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An Overview of the Impact of Design Capacity on Load Cableway

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Abstract

In this paper, we examine the optimal design method of a single-cable freight rope to reduce its manufacturing cost. It can be understood that the pitch and height of the middle support, the main tensile force of the load-bearing ropes, is the main factor in increasing the cost of the cable car. A nonlinear optimization method is determined by the above factors, ensuring the minimum cost of a cable bundle with a maximum design capacity of up to 600 tons per hour. The purpose of optimization is examined by considering the limitations of design, assembly, deformation, and strength. The criteria for changing the optimal parameters of the intermediate supports and ropes carrying the load and tension were shown in changing the design capacity of a cable road based on the analysis of the calculations performed. The results of this optimization work will significantly reduce the cost of building freight air railway.

Keyword:ropeway, optimal design method,cable design, railways.

1-Introduction

At present, aerial cableways are considered as a promising mode of transport that solving transport and logistics problems in various sectors of the economy [1, 2] and urban environment [3, 4]. Freight cableways have long been used to transport various piece and bulk loads in mining, coal, chemical, metallurgical, energy, and agricultural industries. In terms of economy and environment, cable transport is often more profitable than land transport (road, conveyor, and rail) [5]. Cable transport is particularly effective when terrain relief (mountain, low-density, difficult-to-travel, remote regions), high density of residential or industrial development, and various natural and urban planning restrictions prevent the development of land traffic [1, 6].

For remote high-mountain areas, cable transport can be almost a non-alternative Shipping style for freight and passenger transport [7].

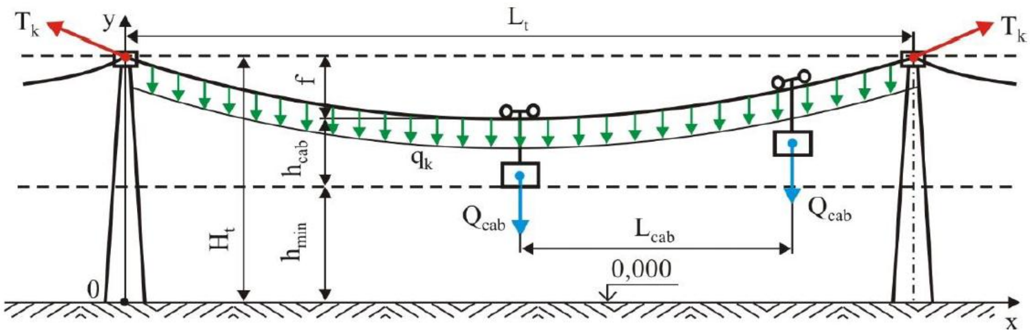

Figure 1- Design diagram of a cableway route section

Of all the various types of ropeway or cableway systems, the aerial is the best known and is generally considered to be an especially significant means of transport in alpine tourist areas; they are also enjoying growing popularity as a transportation mode in theme parks and hilly urban environments. In particular locations, thanks to their ability to transport a relatively high number of passengers uphill or over obstacles at relatively low cost, they have become indispensable. Normally they are characterized by at least one rope connecting at least two stations, which permits the bridging of steep slopes, watercourses, buildings, and other natural or man-made barriers. The ropes carry and pull gondolas or similar carrying devices along their route, utilizing either one or multiple ropes. The different technologies employed within these systems have been best summarized by Alshalalfah et al. (8). Further positive benefits include a minimum of infrastructure leaving the surface below largely untouched, low power consumption, and the motive effort provided by electricity thus eliminating exhaust emissions. A comparison of energy consumption between ropeways and other means of transport is shown in figure 1. innovative and beneficial public transport solutions in urban areas. However, apart from the common applications, few mixed-mode ropeway projects have been realized so far. As transport by ropeways in urban areas is fundamentally different from The most common methods of urban transportation, possible promotors for and obstacles to increased use of this technology can be identified (9). An example of the integration of a ropeway into a public transport system can be found in La Paz-El Alto, Bolivia. Here a ropeway led to a significant decrease in commuting times and costs (10). Another successful and well-known implementation is Aerial cable car systems in Medellín, Colombia (11). More than 53 further examples of fully implemented urban ropeways can be found in the urban-specific brochures or webpages of the three leading ropeway construction companies (12). Simpson (2017) suggests that the aerial ropeway concept could be a promising enhancement to the public transportation system in Honolulu, U.S.A. Except for Fessler and Luger (2016), the ropeway transportation of freight alone or in combination with passenger ropeways has as yet escaped the attention of researchers. This study fills that gap by analyzing the performance of a combined freight and passenger ropeway and showing the potential of integrating such a system into public transportation by way of an example for an alpine tourist area. The remainder of the paper is structured as follows: Section 3 presents a case study that evaluates a specific potential application of a combined passenger and freight transport ropeway system connecting two railways in a tourist area. The goal of the case study is to determine the system's capacities of passenger and freight transport under different terms of operation and operational rules. It further analyses the tradeoffs between both modes. Having also described the data and simulation model, in section 4 we explain model parameters and experimental design. The results of the case study are shown in section 5. Section 6 provides a discussion and the paper is finally concluded in section.

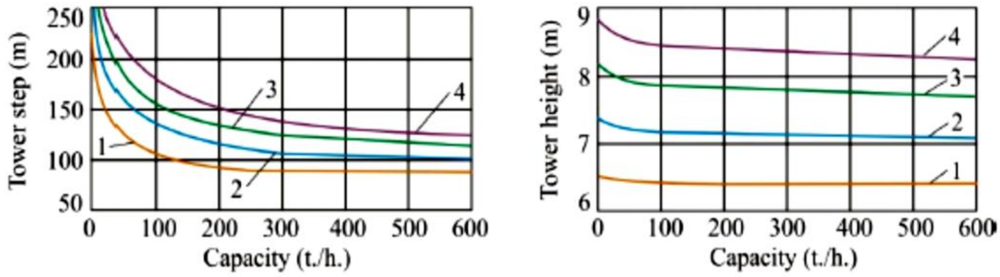

Figure 2- Optimal parameters of intermediate supports

The aerial ropeway is an effective means of widely used modes of public land transport in metropolitan areas. Building a passenger air route in urban environments is very costly in terms of engineering and time-consuming and requires a lot of financial resources. This paper reviews passenger air rope design methods, with the assurance of reducing its manufacturing costs...
For this purpose, the individual components of the construction cost are considered, and the approximate calculation-dependencies are proposed. It can be said that the cost of the air rope will be mainly affected by the installation phase, the height of the middle towers, and the tension of the transport rope. The goal of nonlinear optimization is parameters in the research that include solved relationships and methods. This will minimize the cost of the air rope. The purpose of optimization is done due to the possible limitations of rope installation in a completely urban environment (land, urban infrastructure, technical specifications of the carrier rope, etc.). Implementing the findings of the given optimization task solution will significantly reduce the cost of constructing aerial rope routes in the urban environment.

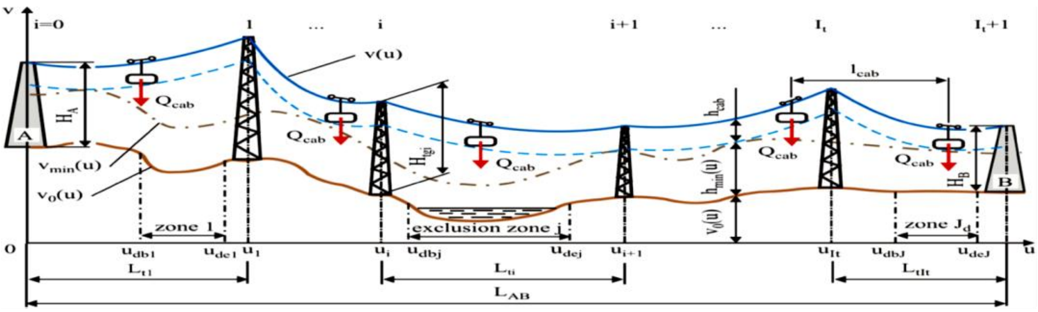

Figure 3-A design diagram of the optimized aerial ropeway section line between two neighboring boarding stations (A and B)

A study shows that the operation of aerial ropes has been proposed in different cities. In the urban environment, aerial ropes have played an important role in the last 10 * 15 years [13]. Therefore, due to the lack of theoretical studies and scientific articles on this subject, at this time many specific questions related to structural design, calculation, and modeling of operational processes in overhead ropes should be considered specifically for the urban environment. One of the earliest articles on this subject is the research presented in [14].
Issues related to system operation, cost, and the possibility of using overhead cable systems in urban areas will be examined in this article. Several articles have dealt with the effective factors, including climatic factors (temperature difference between day and night and monsoon winds) on the agility of the passenger cabin and the cable rope system [15, 16]. Calculating the amount of strength and tensile strength of carrier ropes [17-18]. Passenger transport safety [2, 3]. Lack of research on passenger cable car routes will not only include the technical aspect.
For example, [4] questions the social and economic impact of air rope construction on the development of adjacent deprived areas. [19] deals with access to airspace rights in urban environments for tug-of-war. Until now, the economic and psychological aspects of ropeway construction have not been sufficiently discussed in previously published authoritative articles.

However, approaches and the possibility of economization, and the need to modernize the infrastructure required in urban transport will be determined based on passenger air ropes.

2-Solutions Findings of the Optimization Taskand Their Analysis

The process of optimally designing an air passenger rope for a completely urban environment with high ground clearance is a very complex engineering task. Therefore, with the distance between the bases of adjacent stations for boarding people, which is the main feature of rope lines, the number of variable factors in solving this optimization problem can reach up to 100 undefined values. The number of these unknown factors determines the complexity of the optimization problem. At present, it is important to pay attention to 11 types of structural, robust, and operational constraints, which should be considered when solving the optimization problem. These problems will be expressed unequally using 99 mathematical dependencies. However, the practical implementation of the applied mathematical model and the problem of minimizing the objective function (Equation 1) is possible only by using numerical mathematical methods and computer facilities. To that end, the authors developed a program called RopewayOptimization. The original text of the program has been approved by the Patent Office of the Russian Federation [20]. As a method of mathematical optimization, the Hooke-Jeeves method has been used [21].

The need to consider a large number of constraints unevenly will complicate the range of possible solution methods for the next space optimization problem of N variables. Therefore, the presence of a large number of unconventional variables will cause the objective function to have several possible local minimums. Optimization time for real-time experiments, cable route design, the researchers recorded 3 to 7 minimum minimums for target performance. Only one of these local minimums can be considered as the most important solution to the problem. Due to this, some local minimums have target performance values that are quite close in size to the value of the objective function in the global minimum. As a result, a point is selected from the set of local minimum points that has the minimum value of the objective function. This point is at least international and accordingly, the method of solving the problem is optimization. The operation of the computer program "Ropeway Optimization" was tested by solving several experimental problems. The tests had other dimensions (the number of parameters of the optimization problem varied from 10 to 400), quantitative tools were considered including the shape of the ground surface and the location of areas, regular and irregular ground height level in the rope line.

The regular shape is modeled by simple linear functions (horizontal and oblique with a slope of up to 60 degrees) and sine. Actual topographic plans of large cities of Rostov (Russian Federation) have been used to simulate irregularities in altitude. Based on the calculated information, proposals have been prepared for the development of passenger air rope infrastructure in these densely populated cities [2, 11]. To test the capabilities of the mathematical model developed by the researchers when using it to design aerial rope lines, aerial rope model calculations were performed. The earth was modeled in the form of a sine wave with a different number of major half-waves along the overhead line and at different altitudes.

3-Study Design

The cost of air rope is expressed in customary units (C.U.). As the main unit, the Russian ruble has been used as cost parameters. When performing cost optimization in other countries, they must be expressed in the national currency of the country of origin. However, mathematical modeling and the calculation process, and the optimization goal do not change. The cost of constructing a passenger air rope line is very reasonable about the number of intermediate stations and the structural diversity of the land (Figure 5). When the number of middle columns is small 7, as the number decreases, the total cost increases sharply, from 140 million to double. To * 280 million C.U.This process is due to the rapid growth of the height of the columns Ht due to the need to balance the increase in the slope of the rope carrying the rope with the increase of the distance between the neighboring columns. When it 2; 8; 14, the total cost is minimal and almost the same and will be 140 million C.U. Then, as the height of the pylons decreases to near ground level in passenger cabins, it begins to increase. Increasing the number of masts and thus reducing the distances between them will increase the cost of installing unnecessary structural masts.

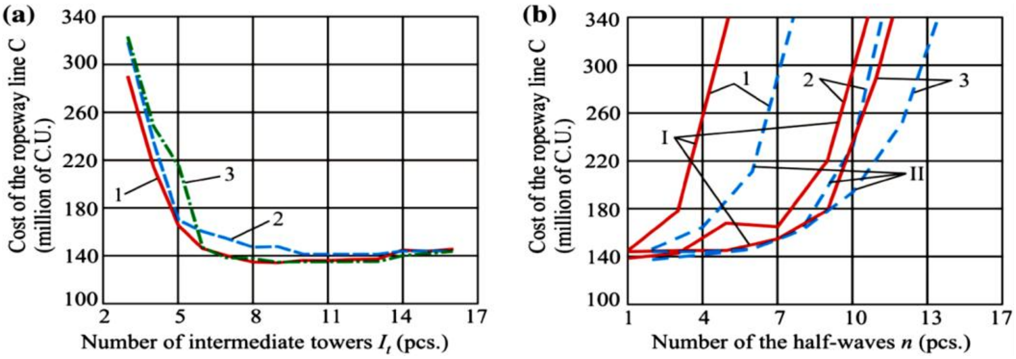

Figure 4- influence of the terrain diversity on the aerial ropeway line

The figures in Figure 5 show that the effect of ground diversity on the overhead line is important. If the ground is slightly uneven (n.3), the construction cost for a different number of features is low and almost the same. Therefore, when the ground surface is very uneven (n.4), it has a positive effect on cost due to the installation of masts in high areas. In Figure 5, we can see the type of ground and the height of the middle masts (n = 15) for optimal conditions of the aerial rope with a length of 3000 meters. Therefore, the desired mast height and the total cost of their implementation from the air rope to the diversity of the ground is acceptable.

3-1- Air rope transport system (new cable car)

Ropeway Air Transit (ART) or Ropeway System is known as tram, air tram, air tram, and so on. In India, it is also called Udan Khatola, Gagan Khatola, and so on. Cable car is a means of transporting passengers in a cabin that is suspended and intertwined by cables. It consists of one or two carrying cables, an actuator ring, and passenger cabins. The drive cables support the cab while the carrying rope driven by the electric motor exerts the driving force. Hence, cabins are pulled by a load cable and rotated by an engine. Air cable cars move back and forth in a fixed direction. However, cable cars have different cargo and passenger capacities. In a basic system, there is only one cable car, while in an advanced system, several vehicles are placed at regular intervals along with each other. Cable cars are usually a safer mode of transport than other methods and provide a direct connection between the two main points. It has been used in many cities such as Las Vegas, Auckland, Koblenz (Germany), Istanbul, Rio de Janeiro, Zurich, Singapore, Wellington (New Zealand), London, Mauritius, etc. The choice of such a transportation system depends on parameters such as terrain topography, length, capacity (both cabins and the whole system), speed, total operating system (one-way/two-way),system purpose (passengers/tourists), costs Construction, and maintenance

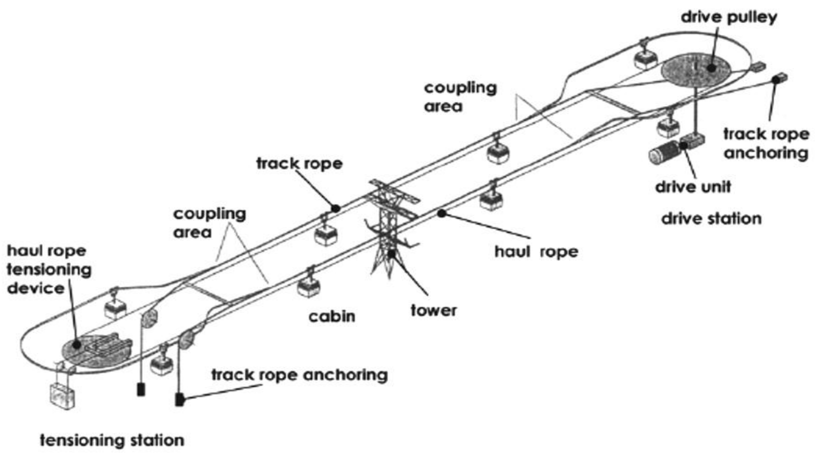

Figure 5- Detachable Bi-cable Cable Car (Source: Hoffmann, K. (2009), oscillating effects of ropeways caused by cross-wing and other influences, FME Transaction, No. 37, pp 175-184)

3-2-Components of Aerial Rope Transit (Cable Car)

The simplest system of cable cars consists of cable(s), cable car vehicle(s), and supporting structure(s). It is an integrated mechanical system based on principles of mechanics to carry passengers from one elevation to another elevation, particularly in undulating terrains. Figure 1 illustrates the running system of the detachable bi-cable cable car. The whole system has two components, broadly: civil works (related to brick/RCC/steel structure, basic facilities for passengers, etc), and the second is the installation of plants and machinery to provide mechanical and electrical support in the running of cable car vehicles.

Table 1- describes various components of the cable car and their functions in the mechanical shifting of passengers from one location to another location.

S.N.	Components	Description	Function
i.	Cable car vehicle (cabin/gondolas)	Consists of carriage/grip, hanger, and passenger cabin. Vehicle may be fully enclosed carrier, semi-open, seating chair with standing space, etc. The vehicle has a different capacity.	Structural and mechanical assemblage in which passengers are shifted.
ii.	Terminal Stations	Minimum two stations i.e. lower terminal station and upper terminal station are required.	Stations need a Drive Machines System which consists of motor and drive. (motor as mechanical device generates rotational/linear forces used to power a machine whereas driving as an electronic device harnesses electrical energy sent to motor)
iii.	Intermediate Towers	Intermediate structures to support both track cable (loads) and haulage rope (bundles) between terminals.	For a longer span, towers are required to provide support at various intermediate points.
iv.	Cables	Cables i.e. ropes are a major component	The cable pulls the cable car vehicles from one location to another for transporting passengers.
v.	Plants and Machinery	Drive (main & auxiliary), gearbox, tension/counterweight trolley, grip system, generator, emergency pulley, speed reducer, Diesel Generator (DG) set, etc.	Provide movement by using electrical and mechanical support.

Figure 6- Mechanical System and Passenger Cabin of Bhopal Ropeway at Manuabhan Tekri (photo by authors)

4-Cable Car: An Integrated Public Transport

Telecabin as a means of mass transportation in developed countries in the world to deal with natural obstacles, unfavorable weather conditions, hilly lands and .....

Which require special technologies to operate. Such systems have both advantages and disadvantages but if public transport is not used, it provides efficient mobility. The Medellin (Colombia) metro-cable car system is an example of general public transport. The city of Medellin is located in a valley and is surrounded by hills. Towns in the city will not be connected by bus or metro, so a metro cable system has been set up to provide a complementary mode of transport to the Medellin metro. In India, there is great potential for the use of cable cars as the main transport. Government agencies, transportation agencies, cable car manufacturers, etc., should take initiatives to upgrade cable car systems as an alternative mode of transportation, especially in hilly countries.

5-Concluding remarks

Computational modeling of a sloping multi-station cable car that is subject to nonlinear dynamic load due to passenger transport is investigated in this paper. For numerical modeling, a special computational method has been developed in this paper. This proposed method provides a fairly simple solution to the advanced nonlinear problem that will be determined when nonlinearity appears in the structural stiffness matrix as well as the mass matrix and the damping matrix of the equations of motion.

This goal is especially used to solve the nonlinear motion equations of cable car systems, where nonlinearity is related to angular motion. Some results related to a two-span sample rope path are shown in this paper. According to numerical analysis, we concluded that the behavior of nonlinear components of the system is not significant and can be ignored in simulating rope vibrations. Because these components are complex equations of motion and their numerical solution, this conclusion is valuable - it allows us to simplify a complex computational method, which will be useful in later articles that consider wind vibrations.

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