CHAPTER – III

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CHAPTER – III

3.1 SURVEY OF LITERATURE

In this chapter, the review of literature relevant to the study carried out and the latest work done by different researchers in the areas of macroeconomic variables, forecasting, replacement theories, inflation, forecasting, and Markov processes.

3.2 FUNDAMENTALS OF MACROECONOMIC VARIABLE – INFLATION, FORECASTING, REPLACEMENT MODELS, AND MARKOV PROCESS

Different economists have defined the term inflation in different ways. In fact, a glut of definitions for ‘inflation’ are found in literature. In general, inflation is ‘the phenomenon of sizeable and rapid increase in general price level of products and services in a particular economic domain’. According to Irwing 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 leads to higher prices. Higher prices again lead to higher wages, higher costs and so on”.

The authors found various causes of inflation and propose various methods to control inflation.

Several researchers viz., Seth (1989) [29], Gregory and Schweitzer (2000) [34] and Khanna (1992) [7] discussed the concept of inflation with different perceptions.

Riggs (1987) [35], Makridakis and Wright (1989) [37] defined forecasting as a managerial tool, which is used to estimate the occurrence, timing or magnitude of future events. Forecasting gives operations manager a rational basis for planning and scheduling activities, even though actual demand is quite uncertain. The authors proposed various quantitative methods like Smoothing Methods, Decomposition Method for Time Series forecasting, Autoregressive / Slash Moving Average Methods, Simple Regression Methods, Multiple Regression Methods, and Econometric Modeling.

Maurice Sasienni et al. (1966) [1], Richard Bronson (1986) [2], Hiller et al. (2001) [3], Kanti Swarup (1992) [4], Wagner (1993) [5] and Sharma S.D (2004) [6] discussed the replacement policies for items that deteriorate gradually with different failure mechanisms, considering and without considering the time value of money. They have done work on the development of different conventional replacement models taking into account the various costs of maintenance. They also developed a model for replacement of sudden and complete failure items.

Sharma S.D (2004) [6] has developed various replacement policies like “Replacement Policy For Items Whose Maintenance Cost Increases With Time, and Money Value is Constant” and “Replacement Policy For Items Whose Maintenance Cost Increases With Time, and Money Value is Changed With Constant Rate”. He has also developed replacement model for items that fails completely.

3.3 PREDICTION OF INFLATION USING FORECASTING TECHNIQUES

Choudhary K N and Choudhary A K S (2001) [42] forecasted the demand for multimedia industry using exponential smoothing method. The need for prediction of inflation was discussed by Michael Berleman and Forrest Nelson (2002) [43] in their paper. To forecast the inflation, they have used two different approaches viz. Econometric approach and Expectations approach. In their paper, they offered a new procedure to forecast the inflation ‘through a virtual electronic market, which is organized on Internet based on real money transactions. Presenting results for classroom experiment, they demonstrated how the market data of a well-defined electronic market can be used to forecast mean inflation as well as the probability of different inflation scenario at low costs. The promising results from the prototype market suggest that the electronic market instrument is a useful forecasting device’.

Further, to forecast inflation for Netherlands and the Euro area, Ard den Reijer and Peter Vlaar (2004) [44] developed two forecasting models in their study. Inflation is “the yearly change in the Harmonized index of Consumer Prices (HICP)”.

The model provide point forecasts and prediction intervals for both the components of the HICP and the aggregated HICP-Index itself.

The application of Time-series and Causal forecasting techniques in forecasting the inflation of Computer and Computer Based System in India and the results were discussed by K.Naveen and Ndamuni Reddy C (2009) [50].

‘Forecasting of inflation for air conditioners in India’ is studied and analyzed by Hariprasada Reddy Y, et al. (2012) [51]. A mathematical model was developed to predict the inflation for future periods, assuming that a trigonometric function accommodating cyclical fluctuations of real time inflation. The actual inflation (based on WPI) for Air Conditioners in India is studied over a period of time. Then, the inflation is forecasted to compare with actual values for the known periods. For this, various forecasting techniques are used and the best forecasting model is identified that best suits to the available data. In addition, from the developed model, an attempt is made to forecast inflation of Air Conditioners for forthcoming periods. It is observed that the developed model with trigonometric function resulted in comparatively least errors.

A ‘novel networked traffic parameter forecasting method was introduced by Jianming HU, Jingyan SONG, Guoqiang YU & Yi Zhang (2003) [45]. They simplified the traffic network in Beijing city by System Clustering analysis and used Markov Chain model to predict the traffic parameter’. The algorithm proposed in their study dealt with the traffic parameter forecasting problem in the road network level, which went out of the existed prediction method nesting on link level.

Iyad A. Salman (2004) [52] in his paper presented the results of applying time series forecasting techniques to forecast maintenance workload with seasonal components. The paper discusses several models developed to forecast the electronic maintenance workload for a weather forecasting system. The paper presents causal and stochastic time series forecasting methods and seasonal workload behavior was
modeled using seasonal (quarterly, monthly) and cyclical indicator variables, as well as seasonal ARIMA methods.

*J. Scott Armstrong* (2005) [53] proposed seven methods of forecasting, out of which two are universal applications i.e., they applicable to all types of data. 'Combined forecasting with an estimation of 12% error reduction and Delphi method, improved the accuracy to 79%, though there was insufficient information to estimate the amount of error reduction. Three methods are applicable to cross sectional data: Causal forecasting models with a 10% error reduction, judgmental boot strapping at 6% error reduction and structured judgment for which no estimate of the savings. Two methods applicable to time series data: damped trend with a 5% error reduction, and causal models with improved accuracy for 2/3 of the 534 comparisons’. These methods applicable to a broad range of conditions.

*Gajanana S, Dr. G.Krishnaiah and Dr. C.Nadhamuni Reddy* (2005) [54] have studied various forecasting techniques and developed 'regression model with trigonometric function to accommodate cyclical fluctuations of prices of items or inflation’.

### 3.4 STUDY OF REPLACEMENT MODELS THAT CONSIDERS REPAIRS, INFLATION, AND MONEY VALUE (REAL INTEREST RATE)

Several researchers investigated the optimal age replacement models to modify them to suit various real time conditions and minimize the cost.

Improvement and deterioration in performance of a repairable system in terms of effect of ageing on the distribution of the time to first failure under a non-homogeneous Poisson process was studied by *Isha Bagai and Kanchan Jain* (1994)
[16] studied. This study also discussed the optimal age replacement policy in which items are replaced on failure or at predetermined time. For a repairable system undergoing minimal repair, the optimal replacement time under the age replacement policy is discussed.

_Thomas W Archibald and Rommert Decker_ (1996) [17] proposed Modified Block-Replacement Policy (MBRP) of Berg & Epstein (1976) in two ways, considering i) discrete time framework, which allows the use of any discrete lifetime distribution, and ii) multi-component systems. Both the ways increase the practical value of MBRP. In MBRP, the components replaced immediately on failure and Preventive Maintenance (PM) is performed at regular intervals.

Uma Sankar and Nadamuni Reddy (1997) [18], considered combined influence of value of money and inflation, while developing a replacement model. They tried to study the effect of inflation on a replacement time of capital equipment like high cost machinery or equipment.

_Nadamuni Reddy C and Uma Shankar C and Raghu Ramulu S_ (1997) [19] discussed a replacement model for Capital Equipment like machine tools on purchasing power of money criterion instead on mere cost of money. _‘Chein Y H and Chen J A_ (2007) [14] presented an optimal age-replacement policy with minimal repair based on cumulative repair cost limit. They considered complete repair cost data 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.’

The impact of inflation on replacement costs of tractor was studied by _Nuthall et al._ (1983) [21]. They considered in their model, the influence of method of financing, and increased or decreased hours of usage. The replacement models for finite time tasks by considering NPV (Net Present Value) of costs was explored by
Jason W Rupe and West US (2000) [23]. Ruey Huei Yeh, et al. (2005) [25] examined the influence of a renewing free-replacement warranty on the age replacement policy for a non-repairable unit. Cost models are developed for both warranted and non-warranted items. The obtained optimal replacement ages corresponding to the minimum long-run expected cost.

Vasumathi A, Dr. P. Dhanavantha, and Anil. C [26] proposed a mathematical model by using differential equations under the given assumptions. This model is highly useful to construct functions and find out optimal replacement period. The authors applied this model for certain equipment, which is useful in leather industry.

Robert Cleroux (1998) [56] described the preventive replacement model for randomly deteriorating systems and illustrated some of the main difficulties met in practical situations. Two special cases are discussed: i) a replacement model with a mixture of actions at failure and a non-parametric replacement model based on the bootstrap methodology.

3.5 STUDY ON DEVELOPMENT OF REPLACEMENT MODELS USING MARKOV PROCESS (CHAIN)

Umasankar C, et al. (1997) [59] used First Order Markov Chains to compute the transition probabilities for different states during different periods, and developed group replacement model for a group of industrial items that fail completely on usage. The optimal replacement decision is corresponding to minimum average cost.

Liana Cazacioc and Elena Corina Cipu (2004) [67] proposed Markov chain models that are used to forecast the weather states at some future time using information given by the current state. They have studied applications of Markov chain model considering two states for daily precipitation in summer and winter.
seasons. They computed and evaluated the sets of conditional (or transition) probabilities for first order, second order and third order Markov chains’.

3.6 STUDY OF HIGHER ORDER MARKOV CHAIN AND ITS APPLICATIONS


Lawrence K Saul & Michael I Jordan (1999) [68] ‘proposed many parameters for probabilistic models of time series. The mixed memory models in this note have three distinguishing features. First, they can express a rich set of probabilistic dependencies, including coupled dynamics in factorial models. Second, they can be fitted by EM algorithms, thus avoiding potential drawbacks of gradient descent. Third, they are compact and easy to interpret, notably as in ordinary Markov models; every parameter defines a simple conditional probability’.

The techniques that are necessary to estimate and interpret higher order Markov models were proposed by David L Epstein and Sharyn O’Halloran (2005) [62]. These models were applied in political science to study the democratic transitions. They observed that a three state model including an intermediary “partial democracy state” outperforms than the previous two state model of Przeworski.

The procedure for computing transition probability matrix for higher order Markov chain with finite state space was explored by Zhengqing Li and Weiming Wang (2006) [63]. They converted the problem into a matrix equation, applying the methods and theories of computer algebra and stochastic process to get the solution. They tried
to solve the Transition Probability Matrix of higher order Markov Chain using a computer aided program.

_Wai-Ki Ching, Eric S. Fung and Michael K. NG_ (2004) [66] ‘presented the higher order Markov Chain model for categorical data sequences. The model can easily be implemented in EXCEL worksheet. Once all the data is entered and parameters are estimated, prediction table can be created. The result of the prediction accuracy can be obtained’.

_Liana Cazaciu and Elena Corina Cipu_ (2004) [67] have developed transition probabilities for second order and third order Markov Chains. Summarization of suitable techniques in order to compute the TPM for discrete-time homogeneous Markov chains in various combinations of cycle length and observation time intervals was done by _Bruce A Craig and Peter P Sendi_ (1998) [61].

The spectral representation of transition probabilities was studied by _Sutawanir Darwis and Kulso_ (2008) [65]. They applied spectral decomposition method for computing transition probabilities for a multi-state Markov process because the computation of transition probabilities of a Markov process with more states is much time consuming one.

_Dastidar A G, et al._ (2010) [70] simulated the trends in rain fall over Gangetic West Bengal in India during monsoon season with the application of two-state higher order Markov chain models. They observed that ‘the climatological probabilities predicted using high order Markov chains are almost similar to the values predicted using first order Markov chain’.

_Stelios H Zanakis and Martin W Maret_ (1980) [71] ‘applied Markov process for modeling manpower supply of around 1000 engineers in a large chemical company. In their work, they developed Markov chain based manpower model to
predict future organizational manpower loss and gain position wise distribution for different hiring quotas.

*Ying-Zi Li, Jin-cang Niu (2009) [72]* ‘applied Markov chain based forecasting for Power generation of Grid connected Photovoltaic system. Forecast results showed that Markov chain based forecast of power generation is accurate and has practical value. Moreover, they could not see much significance of forecast for power generation when the order of Markov chain is too high’.

*Shamsad A, et al. (2005) [73]* ‘used first and second order transition probability matrices of Markov chain to predict the time series of wind speed values. In their work they used hourly wind speed time series data of two stations in Malaysia for stochastic generation of wind speed data. A satisfactory relation was found between the actual and the generated wind speed time series data. A second order Markov model has shown a slight improvement in the wind speed behavior’.

### 3.7 BLOCK REPLACEMENT MODELING UNDER THE INFLUENCE OF INFLATION USING HIGHER ORDER MARKOV PROCESS

So far, the application of Markov models in replacement decisions can be scarcely found. The little available too is at budding stage with mostly hypothetical data. Consideration of macroeconomic variables in replacement theory started in recent times.

Group replacement model for a group of pressure gauges in a filling plant was developed by *Umasankar C, et al. (1997) [57]*. They used First order Markov chain technique to compute the transition probabilities for different states during different periods. The decision of optimal replacement was depending upon the minimum average maintenance cost.
In this research work, the concept of Markov models is employed to a particular area of interest. The objective of the study is to arrive at an optimal replacement decision pertaining to Air Conditioners in India considering the real time data. The five states are considered in the study. They are working state, minor-repair state, semi-major repair state, major-repair state, and complete failure state. The replacement decision arrived at is based on minimum average annual maintenance cost.

Conventional models are already available to assess different replacement strategies for a group of similar equipment of different ages considering and without considering the time value of money. Here, NPV criterion based on nominal interest rates does not reflect the real increase in the value of money. A replacement model is developed taking into account, the combined influence of predicted inflation based on real time data for Air Conditioners and the time value of money. Considering Fisherman’s relation, the real increase in value of money is accounted. Furthermore, in stable economies maximum weightage may be given to the most recent data and less weightage may be given to the old data. This is because, the fluctuations in economy may be gradual and not all of a sudden in those economies. The trends are determined using the developed model and hence they will be reliable. Therefore, the model is intensified further by using “Weighted Moving Transition Probabilities” technique and the decision is arrived at. WMTP technique, a parsimonious model that approximates the higher order Markov chain is introduced to consider the spread of sizeable data instead of single period’s past data.
**Summary:** The summary of the past research is shown in the Table 3.1.

**Table 3.1: Summary of the past research**

<table>
<thead>
<tr>
<th>Area of research</th>
<th>Author(s)</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replacement models</td>
<td>Frederick S Hiller &amp; Gerald J Lieberman (2001) [3], Kanti Swarup, Gupta P.K (1992) [4] and Sharma(2004) [6]</td>
<td>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.</td>
</tr>
<tr>
<td>An optimal age-replacement policy with minimal repair</td>
<td>Chein Y H and Chen J A (2007) [14]</td>
<td>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.</td>
</tr>
<tr>
<td>Impact of inflation on tractor replacement costs</td>
<td>Nuthall P L, Woodford K P and Beck AC (1983) [21]</td>
<td>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.</td>
</tr>
<tr>
<td>Optimal age replacement policy in which items are replaced on failure or at predetermined time</td>
<td>Isha Bagai et al (1994) [16]</td>
<td>Studied improvement and deterioration in performance for a repairable system with minimal repairs under non-homogeneous Poisson process. This study also discussed the optimal age replacement policy in which items are replaced on failure or at predetermined time.</td>
</tr>
<tr>
<td>Replacement model considering combined influence of assumed inflation</td>
<td>Nadamuni Reddy et al (1997) [18]</td>
<td>Have developed replacement model considering combined influence of assumed inflation and cost of money</td>
</tr>
</tbody>
</table>
Research Gaps:

Till now, the use of Markov models in replacement decisions can be hardly found. Whatever available is at nascent stage that too limited to the first order Markov chain with predominantly assumed data. There is no much focus on Higher Order Markov Chain approach. Though the models are available for group replacement strategies, there can be hardly found the models for block replacement policies.

In the replacement models explored so far, only single repairable state is considered. But in practical, multi repairable states of different magnitude exists.
Hence, in the present study five different states (working, minor repair, semi-major, major repair and break-down) are considered for block replacement policy.

Conventional models are available to evaluate different replacement strategies for a combination of similar machine tools of different ages considering and without considering money value. Here, Net Present Value (NPV) criterion based on nominal interest rates does not reflect the real increase in the value of money. In this study the author has considered real increase in value of money by considering Fisherman’s relation.