ENGINEERING NOTE

LIFE CYCLE COST OF A SIX TON HELICOPTER

N. Satpathy* and Krishna Murari**

Abstract

The operating cost of a helicopter basically comprises of Direct operating cost and fixed operating cost. Direct operating cost are those costs that are related directly to the hourly operation of the helicopter. These are cost of fuel, lubricants, maintenance, overhaul, replacement of parts for the Airframe and engine. The fixed operating costs are those related directly to crew cost, insurance cost, depreciation, Hangar rentals, landing charges etc., This paper gives a method to calculate the direct and fixed operating cost for a 6 ton class civil helicopter. Realistic assumptions are made in the calculation taking into account prevailing rates wherever applicable. This cost is compared with the operating cost of various other presently flying helicopters of same category. Although operating cost of fixed wing levels can not be achieved, helicopter operators can economically compete in the short haul transportation markets where VTOL capabilities offer unique advantage. Operating cost can be reduced by Technology improvement, low cost design philosophy and progressive business policy.

Introduction

Recently many new generation helicopters are developed in Europe and USA as well as by India. Advanced Light Helicopter (ALH) has been designed and developed by India. This is a 6 ton category helicopter. Although, there is a good market potential for the military and civil variant of the ALH, both in domestic as well as international market, there is a tough competition to market these helicopters. Along with advanced features, price plays a major role to sell a helicopter. In addition to price, customer is also interested low life cycle cost or operating cost.

The operating cost i.e., the life cycle cost is divided into two parts: (i) Indicated direct operating cost and (ii) Indicated fixed operating cost.

The indicated direct operating cost is those incurred on day to day basis to fly the helicopters. Examples being fuel, lubricants, maintenance, life limited parts, cost for replacements, miscellaneous flight expenses, crew expenses, small supplies and catering if any. The indicated fixed operating cost consist of crew salaries, hangar rent, hull insurance, legal liability, landing charges and miscellaneous overhead like recurring training, uninsured damage, navigational chart service, refurbishing, computerized maintenance programme, weather service, book depreciation and market depreciation.

The operating cost can be reduced by advance technology usage, low cost design methods and progressive business policy. It requires to review the import duty policy for indigenously produced helicopters so as to reduce the customs duty for the parts, consumables etc., to a large acceptable level in a stipulated time frame till all the items are indigenously produced.

In this paper, an attempt is made to estimate the life cycle cost of a 6 ton helicopter with advanced features like those of Advanced Light Helicopter (ALH). Internationally agreed norms have been followed for cost calculation. Ways and means to reduce the operating cost are also discussed in this paper.

Helicopters and its Roles

Helicopters are rotary wing aircraft and play many roles in peace and war times. Modern generation helicopters like ALH are cost effective multi-role, multi-mission helicopters catering to the needs of defence and civil operators incorporating state of the art technology. The roles are explained briefly below:

* Chief Manager ** Manager (Methods)
Composite Production Engineering, Aircraft Research and Development Centre (ARDC), Hindustan Aeronautics Limited
Marathahalli Post, Bangalore-560 037, India
Manuscript received on 25 Oct 2004; Paper reviewed and accepted on 29 Nov 2004

Un-armed Roles:

- Heliborne assault
- Logistic support
- Reconnaissance
- Airobservation post
- Casuality evacuation
- Training

Armed roles:

- Anti tank
- Close air support
- ASW
- ASV

Civil roles:

- VIP Travel
- Commuter
- Search and Rescue
- Emergency medical service
- Under slung load
- Disaster relief
- Off shore operation

Operating Cost

Operating cost estimate has been done for 6 ton advanced helicopter like ALH to compare with the operating cost of other competing helicopters. In order to have a common definition of operating cost standard international norms have been used. The operating cost of a helicopter has got two parts.

1. Direct operating cost
2. Fixed operating cost

Direct operating cost are incurred on day to day basis of flying the helicopters. It is calculated on hourly basis of flight operation. Cost of fuel, lubricants, maintenance cost, labour cost and spares of the airframe and engine are included in this cost.

The fixed operating costs are indirect costs that are not included in the hourly flying cost of the helicopter. These are crew costs, insurance cost, depreciation, hangar rentals, landing charges etc.

Method of Estimation

Certain assumptions have been made to estimate the indicated direct and fixed operating cost for helicopter configuration, average cost, per flight hours, life cycle, warranty and discounts. Standard configuration for the helicopter is assumed. This doesn't include operational equipments or accessories. Hourly labour rates, fuel and oil consumptions are considered to be reasonably average. These costs are taken as an aid to calculate the operating costs. Actual cost will vary according to environmental operative conditions, experience of maintenance personnel, age and use of the helicopter. In order to put the cost information into a more meaningful form for the user, the direct operating cost is divided by the flight hours. Flight hour is the period of flight time in which an operation will incur most of the overhauls and replace most of the life limited parts. The life cycle of 6 ton helicopter is estimated to be 5000 hrs. Warranty and discounts are excluded. It is assumed at list price for replacement parts. Value per life limited parts, spares, major components and engine overhaul and repairs and TBO (Time between overhaul) are estimated. These costs are to be validated after development and service experience.

The basis elements involved in the cost estimation and values of these elements taken for estimate are given in Table-1. These values are based on the prevailing rates and prices.

Number of passengers for normal version is taken as 12 and for high density version 14. Based on feed back from M/s. Pawan Hans on their experience with dauphin Helicopters, the annual flight hours is taken as 1200. Assuming an average of 2 hours per flight, number of flights per year works out to be 600.

Estimation of Direct Operating Cost

Direct operating cost consists of cost of consumables like fuel and lubricants, reserve for retirement life components, reserve for aircraft spares, reserve for major component overhaul and miscellaneous flight expenses. These are discussed in the following paragraphs:

Consumables (Fuel, Lubricants) : The average fuel flow per hour (ltr/hr) is generally derived from flight manuals, based on the recommended cruise speed at ISA, 1000ft altitude and at a gross weight 10% less than the maximum gross weight for the helicopter. The fuel consumption depends on speed, temperature, externally mounted items etc., The fuel cost also depends on the place of purchase

Table-1 : Basis elements for cost estimates

Sl.No.	Element	Values
1	Initial cost of Helicopter	Rs. 30 crores
2	No. of passengers	12 (14)
3	Annual flights Hours	1200
4	Annual flights	600
5	Cruise speed	245 Kmph
6	Fuel consumption rate	365 litres/hr.
7	Maintenance Manhour rate	Rs.450.00
8	Cost of fuel per litre	Rs.28.00
9	Cost of Lubricant	3% of fuel cost
10	Depreciation period	15 years
11	Depreciation rate	6.67%
12	Hull insurance	7.2%
13	Pilot insurance per flight	Rs.300.00
14	Passenger insurance per flight	Rs.60.00

Table-2 : Cost of consumables

Sl.No.	Item	Cost
1	Cost of fuel per litre	Rs.28,00
2	Average fuel consumption rate	365 ltr/hr.
3	Fuel cost per hour	Rs.10,220.00
4	Cost of lubricants (3% of fuel cost)	Rs.307.00
	Cost of consumables/flight hr.	Rs.10,527.00

as the prices are mostly controlled by the government agencies at that place. In the sample data the fuel consumption and cost of consumables are considered to be reasonably average. The consumables mainly include all lubricants such as engine oil and transmission oil. Average cost of consumable for 6 ton helicopter while operation in India is given in Table-2.

Maintenance (Labour) : Airframe maintenance is grouped into line maintenance, overhauls, replacement of the limited parts and unscheduled maintenance. The estimated man-hour for the maintenance of 6 ton helicopter is given in Table-3.

The cost of routing, scheduled and unscheduled maintenance labour for the airframe, avionics and engines includes all labour to perform required inspections, life replacements of parts, removal/replacement labour incident to overhaul of components and labour associated with performing airworthiness directives, accomplishing required service bulletins etc., The labour required for off aircraft overhaul or repair of component is not included in this cost.

Reserve For Retirement Life Components (For Dynamic Components and Life Limited Parts) : The cost of both parts and labour required for replacement of life limited parts identified by the manufacturer at a specified time interval is included in this. The operating time is slated for all these items identified as dynamically loaded critical components which are to be replaced after certain flight hours. These parts are mainly from rotor system and control system. They are designed and tested for use over a defined number of flight hours rather than on their

Table-3 : Estimated maintenance hours for 6 ton Helicopter

Sl.No.	Item	No. requred/1200 Hrs	Total Man Hour
1	Preflight and post flight insp.	360 nos. (360 days)	360
2	150 hr. insp.	4 times	150
3	300 hr. insp.	2 times	325
4	600 hr. insp.	1 time	240
5	1200 hr.insp.	1 time	475
6	Unscheduled	-	750
	Total maintenance hours		**2400**
a.	Maintenance man-hour/flight hours	2400/1200	2.0
b.	Maintenance man-hour rate		450
	Maintenance labour cost.flight hours	**a x b**	**900**

condition. Estimated cost of life components for 6 ton helicopter is given in Table-4.

Reserve for Aircraft Spares : This cost includes cost of replacement of airframe components, accessories and equipment. Estimated cost for reserve for aircraft spares for a 6 ton helicopter is given in Table-5.

Reserve for Engine Overhaul and Repair : The costs are based on complete cycle of modular components overhaul and maintenance inspections over 2000 hours. Estimated cost is given in Table-6.

Reserve for Overhaul of Major Components : It includes removal, disassembly, inspection, parts replacement re-assembly and reinstallation of certain components/assemblies at the periods stated in the maintenance manual. Overhaul manhour and parts requirements experience considerable variations due to helicopter operation and environment in which it operates. The cost is associated with the minor airworthiness directives, service bulletins and minor engine parts (filters, O rings etc.) It doesn't include inventory cost. Estimated cost of overhaul for major components of a 6 ton helicopter is given in Table-7.

Total Estimated Direct Operating Cost of a 6 Ton Helicopter : Total estimated direct operating cost is computed based on the above factors. This is given in Table-8.

Fixed Operating Cost of a 6 Ton Helicopter

The fixed operating costs are indirect costs that are not included in the hourly flying cost of the helicopter. These are crew costs, insurance cost, depreciation, hangar rent-

Table-4 : Estimated cost of life components for 6 ton Helicopter

Sl.No.	Item	Life flight hours	Unit price (in lakhs)	Cost/hour. Rs.
1	Main rotor hub plate (set)	10000	40.00	400
2	Main rotor blade (set)	10000	156.00	1560
3	Tail rotor blade (set)	10000	34.00	340
4	Main flexishaft	7200	15.00	208
5	Tail drive shaft	1200	4.0	338
6	Others like engine mount, mast bearing	3500	30.0	857
7	Reserve for retirement life items			3698
8	Reserve for rework and/or inspection (60% of retirement work cost)			2219
Total reserve for retirement life items/flight hour				**5917**

Table-5 : Reserve for Aircraft spares

Sl.No.	Item	Cost
1	Estimated cost of airframe spares with basic duty	Rs.37.25 lakhs
2	Total cost of airframe per flight hr.	Rs.3104.00
3	Cost of accessories and equipments/flight hrs. (50% of total cost of airframe spares)	Rs.1552.00
Total reserve for aircraft spares/flight hr. (2+3)		**Rs.4656.00**

Table-6 : Reserve for Engine Overall and repair

Sl.No.	Item	Cost
1	Estimated cost of engines (2 Nos)	Rs.450 lakhs
2	TBO of engine	2000 hrs
3	Cost of overhaul, 40% of cost of engine	Rs.180 lakhs
4	Cost of overhaul hr.	Rs.9000
5	Cost of repair and spares = 15% of overhaul cost	Rs.1350
Total reserve for engine overhaul and repair/flight hr. (4+5)		Rs.10350.00

Table-7 : Reserve for overhaul of major components of a 6 ton Helicopter

Sl.No.	Item	TBO Hour	Estimated unit price Rs.in Lakhs	Overhaul cost (30% of unit cost Rs. in Lakhs)	Overhaul Cost/Hour Rupees
1	Main Gear box	1500	100.00	30.00	2000.00
2	Tail Gear box	1500	9.00	2.7	180.00
3	Auxillary Gear box	1500	9.70	2.9	193.00
4	Intermediate Gear box	1500	6.00	1.8	120.00
5	Main Rotor Hub	1500	2.16	0.648	44.00
6	Tail Rotor Hub	2400	0.48	0.14	6.00
7	Free wheel unit	1500	9.00	2.7	180.00
8	Hydraulic actuator (4 nos.)	3600	11.25	3.375	375.00
9	Hydraulic power pack (3 nos.)	2500	14.00	4.2	504.00
10	Hydraulic pum (3 nos.)	2500	4.7	1.4	168.00
11	Fuel cell (set)	2400	16.0	4.8	200.00
12	Cost of overhaul/flt.hr				3970.00
13	cost of repair and on condition maintanance (15% of cost of overhaul)				596.00
	Total reserve for major components Overhaul/flt.hr.				**4596.00**

Table-8 : Total estimated direct operating cost

Sl.No.	Item	Rs/Hr
1	Consumables	10527
2	Maintenance labour	900
3	Reserve for retirement life item	5917
4	Reserve for aircraft spares	4656
5	Reserve for engine over and repair	10350
6	Reserve for major component overhaul	4566
7	Miscellaneous flight expenses (crew expenses, small supplies and catering in flight)	2000
Total direct operating cost/Flt. hr.		**Rs. 38916**

als, landing charges etc. Estimate of these factors are given below :

Crew Cost : Crew cost includes the salary of the pilots, salary of maintenance crew and other benefits. Details are given in Table-9.

Table-9 : Crew cost

Sl.No.	Item	Cost, Rs.
1	Salary of pilots/year (2 pilots Rs. 60,000 per month)	14,40,000
2	Salary of maintenance crew/year (5 crews at Rs.20,000 per month)	12,00,000
a	Total Salary (1+2)	26,40,000
b	Other benefits 30% of total wage	7,92,000
c	Annual crew cost (a+b)	34,32,000
Crew cost per flight hr with average fight 1200 hrs/year		**Rs.2860/ per hour**

Insurance : It is the cost of insuring the aircraft against damage. This can be either the cost of the insurance premium or the allocated cost of self insurance against aircraft damage. Flight hour cost for insurance depends on three factors namely the amount of investment being insured, the annual rate and utilization. Taking flight risk as 6% and Ground risk as 1.2%, the Annual rate works out to 7.2%. Insurance cost is given in Table-10.

Table-10 : Insurance		
Sl.No.	Item	Cost Rs.
1	Hull coverage (7.2% for 30 crores)	216,00,000
2	Pilots coverage : 300 x 2 x 600 (Rs.300 per flt, 2 pilots, 600 flts)	3,60,000
3	Passengers coverage : 60 x 14 x 6 (Rs.60 per flt, 14 passsengers, 600 flts)	5,04,000
4	Annual Insurance cost (a+b+c)	224,64,000
Insurance cost/flight hours		Rs. 18,720

Table-11 : Depreciation		
Sl.No.	Item	Cost
1	Initial cost of Helicopter	Rs. 3000 lakhs
2	Service life	Rs. 15 Years
3	Rate of Depreciation	6.67%
	Depreciation cost/flight hrs.	$\frac{30,00,00,000 \times 6.67}{1200 \times 100}$
Depreciation cost/flight hr		Rs. 16,675

Table-12 : Overheads		
Sl.No.	Item	Rs. Lakhs
1	P&T, Water, Electricity, Stationery	1.0
2	Building rent	2.4
3	Landing charges (Rs.750 x 2400 landing & T.O. per year)	18.0
4	Salaries of Admin. Staff (5 x Rs.10,000 x 12)	6.0
5	Depreciation of vehicles and equipment (Rs.100 lakhs, 15 years, 15% residual)	5.67
	Annual overheads (1+2+3+4+5)	33.07
Overheads/Flight hours		Rs. 2756

Depreciation: Depreciation cost depends on three factors namely the magnitude of the initial investment, the number of years over which it is expensed and the residual value of the asset at the end of the depreciation period. Since this result in an annual cost, it must be divided by the utilization to derive cost pre flight hour. Zero residual value is assumed for the estimate. This cost for a 6 ton helicopter is given in Table-11.

Overheads : Over heads cover telephone, water, electricity, stationary, rent etc. The estimate of these factors is given in Table-12.

Fixed Operating Costs: Total fixed operation cost is computed based on the above factors and given in Table-13.

Total Operating Cost Per Flight Hour

Total operating cost is sum of total direct operating cost and total fixed cost. Estimated total operating cost is given in Table-14.

Table-13 : Fixed operating cost		
Sl.No.	Item	Rs./Hr
1	Crew cost	2860
2	Insurance	18720
3	Depreciation	16675
4	Overheads	2756
5	Contengency (3% of crew cost)	86
Total fixed operating cost/FH		41097

Table-14 : Total operating cost		
Sl.No.	Item	Cost
1	Total direct operating cost/FH	Rs. 38916
2	Total fixed operating cost/FH	Rs. 41097
3	Total operating cost/FH (1+2)	Rs. 80,013
	Operating cost per pax per KM	$\frac{\text{Rs.80,013}}{\text{245km/hr x No.Pax}}$
	Operating cost/pax/Km	**Rs. 27.21 (12 Pax)**
	Operating cost/pax/Km	**Rs. 23.32 (14 Pax)**

Validation of Estimate

Comparison of Direct operating costs of the various capacity helicopters with above estimate is given in Table-15.

Comparison of Operating Cost of Fixed Wing Aircraft and Helicopter

Compared to a fixed wing turboprop aircraft, a helicopter typically costs about 10 times more to operate per seat mile flown because of

- High acquisition cost
- High insurance rates
- High maintenance and parts cost
- Low utilization and limited service life
- Diseconomies of small/dispersed operation

The helicopter ability to avoid airport and ground delays should make it economically viable in short haul transportation.

Operating cost can be divided into following 5 categories for comparing the cost of fixed wing aircraft and helicopters:

- Depreciation
- Insurance
- Maintenance
- Crew
- Fuel

For turboprops crew and fuel accounts for 50% of the total operating cost compared to 10% for the helicopters. However helicopter costs are higher in the areas of depreciation, insurance and maintenance. The comparison of these factors is given in Table-16.

Table-15 : Comparison of direct operating cost of various capacity Helicopters

Sl.No.	Model	AUW (Kg)	Cruise Speed (Km/Hr)	Direct Operating Cost / FH $
1	Above Estimate	5500	245	$ 828 (Rs.38,916)
2	Bell 430	4100	230	$ 695.10
3	As 365N-2	4300	260	$ 889.29
4	Bell 212	5100	189	$ 763.72
5	Bell 412EP	5400	230	$ 890.60
6	S-76A	4800	250	$ 889.21
7	S-76B	5400	250	$ 983.90
8	S-76C	5400	250	$ 918.27

1$ = Rs.47.00

Source Book : The Aircraft Cost Evaluator, Helicopter Fall 1997, Conklin and de Decker Associates, Inc, USA

Table-16 : The operating cost percentage for Helicopters and Turboprops

	Typical Helicopter	Typical Turboprop Aircraft
Depreciation	36%	27%
Insurance	29%	5%
Maintenance	24%	20%
Flight Crew	6%	25%
Fuel	5%	23%

Table-17 : Factors of Maintenance cost

Sl.No.	Item	Cost
1	Engine	26.4%
2	Airframe	18.4%
3	Rotors	18.1%
4	Drive system	17.7%
5	Avionics	2.4%
6	Labour	17.0%
Total		**100.0%**

Means to Reduce Operating Cost of Helicopters

Operating cost can mainly be reduced by reducing depreciation cost, insurance and maintenance cost. The means of reducing these costs are discussed in the following paragraphs :

Depreciation Cost

It can be reduced by minimizing initial investment and increasing life of utilization. Initial cost i.e., procurement cost can be reduced by

a) Reduced airframe manufacturing cost
b) Use of proven engines and avionics
c) Reduction of spares inventory
d) Reduction of pilots/mechanics training cost
e) Innovative financial support to the user

Fixed wings fly around 2500 hrs annually compared to 1000 hrs for helicopters which doubles the operating cost of the helicopter. By increasing the utilization, depreciation cost can be reduced.

It is observed that fixed wing has depreciation periods of 20 years compared to 10 years for helicopter, thereby doubling the operating cost. Helicopters are more complex and rate of wear & tear is higher than fixed wing aircraft. Durability and built-in margins will increase longevity by over sizing and derating the components which induces weight penalty. Some weight and / or performance have to be sacrificed for lower cost and larger useful life.

The guide lines for reducing the depreciation cost are

- Weight and performance to be optimized for lower selling price
- Use of common interchangeable commercial components
- Use oversized/derated components
- Provide robust design
- Use TBO instead conditional maintenance
- Evolve financial start up capital
- Design of simulators to train crew

Insurance

Helicopter hull insurance is 7% per year compared to 1% for fixed wing aircraft. It is more burdensome as helicopter logs lesser flight hours than that of fixed wing. To reduce insurance we have to increased the dependability of operation both by operator and the helicopter model. Reliability has to be improved through

- Greater performance margins
- Derated engines leading to reduced failure rates
- Use of well proven technology
- Fail safe design
- Health and usage monitoring system with preflight integrity checks
- Improved crash worthiness
- Damage tolerant rotors, structures
- Dual hydraulic, flight control system. Back up system for all the items, failure of which endanger flight.

Maintenance

A typical breakdown of the helicopter maintenance costs are given in Table-17.

Engine and airframe accounts to 40% of the total maintenance cost. Means of reducing the maintenance cost are as follows :

- Standardising and minimising the number of different maintenance tools required
- Maximising accessibility by providing large quick opening facility for the panels
- Incorporating health and usage monitoring to reduce frequent inspections
- Using of captive fasteners and hinged panels
- Using modular design to permit quick replacement of sub-systems for repair

Conclusion

The direct operating cost of a 6 ton helicopter can be calculated by using the method explained in this paper, It also can be reduced by following the suggestion discussed in this paper so that the helicopter can be operated in competitive market.

Although operating cost of the fixed wing levels can not be achieved, helicopters can compete in the short haul transportation markets where VTOL capabilities offer unique advantages. There are three methods of reducing the operating costs.

- Technological Exploitation
- Low cost design methods
- Sound business policy

Well proven technology is better method as the cost would have been minimized by the proven long time experience. Inboard health monitoring system and usage, self checks, bearing less rotors, vibration control methods etc., will help in reducing the cost.

Design approaches like use of derated engine, robust structural design with growth potential, interchangeable parts, modular concepts of component design to be followed to reduce the cost of operation. Establishment of finite component TBO in lieu of on condition unpredictability and endorsement of on-site overhaul and repair by qualified operators will go a long way in reducing various costs.

The manufacturer of the Helicopters can also help in initial financing proposals, training and start up costs. Adequate qualified representation and strategically located service centres can assure fast response to operator needs.

In our country high cost of import duty on spares, replacement items, consumables pushes the cost further up. Progressive indigenization would help in brining down the cost in the long run. Customs duty policy may be reviewed in order to give a boost to indigenously produced helicopters.

Reference

1. "The Aircraft Cost Evaluator, Helicopter Fall 1997", Conklin and de Decker Associates, Inc., USA, pp.92-94.