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Quadratic Trend Running Cost Replacement Model with Linear Trend Salvage and Predicted Inflation

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Abstract
The paper Quadratic Trend Running Cost Replacement Model with Linear Trend Salvage and Predicted Inflation is an attempt made to develop right replacement strategy to determine an age of equipment at which the replacement is most economical. The annual maintenance or running cost of equipment is assumed to follow quadratic trend and salvage as linear trend. Using trend equations along with parameters like money value, predicted inflation economic replacement model has been developed.
Keywords: *Replacement, Inflation, Forecasting, Interest rates, Money value.*

Introduction

The replacement problems are concerned with the situation that arises when the efficiency of item decreases, failure or breakdown occurs. The decrease of efficiency or breakdown may be either gradual or sudden. The objective of replacement is to decide best policy to determine an age at which the replacement is most economical instead of continuing at increased maintenance costs. The fundamental objective of replacement is to direct the organization for maximizing its profit (or minimizing the cost). Formulation of problem is done for a situation "Quadratic Trend Running Cost Replacement Model with Linear Trend Salvage and Predicted Inflation" and a case study is conducted considering the machine maintenance data. Forecasts are estimates of the occurrence, timing or magnitude of future events and forecasting is a technique, which is used for estimating. Forecasting gives operations manager a rational basis for planning and scheduling activities, even though the actual demand is quite uncertain. Every day the managers have to take decisions in the face of uncertainty, without knowing what would happen in future. The manager strives to reduce this uncertainty and make better estimates of what is likely to happen in future. This is what forecasting aims to accomplish. Thus, whether it is inventory control, marketing strategy formulation, financial planning, production planning or any other such area of operations, managers have to employ the tool of forecasting

Inflation, Real Interest Rate, Nominal Interest Rate

Inflation means a process of rising prices. Different Economists have defined the term inflation in different ways. According to Irving Fisher "Inflation occurs when the supply of money actively bidding goods and services increases faster than the available supply of goods". Inflation leads to Inflationary spiral. When prices rise, workers demand higher wages. Higher wages leads to higher costs. Higher costs lead to higher prices. Higher prices again lead to higher wages, higher costs and so on. The amount charged, expressed as a percentage of principal, by a lender to a borrower for the use of assets. Interest rates are typically noted on an annual basis, known as the annual percentage rate (APR). The assets borrowed could include, cash, consumer goods, large assets, such as a machine. Interest is essentially a rental, or leasing charge to the borrower, for the asset's use. In the case of a large asset, like a machine or building, the interest rate is sometimes known as the "lease rate".

Nominal interest rate or nominal rate of interest refers to the interest rate on an investment or loan without adjusting for inflation. The nominal interest rate is simply the interest rate stated on the loan or investment agreement. If one makes a loan at a high nominal interest rate, this does not guarantee a real profit. Real interest rate refers to an interest rate that has been adjusted to remove the effects of inflation to reflect the real cost of funds to the borrower, and the real yield to the lender. The real interest rate of an investment is calculated as the amount by which the nominal interest rate is higher than the inflation rate.

Real Interest Rate = Nominal Interest Rate - Inflation (Expected or Actual)

Irving Fisher theory of interest rates relates the nominal interest rate "i" to the rate of inflation "ϕ"and the real interest rate "r". The real interest rate "r" is the interest rate after adjustment for inflation. It is the interest rate that lenders have to have to be willing to loan out their funds. The relation Fisher posted between these three rates is:

$$(1 + i) = (1 + r)(1 + \phi) = 1 + r + \phi + r\phi$$

This is equivalent to $i = r + \phi(1 + r)$

Thus, according to this equation, if 'ϕ' increases by 1% the nominal interest rate increases by more than 1%. This means that if 'r' and 'ϕ' are known then 'i' can be determined. On the other hand, if 'i' and 'ϕ' are known then 'r' can be determined by the relationship is

$$1+r = (1+i) / (1+\phi) \quad \text{or } r = (i-\phi) / (1+\phi)$$

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Regression Model of Inflation with Trigonometric Function

In the current model it is assumed that inflation which plays vital role in calculation of real interest rate is assumed to be a regression model with trigonometric function to accommodate cyclical fluctuation of prices. Forecasting of inflation is carried out for 20 years based on the regression equation generated.

A model for a seasonal variation might include transcendental functions. The cycle of the model is as below. The model might be used to represent data for the four seasons of the year.

$$\phi = a + b\,n + c \sin(T\pi/2)$$

Here 'ϕ' is inflation, 'n' is a variable and 'T' period, *a*,*b*,*c* are the coefficients. Table-1 gives the quarterly data of inflation for two years.

Table-1: Quarterly data of Inflation

Year(T)	0	1/4	1/2	3/4	1	5/4	3/2	7/4	2
ϕ	3.0	3.35	3.2	3.15	3.4	3.75	3.6	3.45	3.8

Following set of equations are used to obtain the values of coefficients of regression model

$$\phi = a + b\,n + c \sin(T\pi/2) \quad (1)$$

$$\sum\phi = n\,a + b\sum n + c\sum \sin(T\pi/2) \quad (2)$$

$$\sum(\phi\, n) = a\sum n + b\sum n2 + c\sum n.\sin(T\pi/2) \quad (3)$$

$$\sum(\phi\, n2) = a\sum n2 + b\sum n3 + c\sum n2.\sin(T\pi/2) \quad (4)$$

When time origin is taken between middle of years the equation reduces to

$$\sum\phi = n\,a + c\sum \sin(T\pi/2) \quad (5)$$

$$\sum(\phi\, n) = b\sum n2 \quad (6)$$

$$\sum(\phi\, n2) = a\sum n2 + c\sum n2.\sin(T\pi/2) \quad (7)$$

by solving above equations we get the values of regression coefficients

a = 3.41 b = 0.082 c = - 0.25

The final regression equation is:

Fn = 3.41 + 0.082 n – 0.25 sin (T π /2)

Table-2: *Forecasted Inflation for 20 years*

Year(n)	1	2	3	4	5	6	7	8	9	10	11
R(n)	720	740	770	820	870	930	1000	1080	1180	1280	1390

Replacement Problem with Quadratic Trend Running Cost and Linear Trend Salvage.

The replacement problems are concerned with the situation that arises when the efficiency of item decreases, failure or breakdown occurs. The decrease of efficiency or breakdown may be either gradual or sudden. The objective of replacement is to decide best policy to determine an age at which the replacement is most economical instead of continuing at increased maintenance costs. The problem of replacement is encountered in the case of both men and machines. It is possible to estimate the chances of failure of various ages. The fundamental objective of replacement is to direct the organization for maximizing its profit (or minimizing the cost). In the current paper it is assumed that maintenance cost of a machine follows quadratic trend with governing relation as:

$R(t) = c_0 + c_1 t + c_2 t^2$

't' is time period, c_0, c_1 are parameters or coefficients. The model can be fitted to the data by using ordinary least square method. Following set of equations are used to obtain the values of coefficients of regression model

$R = c_0 + c_1 t + c_2 t^2$ (8)

$\sum R = n c_0 + c_1 \sum t + c_2 \sum t^2$ (9)

$\sum(R t) = c_0 \sum t + c_1 \sum t^2 + c_2 \sum t^3$ (10)

$\sum(R t^2) = c_0 \sum t^2 + c_1 \sum t^3 + c_2 \sum t^4$ (11)

The following yearly maintenance cost (in rupees) of a machine is used to get trend equation of maintenance. The machine is purchased at a total cost of C = Rs.6300. The nominal rate of interest is assumed as i =18%.

Table-3*Maintenance cost of Machine*

x *x*	*T(period in years)* *(Period in years)*	ϕ
-4	0.00	4.00
0	1.00	4.40
4	2.00	4.80
8	3.00	5.062
12	4.00	5.338
16	5.00	5.658
20	6.00	6.022
24	7.00	6.342
28	8.00	6.618
32	9.00	6.938
36	10.00	7.302
40	11.00	7.622
44	12.00	7.898
48	13.00	8.218
52	14.00	8.582
56	15.00	8.902
60	16.00	9.178
64	17.00	9.498
68	18.00	9.862
72	19.00	10.182
76	20.00	10.458

by solving above equations we get the final regression equation as **$R(t) = 895 + 67.5\, t + 8.5\, t^2$** and using this trend, maintenance costs are forecasted and used in replacement decision making.

It is assumed that salvage value follows linear trend with governing relation as: $S(t) = s_0 - s_1 t$.

Following set of equations are used to obtain the values of coefficients of regression model

$S = s_0 - s_1 t$ (12)

$\sum S = n s_0 - s_1 \sum t$ (13)

$\sum(S t) = s_0 \sum t - s_1 \sum t^2$ (14)

Table-4: *Salvage cost of Machine*

Year(n)	1	2	3	4	5	6	7	8	9	10	11
S(n)	2200	2150	2100	2050	2000	1950	1900	1850	1800	1750	1700

by solving above equations we get the final regression equation as **$S(t) = 1950 – 50\, t$**

Table –5 Calculation of average annual cost with money value (Forecasted maintenance cost, inflation and real rate of interest)

1	2	3	4	5	6	7	8
Period ***n***	*Inflation* ϕ_n	*Real interest rate* r_n	*Present worth factor* v	*Discount factor* v^n	*Discount factor* v^{n-1}	*Dividing discount factor* $\sum v^{n-1}$	*Maintenance Cost (Forecasted)* R_n
1	3.4	3.32	0.97	0.97	1.00	1.00	971
2	3.8	2.96	0.97	0.94	0.97	1.97	1064
3	4.04	2.77	0.97	0.92	0.95	2.92	1174
4	4.37	2.54	0.98	0.90	0.93	3.85	1301
5	4.69	2.34	0.98	0.89	0.91	4.76	1445
6	5	2.17	0.98	0.88	0.90	5.66	1606
7	5.33	2.00	0.98	0.87	0.89	6.54	1784
8	**5.65**	**1.86**	**0.98**	**0.86**	**0.88**	**7.42**	**1979**
9	6.03	1.70	0.98	0.86	0.87	8.30	2191
10	6.29	1.61	0.98	0.85	0.87	9.16	2420

9	10	11	12	13	14
Maintenance Cost with money value $R_n v^{n-1}$	*Cumulative Maintenance Cost with money value* $\sum R_n v^{n-1}$	*Salvage (Forecasted)* S_n	*Salvage with money value* $S_n v^n$	*Total annual cost* $TC = (C - S_n v^n + \sum R_n v^{n-1})$	*Average annual cost* $TC/\sum v^{n-1}$
t	971.00	1900	1838.98	5432.02	5432.02
1033.43	2004.43	1850	1745.21	6559.21	3327.41
1111.57	3116.00	1800	1658.35	7757.65	2658.47
1206.76	4322.76	1750	1583.05	9039.70	2350.63
1317.35	5640.10	1700	1514.39	10425.71	2191.51
1442.78	7082.88	1650	1450.87	11932.01	2109.74
1583.99	8666.87	1600	1392.75	13574.13	2074.42
1739.82	**10406.70**	**1550**	**1337.83**	**15368.87**	**2070.52**
1914.18	12320.88	1500	1288.54	17332.33	2089.15
2096.67	14417.54	1450	1236.41	19481.14	2126.12

Table –6: Calculation of average annual cost without money value

Year (n)	**Forecasted Maintenance cost(R_n)**	**Cumulative Maintenance Cost($\sum R_n$)**	**Resale value (S)**	**Total cost TC=(C+$\sum R_n$ - S)**	**Average cost per year TC / n**
1	971.00	971.00	1900.00	5371.00	5371.00
2	1064.00	2035.00	1850.00	6485.00	3242.50
3	1174.00	3209.00	1800.00	7709.00	2569.67
4	1301.00	4510.00	1750.00	9060.00	2265.00
5	1445.00	5955.00	1700.00	10555.00	2111.00
6	1606.00	7561.00	1650.00	12211.00	2035.17
7	1784.00	9345.00	1600.00	14045.00	2006.43
8	1979.00	11324.00	1550.00	16074.00	2009.25
9	2191.00	13515.00	1500.00	18315.00	2035.00
10	2420.00	15935.00	1450.00	20785.00	2078.50
11	2666.00	18601.00	1400.00	23501.00	2136.45
12	**2929.00**	**21530.00**	**1350.00**	**26480.00**	**2206.67**
13	3209.00	24739.00	1300.00	29739.00	2287.62

Results and Conclusion

When money value with inflation is considered, it is observed from the table 5, that the average annual cost of machine is decreasing gradually up to 8th year and from 9th year it is increasing. So it is advisable to replace the machine at the end of 8th year. But when money value is not considered the replacement period comes to 12th period (table 6). In general real time decision making depends on various uncontrollable parameters. In the current work of replacement of machine, only some macroeconomic parameters are considered with an assumption that the running cost has linear trend, but there is a lot of scope to develop a robust model considering different patterns of running cost, mileage of machine , technological changes, government policies (taxes etc.,).

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Dr S. Gajanana, worked as Head of the Department and presently working as Professor. Presented many papers in national and international conferences and published papers in national and international journals.
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