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Block Replacement by Considering Influence of Inflation and Time Value of Money on the Optimal Replacement Policy

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ABSTRACT

This work aims at finding the block replacement period for a block of items (a block of computers, a block of LCD televisions in hotel industry, a block of pressure gauges in filling plants, a block of cutting tools in a work shop etc.) that may consist of many intermediate repairable states like minor repair, major repair etc. between functional and complete failure states that are more realistic in practice.The objective of replacement is to decide best policy to determine an age at which the replacement is the most economical instead of continuing at increased maintenance costs. The fundamental objective of replacement is to direct the organization for maximising its profit (or minimizing cost).The main objective of the model is to provide means for analyzing the behaviour of the system for the purpose of improving its performance. Consequently this study aims at exploring and evaluation of an option of reengineering in lieu of replacement. The objective of reengineering is to improve the process performance by alteration, or partial replacement of a process and thereby reducing the maintenance costs.

Keywords: replacement, Inflation Markov Chain, mathematical model.

1.0 Introduction

Before considering the purchase of any capital equipment, the evaluation of its reliability is essential, which directly depends upon the probability of failures. It is desirable to obtain a reliability index (numerical value) for each machine which is based on such factors as visual inspection tests and measurements, age, environment duty cycle of the equipment. These numbers, so calculated, represent the reliability of particular equipment. It is also possible to combine these indices and express an aggregate reliability index number for the complete system.

From the evaluation of the above index numbers, schedules can be set for equipment maintenance. Wherever needed, the maintenance efforts can be expanded. From the reliability reports it is possible to determine the actions that are required to maintain the operational availability at the desired level. Cost estimates for such maintenance for much maintenance functions can also be prepared based on the reliability information.

The replacement problems are concerned with the situations that arise when the efficiency of items decreases, failure or breakdown occurs. Sharma(2003)[1], Kanti Swarup(1992)[2] and Hiller et al(20010[3] have listed out replacement policies for items that deteriorate gradually when money value does not change with time and when money value does change with time. They also listed out Replacement model for items that fails suddenly and completely.

Chein et *al* (2007) [4] presented an optimal age-replacement policy with minimal repair based on cumulative repair cost limit. In their study the complete repair cost data was considered with an aim to evaluate whether to repair the unit or to replace. This model considers the costs of equipment downtime and storing spare parts or items.

Nuthall et *al* (1983)[5] studied the impact of inflation on tractor replacement costs along with the impact of some other parameters viz. financing method and increased or decreased hours of use.

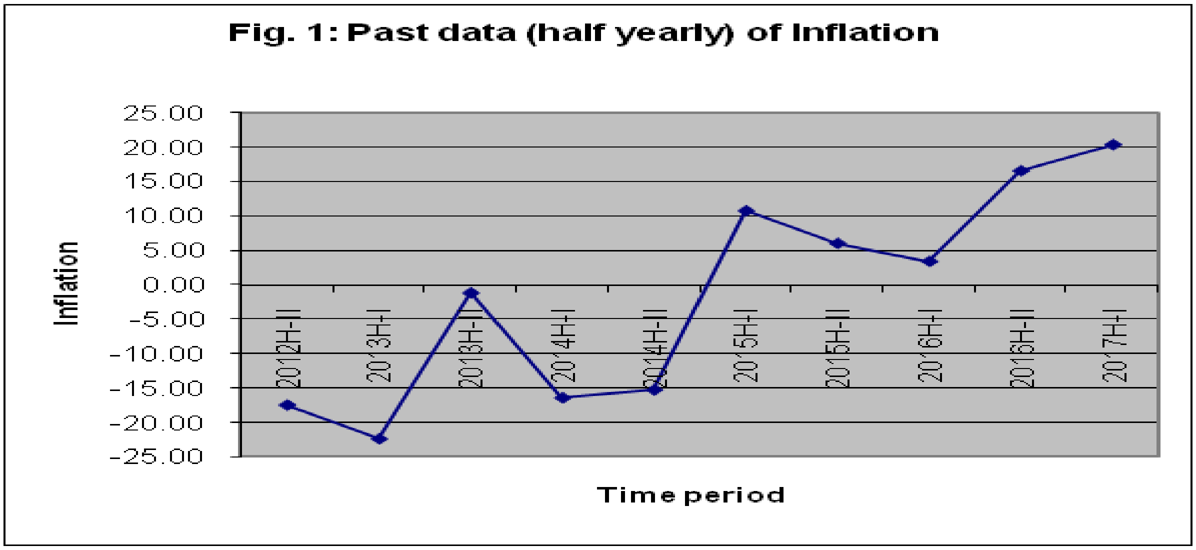
Thomas Archibald et al (1996)[6] proposed Modified Block-Replacement Policy (MBRP) of BERG & Epston (1976) in two ways, considering discrete time framework for multi-component systems. Both the ways increase the practical value of MBRP. In MBRP, the failed components are replaced immediately and preventive maintenance takes place at regular intervals.

2.0 Forecasting of Inflation

In the present study, the half yearly inflation (Table .1) data for ***Computer and Computer based system*** in India from the second half of 2012 to the second half of 2017 which is calculated based on the Wholesale Price is considered. Upward linear trend with nearly sinusoidal fluctuations is observed as plotted in the Fig. #1.

Year	Inflation (ϕ) during	
	Jan. - June	July – Dec.
2012		-17.48
2013	-22.40	-1.18
2014	-16.44	-15.27
2015	10.76	6.03
2016	3.41	16.5
2017	20.38	

Table .1: Past data of (Half yearly) Inflation



Inflation is forecasted using Time Series and Causal forecasting models to identify the underlying model that best fits the time series data. And also an error analysis is made as a measurement of accuracy. The following models are employed for the forecasting of inflation.

1. **Moving Average Method**

$$F_t = (\varphi_{t-4} + \varphi_{t-3} + \varphi_{t-2} + \varphi_{t-1})/4; \qquad \text{---(1)} \quad \text{Refer Table 2}$$

2. **Weighted Moving Average Method**

$$F_t = (\varphi_{t-4} + 2\varphi_{t-3} + 3\varphi_{t-2} + 4\varphi_{t-1})/10; \qquad \text{---(2)} \quad \text{Refer Table 2}$$

3. **Simple Exponential Smoothing Method**

$$F_t = \mu\varphi_{t-1} + (1-\mu)F_{t-1}; \qquad \text{---(3)} \quad \text{Refer Table 3}$$

where μ = Smoothing coefficient

4. **Regression Method** *with trigonometric function*

$$F_t = a + bt + c \sin(t\pi + \pi/4); \quad \text{---(4)} \quad \text{Refer Tables 4 \&.5}$$

where F_t = Forecasted inflation for a time period t.

φ_t = actual inflation for the time period t.

Time period	Inflation rate (ϕ)	Moving Average Method			Weighted Moving Average Method		
		Forecasted inflation(F)	e	|e|	Forecasted inflation(F)	e	|e|
2012H-II	-17.48						
2013H-I	-22.4						
2013H-II	-1.18						
2014H-I	-16.44						
2014H-II	-15.27	-14.38	0.90	0.9	0.00	-0.90	2.11
2015H-I	10.76	-13.82	-24.58	24.58	0.36	-24.22	24.28
2015H-II	6.03	-5.53	-11.56	11.56	10.10	-1.46	9.71
2016H-I	3.41	-3.73	-7.14	7.14	12.18	5.04	2.47
2016 H-II	16.59	1.23	-15.36	15.36	11.33	-4.03	12.79

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	average=	-11.55	11.91	average=	-5.11	10.27

Table .2: Forecasted Inflation data using Moving Average & Weighted Moving Average Methods

Simple Exponential Smoothing							
Time period	Inflation rate (ϕ)	μ = 0.4			μ = 0.2		
		Forecasted inflation(F)	e	|e|	Forecasted inflation(F)	e	|e|
2012H-II	-17.48	-20.00	-2.52	2.52	-20.00	-22.52	2.52
2013H-I	-22.4	-18.99	3.41	3.41	-15.50	-18.91	2.9
2013H-II	-1.18	-20.36	-19.18	19.18	-11.71	-30.89	18.9
2014H-I	-16.44	-12.69	3.75	3.75	-5.54	-9.29	0.14
2014H-II	-15.27	-14.19	1.08	1.08	-3.68	-4.76	1.06
2015H-I	10.76	-14.62	-25.38	25.38	-2.73	-28.11	26.87
2015H-II	6.03	-4.47	-10.50	10.5	2.89	-7.61	16.77
2016H-I	3.41	-0.27	-3.68	3.68	4.42	0.74	10.80
2016 H-II	16.59	1.20	-15.39	15.39	4.27	-11.12	21.82
		average=	-7.60	9.43		-33.64	11.31

Table # 3: Forecasted Inflation data using Simple Exponential Smoothing

3.0 REGRESSION MODEL WITH TRIGONOMETRIC FUNCTION

A sinusoidal trigonometric function is used in the regression model to accommodate cyclical fluctuations of inflation. For this the following mathematical equation is considered.

$$\phi = a + bt + c \sin(t\pi + \pi/4) \qquad \text{- - - (5)}$$

To find the constants a, b & c the following set of equations are used.

$$\sum\phi = na + b\sum t + c\sum\sin(t\pi + \pi/4) \qquad \text{- - - (6)}$$

$$\sum(\phi t) = a\sum t + b\sum t^2 + c\sum[t\sin(t\pi + \pi/4)] \qquad \text{- - - (7)}$$

$$\sum(\phi t^2) = a\sum t^2 + b\sum t^3 + c\sum[t^2\sin(t\pi + \pi/4)] \qquad \text{- - - (8)}$$

where ϕ is the inflation, t is time period, n is the number of time periods and a, b & c are the coefficients. Table #6.1 gives the half yearly inflation data.

By solving the equations (6),(7),and (8) we get the values of regression coefficients.

$$a = -22.51 \quad b = 9.0369 \quad c = 5.5802 \qquad \text{---(9)}$$

The final regression equation is:

$$F_t = -22.51 + 9.0369t + 5.5802\sin(t\pi + \pi/4) \qquad \text{- - - (10)}$$

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And the calculations are tabulated in Table 6.4 and the forecasted inflation is shown in Table 5.

Regression model using trigonometric function										
Year	**Time period (t)**	**t^2**	**t^3**	**ϕ**	**ϕt**	**ϕt^2**	**tπ+ π/4**	**sin (tπ + π/4)**	**t sin (Tπ + h/4)**	**t^2 sin (tπ + π/4)**
2012H-II	0	0	0	-17.48	0	0	45	0.7071	0	0
2013H-I	0.5	0.25	0.12	-22.4	-11.2	-5.6	135	0.7071	0.35355	0.176775
2013H-II	1	1	1	-1.18	-1.18	-1.18	225	-0.7071	-0.7071	-0.7071
2014H-I	1.5	2.25	3.37	-16.44	-24.66	-36.99	315	-0.7071	-1.06065	-1.590975
2014H-II	2	4	8	-15.27	-30.54	-61.08	405	0.7071	1.4142	2.8284
2015H-I	2.5	6.25	15.62	10.76	26.9	67.25	495	0.7071	1.76775	4.419375
2015H-II	3	9	27	6.03	18.09	54.27	585	-0.7071	-2.1213	-6.3639
2016H-I	3.5	12.25	42.87	3.41	11.93	41.77	675	-0.7071	-2.47485	-8.661975
2016 H-II	4	16	64	16.59	66.36	265.44	765	0.7071	2.8284	11.3136
	18	**51**	**162**	**-35.98**	**55.705**	**323.883**		**0.7071**	**0**	**1.4142**

Table4: Calculations for Regression model using trigonometric function

Year	**Time period (t)**	**Inflation (ϕ)**	**F**	**e**	**|e|**
2012H-II	0	-17.48	-18.56424	-1.08	1.08
2013H-I	0.5	-22.4	-14.04579	8.35	8.35
2013H-II	1	-1.18	-17.41886	-16.24	16.2
2014H-I	1.5	-16.44	-12.90041	3.54	3.54
2014H-II	2	-15.27	-0.490441	14.78	14.8
2015H-I	2.5	10.76	4.0280094	-6.73	6.73
2015H-II	3	6.03	0.6549406	-5.38	5.38
2016H-I	3.5	3.41	5.1733906	1.76	1.76
2016 H-II	4	16.59	17.583359	0.99	0.99
			Average=	0.00	6.54

Table 5: Forecasted Inflation data for past time periods using regression model

4.0 MEASURES OF ACCURACY:

An error analysis is made in terms of Mean error and Mean Absolute Deviation (MAD) and the results are tabulated in the Table 6.

Forecasting Model			Mean Error = (∑e) / n	Mean Absolute Deviation= (∑| e |) / n
Moving Average Method	$F_t = (\varphi_{t-4} + \varphi_{t-3} + \varphi_{t-2} + \varphi_{t-1})/4$		-11.55	11.91
Weighted Moving Average Method	$F_t = (\varphi_{t-4} + 2\varphi_{t-3} + 3\varphi_{t-2} + 4\varphi_{t-1})/10$		-5.11	10.27
Simple Exponential smoothing method	$F_t = \mu\varphi_{t-1} + (1-\mu)F_{t-1}$	μ=0.2	-33.64	11.31
		μ=0.4	-7.6	9.43
Regression Model *with trigonometric function*	$F_t = -22.51 + 9.0369t + 5.5802\sin(t\pi + \pi/4)$		0.00	6.54

Table 6: Table of errors and accuracy of Inflation

Though It Seems Mean Absolute Deviation Is A Little Bit Higher, It Is Evident That The Regression Model With Trigonometric Function Is Producing Relatively Minimal Errors. It Can Be Noticed From The Results That The Absolute Deviation For The Forecasted Inflation Is High During The Starting Time Periods (2013 And 2014), And Is Very Minimal During The Latest Time Periods (2015 And 2016).

Subsequently Inflation For The Forthcoming Periods Is Predicted By Using Regression Model With Trigonometric Function And Are Tabulated In The Table 7 And Plotted In The Fig 2.

Year	Time period (t)	Inflation rate (ϕ)	Forecasted inflation (F)
2012H-II	0	-17.48	**-18.56424**
2013H-I	0.5	-22.4	-14.04579
2013H-II	1	-1.18	**-17.41886**
2014H-I	1.5	-16.44	-12.90041
2014H-II	2	-15.27	**-0.490441**
2015H-I	2.5	10.76	4.0280094
2015H-II	3	6.03	**0.6549406**
2016H-I	3.5	3.41	5.1733906
2016 H-II	4	16.59	**17.583359**
2017H-I	4.5	20.38	22.101809
2017H-II	5		**18.728741**
2018H-I	5.5		23.247191
2018H-II	6		**35.657159**
2019H-I	6.5		40.175609

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2019H-II	7		**36.802541**
2020H-I	7.5		41.32
2021H-II	8		**53.73**
2022H-I	8.5		58.24
2023H-II	9		**54.87**

Table 6.7: Forecasted inflation data for future time periods using regression model

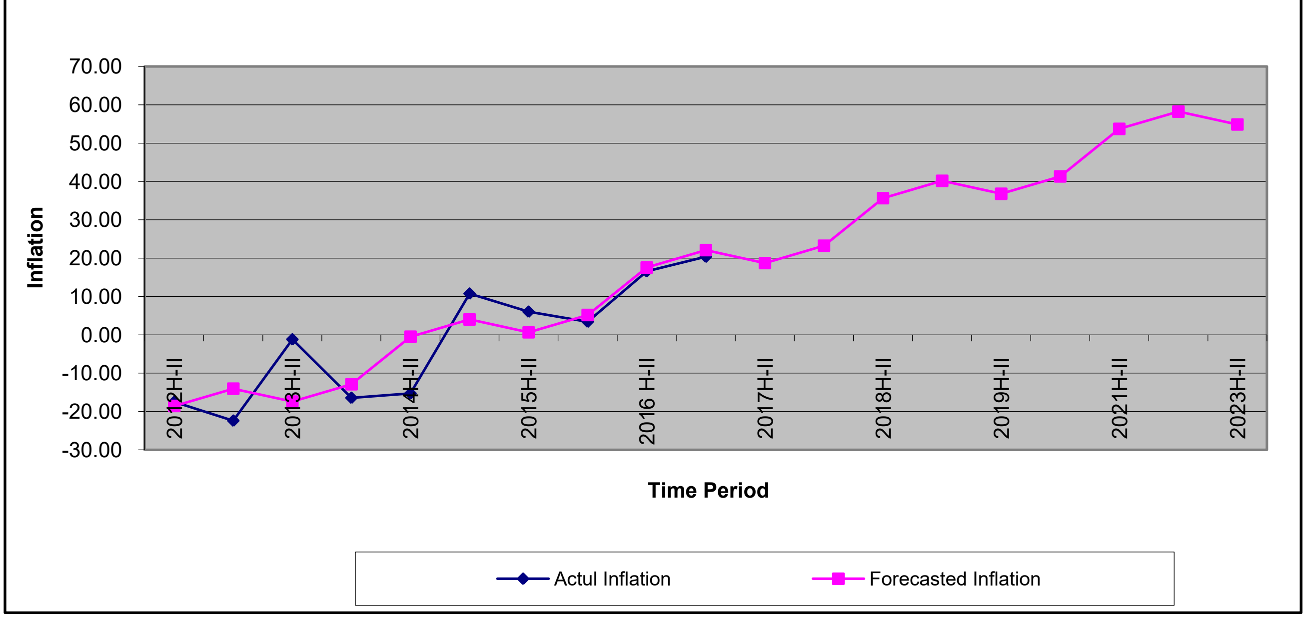

Fig. 2 Forecasted Vs.Actual Inflation

Conclusion

The following conclusions are drawn from current work

1. In the fast growing (Indian) economy with increased business activity, replacement models are meaningless when evaluated in the absence of macro economic variables like inflation, real rate of interest and actual purchase power of money.
2. Researchers started considering macro economic variables in replacement models recently. In these models they considered money value as the bank interest rate. But in reality, real worth of money or real interest rates are to be considered to compute present worth of future investments made at various points of time.
3. Hence, inflation is accounted from which real interest rates are computed. It is quite natural that prices of items/industrial units

fluctuate with respect to prices in a base year/period. If real increase/decrease in value of money is not considered and instead nominal increase in the value of money (bank interest rate) is employed in replacement model, reality or practicality is neglected and the solution obtained will not be reliable.

4. Hence, the intention of predicting inflation with best forecasting methods (a method with Minimum forecast errors) paved the way for the development of this "Block Replacement Model". The inflation (based on WPI for *Computer and Computer based system)* over a period of time is studied, forecasted and compared with actual values for the known periods by employing various forecasting techniques to identify the underlying model that best fits the time series data. Also inflation is predicted for the forthcoming time periods by the developed Regression model with trigonometric function, which yielded relatively minimal errors.
5. The output of this regression model forms a class of input for replacement problem defined along with other inputs like initial cost, repair cost, number of items etc. in a system.

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