) which means that it can be the cheapest ropeway transportation system (RTS). For the prototype 20m long, the cost is given in the table 1.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Particular</th>
<th>Quantity</th>
<th>Cost rate (NPR)</th>
<th>Total (NPR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pulleys</td>
<td>2</td>
<td>3000</td>
<td>6000</td>
</tr>
<tr>
<td>2</td>
<td>Circulating rope</td>
<td>40m</td>
<td>200</td>
<td>8000</td>
</tr>
<tr>
<td>3</td>
<td>Pulley stand construction</td>
<td>2</td>
<td>5000</td>
<td>10000</td>
</tr>
<tr>
<td>4</td>
<td>Mech. Eng. work</td>
<td></td>
<td></td>
<td>8000</td>
</tr>
<tr>
<td>5</td>
<td>Commercial parts (nut bolts, peg, etc)</td>
<td></td>
<td></td>
<td>1000</td>
</tr>
<tr>
<td>6</td>
<td>Safety belt</td>
<td>2</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>7</td>
<td>BCC and its connecting part</td>
<td>2</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>8</td>
<td>Foundation work</td>
<td>2</td>
<td>2000</td>
<td>4000</td>
</tr>
<tr>
<td>9</td>
<td>Walking route construction</td>
<td>1</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>10</td>
<td>Total</td>
<td></td>
<td></td>
<td>40000</td>
</tr>
</tbody>
</table>

From above calculation the total cost per km = (40000/20) x1000 = NPR 20 lakh = IC 12,50,000.

<table>
<thead>
<tr>
<th>S. N.</th>
<th>Mode of Transport</th>
<th>Cost (Crore)/km (IC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MRTS</td>
<td>400</td>
</tr>
<tr>
<td>2</td>
<td>BRTS (single lane 50Cr)</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>Cable Car</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>CASWAT-G</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Source: Kumar [23]
According to Kumar [23], MRTS, BRTS, and cable car respectively cost IC400Crore, IC100Crore, and IC25Crore and from the table 2, we can see how cheap CASWAT-G system is. Baral [18] mentioned that the efficiency of the system is above 80% which is calculated by using data (of harvested force and used force) using equation 5.

Application of the System
This system can be applied to the mountainous areas for easy up-down walking or to climb even difficult mountains as follows:

Public areas for transportation purpose, recreational purpose in tourism for trekking, climbing, tree climbing, etc. This system can also be applied as circulating boating system in the large rivers using the flow of river.

Conclusions
This system having efficiency of more than 80 % [9] is similar with funicular and ski lift systems. Because of the use of simple and less numbers of parts, the system is simple with very low cost. The system can be fitted by utilizing even strong rooted stem of the tree within the jungle without cutting trees. Only gravity and muscle forces are applied to operate the system, the emission from the system is zero. Thus the system is simple, low cost, and environmental friendly that can provide transportation facilities to hilly areas people as well as for recreational purpose to climbers that can enhance the tourism business.

Acknowledgements
We, the authors highly acknowledge to Nepal Academy of Science and Technology (NAST) (Nepal) and Erasmus Mundus Educational Exchange Program (European Union) for the scholarship.

References


12. E. Michailidou, & N. Papakosta, *CASWAT-G the individual transportation system in areas with large slopes* (Course essay), Aristotle University of Thessaloniki, (2015).


