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Aerial Ropeways: Efficient and Economic Transport Systems

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الطرق الحبلية الهوائية : أنظمة كفوءة إقتصادية للنقل

Summary

The technical and economic advantages of aerial ropeways over competitive transport systems are outlined. A detailed cost comparison study of the aerial ropeway with a truck system clearly shows the economic superiority of the ropeway transport system.

1. Introduction

Although the aerial ropeway has a long history of efficiency and reliability in the transportation of bulk materials, today there is a tendency for those responsible for handling decisions to consider only its competitors as systems likely to meet the requirements of modern industry.

For example, a recent study of world coal resources gives an indication of the cost of conveying material by conveyor belts, trucks, barges, rail and slurry pipelines. No mention is made of the ropeway, in spite of the fact that it is now probably the most economic method of transporting material over long distances.

Omissions of this kind are obviously of great concern to the International Association of Ropeway Manufacturers whose membership comprises the acknowledged world leaders in this specialised field. At the association's invitation these companies have now provided factual information giving clear evidence of the viability of the ropeway and its competitiveness against other methods of transport. This includes studies of specific projects, with comprehensive comparisons covering both initial and operating costs and other related factors.

2. Advantages of the Aerial Ropeway

It needs to be emphasised that the modern aerial ropeway bears little resemblance to plants installed over two decades ago when conveying capacity was comparatively low and there was heavy reliance on manual labour. Today, high-capacity ropeways are operating with minimal attendant labour, demonstrating clearly that this form of transportation is very economic by comparison with competitive systems.

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Capacity is, of course, still to some extent a limiting factor, but some ropeways are handling about 4 million tonnes per year, a figure which will no doubt increase as technology continues to advance.

The need for economy by industry at a time of worldwide recession, when oil resources are diminishing and prices constantly rising, has thrown sharply into focus the urgency of investigating all practical alternatives to transport systems depending on petroleum-based fuels. Ropeways can generate their own power and use it efficiently and economically. Often raw material that is extracted from mines or quarries in hills or mountains has to be transported to a lower-lying processing plant, or to a railway or waterway. Unlike lorries, which consume fuel on both the upward and downward journeys, ropeways travelling downhill are braked electrically, usually by the Ward Leonard system or, more recently, by thyristor-controlled DC motors. During this process, they not only consume no energy but in fact produce power which can then be fed into the electricity network. In the event of a failure in the power supply or electrical gear, there is an electro-mechanical braking system (on 'fail safe' principles) available for standby use.

A major advantage of the ropeway is its ability to operate over difficult terrain with great differences in level, making it very cost-efficient compared with other means of transport. Over flat country, too, installation of a ropeway may be preferred to the construction of a new road or erection of belt conveyors. Economies are obtained in operation and maintenance, outweighing the cost of erecting a ropeway, which in most instances would be below the cost of road construction.

Since all handling problems differ, it is clearly advisable to study each case individually before making a final choice from the various alternative methods of transportation available.

On modern high-speed, high-capacity ropeways it is no longer feasible to have manual control of buckets in terminal stations where the buckets are running free of the rope driving system. It has therefore been necessary to develop auxiliary control systems which ensure that the buckets are correctly spaced and moved to and from the loading or unloading positions automatically and without impact with each other. Heavy-duty chain haulage and retarder systems have been developed specifically for this purpose, with minimum maintenance and long life as the prime considerations.

As ropeway capacities have been increased, so it has become necessary to run the line at much higher speeds, 4.5 m/sec being achieved and proved satisfactorily in operation. Higher speed has the advantage of reducing the number of carriages (bucket supports) and the rolling load on the ropes to a minimum. Improved carriage designs have been introduced as a parallel development.

Another technical advance is more efficient loading. The rotary loader provides a highly successful method of dividing a continuous feed of material into individual loads without interrupting the flow. In plants where sticky material is carried, because it is kept moving, the problems associated with storing it in bunkers with choked chutes are eliminated.

Protection of the environment is an important consideration where materials are to be transported. Foremost is the need to avoid atmospheric pollution, and the main problems concerning spillage of materials on ropeways emanate from the nature of the material carried. While some materials, such as limestone, may be dry and harmless in general terms, other fine powdery materials, such as alumina, cannot be carried in open buckets because of the effects of windy weather. Special enclosed buckets and improved methods of filling them have been developed to deal with this problem.

The noise level of the modern ropeway is low. Nylon-tyred or solid nylon wheels are extremely quiet in operation both on terminal rails and particularly on the supporting ropes along the ropeway line, where unacceptable noise is likely to meet criticism. Where plant and machinery are installed at terminal stations there is of course a degree of inherent noise, but this can be minimised by enclosing drives and loading and unloading points within suitably designed and insulated buildings, with excellent results. Compared with road vehicles and the constant noise of conveyors, ropeways are virtually noiseless.

In addition, there is little doubt that ropeways cause the least disturbance to the ground over which the line runs compared with any other type of plant for transportation. Supporting towers can be spaced to span rivers, gorges and other natural obstacles, and a minimum of foundation work and excavation is required to support the line. The terminals and intermediate stations (where required) are the only areas where fairly substantial foundation work is needed to anchor ropes and provide loading and unloading facilities.

Since all the major ropeway parts are elevated above the ground, ample clearance can be provided for wild life to move across the line, free from any restriction that might be required for ground-level conveyors or similar plant which has continuous structures at or above ground level.

Recognising that the landscape is of great importance, many ropeway companies have worked closely with planning authorities to camouflage conspicuous points on the line, sometimes even lowering a ropeway to pass under roads through a tunnel. Design can therefore be more flexible than for other types of plant, with the ropeway's basic simplicity of few supporting structures spaced widely apart at high or low level where found necessary. Tower and rope heights can be arranged so that the ropes follow the curve of valleys, making the ropeway almost invisible beneath a tree line or forest area. Indeed, plants have been erected in areas of natural beauty where some local inhabitants are unaware of the existence of the ropeway or cannot say in which direction the line runs or where it can be seen.

When added to the cost effectiveness of ropeways, it can be seen that there is every reason for companies with handling problems to consider the merits of a well tried system of transport which sometimes tends to be overlooked. Careful study of the feasible alternatives will show that there are many projects where the ropeway is without doubt the best solution to the problem of conveying bulk material.

Fig. 1: Economic operation is an important feature of the bicable ropeway serving Portlandzementwerk, Dotternhausen, in the Federal Republic of Germany. Travelling downhill at 4.25 m/sec, the buckets — each loaded with 1665 kg of limestone — develop surplus power which is controlled by a 250 kW drive/brake gear, the electric motor of which acts as a brake.

3. Cost Efficiency Comparison, Ropeway/Lorry System

One of the Federal Republic of Germany's leading manufacturers of conveying equipment of all types, including ropeways is frequently requested in its planning work to demonstrate the cost efficiency of ropeways compared with lorries. The following describes a case representative of many others, where 1.3 million metric tonnes of limestone per year have to be transported from a quarry to a works located 10 km away (in a straight line). The drop between quarry and works is 700 m. Transport is to be used 310 days per year in two-shift operation. The effective operating time assumed for both ropeway and lorries is 14 hours per day. Consequently, 300 t/h must be transported.

The ropeway can be installed in a straight line from the quarry to the works. Thus, the conveying distance is approximately 10 km.

Transport by lorry would require the construction of a road, the length of which — due to the terrain — must be taken as at least 18 km (the conveying distance). In both cases, capital services were calculated at an interest rate of 7 %. The amortisation periods of the lorries correspond with the average service life as determined on the basis of experience.

In general, the service life of ropeways is longer than the assumed amortisation period. The costs used for the calculations are based on the situation in central Europe in 1979.

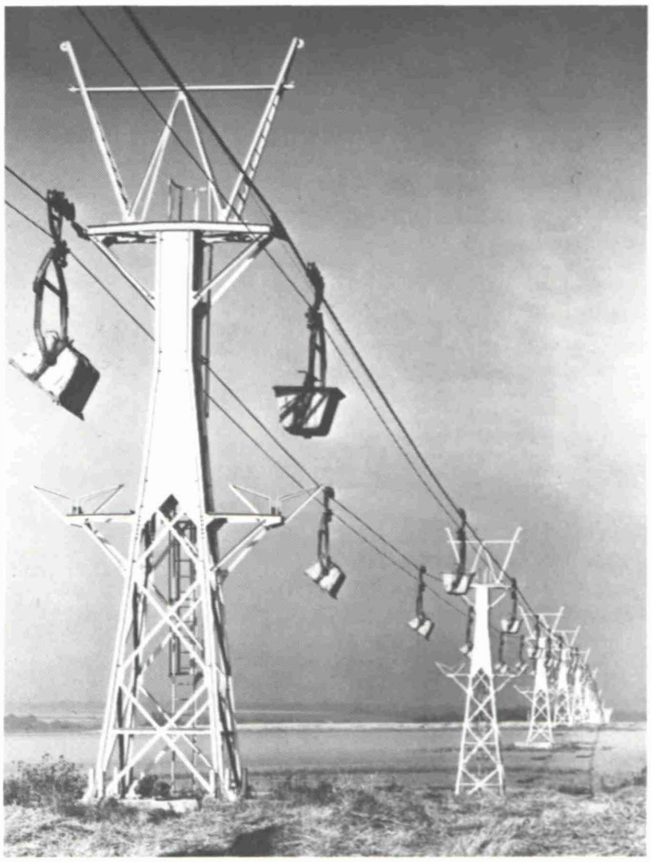
3.1 Ropeway Transport

Characteristics

Length = conveying distance	approx. 10 km
Drop in conveying direction	approx. 700 m
Material conveyed	limestone
Conveying performance	300 t/h
System	2-cable continuous ropeway
Hauling rope speed	4 m/s
Load capacity per ropeway car	1.82 t
Interval between cars	approx. 22 s
Distance between cars	88 m
Drive rating	none
Brake power	450 kW

Investment costs	x DM 1,000 approx.	x £ 1,000 approx.
Machinery parts, steel structures and electrical equipment, free to construction site	9,500	2,100
Ropes, free to construction site	2,000	450
Installation	3,000	650
Construction work	2,500	550
Other expenses	500	110
	17,500	3,860

Fig. 2: Ropeway in France, with fully automatic operation, for transporting iron ore; capactiy 500 t/h.



Operating and transport costs

	x DM 1,000 approx.		x £ 1,000 approx.
7% interest in invested capital	1,225		270
Amortization of system in 20 years, excluding ropes (2.44% of DM 15,500,000)	380	(£ 3,445,000)	85
Amortization of the ropes in 5 years (17.4% of DM 2,000,000)	350	(£ 445,000)	75
Personnel costs (two shifts/day) for a total of:			
1 foreman DM 65,000		(£ 14,000)	
1 specialist DM 45,000		(£ 10,000)	
6 trained workers (+ 1 stand-by) DM 280,000	390	(£ 61,000)	85
Electricity costs not applicable, since the system is generator-braked, feeding electricity into the network	—		
Maintenance, lubricants, etc.	155		35
Operating and transport costs per year	2,500		550
Operating and transport costs per tonne		DM 1.90	42p.

3.2 Lorry Transport

Characteristics

Travelling distance between loading and unloading point = conveying distance	approx. 18 km
Drop in conveying direction	approx. 700 m
Material conveyed	limestone
Conveying performance	300 t/h
Vehicle type	skip lorry
Average travelling speed	25 km/h
Motor rating per lorry	235 kW (320 metric hp)
Fuel Consumption per lorry	approx. 25 t/h
Engine oil per lorry	30 l
Tyres per lorry	6
Load capacity per lorry	30 t

No. of lorries/h $\frac{300\ t/h}{30\ t} = 10$

Interval between lorries $\frac{60}{10} = 6$ min

No. of lorries required:

on the road $\frac{36\ km \times 60}{6\ min \times 25\ km/h} = 15$

at the loading and unloading points	2
in the workshop	1
stand-by	1
	19

Determination of various data

Distance travelled per day and lorry

$$\frac{14\ \text{h} \times 300\ \text{t/h} \times 36\ \text{km}}{30\ \text{t/lorry} \times 15\ \text{lorries}} = 336\ \text{km/day}$$

Oil change after 6,000 km, i.e. per lorry after

$$\frac{6{,}000\ \text{km}}{336\ \text{km/day}} = 17\ \text{to}\ 18\ \text{days.}$$

Subsequently $\frac{15}{17}$ = approx. 1 lorry is permanently in the workshops.

Service life:

The service life of a lorry is as follows: approx. 350,000 km or 14,000 operating hours; if repairs are not to increase the operating costs beyond measure.

Each lorry travels 336 km/day x 310 days/year = approx. 100,000 km/year.

The lorries must be replaced after

$$\frac{350{,}000\ \text{km.}}{100{,}000\ \text{km/year}} = 3\ 1/2\ \text{years.}$$

Fig. 3: Monocable ropeway in Bahrain for transporting alumina from a jetty some 5,000 m offshore to an aluminium smelter inland.

The line has a total length of 9,800 m and the ropeway has a dual purpose of transporting aluminium ingots on the return side of the ropeway back to the jetty.

The service life of the tyres will be 30,000 km. Subsequently, lorries with six tyres will require the following:

$$\frac{100{,}000\ \text{km/year} \times 15\ \text{lorries} \times 6\ \text{tyres/lorry}}{30{,}000\ \text{km.}} = 300\ \text{tyres/year.}$$

Road Construction:

The service life of a bulldozed road with substructure but without asphalt surface can be taken as not more than 5 years in view of the high loads imposed (one lorry of 50 t overall weight every 7 minutes). Repairs to damaged points, particularly in bends, will be necessary all the time.

Investment costs	x DM 1,000 approx.	x £ 1,000 approx.
19 lorries (skip lorries), 30 t load capacity each, costing DM 330,000 (£ 75,000) each	6,270	1,425
18 km road, stabilized but without asphalt surface, costing DM 200,000 (£ 45,000) km	3,600	810
Other expenses	130	30
	10,000	2,265

Operating and transport costs	x DM 1,000 approx.	x £ 1,000 approx.
7 % interest on invested capital	700	155
Amortization of the lorries in 3 1/2 years (26 % of DM 6,270,000) (£ 1,425,000)	1,630	370
Amortization of the road in 5 years (17.4 % of DM 3,730,000) (£ 840,000)	650	145
Personnel costs (2 shifts/day) for a total of 17 x 2 = 34 drivers; 4 standby drivers for persons ill or on holiday; — 38 drivers at DM 40,000 (£ 9,000)	1,520	342
Fuel (diesel oil, DM 1.00/litre (22p/litre) 15 lorries x 14 h/day x 310 days/year x 25 l/h = approx. 1,600 litres	1,600	358
Engine oil (DM 7.00/litre) (£ 1.55/litre) $\frac{15\ \text{lorries} \times 336\ \text{km/d} \times 310\ \text{d/y} \times 30}{6000}$ = approx. 7,800 litres	50	12
Tyres (DM 3,800 each) (£ 840 each) 300 tyres/year are worn out	1,140	252
Expenditure for various lubricants and lorry maintenance	200	45
Road maintenance and repairs	110	25
Operating and transport costs/year	7,600	1,704
Operating and transport costs/metric tonne	DM 5.80	131 p.

These results are presented in summary form below:

	Ropeway x DM 1,000 approx.	Ropeway £ 1,000	Lorry x DM 1,000 approx.	Lorry £ 1,000
Investment cost	17,500	3,860	10,000	2,265
Operating and transport costs per year	2,500	550	7,600	1,704
Operating and transport costs per tonne	DM 1.90	42p	DM 5.80	131p

Fig. 4: Ropeway in Taiwan for transporting 420 t/h of limestone from quarry to the cement factory.

The line has a length of 8,800 m and overcomes a difference in level of 1,130 m in most adverse terrain; spans up to 800 m.

It is seen that the ropeway involves more investment than would lorries and road. On the other hand, the operating and transport costs of the ropeway are only a fraction of those involved in the use of lorries.

According to the values determined, the higher investments required for the ropeway pay for themselves after only approx. 1 1/2 years.

As already mentioned, the values determined are based on the costs customary in central Europe in 1979. Variations are possible, particularly in countries outside Europe, and suitable adaptations must then be made.

However, the operating and transport costs of the ropeway will continue to be lower than those of lorries. A calculation was made in favour of lorry transport, using extremely low values for this method:

1. Elimination of all costs for road construction and maintenance.
2. Annual costs for a lorry driver of only DM 10,000 (£ 2,250) (the wage costs of the ropeway staff were lowered accordingly).
3. Diesel oil at a cost of only DM 0.30/litre (7p/litre).

On this calculation basis, the following result is obtained:

	Ropeway x DM 1,000 approx.	Ropeway £ 1,000	Lorry x DM 1,000 approx.	Lorry £ 1,000
Operating and transport costs per year	2,200	490	4,300	960
Operating and transport costs per tonne	DM 1.70	38p	DM 3.30	73p

In this case, the higher investments for the ropeway are covered after 3 1/2 years. It should also be mentioned that, during downward travel, the ropeway supplies almost 2 million kWh/year electricity into the network. On the other hand, the lorry consumes approx. 1.6 million litres diesel oil/year.

The same calculations were made for upward transport over the same conveying routes, i.e., with a 700 m climb. The results were as follows:

1. Wage and fuel costs as in the detailed calculations: electricity costs for ropeway: DM 0.10/kW/h (2p./kW/h)

	Ropeway x DM 1,000 approx.	Ropeway £ 1,000	Lorry x DM 1,000 approx.	Lorry £ 1,000
Operating and transport costs per year	2,700	600	8,600	1,910
Operating and transport costs per tonne	DM 2.10	47p	DM 6.60	147p

The ropeway will have made good the higher investment costs after 1 1/4 years.

2. Reduced wage and fuel costs, elimination of all costs for road construction and maintenance

	Ropeway x DM 1,000 approx.	Ropeway £ 1,000	Lorry x DM 1,000 approx.	Lorry £ 1,000
Operating and transport costs per year	2,400	530	5,200	1,150
Operating and transport costs per tonne	DM 1.85	41p	DM 4.00	90p

In this case, the higher investments for the ropeway are covered after 2 1/2 years. For upward transport, the ropeway consumes approx. 2.2 million kWh electricity, the lorries consuming almost 2.3 million litres diesel oil per year.