Investment appraisal for reparable assets using Performance costing approach: A case study on reliability investment on Helicopter systems.

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Abstract: Traditionally, in competitive markets, bids for procurement of capital equipment are evaluated based on least acquisition cost. Sellers strategies to minimize the initial acquisition cost of their product while building in profits through upgrade offers, spares and maintenance services. For long life cycle assets requiring recurrent maintenance interventions, cost of ownership gets skewed by adopting least acquisition cost philosophy. In order to overcome this, organizations are adopting Life Cycle Costing (LCC) approach for high value procurement of repairable assets.

In the LCC approach, the seller has to optimize for lesser operational and maintenance costs in addition to the initial costs. One method of reducing maintenance cost is investment in product reliability, but this entails an upfront investment. The reliability-cost trade off function envisages a particular value of reliability beyond which investment in reliability will increase the total life cycle cost of the equipment.

Revenue generation for the customer is a direct function of reliability. However LCC approach does not incentivize reliability improvement beyond a particular value. Hence, an alternative approach to investment appraisal that seeks to maximize performance of the assets while optimising life cycle costs needs to be evolved. This paper discusses the concept of marginal cost of availability as an alternate metric for capital appraisal for repairable assets and discusses the concept using a case study on helicopter systems. Depending on whether the customer wants to minimize his life cycle costs or enhance his revenues through operations, the appropriate capital investment strategy can be adopted.

Key words: Availability, Aviation assets, Design investment, Life Cycle Costs, Marginal cost of availability, Performance Contract, Reliability.

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1. INTRODUCTION

Decision making on investment in capital assets forms a major managerial activity of Project Managers, Investment planners and Entrepreneurs. Capital equipment investment decisions have long standing effects on the business performance and need to be carefully carried out. Typical investment decisions for Capital procurements follow the least initial investment cost method (L1 process). A product low in capital investment may be beset with high operating cost, poor reliability, low maintenance support and incongruent performance.

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Life Cycle Costing (LCC) approach takes into account operating and maintenance cost. But it does not link investment appraisal to asset availability, effectiveness or performance.

A product low in total life cycle cost may also be low in performance. There is a need to link investment appraisal to performance over the life cycle of the product. This paper analyses capital investment in military aviation assets with a view to optimize the conflicting objectives of performance maximization and life cycle cost minimization.

2. BACKGROUND

2.1 Aviation asset costs

Aviation assets are characterized by high value, technologically intensive, long life cycle, and maintenance intensive repairable equipment. Example of these types of equipment include aircrafts, helicopters, missiles, communication systems, test facilities, industrial machinery etc.

The cost of maintenance and operations over the life cycle is quite significant compared to the acquisition costs. Table I shows the relative costs of various typical aerospace products which reveal the significant elements of costs that need to be considered while making an investment appraisal for an aviation asset.

TABLE I
LIFE CYCLE COSTS OF TYPICAL AEROSPACE ASSETS

In Rs. Crores

Type of asset	Life cycle cost		Acquisition cost		Operation Cost		Maintenance cost		Salvage cost
Luxury Car	0.22	=	0.12	+	0.09	+	0.04	-	0.03
Helicopter	120	=	40	+	40	+	60	-	20
Aircraft: Military	520	=	300	+	200	+	100	-	80
Aircraft : Civil	680	=	350	+	300	+	150	-	120

Source: Conklin & Decker 2013

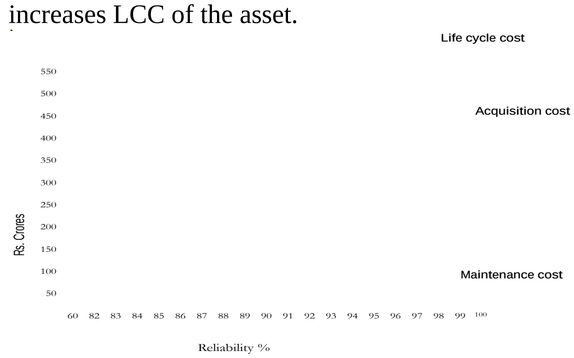
2.2 Aviation asset procurement

The procurement methodology of aviation assets is different for civil aviation products and for defence aviation products. Civil aviation assets are intended for immediate capitalization and return of investment in short term. Accordingly, buyers do not go for outright purchase of the product but rather adopt alternate asset utilization practices like term lease, dry lease or buy back agreements with the suppliers. Defence aviation assets are procured for strategic and long term requirements of the forces, focusing more on combat readiness rather than operational utilization. Public procurement of capital assets are usually governed by the least Acquisition cost process (L1 process). But in case of repairable assets, the life time cost of maintenance far outweighs the acquisition cost.

Hence, in case of high value reparable capital assets, public procurement has shifted to the Least Life Cycle Cost(LCC) methodology. This approach includes discounted costs of acquisition, operation, and maintenance and salvage value of the equipment. The approach makes sense in cases of high value repairable assets like aircrafts, helicopters and their sub systems where the cost of maintenance constitutes a significant portion of the life cycle Cost of the product. In the LCC approach, the seller has to optimize for lesser operational and maintenance costs in addition to the initial costs. Maintenance costs can be reduced by a combination of investment upfront in reliability, maintainability and repairability.

2.3: Investment in Reliability & Life Cycle Costs

One method of reducing maintenance costs is investment in product reliability, but this entails an upfront investment. As investment in reliability is increased, the Mean Time Between Failure (MTBF) increases. This means lesser number of repair withdrawals over the life cycle and hence lesser maintenance costs. There is a particular value of reliability investment beyond which the benefits of lesser maintenance costs is more than offset by the investment there-of. Any investment in reliability beyond the threshold value will increase the total life cycle cost as reflected in the Graph I. Hence, the seller will maintain this level of reliability. There is no incentive for the seller in the LCC approach to maximize reliability beyond a point where it increases LCC of the asset.



GRAPH I
IMPACT OF RELIABILITY INVESTMENT ON LIFE CYCLE COST

2.4: Reliability- Performance relationship

As reliability of the asset increases, the availability of the assets for profitable deployment increases. Reliability and Availability are related by the function

Ao = MTBF / (MTBF+MTTRS)

MTTRS = f(MLDT, MTTR)

where,

Ao = Availability
MTTRS = Mean Time To Restore System
MTBF = Mean Time Between Failure
MLDT = Mean Logistics Down Time
MTTR = Mean Time To Repair

A more reliable asset has more available time for productive use during its life span than a less reliable asset. A less reliable asset may have a low life cycle cost but may be inoperative for a significant period of its life. These assets are classified as Non Productive Assets (NPAs) of the organization. As the NPAs of an organization keep increasing, more number of assets are procured to build in redundancy to maintain the required performance requirements of the organization.

If reliability can be improved (even beyond the LCC ordained value) to ensure more number of available days in the asset's life cycle, the productivity of the organization can increase. Revenue generation for the customer is a direct function of availability. However LCC approach does not incentivize reliability improvement beyond a particular value. Hence, an alternative approach to investment appraisal that seeks to maximize performance of the assets while optimising life cycle costs need to be evolved. This paper seeks to introduce the concept of costs per availability of the asset over its life span and marginal cost of availability. Marginal cost of availability is a preclude to Performance based costing and Performance based Contracting. The paper explores the concept using a live case study.

3. LITERATURE SURVEY

Life cycle costing approach to costly repairable assets has been a field of wide research. The Life Cycle Costing guidelines issued by New South Wales Treasury provides the early attempts at standard processes and templates to be followed for life cycle analysis. The life cycle planning and execution is divided into six phases involving the scope, assumptions, identification of cost elements, modeling, analysis and monitor and control phases. The appropriate capital investment in asset design and maintenance strategy is evolved in the planning phase of the life cycle of the asset. Most of the life cycle costs are frozen in the planning stage and hence detailed analysis of the investments in various elements contributing to life cycle have to be exercised at this stage. Systems engineering approach to life cycle management is proposed by Ingrid Hollander to decide on investment in reliability and maintainability.

An analysis of published papers on the use of LCC approach in decision making by Eric Korpi reveals that while the construction industry dominated the LCC environment, there was hardly any presence of defence and aerospace cases. An important outcome of the analysis revealed that many of the LCC analysis was done from the buyer point of view with a fewer LCC analysis from manufacturer point of view. There was no case of LCC involving manufacturer maintaining the product also. Design trade-off requirements triggered LCC analysis in about 25% of the cases which justifies design efforts being evaluated from an LCC point of view.

Optimising inventory levels of maintenance spares to reduce stock out has been a major area of research in the field of repairable asset management. The METRIC model (Multi-Echelon Technique for Recoverable Item Control) proposed by Sherbooke looks at optimization of stocking levels of one to one replacement of spares at multiple echelons assuming mean values of appropriate probability distributions for arrival rate and service rates. The VARIMETRIC model proposed by Manuel Rosetti extends the model considering not just the means but also the variabilities in the arrival and service rates. Both the models assume putting the system back to service by replacement using a serviceable part or sub assembly but ignore the reverse supply chain of repairing and putting back the unserviceable asset back into service. As the system gets more and more costly, it may not be feasible to hold replaceable spares as inventory but need to establish an efficient repair recycle loop so as to reduce the investment cost in spares build up and hence the total life cycle cost.

Cryut & Ghobbar discuss the impact of supportability in terms of spares inventory on incremental availability for a given level of reliability of Aircraft. The paper focuses on entry into service period of aircraft and utilizes Monte Carlo simulation for stochastic arrival patterns. The effect of variable reliability levels is discussed in the present paper since it is considered that reliability

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has a greater impact on availability compared to supportability in terms of spares stocking.

Linking of the life cycle cost to availability of the asset has been carried out by Dinesh Kumar et al in which the significance of total cost of ownership has been brought out. A case study on railway wagons is carried out to bring out relevant costs of ownership. A mathematical model for determining availability and total life cycle costs is made to evolve a criterion for evaluation of alternate decision parameters. The concept of arriving at availability from MTBF has been used in this subject paper.

Incorporation of life cycle cost analysis in the Performance based Contracting scenario has been discussed in the ATTAC Contracting for Availability handbook which chronicles the issues of PBL in the Tornado aircraft program. In the absence of a suitable reward structure, the designer does not invest in reliability beyond a level of least life cycle costs. The PBL concept introduced for the Tornado aircrafts had focused on spares support structure rather than on reliability more because of the multiple design agencies involved and the lack of maturity of a sustained PBL model. The performance based contract approach is currently practiced mostly in road maintenance projects, warehousing and logistics service providers where the contract links output in the form of service level agreements. The input is not a capital intensive asset where the supplier builds in reliability features which impact the service levels.

Research thus far has been carried out either from an operator's point of view or from a supplier point of view. In usual practice, the operator is also responsible for maintenance; hence there are conflicting goals of the supplier and the operator. The supplier focuses on least life cycle cost as the selling proposition of his product while the operator looks for maximizing utility of the product. This paper attempts to optimize the requirements of both the supplier and the operator by combining the metrics of cost and performance so that the objective function would be to minimize cost per unit performance. The paper discusses this proposition using a case study of a critical helicopter sub system; the Drive system.

4. CASE STUDY

4.1. Background

The helicopter industry is of a very recent origin; the first commercial helicopter production hardly 50 years old. It is an oligopolistic market populated by companies from not more than four to five countries. So, when a developing country embarks on design and production of helicopters, it is faced with decision making with limited information or experience.

Being costly equipment, the customer looks for value for money when making investment in helicopter procurement; more so when the quantities are large. Helicopters are highly maintenance intensive assets since it involves high technology, dynamic systems subject to mechanical, vibratory and aerodynamic loads and the safety and regulatory requirements demand a high level of reliability of its systems and sub-systems.

The cost of operations and maintenance outweighs the cost of acquisition as illustrated in Table II. Hence operators look for life cycle costs rather than initial acquisition costs while making investment appraisals. The operator and the OEM are in constant effort to redesign the product to reduce operation and maintenance costs and increase the total uptime of the product. Under a life cycle costs framework, the OEM will invest in reliability as long as the life cycle costs are coming down and will stop investing in redesign if the cost of such design is more than the life cycle cost benefits due to reduction in maintenance and operation costs. Under Performance Contracting, the OEM looks to optimising the operational availability and has an incentive to improve reliability beyond LCC ordained values if it improves performance metrics defined by the contract.

TABLE II
TYPICAL COSTS FOR VARIOUS HELICOPTERS Rs. Crores

Type	Mfr	Acquisition cost	Operation cost (10 years)	Maintenance cost (10 years)	Life cycle cost (10 years)	Seating capacity	Cost per seat
AW109A	UK-1987	10.15	17.78	26.76	54.70	7+1	7.81
B205A	USA-1980	5.91	26.50	32.74	65.15	7+1	9.31
MD500C	USA-1976	1.07	10.83	16.17	28.07	3+1	9.36
ALH	INDIA-2001	42.50	40.00	60.00	142.50	12+2	11.88
EC225	FRANCE-2005	90.87	44.99	57.36	255.62	12+2	16.10

4.2 Definition of the problem

The particular helicopter under study was selected by the customer after intense negotiations with the OEM under the mandate of life cycle costs. One of the critical success factors for a military helicopter fleet is its operational readiness which depends on helicopter availability. The availability of this helicopter was very low to maintain the minimum operational readiness and the OEM took up redesign activities to improve availability.

The helicopter has about twelve major repairable systems each with its own level of reliability. Helicopter reliability is the product of the reliability of the individual systems. One such critical system is the Drive system which moderates the power from the twin engines to the rotor system. The Drive system re-engineering efforts and its implication on cost & availability was to be analyzed to meet the twin objectives of reduced life cycle costs and improved availability. The helicopters are proposed to be taken up under a Performance based Contracts approach at a later point in time based on which the OEM has to plan his capital investment appraisal.

4.3. Alternate Propositions

The re-engineering of the Drive system was taken up by the design organization and alternate propositions worked out. The summary of the design propositions is as below:

Revision O: This was the first prototype built by the design group at a cost of Rs. 90 lakhs, but it did not meet the minimum requirements of the specification of the helicopter during tests and needed modifications.

Revision I: Improvements in Lubrication sub-system involving improved filtration systems and introduction of by-pass value costing an additional Rs.30 lakhs. The Revision I was the standard of the Drive system installed on the existing first phase of helicopter. The drive system had an MTBF of 300 hours. Defects arising of this system was of two types; Oil leak defect in the lubrication system and Gear mesh spalling in the drive train. The design organization proposed three alternate design propositions to enhance the reliability of the system.

Revision II: A re-engineering of the sealing and pumping systems was proposed which will eliminate completely the oil leak defect. This modification costs an additional Rs.10 Lakhs to incorporate.

Revision III: This revision envisaged modification of the entire gear train by using carburized gears and high endurance bearings (akin to the drive system for fighter helicopters). The modified Drive system including Revision II modification was estimated to cost Rs 250 Lakhs. FMEA (Failure Mode Effect Analysis) analysis predicted an enhanced MTBF of 700 hrs for this system.

Revision IV: This is not a revision of the existing Drive system but actually adapting a new system designed for civil helicopter applications which was still in the initial stages of design. It had a targeted MTBF of 1000 hours and with the additional reliability features estimated to cost Rs 320 Lakhs. The summary is placed in Table III.

4.4. Evaluation of alternate proposals

4.4.1 Evaluation on Life Cycle Costs: Based on the acquisition cost related to design from the above table and available values of maintenance and operations, the life cycle costs for each of the propositions is computed. To arrive at the Net present value (NPV) a discount rate of 6% per annum has been applied which is the cost of capital for a Government organization. Material costs are computed with an annual escalation of 8 % based on average metal price index rates for aerospace materials. The discounted Life cycle cost computation for the four revisions is placed in Table IV and the same is summarized in Table V. It can be seen that Revision I has the least Acquisition cost and Revision II Drive system has the minimum Life cycle cost and is preferred by the customer.

TABLE III
ALTERNATE DESIGN PROPOSITIONS

Rev No.	Design	Cost (Lakhs)	MTBF (Hrs)	Outcome
Rev 0	Initial prototype design	90	<<<	Not meeting RFQ
Rev I	Existing design	120	300	Low availability
Rev II	Modified sealing	130	300	MTTR reduced by 1 day
Rev III	Gear mesh change	250	700	Gear wear reduction expected
Rev IV	New configuration	320	1000	Higher reliability expected

TABLE IV
DISCOUNTED LIFE CYCLE COST COMPUTATION

YEAR No.	0	1	2	3	4	5	6	7	8	9	10	Total Cost
REVISION 1												
Acquisition cost	12000000	0	0	0	0	0	0	0	0	0	0	12000000
Operation cost	1500000	1590000	1685400	1786524	1893715	2007338	2127779	2255445	2390772	2534218	2686272	
Operation cost (Discounted NPV)	1500000	1446900	1395680	1346273	1298615	1252644	1208300	1165526	1124267	1084468	1046077	13868749
Maintenance cost (oil leak defect)	300000	324000	349920	377914	408147	440798	476062	514147	555279	599701	647677	
Maintenance cost (Gear mesh defect)	0	2000000	2160000	2332800	2519424	2720978	2938656	3173749	3427649	3701860	3998009	
Total maintenance cost(Inflation adjusted)	300000	2324000	2509920	2710714	2927571	3161776	3414718	3687896	3982928	4301562	4645687	
Maintenance cost (Discounted NPV)	300000	2114840	2078465	2042715	2007580	1973050	1939114	1905761	1872982	1840766	1809105	19884378
LIFE CYCLE COST												45753127
REVISION 2												
Acquisition cost	13000000	0	0	0	0	0	0	0	0	0	0	13000000
Operation cost (inflation adjusted)	1500000	1590000	1685400	1786524	1893715	2007338	2127779	2255445	2390772	2534218	2686272	
Operation cost (Discounted NPV)	1500000	1446900	1395680	1346273	1298615	1252644	1208300	1165526	1124267	1084468	1046077	13868749
Maintence cost (Inflation adjusted)	0	2000000	2160000	2332800	2519424	2720978	2938656	3173749	3427649	3701860	3998009	
Maintenance cost (Discounted NPV)	0	1820000	1788696	1757930	1727694	1697978	1668772	1640070	1611860	1584136	1556889	16854026
LIFE CYCLE COST												43722775
REVISION 3												
Acquisition cost	25000000	0	0	0	0	0	0	0	0	0	0	25000000
Operation cost (inflation adjusted)	1500000	1590000	1685400	1786524	1893715	2007338	2127779	2255445	2390772	2534218	2686272	
Operation cost (Discounted NPV)	1500000	1446900	1395680	1346273	1298615	1252644	1208300	1165526	1124267	1084468	1046077	13868749
Maintence cost (Inflation adjusted)	0	0	1080000	1166400	1259712	1360489	1469328	1586874	0	1850930	1999005	
Maintenance cost (Discounted NPV)	0	0	894348	878965	863847	848989	834386	820035	0	792068	778445	6711083
LIFE CYCLE COST												45579832
REVISION 4												
Acquisition cost	32000000	0	0	0	0	0	0	0	0	0	0	32000000
Operation cost (inflation adjusted)	1500000	1590000	1685400	1786524	1893715	2007338	2127779	2255445	2390772	2534218	2686272	
Operation cost (Discounted NPV)	1500000	1446900	1395680	1346273	1298615	1252644	1208300	1165526	1124267	1084468	1046077	13868749
Maintence cost (Inflation adjusted)	0	0	1080000	0	1259712	1360489	0	1586874	0	1850930		
Maintenance cost (Discounted NPV)	0	0	894348	0	863847	848989	0	820035	0	792068		4219287
LIFE CYCLE COST												50088036

TABLE V
LIFE CYCLE COST FOR VARIOUS REVISIONS OF DRIVE SYSTEM

Rs. Lakhs

	Acquisition cost	Maintenance cost	Operational Cost	Salvage Cost	Life Cycle cost	Discounted LCC
Revision I Existing design	120	230	150	0	**500**	**457.53**
Revision II Oil leak Modfn	130	200	150	0	**480**	**437.23**

Revision III Modified gear train	250	85.7	150	0	**486**	**455.80**
Revision IV Civil Version adaptn	320	50	150	0	**520**	**500.88**

<u>4.4.2 Evaluation on Performance Index</u>: Performance of an asset is measured by means of its availability for useful deployment. Availability for the various proposals are computed based on the MTBF and MTTRS values. A higher availability means that in a 10 year life span, the asset is available for more number of days for deployment. Accordingly, the life cycle cost can be divided over the usable life of the asset to obtain cost per flying day in each of the four cases. The summary is presented in the Table VI. It can be seen that Revision III has the least marginal cost of availability while Revision IV has the highest number of available hours in a ten year life.

TABLE VI
PERFORMANCE COSTING FOR VARIOUS REVISION DRIVE SYSTEM

	Life Cycle Cost (Rs. Lakhs)	Discounted Life cycle cost (Rs. Lakhs)	Availability (%)	Availability in 10 years life cycle (Days)	Cost of Availability (Rs/ flying day)
Revision I Existing drive system	**500**	**457.53**	**83.33 %**	**3000.00**	**15,251**
Revision II Oil leak Mod drive system	**480**	**437.23**	**85.71 %**	**3085.71**	**14,169**
Revision III Modified gear train drive system	**486**	**455.80**	**93.33 %**	**3360.00**	**13.565**
Revision IV Civil Version drive system	**520**	**500.88**	**95.24 %**	**3428.57**	**14,609**

5. DISCUSSIONS

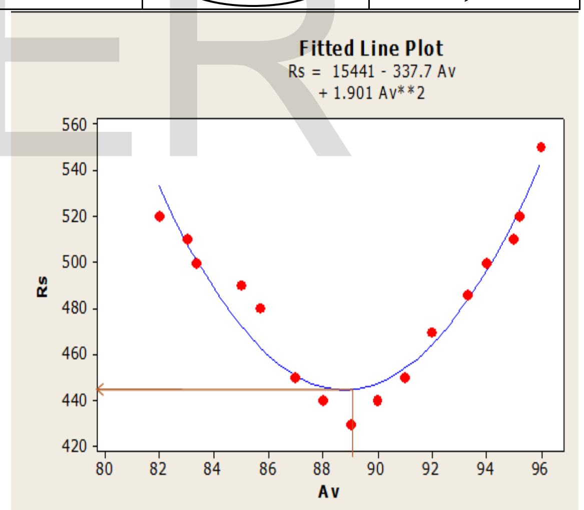
The results of the evaluation on life cycle costs (Table V) and the evaluation on Performance Index (Table VI) are plotted on a graph and the salient points identified for discussion. The best fitting curve is fitted using Minitab software and its equation determined. Graph II shows the plot of life cycle cost.

The best fitting equation to the curve is

$$LCC = 1.901x^2 - 337.7x + 15441.$$

Differentiating and equating to zero, the minimum LCC = 443.45 Cr at an availability of 88.82%. Revision II drive system is close to the theoretical minimum.

GRAPH II
LIFE CYCLE COST CURVE USING MINITAB



Similarly, the Performance costs are plotted in Graph III.

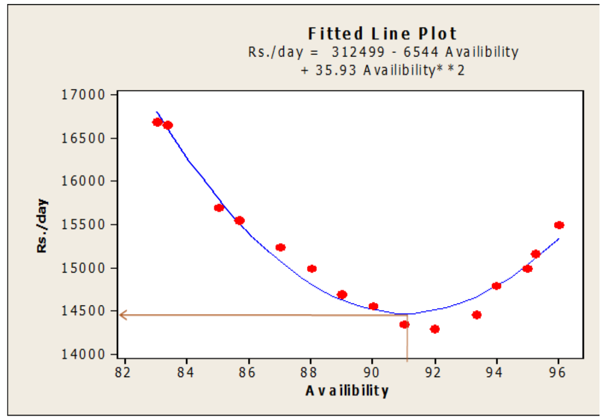
The Equation for performance costs is

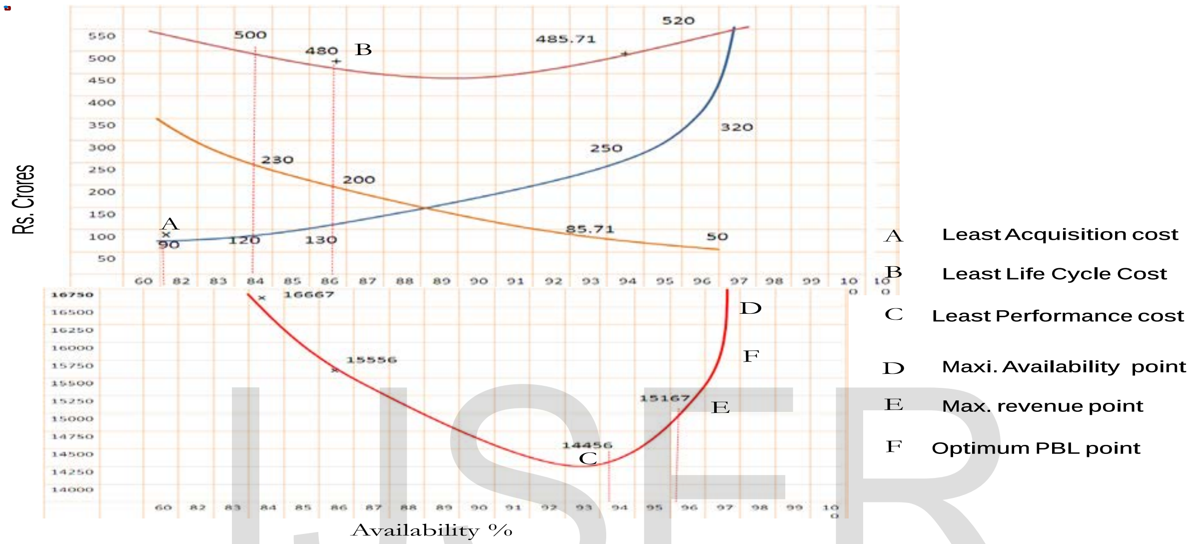
$$PC = 35.93x^2 - 6541x + 312499.$$

Differentiating and equating to zero to get the minima, we get Minimum Performance cost = 13752 Rs/flying hour at an availability of 91.70 %. We find that the Revision IV drive system is close to the theoretical minima for performance costs.

The values of least acquisition cost, least life cycle cost, least performance cost are plotted on a common axis for further discussion in Graph IV.

GRAPH III
PERFORMANCE COST GRAPH





GRAPH- IV
LIFE CYCLE COSTS AND MARGINAL PERFORMANCE COSTS

Based on least acquisition cost framework, as seen from Table III the existing Revision I of the Drive system is preferred as it involved an investment of Rs. 120 lakh and it meets the minimum requirements of the specifications (Point A). On a life cycle costing approach, it can be observed that Revision II is preferred since it has a least life cycle cost (Point B). Revision III and Revision IV entail a higher level of life cycle costs and are discarded under the life cycle costing approach.

However, it would be worth examining Revision III from the performance approach. As can be seen from Table VI,, Revision III has a quantum jump in availability from 85.71 % to 93.33 %. This means that within the life span of the helicopter, Revision III is available for 3360 days as against 3085 days in Revision II: an increase of 9.0 %. The increase in number of deployable days of the helicopter has many implications. The life cycle cost is now spread over a larger number of flying days so that the cost per flying days is reduced. The cost per flying day in Revision II is Rs 14,169 per flying day, while that in Revision III is Rs 13,565 per flying day. Hence, it can be seen that the actual cost per unit performance is better in Revision III than in Revision II. (Point C).It can be deduced that performance costing is a better approach to life cycle costing on high value reparable assets with significant down-time affecting the actual number of available days in the life span.

An increase in the number of days deployment of an asset increases the revenue that can be earned from the asset by increased operations. In case of civil operations, every single additional hour of operational deployment during the life span of an asset increases the sales earned by the customer (or operational readiness in case of military operations)(Point D).

In some case, maximized availability of the assets would be the operational objective, if non availability of the asset affects the revenue earned or business lost or from strategic perspectives in case of military assets. In such case, Performance maximization precedes cost optimization as the objective criterion in investment appraisals (Point E).

In Performance Contracting regimes, where the revenues for the services contractor is directly proportional in slabs to the level of availabilities, the service provider will go in for investment that provides maximum performance within the contracting slab, to maximize his revenues (Point F).

Summarizing, the reliability investment decision on Capital assets is governed by the performance objective of the asset and it would be unwise to do such capital investment appraisal solely on least acquisition cost or least life cycle cost alone.

TABLE VII
SUMMARY OF DISCUSSIONS

Decision criterion	Method	Metric for analysis	REVISION	Point on Graph
Minimise acquisition cost	Least acquisition cost method	Cost of acquisition	Revision I	**A**
Minimise Life cycle cost	LCC Method	Total life cycle cost	Revision II	**B**
Availability linked Life cycle cost	Performance method	Cost per unit performance	Revision III	**C**
Availability at any cost	Performance maximization	Maximum availability	Revision IV	**D**
Revenue linked life cycle cost	Life cycle break even	Break even availability	Revision III	**E**
Performance based contracting	Slab optimization method	Maximum profit point	As applicable	**F**

6. AREAS OF APPLICATION

Investment decisions on high value repairable assets need to be made not just on life cycle cost optimization but also on performance during life time. Assets may have a low life cycle cost but may not be adequately available for the purpose it is procured rendering the very investment non-productive. Non Performing Assets (NPAs) are a major investment malady in various segments of industry, more so in the defence sector. From strategic, operational and market point of view, assets in certain segments of industry cannot remain idle. Examples of these include front line defence equipment, process oriented industries like petroleum, thermal plant etc.., market sensitive industries like services sector (hospital equipment, hotel equipment). In such a case, performance linked costing or revenue based investment analysis would include all aspects of investment appraisal. Different organizations would decide to operate on different points on the life cycle cost curve based on Business needs. This paper provides a basis for decision making for such investments.

In Performance Contracting regimes, the revenue stream of the service provider is dependent on the levels of performance/availability that he guarantees. There are slab-wise incentives for ensuring availability of assets. Hence, the service provider would like to maintain the availability at the most optimum to facilitate maximization of incentives. Equipment on Annual Maintenance Contract, wet/dry lease of specialized transport equipment (including aircraft, helicopters, heavy duty material handlers and movers) would perform at much higher levels than what the LCC model stipulates since they are performance sensitive areas. By juxtaposing the performance contracting revenue model over the equipment costing model, optimum levels of availability can be arrived at.

7. SCOPE FOR FURTHER STUDY

This paper has considered only one of the various systems involved in a multi-system asset like helicopter. Such an exercise has to be performed at a complete aircraft level to understand the relative trade-offs in investments in various systems. Systems Engineering approach can be employed for such trade-off analysis. While the paper has focused on reliability improvement through investment in design as a means to improve availability, availability can also be improved through multi-echelon servicing and spares management activities. These will also reduce the downtime and hence improve availabilities. The paper can form a basis for similar such investment analysis on reparability and maintainability. The costing model has to be linked with the revenue model as contracted under the Performance based contracting maintenance model to obtain optimum values of reliability for the supplier who also becomes the maintainer of the system.

Summarizing, the paper has attempted to highlight the need to combine the minimizing of life cycle cost objective with the maximizing of availability objective (proxy for revenue generating capability) by reformulating the objective function. For this purpose, the paper has defined performance cost or the cost per unit performance as a better metric for decision making especially in the realms of performance contracting wherein the objectives of the supplier and the maintainer converge.

ADDITIONAL RESOURCES

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