A Comparative Evaluation of Operation of Airships and Helicopters in Uttaranchal

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Abstract

This paper discusses a comparative study of airships and helicopters as an alternative means of transportation in Uttaranchal. In this study, the cruising altitude and payload carrying capability of two five-seater airships and helicopters were compared. The Direct operating Cost (DOC) of airships and helicopters for operation over three routes in Uttaranchal were also estimated, and the sensitivity of DOC to annual utilization was investigated. The study showed that helicopters had better payload capability at all operating altitudes. Although the overall annual DOC of airships was significantly higher than helicopters, when hourly DOC was compared it was seen that airships held the economic advantage. Further, the DOC of airships and helicopters were found comparable when equal annual utilization was considered.

Background

Uttaranchal is located in the Himalayan region with many important cities, hill stations and scenic locations. A large fraction of revenue in Uttaranchal is generated by tourism. However, a majority of the land Uttaranchal is mountainous and is difficult to navigate. Added to this, the condition and quality of the existing road network is poor, and many major roads are poorly maintained. Journeys of 100 km can take up to 4 hours, sometimes even longer, depending on the weather and visibility. This causes frequent traffic bottlenecks and delays, leading to the need for an alternative that does not depend on existing road or rail networks. Aircraft are ruled out since the terrain features preclude the possibility of building airports. Airships and Helicopters are the only possible forms of aerial vehicles that can circumvent some of these difficulties.

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Airships vs. Helicopters

Airships and helicopters both have the ability to hover in the air as well as fly backwards and forwards. Compared to fixed-wing aircraft, they can be operated over mountainous terrains more safely, since they can be flown at much lower speeds. Thus they can fly through relatively narrower valleys or corridors with higher levels of tolerance and safety since their flight dynamics do not require large forward velocity as the prime source of lift. They also require significantly lesser area for landing, parking and taxiing, which makes them ideally suited for operations in mountains, where it is impossible to construct regular runways due to unavailability of large areas of flat land. However, increase in temperature and operating altitude adversely affect the performance capability and payload carrying capacity of both airships and helicopters much more than that for a fixed wing aircraft.

Compared to helicopters, airships have significantly lower fuel consumption, higher endurance, and offer a much better ride quality to the occupants. Airships, on the other hand, are more sensitive to weather fluctuations, and larger in dimensions compared to helicopters of similar capacity. This paper reports the results of a comparative study of airships and helicopters as a mode of passenger transportation in Uttaranchal [1]. A methodology for estimation of the Direct Operating Cost (DOC) of airships and helicopters was developed, and the DOC and payload capability of two 5-seater non-rigid airships and two 5-seater helicopters were compared for operation over three specific routes in Uttaranchal.

Selection of Airships, Helicopters & Routes

Table 1 lists the values of a few important parameters of the two 5-seater non-rigid airships and two 5-seater helicopters that were considered for this study. The basis for selection of the airships & helicopters was their commercial availability, and accessibility of relevant data and from various sources, such as Jane's report on world aircraft [2], and detailed technical information provided by the helicopter manufacturers [3].

	TLG A60+	US-LTA 138S	Bell 206L-4	Bell 407407
Envelope Volume	1,926 m3	3,908 m3	n / a	n / a
Rotor Diameter	n / a	n / a	11.28 m	10.70 m
Empty Weight	1,300 kg	2,676 kg	1,046 kg	1,178 kg
Max Takeoff Weight	1,814 kg	4,032 kg	2,018 kg	2,267 kg
Length	39.6 m	48.8 m	10.2 m	12.70 m
Diameter	10.1 m	12.7 m	1.3 m	1.74 m
Height	13.4 m	17.3 m	1.3 m	1.28 m
Cruise Ceiling	2,225 m	2,743 m	1,981 m[1]	3,170 m

Table 1: Important parameters of the selected airships & helicopters [2] & [3]

Selection of Routes

Figure 1 is a physical map of Uttaranchal, which depicts terrain elevation in various regions.

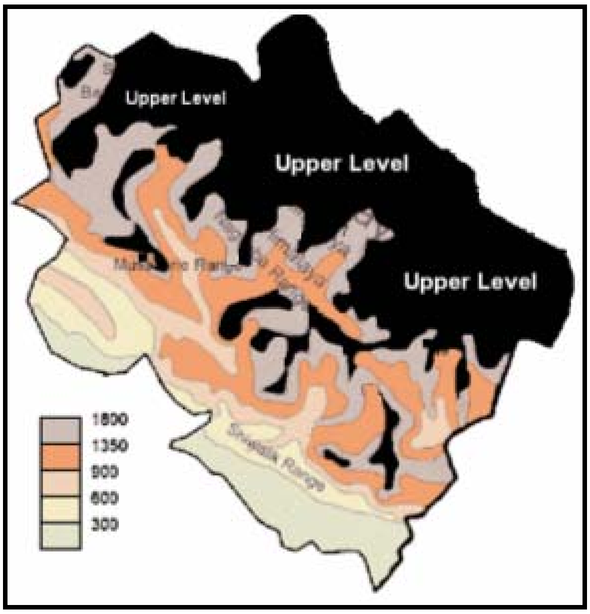

Figure 1: Upper & Lower Levels of Uttaranchal [1]

[1] OGE Cruise Ceiling

After studying the geology and topology of Uttaranchal, two levels of operation for airships & helicopters can be considered - the lower level comprising all locations below an altitude of 2000 m; and the upper level consisting of locations situated above this altitude (indicated in black in Figure 1) [1]. An analysis of the population distribution of Uttaranchal revealed that nearly 70,54,700 people live in the lower level, which constitutes nearly i.e. 68% of the total population [4]. Further, the majority of agricultural and commercial activity takes place in this level. Only adventure tourism (such as mountaineering) and pilgrimage (such as Char Dham Yatra and Hemkund Sahib) take place in the upper level, which are beyond the meaningful reach of the airships and helicopters, Hence, this study was limited to operation only in the lower level where three routes were chosen for a detailed study. Details on the routes have been presented below.

Route Details		**Distance**
Route - 1	Dehradun to Nainital	169 km
Route - 2	Pauri to Almora	102 km
Route - 3	Uttarkasi to Pithoragarh	213 km

Table 2: Three routes considered for airship & helicopter operations

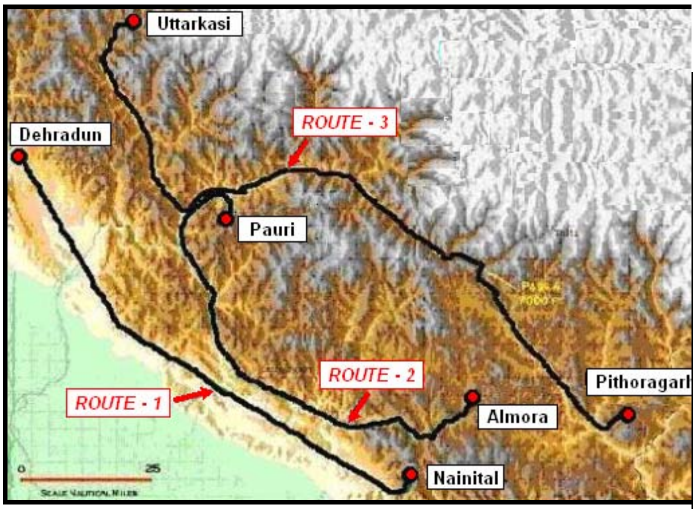

Figure 2: Map of the three routes selected for airship & helicopter operations [5]

Effect of Terrain and Temperature on Airship Performance

The performance of airships is mainly affected by the increase in ambient temperature and terrain elevation. Reviews of annual climatic conditions of Uttaranchal revealed that their operation during the monsoon season (mid June to mid September) would not be feasible. During this period, flights are greatly curtailed due to low cloud ceilings, low visibility and moderate to heavy rainfall.

Temperatures above ISA also have an adverse effect on buoyancy, since at higher temperatures, the expansion of the surrounding air is more pronounced than that of Helium. Typically, airship buoyancy is lowered by 1% every 2.7°C rise above standard temperature due to expansion of air and Helium [5]. The high terrain elevation in Uttaranchal also has an adverse effect on the airship's useful lift. Typically, airship lift is reduced by 1% for every 109.7 m of altitude [5]. Thus, if the elevation of a destination is 2000 m above sea level, the loss in buoyancy amounts to 18.23%.

Effect of Terrain and Temperatures on Helicopter Performance

Helicopter performance is usually presented in the form of a Weight-Altitude-Temperature (WAT) Chart [6] where one parameter (either weight or temperature) is kept constant and curves of altitude vs. the other are plotted for different values of the constant parameter. In every case, powered and controlled flight is not possible outside the limits of the WAT line [6]. Thus the WAT line gives us an indication of the maximum flight envelope at a particular weight, altitude and temperature for the helicopter.

Figure 3 represents the WAT Chart for Bell 206L-4 [1]. By keeping gross weight as the constant quantity and seeing the variation in maximum OGE hover ceiling with altitude, the performance curves of Bell 206L-4 have been drawn.

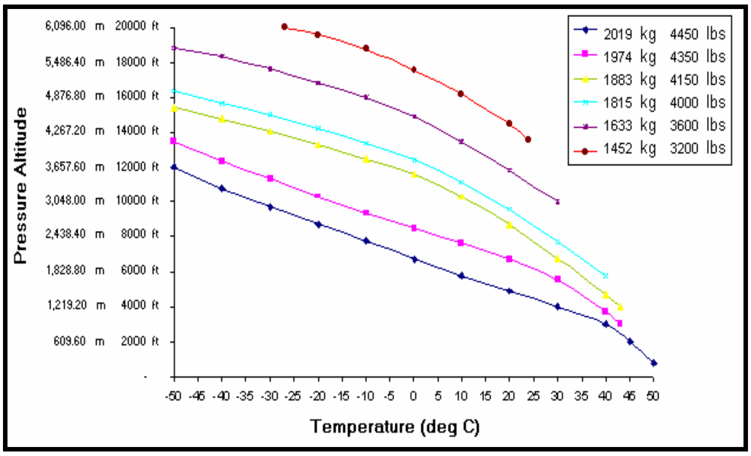

Figure 3: Constant Weight WAT curves for Bell 206L-4 [1]

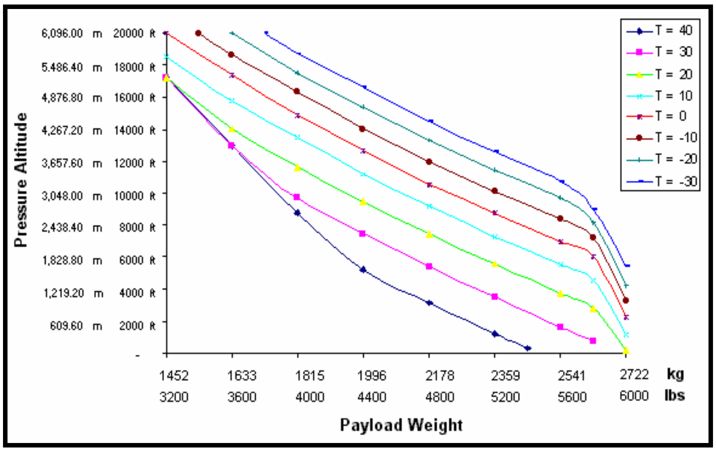

Figure 4: Constant Temperature WAT curves for Bell 206L-4 [1]

In Figure 4, the WAT chart for Bell 407 has been shown [1]. In this case, by keeping the temperature constant and observing the variation of gross weight with altitude, the performance curves of Bell 407 can be drawn.

Operating Costs

Operating Costs are applicable to all aircraft and are often a decisive factor while evaluating the relative merits of certain aircraft having comparable performance characteristics.

Factors Affecting Operating Cost

The following factors that contributed to Direct Operating Cost (DOC) have been considered for the purpose of this study: depreciation & insurance, maintenance (labor & spares), crew remuneration and fuel costs. A description of the methodology adopted for estimation of the DOC due to these factors follows.

Depreciation & Insurance

Since there are no existing airship-ports, the costs of building, maintenance and operation of an airship port falls entirely on the airship operator. These costs must be recovered from fare paying passengers or from the airship’s direct commercial operations. Thus the annual depreciation on ground support infrastructure must be included in the operating cost figures of the airship. Annual cost of depreciation was taken as 10% of the purchase price of the airship or helicopter and as 20% for ground infrastructure (for airships only). Annual insurance premium has been taken at 10% of the insured value of the airship/helicopter and its equipment, as suggested in a previous study [7].

Maintenance

Since information about airship maintenance schedules was unavailable, it was decided to adopt a schedule similar to those used by commercial aircraft operators with requisite modifications wherever applicable. The following maintenance schedule (in terms of Maintenance Man Hours per Flight Hour, or MMH/FH) was chosen for the airships: ½ MMH every 2 FH towards line maintenance & preflight checks, 2 MMH every 8 FH towards a daily envelope/gondola/hull integrity check, 5 MMH every 60 FH for weekly inspections and routine maintenance, 8 MMH every 240 FH for monthly maintenance and/or part replacements, and finally, 50 MMH very 2000 FH towards complete engine overhaul (or replacement). This works out to a total of 0.641 MMH/FH for each airship that undergoes the same maintenance schedule. Helicopter manufacturers provided data for expenses towards maintenance where Bell 206L-4 took 0.698 MMH/FH and Bell 407 took 0.807 MMH/FH towards maintenance. Subsequent discussions with aviation professionals in the field of maintenance were made to arrive at cost figures, which have been presented below.

			Annual Cost1	
Name	**MMH/FH**	**AMT2**	**Labor3**	**Spares3**
			Annual Cost1	
Name	MMH/FH	AMT2	Labor3	Spares3
TLG A60+	0.641	1,094 h	Rs 32.81 lakh	Rs 55.19 lakh
US-LTA 138S	0.641	1,114 h	Rs 33.41 lakh	Rs 56.20 lakh
Bell 206L-4	0.698	725 h	Rs 21.77 lakh	Rs 23.05 lakh
Bell 407	0.807	771 h	Rs 128.67 lakh	Rs 163.33 lakh

1: Gives monthly usage for 8 months; 2: AMT stands for Annual Maintenance Time;

3: Cost estimates for Indian operating conditions; labor charges taken to be Rs 3,000 per hour [8].

Table 3: Annual costs of maintenance for the selected airships & helicopters

Fuel Expenditure

Table 4 shows the results obtained on the three routes for the airships & helicopters.

Name	**Route**	**Speed**	**Range**	**Time**	**Fuel**
TLG A60+ (5-seater airship)	Dehradun to Nainital	88 km/h	169 km	2.42 h	47.91 kg
	Pauri to Almora		102 km	1.66 h	28.91 kg
	Uttarkasi to Pithoragarh		213 km	2.92 h	60.38 kg
US-LTA 138S (5-seater airship)	Dehradun to Nainital	86 km/h	169 km	2.47 h	62.74 kg
	Pauri to Almora		102 km	1.69 h	37.86 kg
	Uttarkasi to Pithoragarh		213 km	2.98 h	79.07 kg
Bell 206L-4 (5-seater helicopter)	Dehradun to Nainital	175 km/h	169 km	1.47 h	155.75 kg
	Pauri to Almora		102 km	1.08 h	77.67 kg
	Uttarkasi to Pithoragarh		213 km	1.72 h	298.97 kg
Bell 407 (5-seater helicopter)	Dehradun to Nainital	200 km/h	169 km	1.35 h	145.27 kg
	Pauri to Almora		102 km	1.01 h	71.27 kg
	Uttarkasi to Pithoragarh		213 km	1.57 h	272.48 kg

Table 4: Block time and block fuel results for the airships & helicopters [1]

Since we know that potentially hazardous weather conditions can pose a serious threat to airship operations for approximately three months of the year, we have based our calculations for eight months keeping the extra one-month as a contingency time margin. The daily and annual totals of flight time and cost of fuel over the three routes have been shown in Table 5.

Airship	Daily Total			Annual Total (8 Months)		
	Time	Fuel	Fuel Cost	Time	Fuel	Fuel Cost
TLG A60+	7 h 00 min	172 kg	Rs 4,030	1,687 h	41,760 kg	Rs 9,81,366
US-LTA 138S	7 h 08 min	225 kg	Rs 5,278	1,718 h	54,687 kg	Rs 12,85,146
Bell 206L-4	4 h 16 min	533 kg	Rs 12,511	1,039 h	129,636 kg	Rs 30,46,453
Bell 407	3 h 55 min	489 kg	Rs 11,492	955 h	119,077 kg	Rs 27,98,306

Table 5: Block time and block fuel cost estimates for the airships [1]

Crew Compensation

Figures pertaining to annual crew remuneration have been taken from a previous study [7]. Pilot salaries were taken as Rs 24,00,000 for three pilots & one trainee, salaries for 10 technicians and ground crewmen were taken as Rs 14,40,000 and salaries for four sales & marketing personnel were taken as Rs 3,24,000.

Airship & Helicopter DOC Results

	5-seater Airships		5-seater Helicopters	
Operating Cost Table	TLG A60+	US-LTA 138S	Bell 206L-4	Bell 407
Airship Cost	Rs 14.7 crore	Rs 14.6 crore	Rs 7.37 crore	Rs 8.61 crore
Utilization per Month	213 hours	217 hours	130 hours	119 hours
Annual Pilot Salaries	Rs 24.00 lakh	Rs 24.00 lakh	Rs 24.00 lakh	Rs 24.00 lakh
Annual Ground Crew Salaries	Rs 14.40 lakh	Rs 14.40 lakh	Rs 14.40 lakh	Rs 14.40 lakh
Annual Salary of Marketing Staff	Rs 3.24 lakh	Rs 3.24 lakh	Rs 3.24 lakh	Rs 3.24 lakh
Annual Insurance Premium	Rs 147 lakh	Rs 146 lakh	Rs 73.7 lakh	Rs 86.1 lakh
Annual Fuel Cost	Rs 9.81 lakh	Rs 12.85 lakh	Rs 37.26 lakh	Rs 41.29 lakh
Annual Maintenance	Rs 32.81 lakh	Rs 33.41 lakh	Rs 21.77 lakh	Rs 23.05 lakh
Annual Spares	Rs 55.19 lakh	Rs 56.20 lakh	Rs 128.67 lakh	Rs 163.33 lakh
Depreciation of Hull	Rs 147 lakh	Rs 146 lakh	Rs 73.7 lakh	Rs 86.1 lakh
Depreciation of Ground Infrastructure	Rs 29.26 lakh	Rs 29.26 lakh	n / a	n / a
Annual DOC (for 8 months)	Rs 4.63 crore	Rs 4.65 crore	Rs 3.77 crore	Rs 4.41 crore
Hourly DOC	Rs 27,147	Rs 26,763	Rs 36,223	Rs 46,359

Table 6: Estimation of DOC for two 5-seater airships & two 5-seater helicopters [1]

Sensitivity Study on Airship & Helicopter DOC

We have assumed normal operations for 8 months of the year. In this study, we will compare the DOC results obtained while considering 6, 7, 8, 9 and 10 months of annual operations for airships. The results obtained indicated a clear trend of increasing DOC per hour with decrease in number of flight hours for all five airships and vice versa.

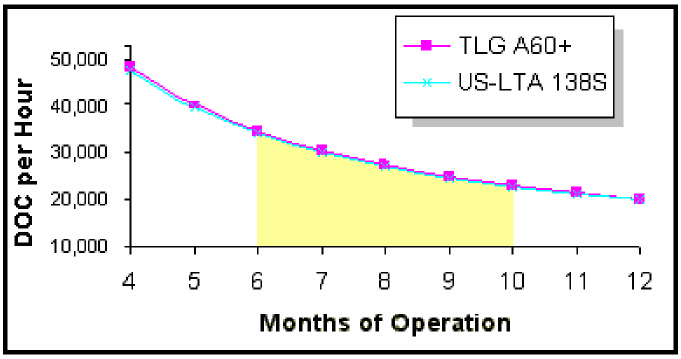

Figure 5: Results of Sensitivity Study for Airships

In the case of airships, we can clearly see that fewer months of operation will lead to an increase of 22% to 28% in the DOC per hour of airships whereas increasing the operational time by a few months can lead to a decrease of 14% to 17% in DOC per hour.

In the case of helicopters, We can clearly see that fewer months of operation lead to an increase of 22% to 28% in the DOC per hour of helicopters whereas increasing the operational time can lead to a decrease of 13% to 17% in DOC per hour for the helicopters.

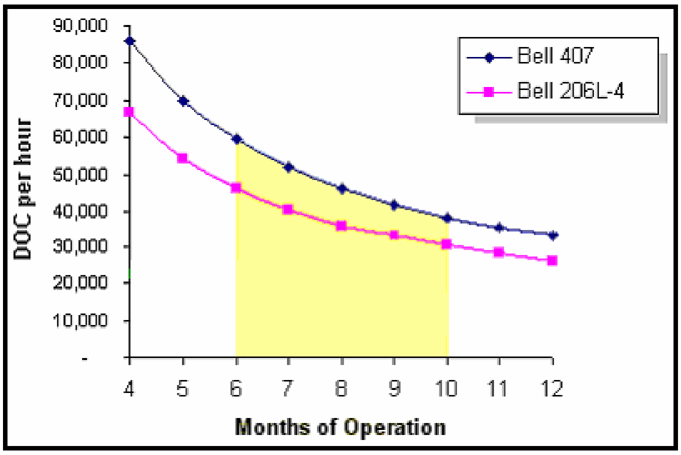

Figure 6: Results of Sensitivity Study for Helicopters

Comparing the Performance of Airships & Helicopters

By fixing weight for our selected airships and plotting the trend of temperature vs. altitude we can compare their performance characteristics with helicopters. We have assumed that all airships and helicopters will carry a single pilot weighing 85 kg and fuel weighing 100 kg. The additional payload complement corresponding to the WAT curves of Bell 206L-4 and Bell 407 at 1452 kg, 1633 kg, 1815 kg and 2019 kg were calculated to be 221 kg, 403 kg, 584 kg and 788 kg respectively. Observing the WAT curves for the airships and helicopters provides evidence that the performance of both, airships and helicopters decreases with increase in temperature and altitude. From the graphs shown below, we can observe that both the helicopters outperform the airships.

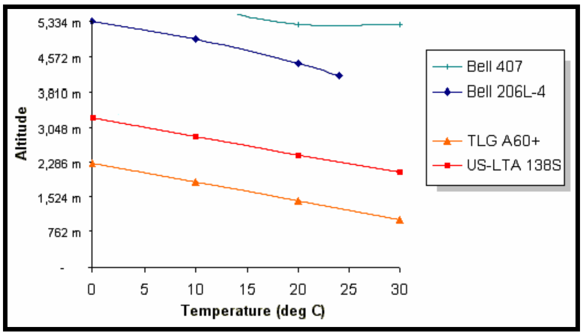

Figure 7: Comparison of two 5-seater helicopters with

two 5-seater airships for payload weight of 221 kg

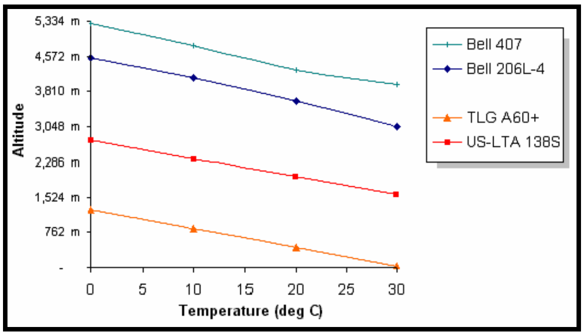

Figure 8: Comparison of two 5-seater helicopters with

two 5-seater airships for payload weight of 403 kg

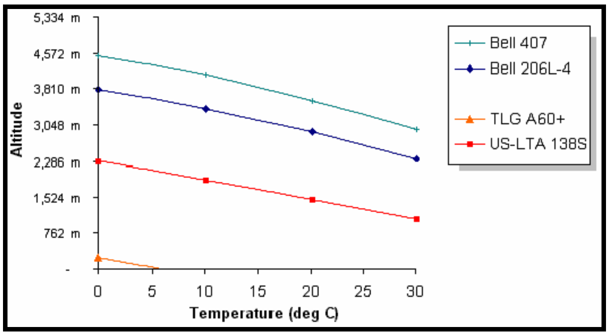

Figure 9: Comparison of 5-seater helicopters with two 5-seater airships for payload weight of 584 kg

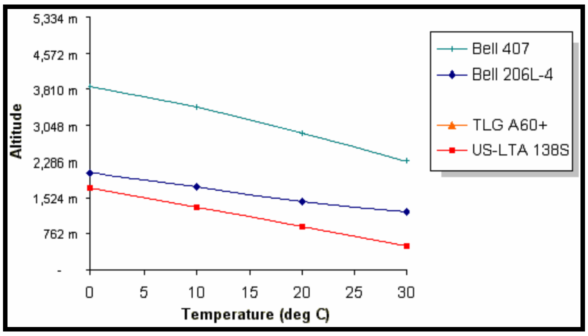

Figure 10: Comparison of two 5-seater helicopters with two 5-seater airships for payload weight of 788 kg

Case Study on Equal Utilization

So far, we have based all our DOC calculations on the fact that the airships travel at different speeds. Thus our study, although based on actual time taken by each airship, results in unequal annual utilization. We will now consider a case where the airships and helicopters are utilized equally for 1,200 hours annually (120 hours/month for a maximum of 10 months) over the same three routes and see how this affects their hourly DOC. While calculating DOC per seat, the passenger load factor was assumed to be 100%.

Model	**Annual DOC**	**Hourly DOC**	**DOC per Seat**
TLG A60+	Rs 4.39 crore	Rs 36,594/-	Rs 7,319/-
US-LTA 138S	Rs 4.40 crore	Rs 36,672/-	Rs 7,334/-
Bell 407	Rs 4.58 crore	Rs 38,175/-	Rs 7,635/-
Bell 206L-4	Rs 3.86 crore	Rs 32,151/-	Rs 6,430/-

Table 7: DOC estimates based on 1,200 hours annual utilization

Results

It was observed that airships suffer massive losses in payload capacity due to increases in altitude and. For example, under ISA+10°C conditions the expected altitude (with margin of safety) is ~1500 m, we see that this results in a combined total of 3.2% + 13.6% = 17.8% reduction in total buoyancy. In reality, the loss of buoyancy directly translates to the loss of available or useful lift, and hence payload.

Results of Studies on Technical Feasibility

From the WAT curves, we were able to observe the performance of the five selected airships by comparing them with those of the helicopters. Both the helicopters easily outperformed the airships for all values of temperature and payload weight up to 1,287 lbs (584 kg). The graphs shown below clearly show the decreasing trend of payload capacity with rise in altitude at ISA (15°C) and ISA+15 (30°C) conditions respectively.

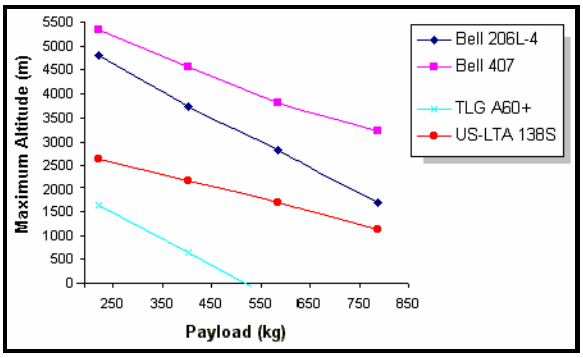

Figure 11: Decreasing trend of payload capacity with rise in altitude at ISA conditions [1]

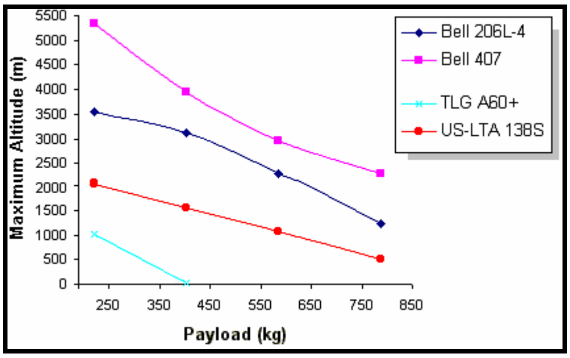

Figure 12: Decreasing trend of payload capacity

with rise in altitude at ISA+15 conditions [1]

Results of DOC Estimation

While comparing DOC of airships with DOC of helicopters, it was observed that the operating costs of airships and helicopters are in fact quite similar.

Name	Annual Usage	Annual DOC	Annual Cost per Seat3	Hourly DOC	Hourly Cost per Seat
US-LTA 138S	1,736 h	Rs 4.65 crore	Rs 92.90 lakh	Rs 27,147/-	Rs 5,430/-
TLG A60+	1,705 h	Rs 4.63 crore	Rs 92.54 lakh	Rs 26,763/-	Rs 5,353/-
Bell 407	1,016 h	Rs 4.41 crore	Rs 88.27 lakh	Rs 46,359/-	Rs 9,272/-
Bell 206L-4	1,040 h	Rs 3.77 crore	Rs 75.34 lakh	Rs 36,223/-	Rs 7,245/-

Table 8: Comparison of DOC for airships & helicopters [1]

It was found that annual DOC & annual cost per seat for all airships was higher than that of helicopters. But the hourly DOC as well as hourly DOC per seat for airships is significantly lower than the corresponding figures for helicopters.

Results of Sensitivity Study on DOC

- **For Airships**

  We can clearly see that fewer months of operation will lead to an increase of 22% to 28% (spanning an overall 6% from the baseline) in the DOC per hour whereas increasing the operational time by a few months can lead to a decrease of 13% to 17% (spanning an overall 4% from the baseline) in DOC per hour.

- **For Helicopters**

  We can clearly see that fewer months of operation lead to an increase of 20% to 29% (spanning an overall 9% from the baseline) in the DOC per hour whereas increasing the operational time can lead to a decrease of 12% to 17% (spanning an overall 5% from the baseline) in DOC per hour.

We can summarize that in both cases, reducing operating time per year meant higher DOC per hour and increasing the operating time per year led to reduction in DOC per hour. Also, if both the graphs are superimposed, we can see that the sensitivity of airships and helicopters to increase or decrease in annual operating time is quite similar.

Conclusions

- Helicopters consistently showed superior performance when compared with airships over all operating conditions.

- Even though helicopters have 2.67 to 4.24 times higher fuel consumption than airships, they are capable of attaining significantly higher altitudes for the same payload over all temperature levels and thus display superior performance.

- Sensitivity studies showed that with sufficient long-term operation, the net effect on DOC of airships & helicopters were quite similar.

- Even though airships are much more fuel-efficient than helicopters, their annual costs of operation are still significantly higher than helicopters. The initial investment required for introduction of airship operations is much higher than that for helicopters, since there is wide proliferation of available ground support infrastructure for the latter. Airships will incur considerable initial expenditure for building of adequate ground support infrastructure.

- Airships are able to offer far superior levels of comfort due to larger cabin space and lower vibration levels. If we calculate and compare the DOC per seat of airships & helicopters, we see that airships are indeed economically more advantageous to operate since their DOC per hour is just 0.59 to 0.74 times that of the helicopters over the three routes in Uttaranchal.

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