

# Life cycle costing of MRI machine at a tertiary care teaching hospital

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## Abstract

**Background:** Life cycle costing (LCC) is an excellent decision-making tool that can assist a hospital administrator in seeking more cost-effective decisions to select the best course of action. LCC can be defined as “an economic assessment of competing design alternatives, considering all significant costs of ownership over the economic life of each alternative, expressed in equivalent rupees. **Aim:** To determine the LCC of magnetic resonance imaging (MRI) machine at a tertiary care teaching hospital. **Settings and Design:** A descriptive, observational study in MRI scan center of a tertiary care teaching hospital. **Materials and Methods:** LCC analysis (LCCA) was performed to ensure total cost visibility for the entire life span of the MRI scan equipment, which was assumed to be 10 years. **Statistical Analysis:** Data were analyzed using MS Excel. **Results and Conclusions:** The total cost per MRI scan was calculated to be Rs. 2944. It was estimated that the MRI scan center would reach the break-even point by the end of the third year.

**Key words:** Break-even point; cost effectiveness; life cycle cost; MRI Centre; MRI costing

## Introduction

Life cycle costing (LCC) is defined in the International Organization for Standardization standard, as an “economic assessment considering all agreed projected significant and relevant cost flows over a period of analysis expressed in monetary value. The projected costs are those needed to achieve defined levels of performance, including reliability, safety, and availability.”<sup>[1]</sup>

LCC is an excellent decision-making tool that can assist a hospital administrator in seeking more cost-effective decisions to select the best course of action. LCC can be defined as “an economic assessment of competing design alternatives, considering all significant costs of ownership over the economic life of each alternative, expressed in equivalent rupees”.<sup>[2]</sup>

In the context of sustainable public procurement (SPP), the use of LCC is essential to demonstrate that procurement processes and decisions have to move beyond considering the purchase price of a good or service because the latter does not reflect the financial and non-financial gains that are offered by environmentally and socially preferable assets as they occur during the life cycle of the asset.

Typical LCC analyses are based on:

- Purchasing and all associated costs such as delivery, installation, commissioning, and insurance
- Operating costs including utility costs such as energy, water, and maintenance costs

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- End-of-life costs, such as removal, recycling, refurbishment, and decommissioning
- Longevity and warranty time frames of the asset.

LCC analysis (LCCA) can explore trade-offs between low initial costs and long-term cost savings and identify the most cost-effective system for a specific setting. In addition, it can also determine how long it will take for a specific system to “pay back” its incremental cost. Since creating an exhaustive LCC estimate for every potential element is not practical, the guidelines for LCCA focus on features and systems most likely to impact long-term costs.<sup>[3]</sup> Considering all the above inputs, a study was carried out to analyze LCC of 1.5 Tesla magnetic resonance imaging (MRI) scan facility to evolve a decision matrix for cost-effectiveness analysis of the future technology.

#### Aim

LCC of MRI machine at a tertiary care teaching hospital.

#### Objectives

- To determine the unit cost of the scans conducted at the MRI scan center
- To calculate the break-even point for 1.5 Tesla MRI machine in the scan center
- To conduct cost-effectiveness analysis using LCC method for MRI machine.

#### Scope

Due to constraints of time and resources, all types of MRI scans carried out were clubbed together while calculating the unit cost and no attempt was made to calculate the unit cost of various types of MRI scans.

### Materials and Methods

It was a descriptive and observational study. Direct observations were made to determine the entire process of carrying out an MRI Scan. The following records were also reviewed:

- Standard Operating Procedures (SOPs)
- Various policy letters
- Financial documents for technology acquisition
- Miscellaneous records.

Further, the staff of the MRI facility was interviewed to ascertain the organization, staffing, and functioning of the center.

#### Costing method

The operating costing method was used to estimate unit cost per scan, which was derived by calculating and adding the fixed and variable costs.

#### Fixed cost-The following contributed to the fixed cost

- Salary
- Cost of building
- Maintenance costs of building

- Cost of equipment
- Equipment maintenance cost.

#### Variable cost

The variable costs incurred during an MRI scan included the following-

- Films and Contrast cost
- Consumables (stationery, drugs, medical supplies and cleaning materials)
- Cost of electricity
- Cost of diesel.

#### Life cycle cost analysis

LCCA was performed to ensure total cost visibility for the entire life span of the MRI scan equipment, which was assumed to be ten years. Cost inputs were divided into the fixed and variable cost for determining the unit cost of MRI scan and for carrying out break-even analysis.

The “time value of money” states that money received at a different time is not equally valuable. For a comprehensive analysis of the technology, a discounted cash flow technique of net present value (NPV) was employed. Costs for each year in the life cycle of the MRI equipment were discounted to the NPV.

A discounting factor of 10% which was compounded annually was taken for the study. Cost in respect of cash flow for each year of the life cycle was multiplied by the discounting factor (worked out from a standardized annuity table) to arrive at the present value of the cash flow.

### Results

#### Calculation of unit cost of MRI scan

The unit cost of MRI scan performed on the equipment was arrived at by calculating the cost of each item consumed during the scan.

#### A. Fixed Cost

**a) Manpower Cost** = Total monthly salary of staff

Average number of scans per month

$$=360104/413 = \text{Rs } 872/-$$

#### b) Cost of Building

Documents of the turnkey projects were perused and cost of the building was ascertained to be Rs 65, 36,000/-. The life of the building was assumed to be 100 years.

$$\text{Cost of building per year} = 65, 36,000/100 = 65, 360/-$$

Hence, **Cost of building per scan** = 65, 360/number of scans per year

= 65, 360/4957 = Rs. 13.18

### c) Maintenance Costs of Building

The annual cost of Building/Repair and Electrical/Mechanical maintenance for MRI center was Rs. 29,487.

Maintenance cost per scan = 29487/4957 = Rs 5.95

### d) Cost Profile of Equipment as in Table -1.

### e) Cost Analysis of Comprehensive Maintenance Cost (CMC) as in Table – 2.

Out of 10 years' life of MRI equipment, the first 5 years were under warranty and the next 5 years under Comprehensive Maintenance Cost (CMC). According to the contract, the amount of CMC was increased by 5% each year.

The cost of CMC per scan was calculated to be Rs. 20.

## B. Variable Costs

### a. Cost of MRI Laser film

Cost of the 14" × 17" laser film which was most commonly used for the scans was taken into consideration. This cost was Rs 13,114 for a pack of 125 films. Hence the cost per film was Rs 105. The annual consumption of films was 4788 leading to an annual expenditure of Rs 5, 02,740 on films. Hence, the cost of laser film per scan was Rs 101.

### b) Electricity as in Table – 3.

### c) Cost of Diesel for DG set as in Table – 4.

### d) MR Contrast Agent as in Table -5.

Gadolinium-based MR contrast was used only in contrast studies and angiographies. The total annual consumption of contrast was calculated to be 2684ml. The cost per 10 ml vial of Inj Gadolinium was Rs. 750. Hence, the annual cost on contrast was Rs 2, 01,300. Based on historic data from the MRI scan center, it was seen that on an average there are 60% plain and 40% contrast MRI scans. Annual MRI scans for the year under study were 4957 (2974 plain scans + 1983 contrast scans).

Cost of Inj Gadolinium per contrast scan = 201300/1983 = Rs 102

Combined film and contrast cost per scan = (101 × 2974) + (203 and 1983)/4957

= Rs. 142 per scan

**Table 1: Cost of MRI equipment**

S. No	Cost of Equipment	Cost (INR)
(a)	Total installation cost	7,50,00,000/-
(b)	Cost of machine per year <sup>#</sup>	75,00,000/-
(c)	Cost of equipment per scan	75,00,000/4957 = Rs. 1513/scan

<sup>#</sup>assuming the life of MRI machine to be 10 years

**Table 2: Cost of comprehensive maintenance contract**

S. No.	Years	Annual Cost
(a)	First 5 yr (warranty period)	Nil
(b)	6 <sup>th</sup> yr	176000
(c)	7 <sup>th</sup> yr	184800
(d)	8 <sup>th</sup> yr	194040
(e)	9 <sup>th</sup> yr	203742
(f)	10 <sup>th</sup> yr	213929
(g)	Total	9,72,511
(h)	Cost of maintenance per yr	97,251
	Cost of maintenance per scan	97251/4957 = Rs. 20

**Table 3: Cost of electricity**

S. No.	Cost Element	Equipment
(a)	Annual consumption	196352 KWH
(b)	Annual cost of Electricity	196352 × 7.88 = 15,47,254
(c)	Cost of electricity per Scan	15,47,254/4957 = Rs 312

**Table 4: Cost of diesel**

S. No.	Cost Element	Equipment
(a)	Average monthly consumption	325 litres
(b)	Monthly cost of diesel @ 64 per litre	325 × 64 = 20, 800
(c)	Cost of diesel per scan	20800/413 = Rs 50

### e. Consumable Cost

Total consumables cost which per scan was calculated to be **Rs 15.49 per scan.**

### BEP analysis

BEP is defined as "The point at which total cost incurred becomes equal to the total revenue generated over the years". It is calculated using the following formula.

**Break Even Point (BEP) = Fixed Cost** \_\_\_\_\_

(Selling Price – Variable Cost)/unit

(a) Fixed cost was taken as the Cost of equipment and CMC cost.

(b) **Selling price/unit:** The selling price was a virtual or notional figure since no revenue was actually been generated. For the BEP calculation, the existing government rates were considered:-

i. Plain MRI scan = Rs 5000/-

- ii. Contrast MRI Scan = Rs 8000/-
- (c) For calculation of average selling price per unit, as mentioned earlier, the MRI scans for the year under study were 4957 (2974 plain scans + 1983 contrast scans).
- (d) Hence, average selling price/unit scan is calculated as under:-  
 $(2974 \times 5000) + (1983 \times 8000) = \text{Rs } 6200/-$   
 4957
- (e) **Variable costs:** Variable cost per unit scan was calculated to be Rs. 519.

**Calculation of BEP as in Table – 6.**

$$\text{Break-Even Point (BEP)} = \frac{\text{FC}}{(\text{SP} - \text{VC}) / \text{unit}}$$

$$\text{BEP (Qty)} = \frac{7,59,72,511}{(6200 - 519)}$$

$$= 13,373 \text{ units}$$

Thus, for 1.5 Tesla MRI machines, the center shall break even towards the end of the third year.

**Table 5: Total cost incurred per MRI scan**

Common Cost Element			
	Fixed Cost	Variable Cost	Cost/scan (Rs)
(a)	Labour cost		872
(b)	Building cost		13.18
(c)	Building maintenance Cost		5.95
(d)		Films and contrast costs	142
(e)		Cost of Consumables	15.49
<b>(A)</b>	<b>Common cost per scan</b>		<b>1049</b>
Specific Cost Element			
	Fixed Cost	Variable Cost	Cost/scan (Rs)
(f)	Cost of equipment		1513
(g)	Cost of equipment maintenance		20
(h)		Electricity	312
(j)		Diesel cost	50
<b>(B)</b>	<b>Specific Cost Element per scan</b>		<b>1895</b>
(c)	Unit cost per scan (Total- (A)+(B))		2944

**Table 6: Calculation of break-even cost**

S. No.	Fixed Cost	Variable Cost	
(a)	Equipment Cost	7, 50, 00,000	Material cost (films and contrast) 142
(b)	CMC (10 year)	9,72,511	Indirect Material Cost 15.49
(c)	Diesel		Electricity 312
(d)			50
(e)	Total	7,59,72,511	519

**Life cycle costing for technology acquisition as in Table – 7.**

The cost categories identified during the cost estimation of MRI procedure were included in the cost break down structure of the life cycle of the equipment. The number of scans to be performed in the first year of installation was assumed to be 3500. Further, the number of scans was assumed to increase by 10% every year till the fourth year, after which the number is expected to stabilize. The cost for each year of the life span of the equipment was estimated by multiplying the expected numbers of scans in the whole year with the cost of performing the unit procedure. All procedures beyond the BEP were multiplied by the average selling price to arrive at the expected virtual benefit cash outlays and cash inflows for each year in the life cycle of the MRI equipment were multiplied by the discounting factor to arrive at the present value. A discounting value of 10% was assumed for annual compounding for each year of the life cycle. The discounting factor was taken from the standardized annuity tables. NPV was then calculated to be Rs. 66,776,174 at the end of 10 years.

**Discussion**

In a study conducted by Chakravarty A. and Debnath J., the unit cost per MRI was found to be Rs. 4244.58 (1.5 T upgrade) and Rs. 6059.37 (3 T MRI).<sup>[4]</sup> The LCCA also revealed that the NPV of the 1.5 T upgrade and new 3 T machine was Rs. 42,148,587.80 and Rs. 27,587,842.38, respectively. In our study, the unit cost per scan was calculated to be Rs. 2944.00, which was considerably lower as compared to this study. For our equipment, the NPV was calculated to be Rs. 66,776,174, which was considerably higher as compared to their study.

A study was conducted by Khurshid Rehana *et al.* to estimate the unit cost of various radiological investigations in a large tertiary care teaching institute in north India.<sup>[5]</sup> The authors included direct and indirect costs but did not adopt LCC method and recorded that the unit cost of an MRI scan was Rs. 4497.50, which was approximately 50% more than the unit cost calculated in our study.

In another study, Col A Chakravarty and Col SS Naware calculated the unit cost of an MRI scan to be Rs 3,875 (Plain) and Rs 4,129 (Contrast), which was higher as compared to our study, Rs. 2944 (Plain) and Rs. 3086 (Contrast).<sup>[6]</sup>

- a. LCC should be an integral part of SPP policies. Since resource allocation and the budget setting is undertaken at a higher level in the organization than routine procurement decision-making, “whole life value thinking” will begin to permeate all public spending decisions.
- b. The management officials responsible for public expenditure policy should be provided with the necessary tools, platforms, budgets, and expertise to perform this analysis in a cost-effective manner.

**Table 7: LCCA of MRI equipment**

S. No.	Year	Number of Scans	Cash Flow				
			Cash inflow	DF (10%)	PV (Benefits)	Cost	PV 99 (Costs)
(a)	1 <sup>st</sup>	3500	21700000	0.909	19725300	1816500	1651199
(b)	2 <sup>nd</sup>	3850	10010000	0.826	8268260	1998150	1650472
(c)	3 <sup>rd</sup>	4235	11011000	0.751	8269261	2197965	1650672
(d)	4 <sup>th</sup>	4659	12113400	0.683	8273452	2418021	1651508
(e)	5 <sup>th</sup>	4659	12113400	0.621	7522421	2418021	1501591
(f)	6 <sup>th</sup>	4659	12113400	0.564	6831958	2418021	1363764
(g)	7 <sup>th</sup>	4659	12113400	0.513	6214174	2418021	1240445
(h)	8 <sup>th</sup>	4659	12113400	0.467	5656958	2418021	1129216
(j)	9 <sup>th</sup>	4659	12113400	0.424	5136082	2418021	1025241
(k)	10 <sup>th</sup>	4659	12113400	0.386	4675772	2418021	933356
		Total			80573638		13797464
					(X)		(Y)
Net Present Value (Rs)					(X - Y) = 66,776,174		

c. LCC should be promoted more as a tool for showing value for money, rather than simply a method for calculating the costs of purchasing environmentally and socially preferable goods, services, and assets.

#### Limitations

All prices are mentioned in Indian Rupees and there may be some variations in cost depending on the geographical location as well as the type of facility (Government/Private) due to variation in the cost of construction, land costs, negotiation capabilities, etc., The cost may vary depending on the vendor that supplies and maintains the equipment also. The cost of procurement and operations of Picture Archiving and Communication System (PACS) is not included in the unit cost.

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Nil.

#### Conflicts of interest

There are no conflicts of interest.

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