01. Dr Sunil Kumari "Investors Attitude Towards Mutual Funds in Rohtak Distrct in State of Haryana" Year 2018

Volume 5, Issue 4 (XII) **ISSN 2394 - 7780**
October - December 2018

Self Signed

UGC
University Grants Commission
Journal No.: 63571

International Journal of

Advance and Innovative Research

Indian Academicians and Researchers Association
www.iaraedu.com

Journal - 63571

UGC Journal Details

Name of the Journal :	International Journal of Advance & Innovative Research
ISSN Number :	
e-ISSN Number :	23947780
Source:	UNIV
Subject:	Multidisciplinary
Publisher:	Indian Academicians and Researchers Association
Country of Publication:	India
Broad Subject Category:	Multidisciplinary

International Journal of Advance and Innovative Research

Volume 5, Issue 4 (XII) : October – December 2018

CONTENTS

Research Papers

International Journal of Advance and Innovative Research
Volume 5, Issue 4 (XII): October - December, 2018
ISSN 2394 - 7780

INVESTORS ATTITUDE TOWARDS MUTUAL FUNDS IN ROHTK DISTRCT IN STATE OF HARYANA

Dr. Sunil Kumari
Assistant Professor, Department of Higher Education, Haryana

ABSTRACT
Mutual funds are seemingly the easiest and the least stressful way to invest in the stock market but same as much difficult to choose the any of the MF schemes offered by mutual fund. So Understanding the attitude of investors on their investment would help the company to increase their profits, so marketer always remains keen in knowing the investors' attitude towards mutual fund. Present study aims at finding the same and results showed that reputation of fund and brand name of sponsor are major determinants of investors' decision and out of all available schemes, balanced fund and income funds were most preferred by investors.

Keywords: Mutual Funds, Scheme, Marketers, Investors.

INTRODUCTION
At present, in economic and financial scenario of India financial instruments, particularly Mutual Funds are emerging in crucial role to allocate the scarce resources from savers to borrowers for making the productive use of idle resources thus accerlating investment in economy. The increasing volatility has pushed the investors towards relatively safe mode of investment and this move seems to mutual fund that mobilizes and channelizes the savings of individuals and institutions in corporate securities to provide the steady stream of returns and capital appreciation. But a lot of mutual fund schemes are available in the market giving different kinds of benefits like growth schemes, income schemes, balanced schemes, tax saving schemes, money market schemes etc. Now question arises how investor selects one or more of the mutual fund schemes, we can say what factors are taken into account in mutual fund investment decision. Need to answer this question initiated the researcher to make the study on this topic.

REVIEW OF LITERATURE
De Bond and Thaler (1985) while investigating the possible psychological basis for investor behavior, argue that mean reversion in stock prices is an evidence of investor over reaction where investors over emphasize recent firm performance in forming future expectations of the investment

Gupta (1994) made a household investor survey with the objective to provide data on the investor preferences on MF's and other financial assets. The findings of the study were more appropriate, at that time, to the policy makers and mutual funds to design the financial products for the future.

Syama Sunder (1998) conducted a survey to get an insight into the mutual fund operations of private institutions with special reference to Kothari Pioneer. The survey revealed that awareness about Mutual Fund concept was poor during that time in small cities. Agents play a vital role in spreading the Mutual Fund culture; open-end schemes were much preferred then; age and income are the two important determinants in the selection of the fund/scheme; brand image and return are the prime considerations while investing in any Mutual Fund.

Shanmugham (2000) conducted a survey of 201 individual investors to study the information sourcing by investors, their perceptions of various investment strategy dimensions and the factors motivating share investment decisions, and reports that among the various factors, psychological and sociological factors dominated the economic factors in share investment decisions.

Akhilesh Mishra (2008) has done a study on the topic "Mutual Fund as a Better Investment Plan" and states that many of the people have the fear of Mutual Funds. "They think their money will not be secure in Mutual funds," says Mishra. He also says that the investors need the knowledge of Mutual Funds and its related terms.

From the above review it can be inferred that Mutual Fund as an investment vehicle is capturing the attention of various segments of the society, like academicians, industrialists, financial intermediaries, investors and regulators for varied reasons and deserves an in depth study.

OBJECTIVES OF THE STUDY
- To study priorities of investors in selection of mutual fund schemes.
- To know the factors affecting investors' decision regarding mutual fund.

RESEARCH METHODOLOGY
1. **Research Design**: Being study exploratory in nature, it will go through primary data collection through questionnaire, its' analysis using mean scores & mean index. The Investors' attitude shall be measured in terms of their preference and factors affecting their decisions which shall be analyzed at two levels:

ISSN 2394 - 7780

- **Ascertaining the level of effectiveness for individual parameters**.

The scores for the parameter are derived by multiplying the number of respondents with the respective score and its subsequent summing. Effectiveness index was calculated by applying the formula:

Actual scores obtained for the statement x 100
Maximum obtainable score for the statement

- **The overall effectiveness Index is calculated by using the formula:**

Top scores obtained for the seven parameters x 100
Sum of maximum scores obtainable for seven parameters

Overall index is taken as benchmark

2. **Data Collection:** Both primary as well as secondary data have been collected.
3. **Sampling:** A questionnaire was structured at five rating scale to meet the stated research's objective and got it filled up by 100 people were selected on the basis of systematic sampling living in Rohtak District of Haryana who were having mutual fund experience.

OVERVIEW OF EXISTING SCHEMES IN MUTUAL FUND INDUSTRY

Each category of funds is backed by an investment philosophy, which is pre-defined in the objectives of the fund. The investor can align his own investment needs with the funds objective and invest accordingly. So **on the basis of investment parameter, Mutual Funds can be broadly classified as**

- **Growth Schemes:** Growth Schemes are also known as equity schemes. The aim of these schemes is to provide capital appreciation over medium to long term. These schemes normally invest a major part of their fund in equities and are willing to bear short-term decline in value for possible future appreciation.
- **Income Schemes**: Income Schemes are also known as debt schemes. The aim of these schemes is to provide regular and steady income to investors. These schemes generally invest in fixed income securities such as bonds and corporate debentures. Capital appreciation in such schemes may be limited.
- **Balanced Schemes:** Balanced Schemes aim to provide both growth and income by periodically distributing a part of the income and capital gains they earn. These schemes invest in both shares and fixed income securities, in the proportion indicated in their offer documents (normally 50:50).
- **Money Market Schemes**: Money Market Schemes aim to provide easy liquidity, preservation of capital and moderate income. These schemes generally invest in safer, short-term instruments, such as treasury bills, certificates of deposit, commercial paper and inter-bank call money.

OTHER SCHEMES

- **Tax Saving Schemes**

Tax-saving schemes offer tax rebates to the investors under tax laws prescribed from time to time. Under Sec.88 of the Income Tax Act, contributions made to any Equity Linked Savings Scheme (ELSS) are eligible for rebate.

- **Index Schemes**

Index schemes attempt to replicate the performance of a particular index such as the BSE Sensex or the NSE 50. The portfolio of these schemes will consist of only those stocks that constitute the index.

- **Sector Specific Schemes**

These are the funds/schemes which invest in the securities of only those sectors or industries as specified in the offer documents. e.g. Pharmaceuticals, Software, Fast Moving Consumer Goods (FMCG), Petroleum stocks, etc. Investors need to keep a watch on the performance of those sectors/industries and must exit at an appropriate time.

RESULTS & DISCUSSIONS

Results are to be discussed into two parts:

1. Parameter wise Investors' Attitude
2. Overall Investors' Attitude towards MF Schemes

1. **Parameter wise Investors' Attitude:** As selection of mutual fund depends upon the various factors but here major 5 factors have been taken into account, in which so many other factors have been comprised of. Example infrastructure consists of fringe benefits, disclosure of investment from original pattern, sponsor's expertise & past performance etc. Flexibility represents the minimal initial investment whereas transparency

ISSN 2394 - 7780

underlies disclosure of periodicity of valuation in the advertisement. Scores were gathered through survey at point rating scale and has been analyzed in table 1

Table-1: Parameter wise Investors' Attitude

S N	Factors/ variables	Strongly Agree	Agree	Not Agree	Disagree	Strongly Disagree	Mean Scores	Mean Index
1	Infrastructure	29	32	26	5	8	456	81
2	Reputation of Fund	35	27	25	7	6	479	86
3	Flexibility	33	25	27	8	7	453	81
4	Transparency	32	24	27	10	7	451	81
5	Brand Name of Sponsor	33	30	22	10	3	470	84
6	Additional facilities	25	30	28	7	10	449	80
	Overall Mean Index						2758	83

Table1 highlights that mean indices of both factors i.e. reputation of fund and brand name of sponsor are 86 and 84 respectively that indicates that these are most influential factors in MF investment decision whereas other factors have almost similar scores in mean index that indicates their less consideration in MF decision in comparison to Funds Repudiation & brand name of sponsor. This doesn't mean that except of two major factors don't affect the MF decision, as overall mean index is 83 and all variables' mean indices are near about this value, so they also have the impact on MF decision. So all stated variables are determinants of investors attitude of Rohtak District in Haryana.

2. Overall Investors' Attitude towards MF Schemes

Table-2: Investors' Preference in Mutual Fund Schemes

MF Schemes	High Favorable	Favorable	Somewhat Favorable	Not very Favorable	Not at All Favorable	Mean Scores	Mean Index
Growth Schemes	3	10	29	26	32	33	28
Income Schemes	35	28	20	12	3	90	78
Balanced Schemes	37	29	21	7	6	93	85
Money Market Schemes	5	15	25	31	29	30	25
Tax Saving Schemes	7	14	24	30	25	31	26
Other Schemes	12	18	25	15	20	40	30
	Overall Mean Index						45

As table 2 shows that mean index of balanced schemes is highest that means it most preferred by investors. Income schemes are at third place that indicates that a big part of MF investors is risk averse and it believes in getting fixed rate of return. Equity schemes got last rank even mean index of them is lesser than overall mean index, so only a small number of investors chooses such funds.

CONCLUSION

Present study discussed investors' priorities in mutual fund schemes as well as factors affecting the MF decision to know investors' attitude towards different MF Schemes and determinants of their attitude. Outcomes of the study reveal that balanced funds are most preferred investment of respondents. Further, all stated variables i.e. infrastructure, flexibility, transparency, reputation of fund, brand of sponsor, and other facilities, affect the investors' MF decision but reputation of fund and brand of sponsor, these two factors are major determinants of this decision.

LIMITATIONS OF THE STUDY

- The project done is restricted to Mutual funds in Rohtak district in Haryana and its surroundings only.
- As the survey was pertaining to investment attitude of investors, biased information may restrict validity of inference possible.
- The study was constrained by limitations of time.
- The raw data was collected with the help of structured questionnaire technique. Therefore study is bounded by the limitation of this technique

ISSN 2394 - 7780

REFERENCES

- Preeti Singh; "Investment Management Security Analysis and Portfolio Management", Himalaya Publishing House, Eleventh Edition, 2003, Pp 1-7
- Prasanna Chandra; "Investment Analysis and Portfolio Management", Tata McGraw-Hill Publishing Company Limited, Third Edition, 2008
- Pal,Cashing in on turmoil, Outlook Money, Oct 8,2008, Pp6
- Preeti Singh, Investment Management Security Analysis and Portfolio Management, Himalaya Publishing House, Eleventh Edition, 2003, Pp1
- Project-on-Mutual Fund-Akhilesh Mishra viewed at http://www.scribd.com/doc/13246827/
- A-STUDY-ON-MUTUAL-FUNDS-IN-INDIA.aspx viewed at http://www.indiastudychannel.com/projects/666
- http://online.wsj.com/article/SB123137479520962869.html?mod=googlenews_ws
- The A to Z of Mutual Funds-The Guide to investments, SBI Mutual Funds, Pp2
- Birenshah, Outlook Money, 30th July 2008, P 30, 56
- Pradeep Kumar S. and Murugavel A., Karvy the finapolis, Volume2, Issue 3, March 2008, Pp11
- SIP Plan, Kotak Mutual Fund, Mutual Fund Insight, 15th October-14th November, Volume VI, Number 2, Pp 139.
- http://economictimes.indiatimes.com/Personal_Finance/Mutual_Funds/Analysis/MFs_offer_investors_more_flexibility/articleshow/msid-3095105,curpg-2.cms
- http://economictimes.indiatimes.com/articleshow/3013728.cms
- http://www.bseindia.com/downloads/MutualFunds.pdf
- http://vidyasagar.ac.in/Journal/Commerce/vol12/10th%20Article.pdf
- http://www.utiicm.com/Cmc/PDFs/2001/rajeswari.pdf

Volume 5, Issue 4 (XX)
October - December 2018

ISSN 2394 - 7780

Self Signed

ज्ञान-विज्ञान विमुक्तये

UGC
University Grants Commission
Journal No.: 63571

International Journal of

Advance and Innovative Research

Indian Academicians and Researchers Association
www.iaraedu.com

Journal - 63571

UGC Journal Details

Name of the Journal :	International Journal of Advance & Innovative Research
ISSN Number :	
e-ISSN Number :	23947780
Source:	UNIV
Subject:	Multidisciplinary
Publisher:	Indian Academicians and Researchers Association
Country of Publication:	India
Broad Subject Category:	Multidisciplinary

International Journal of Advance and Innovative Research

Volume 5, Issue 4 (XX) : October – December 2018

CONTENTS

Research Papers

International Journal of Advance and Innovative Research
Volume 5, Issue 4 (XX): October - December, 2018
ISSN 2394 - 7780

LEVERAGING THE SPIRITUALITY IN MARKETING

Dr. Sunil Kumari
Assistant Professor, Govt. College Meham, Haryana

ABSTRACT
In modern era where logical and rational thinking is taking its height but simultaneously spirituality is also regaining its worth to the society. In this scenario, marketer needs to change his marketing strategy according thereto. Present study focuses on determining the relationship between spirituality and marketing environment. On the basis of survey analysis of 212 people, it has found that marketing is significantly affected by spirituality level of buyers. Consequently, marketers are required to incorporate the spirituality concept in product features.

Keywords: Spirituality, Marketing, Consumers, Buying Decision.

INTRODUCTION
Spirituality refers to truth (Satya). The phrase "Satyamev Jayate" which means truth always wins has been well heard to everyone. In the world of commercialization spirituality had been supposed to be lost somewhere but ignorance of truth cannot run in long run. Thus this is the time when entire world seems to return to its original roots. As level of education is increasing people seems to be free from institutional religions and seek for truth. The 21st century will be spiritual or won't be at all (**Malraux**). Spirituality is a integral part of our human body which represent the existence of human in entirety. This is the inner state of human being which is responsible for all physical acts of a person. All physical activities of a person are backboned by spiritual aspect which is the processed output of unconscious and sub-conscious sheaths of body. What the consumer would purchase is determined by one's internal stimuli. If a marketer is able to connect his products' utility to target customers' spirituality can raise much more demand in market. This is the new age of spirituality which is being taken a big business where new age of spiritualism witnesses truth-seeking buyers who believes in experiments instead of religious obscurantism and hierarchy (**Van Der Veer, 2009**). Such individualism has forced the marketers to rethink upon their marketing philosophy and designing it accordingly. Transformation of consumers' realism to idealism or spiritualism has considerable value to marketers in present scenario. Marketer needs to incorporate the spiritual content in product features to make it high profitable. Human organisms consists of four sheaths – physical, subtle, causal and absolute.

LITERATURE REVIEW
Emre Basci (2015) gave a holistic marketing review by combining the 4Ps of marketing with 1C (customer). Under it four types of spiritualities i.e. anti-capitalist, reformist, consumerist and capitalist, have been studied with their distinctive features. Study found the inner state of world is changing due to political and social factors where marketers need to make marketing strategy accordingly. Liberalized economic policies led to put the spiritual content in the product to make more salable.

Vinod Kumar & Ankit Jain (2016) this paper talks about marketing through spirituality through the case study and success story of Patanjali Yogpeeth. The research uses a qualitative approach to collect data from various officials of Patanjali Yogpeeth through unstructured face-to-face interviews. The study revealed that yoga and pranayam are very effective tools in marketing through spirituality and influence the consumption behavior of masses. Patanjali Yogpeeth is best suited example to study the present topic.

RESEARCH METHODOLOGY
Present research studies the cognition of the buyer in terms of spirituality. Spirituality is an internal stimulus that directs the consumer behavior. However it is very difficult to define the parameters of spirituality but study prescribes the certain measures i.e. religion, nationalism, cognition and subtle sheath of an individual. Study proceeded with a sample size of 212 people through a structured questionnaire as well as personal interviews.

RESULTS & DISCUSSIONS
Majority of the respondents said that they connect their spiritual aspect to the buying decision. Majority (67%) of the rural but minority (33%) of the urban was found connected with nationalism concept like swadeshi, in their buying decision. Religion has been found an eminent concept, majority (71%) of the people don't compromise with their religious view. They always keep priority of their religious view over economic view. In India, sometimes it is named superstition but it is Indian scenario where majority (82%) of the people firmly believe in their traditions and customs without any logic or reasoning. They strongly believe in succeeding their ancient culture. Most of the people surrender and sacrifice a lot of money or things to pay the tribute to their

ISSN 2394 - 7780

God. A significant number of people were found very rigid to their culture. Marketers could be able to sell their product more and more by connecting their products' features with the religious view of the customers. Consumers' cognition is another major factor affecting the purchase decision. Cognition is the inner concept of a person that derives from his own thinking and view point. It is a self concept that also determines the consumer behavior. It is supposed that intelligent people are found more rational and intellectual. They have their own technical view to interpret the things. It is a strong stimuli to behave in righteous manner. Study found the cognition least affected by the external forces like peers, groups and society. Generally it moves genetically from one generation to another generation. In present study majority (%%%) of the people accepted that they use their own sense in buying decision. So marketers should frame such strategy that associate the product with the cognition of the consumers. They should make surveys to know the cognition value of the buyers. The last aspect of the spirituality is subtle sheath of the person. Subtle represents the unconscious sheath of human body. There are so many things which continuously run in unconscious mind of the human body, which is micro in nature but gets activated when certain kinds of external forces interact with them. It is very difficult to measure this subtle aspect of consumer, so there is lot of chances to mismatch the products features to subtle sheath of the buyer. It is a psychological concept that needs a keen and close observation of the behavior of the person. But with the help of past data and behavior, marketers can be able to understand such casual and subtle part of buyer. Majority (61%) of the respondents stated that they don't make deliberate efforts to bring out their subtle sense to use it in their decisions. It works automatically but it becomes important to understand to marketers being its impact on buyer behavior.

CONCLUSION

Present study aims at measuring the impact of spirituality on marketing strategy. Present market scenario is changing where logical attitude as well as rationality is stimulating the people to analyze the things economically but simultaneously, it can not be denied that people' spiritual roots are getting stronger day by day. It can be said that personal, societal, spiritual and economic all aspects move together. With the changing time spirituality may arise in different color but it can not get finished because it is an integral part of a human being. Consequently Giants of corporate world have started to make the studies on how to connect the product's characteristics to the spirituality aspect of target customers. On the basis of data analysis in descriptive manner, study explores that there is a significant relationship between spirituality and buying decision of the people. Hence present study adds value to the existing literature.

REFERENCES

1. Vinod Kumar, Ankit Jain, Zillur Rahman et al (2014). Marketing through spirituality: A case of Patanjali Yogpeeth. *Procedia - Social and Behavioral Science, Volume 236, Pages 1-384 (14 December 2016), International Conference on Communication in Multicultural Society, CMSC 2015, 6-8 December 2015, Moscow, Russian Federation. Retrieved from* http://dx.doi.org/10.1016/j.sbspro.2014.04.215
2. Vinod Kumar & Ankit Jain (2014), Marketing through Spirituality: A Case of Patanjali Yogpeeth, Procedia - Social and Behavioral Sciences 133 (2014) 481 – 490
3. Emre Basci (2015). 4P‟s and 1C of New Age Spirituality: A Holistic Marketing Review. *International Journal of Social Science and Humanity*, Vol. 5, No. 5, May 2015, pp 446-450
4. *Sudhir Kale (2016),"Consumer Spirituality and Marketing", in AP - Asia-Pacific Advances in Consumer Research Volume 7, eds. Margaret Craig Lees, Teresa Davis, and Gary Gregory, Sydney, Australia : Association for Consumer Research, Pages: 108-110, available at http://www.acrwebsite.org/ volumes/13027/volumes/ap07/AP-07*

03. Dr. Shilpi Batra" A Reliability Model for the Optimum Number of Standby Units in a System Working with Two Operative Units" Year 2018

A Reliability Model for the Optimum Number of Standby Units in a System Working with Two Operative Units

Shilpi and Gulshan Taneja*
Department of Mathematics, Maharshi Dayanand University, Rohtak, Haryana
Email:batrashilpi1989@gmail.com, drgtaneja@gmail.com

Abstract

In this paper, we optimize the number of standby units required for a system working with two operative units. For the industries, it is inevitable to maintain some units as standby in order to increase the availability and to work with admirable efficiency. Four models have been developed taking no standby, one standby, two standby and three standby units respectively. Semi-markov processes and regenerative point technique have been used to find the measures of system effectiveness. Comparative study has also been made to find as to which and when one model is better than the other.

Keywords: *System with two operative units, Reliability, Profit Analysis, Optimization of standby units.*

1. Introduction

For continuing increasing demands for more reliable systems, there is a need to increase the system effectiveness, utilize the system properly, reduce the failure frequency, minimize the maintenance cost and increase the reliability as well as availability of a system. The best technique to fill up these needs is standby redundancy.

Various researchers did a lot of work considering one-unit or two-unit standby redundant systems. Lim et al. (2000) analyzed the system reliability with dependent repair modes. Chen and Popova (2002) studied the maintenance policy with two-dimensional warranty period. Chandrasekhar et al. (2004) studied a two unit standby system with erlangian repair time. El-said et al. (2005) dealt with the profit analysis of a two unit cold standby system with preventive maintenance and random change in the units. Parasher and Taneja (2007) studied about the reliability and profit evaluation of a PLC hot standby system based on a master slave concept and two types of repair facilities. Mokaddis et al. (2009) discussed about the stochastic behavior of a two unit warm standby system with two types of repairmen and patience time. Damcese et al. (2010) analyzed the availability for reliability parallel systems with different rates. Eryilmaz and Tank (2012) studied a series system with two active components and a single cold standby unit. Manocha and Taneja (2014) dealt with the stochastic analysis of a two-unit cold standby system with arbitrary distribution for life, repair and waiting times.

*Corresponding Author

Malhotra and Taneja (2015) revealed the stochastic analysis of a two-unit cold standby system wherein both units may become operative depending upon the demand. Sachdeva and Taneja (2016) discussed about the availability and profit analysis of unidirectional and revertible 1:1 protection switching scheme in optical communication process. The concept of optimality for standby systems was studied by some researchers including Yun (1989), Badia et al. (2002), Nakagawa (2005),Wang and Zhang (2014), Liao et al. (2015) but in these studies the optimization of profit did not involve the expressions for availability, busy period of repairman, expected number of visits. The problem will be of more worth if optimality is discussed with respect to economic point of view involving measures of system effectiveness and hence there is need to optimize the number of standby units on the basis of profitability derived from various measures of system effectiveness.

A good number of systems being used in the open market are those where two units of it are required to be used simultaneously and thus the concept of optimality with regard to profitability has been dealt with for such systems in the present paper. The concern lies on the issue that as to how many standby units should be used for such a system so that the maximum profit is achieved. The authors made an attempt to resolve the issue by carrying out the analysis of following four reliability models on such systems:

i) A system comprising two operative units and no standby unit
ii) A system comprising two operative units and one standby unit
iii) A system comprising two operative units and two standby units
iv) A system comprising two operative units and three standby units

The models for systems comprising two operative units with more than three standby units have not been developed in the present study as increasing more standby units will unnecessarily involve lot of expenses and hence such consideration seems to be infeasible.

The present paper, therefore, deals with the above mentioned four models obtaining various measures of system effectiveness by making use of regenerative point technique. The profit aspect has been taken into consideration on the basis of various measures of system effectiveness to arrive at a conclusion as to which and when one of the models is better than the other i.e. as to a system with how many standby units should be used to optimize the profit.

2. Description and Assumptions of the Models

1. The system is operative with two operative units and with either no standby unit or one standby unit or two standby units or three standby units.
2. All random variables are independent.
3. Failures are assumed to follow an exponential distribution, whereas the repair times have arbitrary distributions.
4. After repair unit becomes as good as new.
5. There is only one repairman who is available with the system as soon as required; and the repair is done on FCFS pattern.

3. Nomenclature

λ	Constant rate of failure
$g(t), G(t)$	p.d.f. and c.d.f. of the repair rate
Op	Operative unit
Cs	Standby unit
F_r	Failed unit under repair
F_{wr}	Failed unit is waiting for the repair
F_R	Repair of the failed unit is continuing from previous state
C_0	Revenue per unit up time
C_1	Cost per unit up time for which the repairman is busy
C_2	Cost per visit of the repairman
IC	Installation cost of an additional identical unit
P_i	Profit of model i; i=1, 2, 3, 4
$\Phi_i(t)$	C.d.f. of the first passage time from regenerative state i to a failed state
$q_{ij}(t)$, $Q_{ij}(t)$	Probability density function (p.d.f.), cumulative distribution function (c.d.f.) of the first passage time from regenerative state S_i to a regenerative state S_j
$p_{ij}(t)$	$\lim_{s\to 0} q_{ij}^{*}(s)$
$A_i^j(t)$	Probability that system is up and working in full capacity at the instant t given that system entered regenerative state S_i at t=0 for model j; j=1, 2, 3, 4.
$AR_i^j(t)$	Probability that system is up and working in reduced capacity at the instant t given that system entered regenerative state S_i at t=0 for model j; j=1, 2, 3, 4.
$B_i^j(t)$	Probability that the repairman is busy in repairing the failed unit at instant t given that the system started from regenerative state S_i at t=0 for model j; j=1, 2, 3, 4.
$V_i^j(t)$	Expected number of visits of the repairman in (0, t]; given that the system entered regenerative state S_i at t=0 for model j; j=1, 2, 3, 4.

4. Analysis of the Models

4.1 Model 1

This model is for a system with two operative units and no standby unit. Here states S_0 and S_1 are regenerative states but the state S_2 is non regenerative state. Possible transition from one place to another is given by:

Table 1

From	S_0	S_1	S_1	S_1
To	S_1	S_0	S_1	S_2
Via	...	...	S_2	...

where
$S_0 = (Op, Op)$
$S_1 = (Fr, Op)$,
$S_2 = (F_R, F_{wr})$
The transition probabilities are

$q_{01}(t) = 2\lambda e^{-2\lambda t}dt$ $\quad q_{12}(t) = \lambda e^{-\lambda t}\bar{G}(t)dt$

$q_{11}^{(2)}(t) = (\lambda e^{-\lambda t} \odot 1)g(t)dt$ $\quad q_{10}(t) = e^{-\lambda t}g(t)dt$

The non-zero elements $p_{ij} = \lim_{s\to 0} q_{ij}^{*}(s)$ are

$p_{01} = 1$ $\quad p_{10} = g^{*}(\lambda)$

$p_{11}^{(2)} = (g^{*}(0) - g^{*}(\lambda))$ $\quad p_{12} = \lambda\overline{G}^{*}(\lambda)$

From these probabilities, these relations can be derived that

$p_{01}=1$ $\quad p_{10}+p_{11}^{(2)}=1$

$p_{10}+p_{12}=1$

Mean Sojourn time (μ_i) in state, i.e., the expected time to stay in state i is

$$\mu_0 = \int_0^{\infty} t\lambda e^{-\lambda t}dt$$

$\mu_0 = m_{01}$ $\quad \mu_1 = m_{10} + m_{12}$

$\mu_2 = m_{21}$

Mean Time to System Failure (MTSF)

To determine the mean time to system failure (MTSF) of the system, we regard the failed state as

$\phi_0(t) = Q_{01}(t) \odot \phi_1(t)$

$\phi_1(t) = Q_{10}(t) \odot \phi_0(t) + Q_{12}(t)$

Taking Laplace Steiltjes Transforms of these equations and solving them for $\phi_0^{**}(s)$, we obtain

$$\phi_0^{**}(s) = Q_{01}^{**}(s)\phi_1^{**}(s)$$

$$\phi_1^{**}(s) = Q_{10}^{**}(s)\phi_0^{**}(s) + Q_{12}^{**}(s)$$

MTSF when system starts from the state '0' is

$$\text{MTSF} = \lim_{s\to 0} \frac{1-\phi_0^{**}(s)}{s} = \frac{N}{D}$$

Where

$$N = \mu_0 + \mu_1$$

$$D = p_{12}$$

Availability at Full Capacity

The availability $A_i^1(t)$ is seen to be satisfy

$$A_0^1(t) = M_0^1(t) + q_{01}(t) \textcircled{c} A_1^1(t)$$

$$A_1^1(t) = q_{10}(t) \textcircled{c} A_0^1(t) + q_{11}^{(2)}(t) \textcircled{c} A_1^1(t)$$

Taking Laplace Transforms of the above equations and solving them for $A_0^{1*}(s)$, the availability of the system, in steady state, is given by

$$A_0^1 = \lim_{s\to 0} sA_0^{1*}(s) = \frac{N_{1f}}{D_1}$$

$$N_{1f} = p_{10}\mu_0$$

$$D_1 = p_{10}\mu_0 + \mu_2$$

Availability at Reduced Capacity

The availability $AR_i^1(t)$ is seen to be satisfy

$$AR_0^1(t) = q_{01}(t) \textcircled{c} AR_1^1(t)$$

$$AR_1^1(t) = M_1^1(t) + q_{10}(t) \textcircled{c} AR_0^1(t) + q_{11}^{(2)}(t) \textcircled{c} AR_1^1(t)$$

Taking Laplace Transforms of the above equations and solving them for $A_0^*(s)$, we get

$$AR_0^1 = \lim_{s\to 0} sAR_0^{1*}(s) = \frac{N_{1r}}{D_1}$$

$$N_{1r} = \mu_1$$

D_1 is already given.

Busy Period

By probabilistic arguments we have the following recursive relation for $B_i(t)$

$$B_0^1(t) = q_{01}(t) \textcircled{c} B_1^1(t)$$

$$B_1^1(t) = W_1^1(t) + q_{10}(t) \textcircled{c} B_0^1(t) + q_{11}^{(2)}(t) \textcircled{c} B_1^1(t)$$

In steady state, the total fractions of the time for which the system is under repair is given by

$$B_0^1 = \lim_{s \to 0} sB_0^{1*}(s) = \lim_{s \to 0} \frac{sN_2(s)}{D_1(s)}$$

$N_2 = \mu_2$

D_1 is already specified.

Expected Number of the Visits of the Repairman

By probabilistic arguments, we have the following recursive relations for $V_i(t)$

$$V_0^1(t) = Q_{01}(t) \textcircled{S} [1 + V_0^1(t)]$$

$$V_0^1(t) = Q_{10}(t) \textcircled{S} V_0^1(t) + Q_{11}^{(2)}(t) \textcircled{S} [1 + V_0^1(t)]$$

For steady state, the expected no. of visits of the repairman is given by

$$V_0^1 = \lim_{s \to 0} sV_0^{1*}(s) = \frac{N_3}{D_1}$$

$N_3 = 1$

D_1 is already given.

Profit Analysis

At steady state, the expected total Profit (P_1) per unit time incurred to the system is given by

Profit (P_1) = $C_0 AC_0^1 - C_1 B_0^1 - C_2 V_0^1 - IC$

where

C_0 = Revenue per unit up time.

C_1 = Cost per unit up time for which the repairman is busy

C_2 = Cost per visit of the repairman

IC = Installation cost of a unit per unit time

4.2 Model 2

This model is for a system with two operative units and one standby unit. Here states S_0, S_1, S_2 and S_3 are regenerative states but states S_2 and S_3 are non regenerative state. Possible transition from one place to another is given by

Table 2

From	S_0	S_1	S_1	S_1	S_1	S_4	S_4
To	S_1	S_0	S_1	S_5	S_4	S_1	S_4
Via	...	...	S_2	S_2	S_2 and S_3	...	S_3

where
S_0 = (Op, Op, Cs)
S_1= (Op, Op Fr_s)
S_2 = (F_R, Fwr, Op)
S_3 = (F_R, Fwr, Fwr)
S_5= (Op, Fr, Fwr)
The transition probabilities are

$q_{01}(t) = \lambda e^{-\lambda t}dt$ $\quad$ $q_{10}(t) = g(t)dt$

$q_{11}^{(2)}(t) = (\lambda e^{-\lambda t} \textcircled{\scriptsize C} 1)g(t)dt$ $\quad$ $q_{13}^{(2)}(t) = (\lambda e^{-\lambda t} \textcircled{\scriptsize C} \lambda e^{-\lambda t})\bar{G}(t)dt$

$q_{14}^{(2,3)}(t) = (\lambda e^{-\lambda t} \textcircled{\scriptsize C} \lambda e^{-\lambda t} \textcircled{\scriptsize C} 1)g(t)dt$ $\quad$ $q_{44}^{(3)}(t) = (\lambda e^{-\lambda t} \textcircled{\scriptsize C} 1)g(t)dt$

$q_{41}(t) = g(t)e^{-\lambda t}dt = e^{-\lambda t}g(t)dt$

The non zero elements $p_{ij} = \lim_{s \to 0} q_{ij}^{*}(s)$ are

$p_{01} = 1$ $\quad$ $p_{10} = g^{*}(0)$

$p_{13}^{(2)} = 2\lambda(\overline{G}^{*}(\lambda) - \overline{G}^{*}(2\lambda))$ $\quad$ $p_{14}^{(2,3)} = g^{*}(0) - g^{*}(\lambda) + \lambda g^{*'}(\lambda)$

$p_{11}^{(2)} = g^{*}(0) - g^{*}(\lambda)$ $\quad$ $p_{41} = g^{*}(\lambda)$

$p_{44}^{(3)} = g^{*}(0) - g^{*}(\lambda)$

From these relations it can be verified that

$p_{01} = 1$ $\quad$ $p_{10} + p_{11}^{(2)} + p_{13}^{(2)} = 1$

$p_{10} + p_{11}^{(2)} + p_{14}^{(2,3)} = 1$ $\quad$ $p_{41} + p_{44}^{(3)} = 1$

The unconditional mean time taken by the system to transit for any state j when it is counted from epoch of entrance into state i is mathematically stated as

$$m_{ij} = \int_0^{\infty} t q_{ij}(t)dt = -q_{ij}^{*'}(0)$$

$m_{01} = \frac{1}{\lambda}$ $\quad$ $m_{10} = -g^{*'}(0)$

$m_{41} = -g^{*'}(\lambda)$ $\quad$ $m_{11}^{(2)} = g^{*'}(\lambda) - g^{*'}(0)$

These conclusions are drawn from above relations:

$m_{01}=\mu_0$ $m_{10}+m_{11}^{(2)}+m_{14}^{(2,3)}=k_2$(say)

$m_{10}+m_{11}^{(2)}+m_{13}^{(2)}=k_1$(say) $m_{41}+m_{44}^{(3)}=\mu_3$

Mean Time to System Failure (MTSF)

To determine the mean time to system failure (MTSF) of the system, we regard the failed state as

$\phi_0(t) = Q_{01}(t) \odot \phi_1(t)$

$\phi_1(t) = Q_{10}(t) \odot \phi_0(t) + Q_{11}^{(2)}(t) \odot \phi_1(t) + Q_{12}^{(2)}(t)$

Taking Laplace Steiltjes Transform of these equations and solving them for $\phi_0^{**}(s)$, we get

$$\phi_0^{**}(s) = Q_{01}^{**}(s)\phi_1^{**}(s)$$

$$\phi_1^{**}(s) = Q_{10}^{**}(s)\phi_0^{**}(s) + Q_{11}^{(2)**}(s)\phi_1^{**}(s) + Q_{13}^{(2)**}(s)$$

MTSF when system starts from the state '0' is

$$\text{MTSF} = \lim_{s\to 0} \frac{1-\phi_0^{**}(s)}{s} = \frac{N}{D}$$

$$N = k_1 + \mu_0(1 - p_{11}^{(2)})$$

$$D = p_{13}^{(2)}$$

Availability at full Capacity

The availability $A_i^2(t)$ is seen to be satisfy

$$A_0^2(t) = M_0^2(t) + q_{01}(t) \odot A_1^2(t)$$

$$A_1^2(t) = M_1^2(t) + q_{10}(t) \odot A_0^2(t) + q_{11}^{(2)}(t) \odot A_1^2(t) + q_{14}^{(2,3)}(t) \odot A_4^2(t)$$

$$A_4^2(t) = q_{41}(t) \odot A_1^2(t) + q_{44}^{(3)}(t) \odot A_4^2(t)$$

In steady state, the availability of the system is given by

$$A_0^2 = \lim_{s\to 0} sA_0^{2*}(s) = \frac{N_{1f}}{D_1}$$

where

$N_{1f} = p_{41}p_{10}\mu_0 + p_{41}k_1$

$D_1 = p_{41}p_{10}\mu_0 + p_{14}^{(2,3)}\mu_3 + p_{41}k_2$

Availability at Reduced Capacity

The availability $AR_i^j(t)$ is seen to be satisfy

$$AR_0^2(t) = q_{01}(t) \copyright AR_1^2(t)$$

$$AR_1^2(t) = q_{10}(t) \copyright AR_0^2(t) + q_{11}^{(2)}(t) \copyright AR_1^2(t) + q_{14}^{(2,3)}(t) \copyright AR_4^2(t)$$

$$AR_4^2(t) = M_4^2(t) + q_{41}(t) \copyright AR_1^2(t) + q_{44}^{(3)}(t) \copyright AR_4^2(t)$$

In steady state, the availability of the system is given by

$$AR_0^2 = \lim_{s \to 0} sAR_0^{2*}(s) = \frac{N_{1r}}{D_1}$$

where

$N_{1r} = p_{14}^{(2,3)} \mu_4$

D_1 is already defined.

Busy Period

By probabilistic arguments we have the following recursive relations for $B_i^j(t)$

$$B_0^2(t) = q_{01}(t) \copyright B_1^2(t)$$

$$B_1^2(t) = W_1^2(t) + q_{10}(t) \copyright B_0^2(t) + q_{11}^{(2)}(t) \copyright B_1^2(t) + q_{14}^{(2,3)}(t) \copyright B_4^2(t)$$

$$B_4^2(t) = W_4^2(t) + q_{41}(t) \copyright B_1^2(t) + q_{44}^{(3)}(t) \copyright B_4^2(t)$$

In steady state, the total fraction of time for which the system is under repair is given by

$$B_0^2 = \lim_{s \to 0} sB_0^{2*}(s) = \frac{N_2}{D_1}$$

where

$N_2 = (p_{41} + p_{14}^{(2,3)}) \mu_3$

and D_1 is already given

Expected Number of Visits of the Repairman

By probabilistic arguments, we have the following recursive relations for $V_i(t)$

$$V_0^2(t) = Q_{01}(t) \circledS [1 + V_1^2(t)]$$

$$V_1^2(t) = Q_{10}(t) \circledS V_0^2(t) + Q_{11}^{(2)}(t) \circledS [1 + V_1^2(t)] + Q_{14}^{(2,3)}(t) \circledS [1 + V_4^2(t)]$$

$V_4^2(t) = Q_{44}^{(3)}(t) \textcircled{S} [1 + V_4^2(t)] + Q_{41}(t) \textcircled{S} [1 + V_1^2(t)]$

For steady state, the expected no. of visits of the repairman is given by

$$V_0^2 = \lim_{s \to 0} s V_0^{2**}(s)$$

$$= \lim_{s \to 0} \frac{sN_3(s)}{D_1(s)} = \frac{N_3}{D_1}$$

$$N_3 = (1 - p_{11}^{(2)}) p_{41} + p_{14}^{(2,3)} (1 + p_{41})$$

and D_1 is already given.

Profit Analysis

At steady state, the expected total Profit (P_2) per unit time incurred to the system is given by

Profit (P_2) = $C_0 AC_0^2 - C_1 B_0^2 - C_2 V_0^2 - IC$

where

C_0 = Revenue per unit up time

C_1 = Cost per unit up time for which the repairman is busy

C_2 = Cost per visit of the repairman

IC = Installation cost of a unit per unit time

4.3 Model 3

This model is for the system with two operative units and two standby units. Here states S_0, S_1, S_2, S_4 and S_6 are regenerative states but sates S_2, S_3 and S_5 are non regenerative state. Possible transition from one place to another is given by

Table 3

From	S_0	S_1	S_1	S_1	S_1	S_1	S_4	S_4	S_4	S_4	S_6	S_6
To	S_1	S_6	S_1	S_4	S_5	S_6	S_1	S_4	S_5	S_6	S_4	S_6
Via	...	...	S_2	S_2 and S_3	S_2 and S_3	S_2, S_3 and S_5	...	S_3	S_3	S_3 and S_5	...	S_5

where

S_0 = (Op, Op, Cs, Cs)

S_1 = (Op, Op, Cs, Fr)

S_2 = (Op, F_R, Fwr, Fwr)

S_3 = (Op, F_R, Fwr, Fwr)

S_4 = (Op, Op, Fr, Fwr)

S_5 = (F_R, Fwr, Fwr, Fwr)

S_6 = (Op, Fr, Fwr, Fwr)

The transition probabilities are

$q_{01}(t) = 2\lambda e^{-2\lambda t}dt$ $\quad q_{10}(t) = e^{-2\lambda t}g(t)dt$

$q_{11}^{(2)}(t) = \left[2\lambda e^{-2\lambda t} \copyright e^{-2\lambda t}\right]g(t)dt$

$q_{14}^{(2,3)}(t) = \left[2\lambda e^{-2\lambda t} \copyright 2\lambda e^{-2\lambda t} \copyright e^{-\lambda t}\right]g(t)dt$

$q_{15}^{(2,3)}(t) = \left(2\lambda e^{-2\lambda t} \copyright 2\lambda e^{-2\lambda t} \copyright \lambda e^{-\lambda t}\right)\bar{G}(t)dt$ $\quad q_{41}(t) = e^{-2\lambda t}g(t)dt$

$q_{44}^{(3)}(t) = \left(2\lambda e^{-2\lambda t} \copyright e^{-\lambda t}\right)g(t)dt$ $\quad q_{45}^{(3)}(t) = \left(2\lambda e^{-2\lambda t} \copyright \lambda e^{-\lambda t}\right)\bar{G}(t)dt$

$q_{16}^{(2,3,5)}(t) = \left(2\lambda e^{-2\lambda t} \copyright 2\lambda e^{-2\lambda t} \copyright \lambda e^{-\lambda t} 1\right)g(t)dt$ $\quad q_{46}^{(3,5)}(t) = \left(2\lambda e^{-2\lambda t} \copyright \lambda e^{-\lambda t} \copyright 1\right)g(t)dt$

$q_{64}(t) = e^{-\lambda t}g(t)dt$ $\quad q_{66}^{(5)}(t) = \left(\lambda e^{-\lambda t} \copyright \lambda \copyright 1\right)g(t)dt$

The non zero elements are $p_{ij} = \lim_{s\to 0} q_{ij}^{*}(S)$

$p_{01} = 1$ $\quad p_{10} = g^{*}(2\lambda)$ $\quad p_{11}^{(2)} = -2\lambda g^{*'}(2\lambda)$

$p_{14}^{(2,3)} = 4\left[-g^{*}(2\lambda) + \lambda g^{*'}(2\lambda) + g^{*}(\lambda)\right]$

$p_{15}^{(2,3)} = 4\lambda\left[-\bar{G}^{*}(2\lambda) + \lambda\bar{G}^{*'}(2\lambda) + \bar{G}^{*}(\lambda)\right]$

$p_{41} = g^{*}(2\lambda)$ $\quad p_{44}^{(3)} = 2\left[g^{*}(\lambda) - g^{*}(2\lambda)\right]$ $\quad p_{45}^{(3)} = 2\lambda\left[\bar{G}^{*}(\lambda) - \bar{G}^{*}(2\lambda)\right]$

$p_{45}^{(3,5)} = g^{*}(0) - 2g^{*}(\lambda) + g^{*}(2\lambda)$

$p_{16}^{(2,3,5)} = g^{*}(0) - 4g^{*}(\lambda) + 3g^{*}(2\lambda) - 2\lambda g^{*'}(2\lambda)$

$p_{64} = g^{*}(\lambda)$ $\quad p_{66}^{(5)} = g^{*}(0) - g^{*}(\lambda)$

It can easily verified from these probabilities are

$p_{01} = 1$ $\quad p_{10} + p_{15}^{(2,3)} + p_{11}^{(2)} + p_{14}^{(2,3)} = 1$

$$p_{10} + p_{11}^{(2)} + p_{14}^{(2,3)} + p_{16}^{(2,3,5)} = 1 \qquad p_{41} + p_{44}^{(3)} + p_{45}^{(3)} = 1$$

$$p_{41} + p_{44}^{(3)} + p_{46}^{(3,5)} = 1 \qquad p_{64} + p_{66}^{(5)} = 1$$

Mean Sojourn time (μ_i) in state, i.e., the expected time to stay in state i is

From these values, we conclude that

$$m_{01} = \mu_0 \qquad m_{10} + m_{11}^{(2)} + m_{14}^{(2,3)} + m_{15}^{(2,3)} = k_3 \text{ (Say)}$$

$$m_{10} + m_{11}^{(2)} + m_{14}^{(2,3)} + m_{16}^{(2,3,5)} = k_4 \text{ (Say)} \qquad m_{64} + m_{65}^{(5)} = \mu_5$$

$$m_{41} + m_{44}^{(3)} + m_{45}^{(3)} = k_1 \text{ (Say)} \qquad m_{41} + m_{44}^{(3)} + m_{46}^{(3,5)} = k_5 \text{ (Say)}$$

Mean Time to System Failure (MTSF)

Regarding the failed states as absorbing states and employing the arguments used for regenerative process, we have the following recursive relations for $\phi_i(t)$

$$\phi_0(t) = Q_{01}(t) \textcircled{S} \phi_1(t)$$

$$\phi_1(t) = Q_{10}(t) \textcircled{S} \phi_0(t) + Q_{11}^{(2)}(t) \textcircled{S} \phi_1(t) + Q_{14}^{(2,3)}(t) \textcircled{S} \phi_4(t) + Q_{15}^{(2,3)}(t)$$

$$\phi_4(t) = Q_{41}(t) \textcircled{S} \phi_1(t) + Q_{44}^{(3)}(t) \textcircled{S} \phi_4(t) + Q_{45}^{(3)}(t)$$

Now, taking Laplace Steiltjes Transform on both sides of above equations & solving them for $\phi_0^{**}(s)$, we get

$$\phi_0^{**}(s) = \frac{N(s)}{D(s)}$$

Thus, mean time to system failure (MTSF) when system starts from 0^{th} state, is as follows

$$MTSF = \lim_{s \to 0} \frac{1 - \phi_0^{**}(s)}{s} = \frac{N}{D}$$

where

$$N = p_{14}^{(2,3)}k_1 + (p_{41} + p_{45}^{(3)})k_3 + \left[p_{41}(p_{10} + p_{15}^{(2,3)})\right]\mu_0 + p_{45}^{(3)}\left(1 - p_{11}^{(2)}\right)$$

$$D = p_{14}^{(2,3)}p_{45}^{(3)} + p_{15}^{(2,3)}\left(1 - p_{44}^{(3)}\right)$$

Availability at Full Capacity

Using the probabilistic arguments of the theory of regenerative processes, we have the following recursive relations for $A_i^j(t)$

$$A_0^3(t)A_0(t) = M_0^3(t) + q_{01}(t)\textcircled{c}A_1^3(t)$$

$$A_1^3(t) = M_{1r}^3(t) + q_{10}(t)\textcircled{c}A_0^3(t) + q_{11}^{(2)}(t)\textcircled{c}A_1^3(t) + q_{14}^{(2,3)}(t)\textcircled{c}A_4^3(t) + q_{16}^{(2,3,5)}(t)\textcircled{c}A_6^3(t)$$

$$A_4^3(t) = M_{4r}^3(t) + q_{41}(t)\textcircled{c}A_1^3(t) + q_{44}^{(3)}(t)\textcircled{c}A_4^3(t) + q_{46}^{(3,5)}(t)\textcircled{c}A_6^3(t)$$

$$A_6^3(t) = q_{64}(t)\textcircled{c}A_4^3(t) + q_{66}^{(5)}(t)\textcircled{c}A_6^3(t)$$

In steady state, the availability of the system is given by

$$A_0^3 = \lim_{s\to 0} s\,A_0^{3*}(s) = \frac{N_1(0)}{D_1'(0)} = \frac{N_{1f}}{D_1}$$

$$N_{1f} = \mu_0(p_{64}p_{41}p_{10}) + p_{64}p_{41}k_{41} + p_{64}\left(1 - p_{10}p_{11}^{(2)}\right)\mu_4$$

$$D_1 = p_{64}p_{41}k_4 + p_{64}\left(p_{14}^{(2,3)} + p_{16}^{(2,3,5)}\right)k_5 + p_{64}p_{41}p_{10}\mu_0 + \left(p_{41}p_{16}^{(2,3,5)} + p_{46}^{(3,5)}\left(p_{14}^{(2,3)} + p_{16}^{(2,3,5)}\right)\right)\mu_5$$

Availability at Reduced Capacity

Using the probabilistic arguments of the theory of regenerative processes, we have the following recursive relations for $AR_i^j(t)$

$$AR_0^3(t) = M_0^3(t) + q_{01}(t)\textcircled{c}AR_1^3(t)$$

$$AR_1^3(t) = M_{1r}^3(t) + q_{10}(t)\textcircled{c}AR_0^3(t) + q_{11}^{(2)}(t)\textcircled{c}AR_1^3(t) + q_{14}^{(2,3)}(t)\textcircled{c}AR_4^3(t) + q_{16}^{(2,3,5)}(t)\textcircled{c}AR_6^3(t)$$

$$AR_4^3(t) = M_{4,t}^3(t) + q_{41}(t) \textcircled{\scriptsize C} AR_1^3(t) + q_{41}^{(1)}(t) \textcircled{\scriptsize C} AR_4^3(t) + q_{46}^{(3,5)}(t) \textcircled{\scriptsize C} AR_6^3(t)$$

$$AR_6^3(t) = M_6^3(t) + q_{64}(t) \textcircled{\scriptsize C} AR_4^3(t) + q_{66}^{(5)}(t) \textcircled{\scriptsize C} AR_6^3(t)$$

In steady state, the availability of the system is given by

$$AR_0^3 = \lim_{s \to 0} s\,AR_0^{3*}(s) = \frac{N_{1t}(0)}{D_1'(0)} = \frac{N_{1t}}{D_1}$$

$$N_{1t} = p_{64}p_{41}k_{42} + \left(p_{46}^{(3,5)}\left(p_{14}^{(2,3)} + p_{16}^{(2,3,5)}\right) + p_{16}^{(2,3,5)}p_{41}\right)\mu_6 + k_9 p_{64}\left(p_{14}^{(2,3)} + p_{16}^{(2,3,5)}\right)$$

D_1 is already defined.

Busy Period

By probabilistic arguments we have the following recursive relations for $B_i^3(t)$

$$B_0^3(t) = q_{01}(t) \textcircled{\scriptsize C} B_1^3(t)$$

$$B_1^3(t) = W_1^3(t) + q_{10}(t) \textcircled{\scriptsize C} B_0^3(t) + q_{11}^{(2)}(t) \textcircled{\scriptsize C} B_1^3(t) + q_{14}^{(2,3)}(t) \textcircled{\scriptsize C} B_4^3(t) + q_{16}^{(2,3,5)}(t) \textcircled{\scriptsize C} B_6^3(t)$$

$$B_4^3(t) = W_4^3(t) + q_{41}(t) \textcircled{\scriptsize C} B_1^3(t) + q_{44}^{(3)}(t) \textcircled{\scriptsize C} B_4^3(t) + q_{46}^{(3,5)}(t) \textcircled{\scriptsize C} B_6^3(t)$$

$$B_6^3(t) = W_6^3(t) + q_{64}(t) \textcircled{\scriptsize C} B_4^3(t) + q_{66}^{(5)}(t) \textcircled{\scriptsize C} B_6^3(t)$$

In steady state, the total fractions of the time for which the system is under repair is given by

$$B_0^3 = \lim_{s \to 0} s\,B_0^{3*}(s) = \frac{N_2}{D_1}$$

$$N_2 = \mu_5\left(p_{41}\left(p_{64} + p_{16}^{(2,3,5)}\right) + \left(\left(p_{64} + p_{46}^{(3,5)}\right)\left(p_{14}^{(2,3)} + p_{16}^{(2,3,5)}\right)\right)\right)$$

and D_1 is already defined.

Expected number of the visits of the repairman

By probabilistic arguments, we have the recursive relations for $V_i(t)$

$$V_0^3(t) = Q_{01}(t) \textcircled{\scriptsize S} \left[1 + V_1^3(t)\right]$$

$$V_1^3(t) = Q_{10}(t)\textcircled{S}V_0^3(t) + Q_{11}^{(2)}(t)\textcircled{S}V_1^3(t) + Q_{14}^{(2,3)}(t)\textcircled{S}V_4^3(t) + Q_{16}^{(2,3,5)}(t)\textcircled{S}V_6^3(t)$$

$$V_4^3(t) = Q_{41}(t)\textcircled{S}V_1^3(t) + Q_{44}^{(3)}(t)\textcircled{S}V_4^3(t) + Q_{46}^{(3,5)}(t)\textcircled{S}V_6^3(t)$$

$$V_6^3(t) = Q_{64}(t)\textcircled{S}V_4^3(t) + Q_{66}^{(5)}(t)\textcircled{S}V_6^3(t)$$

For steady state, the expected No. of visits of the repairman is given by

$$V_0^3 = \lim_{s\to 0} s\,V_0^{3**}(s) = \frac{N_3}{D_1}$$

$$N_3 = p_{64}p_{41}p_{10}$$

and D_1 is already defined.

Profit Analysis

At steady state, the expected total Profit (P_3) per unit time incurred to the system is given by

Profit (P_3) = $C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 - 4IC$

where

C_0 = Revenue per unit up time

C_1 = Cost per unit up time for which the repairman is busy

C_2 = Cost per visit of the repairman

IC = Installation cost of a unit per unit time

4.4 Model 4

From	S_9	S_1	S_1	S_1	S_1	S_1	S_1	S_6	S_4	S_6
To	S_1	S_0	S_1	S_8	S_5	S_7	S_6	S_7	S_5	S_6
Via	...	...	S_2	$S_2$and S_3	S_2, S_3 and S_4	S_2, S_3 and S_4	S_2, S_3, S_4 and S_5	...	S_3	S_5
From	S_7	S_7	S_7	S_7	S_8	S_8	S_8	S_8	S_8	
To	S_8	S_7	S_6	S_5	S_1	S_8	S_7	S_6	S_5	
Via	...	S_4	$S_4$and S_5	S_4	...	S_3	S_3 and S_4	S_3, S_4 and S_5	S_3 and S_4	

Table 4

This model is for a system with two operative units and three standby units. Here states S_0, S_1, S_4, S_6, S_7 and S_8 are regenerative states but sates S_2, S_3, S_4 and S_5 are non regenerative state. Possible transition from one place to another is given by

where
S_0 = (Op, Op, Cs, Cs, Cs)
S_1= (Op, Op, Cs, Cs, Fr)
S_2 = (Op, Op, Cs, F_R, Fwr)
S_3 = (Op, Op, F_R, Fwr, Fwr)
S_4= (Op, Fwr, Fwr, Fwr, F_R)
S_5= (F_R, Fwr, Fwr, Fwr, Fwr)
S_6= (Op, Fwr, Fwr, Fwr,Fr)
S_7= (Op, Op, Cs, Fwr, Fr)
S_8= (Op, Op, Cs, Fwr, Fr)

The transition probabilities are

$q_{01}(t) = 2\lambda e^{-2\lambda t}dt$

$q_{10}(t) = e^{-2\lambda t}g(t)dt$

$q_{11}^{(2)}(t) = \left(2\lambda e^{-2\lambda t} \copyright e^{-2\lambda t}\right)g(t)dt$

$q_{15}^{(2,3,4)}(t) = \left(2\lambda e^{-2\lambda t} \copyright 2\lambda e^{-2\lambda t} \copyright 2\lambda e^{-2\lambda t} \copyright \lambda e^{-\lambda t}\right)\bar{G}(t)dt$

$q_{16}^{(2,3)}(t) = \left(2\lambda e^{-2\lambda t} \copyright 2\lambda e^{-2\lambda t} \copyright e^{-2\lambda t}\right)g(t)dt$

$q_{17}^{(2,3,4)}(t) = \left(2\lambda e^{-2\lambda t} \copyright 2\lambda e^{-2\lambda t} \copyright 2\lambda e^{-2\lambda t} \copyright e^{-\lambda t}\right)g(t)dt$

$q_{18}^{(2,3,4,5)}(t) = \left(2\lambda e^{-2\lambda t} \copyright 2\lambda e^{-2\lambda t} \copyright 2\lambda e^{-2\lambda t} \copyright \lambda e^{-2\lambda t} \copyright 1\right)g(t)dt$

$q_{67}(t) = e^{-\lambda t}g(t)dt$

$q_{66}^{(5)}(t) = \left(\lambda e^{-\lambda t} \copyright 1\right)g(t)dt$

$q_{78}(t) = e^{-2\lambda t}g(t)dt$

$q_{77}^{(4)}(t) = \left(2\lambda e^{-2\lambda t} \copyright e^{-\lambda t}\right)g(t)dt$

$q_{76}^{(4,5)}(t) = \left(2\lambda e^{-2\lambda t} \copyright e^{-\lambda t} \copyright 1\right)g(t)dt$

$q_{81}(t) = e^{-2\lambda t}g(t)dt$

$q_{88}^{(3)}(t) = \left(2\lambda e^{-2\lambda t} \copyright e^{-2\lambda t}\right)g(t)dt$

$q_{87}^{(3,4)}(t) = \left(2\lambda e^{-2\lambda t} \copyright 2\lambda e^{-2\lambda t} \copyright e^{-\lambda t}1\right)g(t)dt$

$q_{86}^{(3,4,5)}(t) = \left(2\lambda e^{-2\lambda t} \copyright 2\lambda e^{-2\lambda t} \copyright \lambda e^{-\lambda t} \copyright 1\right)g(t)dt$

$q_{75}^{(4)}(t) = \left(2\lambda e^{-2\lambda t} \copyright \lambda e^{-\lambda t}\right)\bar{G}(t)dt$

$q_{85}^{(3,4)}(t) = \left(2\lambda e^{-2\lambda t} \copyright 2\lambda e^{-2\lambda t} \copyright \lambda e^{-\lambda t}\right)\bar{G}(t)dt$

The probabilities are given by $p_{ij} = \lim_{s\to 0} q_{ij}^{*}(s)$

$$p_{01} = 1 \qquad p_{10} = g^{*}(2\lambda) \qquad p_{11}^{(2)} = 2\lambda g^{*'}(2\lambda)$$

$$p_{15}^{(2,3,4)} = 8\lambda\left[\bar{G}^{*}(\lambda) - \bar{G}^{*}(2\lambda) - \lambda\bar{G}^{*'}(2\lambda) - \frac{\lambda^2}{2}\bar{G}^{*''}(2\lambda)\right] \qquad p_{18}^{(2,3)} = 2\lambda^2 g^{*''}(2\lambda)$$

$$p_{17}^{(2,3,4)} = 8\left[g^{*}(\lambda) - g^{*}(2\lambda) - \lambda g^{*'}(2\lambda) - \frac{\lambda^2}{2}g^{*''}(2\lambda)\right]$$

$$p_{16}^{(2,3,4,5)} = \left[g^{*}(0) - 8g^{*}(\lambda) + 7g^{*}(2\lambda) + 6\lambda g^{*'}(2\lambda) + 2\lambda^2 g^{*''}(2\lambda)\right]$$

$$p_{67} = g^{*}(\lambda) \qquad p_{66}^{(5)} = g^{*}(0) - g^{*}(\lambda)$$

$$p_{77}^{(4)} = 2\left[g^{*}(\lambda) - g^{*}(2\lambda)\right]$$
$$p_{76}^{(4,5)} = g^{*}(0) - 2g^{*}(\lambda) + g^{*}(2\lambda)$$

$$p_{75}^{(4)} = 2\lambda\left[\bar{G}^{*}(\lambda) - \bar{G}^{*}(2\lambda)\right] \qquad p_{78} = g^{*}(2\lambda)$$
$$p_{87}^{(3,4)} = 4\left[g^{*}(\lambda) - g^{*}(2\lambda) - \lambda g^{*'}(2\lambda)\right] \qquad p_{81} = g^{*}(2\lambda)$$

$$p_{86}^{(3,4,5)} = g^{*}(0) - 4g^{*}(\lambda) + 3g^{*}(2\lambda) + 2\lambda g^{*'}(2\lambda) \qquad p_{88}^{(3)} = 2\lambda g^{*'}(2\lambda)$$

$$p_{85}^{(3,4)} = g^{*}(0) - 4g^{*}(\lambda) + 3g^{*}(2\lambda) + 2\lambda g^{*'}(2\lambda)$$

By using these probabilities, we can find the relations

$$p_{01} = 1 \qquad p_{10} + p_{11}^{(2)} + p_{15}^{(2,3,4)} + p_{18}^{(2,3)} + p_{17}^{(2,3,4)} = 1$$

$$p_{10} + p_{11}^{(2)} + p_{18}^{(2,3)} + p_{17}^{(2,3,4)} + p_{16}^{(2,3,4,5)} = 1 \qquad p_{67} + p_{66}^{(5)} = 1$$

$$p_{78} + p_{77}^{(4)} + p_{76}^{(4,5)} = 1 \qquad p_{81} + p_{88}^{(3)} + p_{87}^{(3,4)} + p_{86}^{(3,4,5)} = 1$$

$$p_{78} + p_{77}^{(4)} + p_{75}^{(4)} = 1 \qquad p_{81} + p_{88}^{(3)} + p_{87}^{(3,4)} + p_{85}^{(3,4)} = 1$$

Mean Sojourn time (μ_i) in state, i.e., the expected time to stay in state i is

$$\mu_0 = \frac{1}{2\lambda} \qquad \mu_1 = \frac{1-g^*(2\lambda)}{2\lambda} = \mu_2 = \mu_3 = \mu_7 = \mu_8$$

$$\mu_4 = \frac{1-g^*(\lambda)}{\lambda} = \mu_6 \qquad \mu_5 = \int_0^\infty \bar{G}(t)dt$$

From these values, we can find the relations

$$m_{10} + m_{11}^{(2)} + m_{18}^{(2,3)} + m_{17}^{(2,3,4)} + m_{15}^{(2,3,4)} = k_6 \text{ (say)}$$

$$m_{10} + m_{11}^{(2)} + m_{16}^{(2,3,4,5)} + m_{17}^{(2,3,4)} + m_{18}^{(2,3)} = \mu_5$$

$$m_{67} + m_{66}^{(5)} = \mu_5 \qquad m_{78} + m_{77}^{(4)} + m_{75}^{(4,5)} = \mu_5$$

$$m_{81} + m_{88}^{(3)} + m_{87}^{(3,4)} + m_{85}^{(3,4,5)} = \mu_5$$

Mean Time to System Failure (MTSF)

To determine the mean time to system failure (MTSF) of the system, we regard the failed state as

$$\phi_0(t) = Q_{01}(t) \textcircled{S} \phi_1(t)$$

$$\phi_1(t) = Q_{10}(t) \textcircled{S} \phi_0(t) + Q_{11}^{(2)}(t) \textcircled{S} \phi_1(t) + Q_{18}^{(2,3)}(t) \textcircled{S} \phi_8(t) + Q_{17}^{(2,3,4)}(t) \textcircled{S} \phi_7(t) + Q_{15}^{(2,3,4)}(t)$$

$$\phi_7(t) = Q_{78}(t) \textcircled{S} \phi_8(t) + Q_{77}^{(4)}(t) \textcircled{S} \phi_7(t) + Q_{75}^{(4)}(t)$$

$$\phi_8(t) = Q_{81}(t) \textcircled{S} \phi_1(t) + Q_{88}^{(3)}(t) \textcircled{S} \phi_8(t) + Q_{87}^{(3,4)}(t) \textcircled{S} \phi_7(t) + Q_{85}^{(3,4)}(t)$$

Now, taking Laplace Steiltjes Transform on both sides of above equations & solving them for $\phi_0^{**}(s)$, we get

$$\phi_0^{**}(s) = \frac{N(s)}{D(s)}$$

Thus, mean time to system failure (MTSF) when system starts from 0^0 state, is as follows

$$MTSF = \lim_{s\to 0} \frac{1-\phi_0^{**}(s)}{s} = \frac{N}{D}$$

where

$$N = \left\{p_{78}p_{17}^{(2,3,4)} + p_{18}^{(2,3)}\left(p_{78} + p_{75}^{(4)}\right)\right\}\mu_5 + \left\{p_{17}^{(2,3,4)}\left(p_{81} + p_{85}^{(3,4)} + p_{87}^{(3,4)}\right) + p_{18}^{(2,3)}p_{87}^{(3,4)}\right\}k_1$$
$$+ \left\{p_{78}p_{81} + p_{75}^{(4)}\left(p_{81} + p_{87}^{(3,4)} + p_{85}^{(3,4)}\right)\right\}k_6 + \left[\left\{p_{78}\left(p_{81} + p_{85}^{(3,4)}\right) + p_{75}^{(4)}\left(p_{81} + p_{87}^{(3,4)} + p_{85}^{(3,4)}\right)\right\}\left(p_{01} + p_{15}^{(2,3,4)}\right)\right]\mu_0$$

$$D = \left(1 - p_{11}^{(2)} - p_{10}\right)\left[\left(1 - p_{77}^{(4)}\right)\left(1 - p_{88}^{(3)}\right) - p_{78}p_{87}^{(3,4)}\right] - p_{81}\left[p_{78}p_{17}^{(2,3,4)} + p_{18}^{(2,3)}\left(1 - p_{77}^{(4)}\right)\right]$$

Availability at Full Capacity

Using the probabilistic arguments of the theory of regenerative processes, we have the following recursive relations for $A_i^j(t)$

$$A_0^4(t) = M_0^4(t) + q_{01}(t) \odot A_1^4(t)$$

$$A_1^4(t) = M_{11}^4(t) + q_{10}(t) \odot A_0^4(t) + q_{11}^{(2)}(t) \odot A_1^4(t) + q_{16}^{(2,3,4,5)}(t) \odot A_6^4(t) + q_{17}^{(2,3,4)}(t) \odot A_7^4(t) + q_{18}^{(2,3)}(t) \odot A_8^4(t)$$

$$A_6^4(t) = q_{67}(t) \odot A_7^4(t) + q_{66}^{(5)}(t) \odot A_6^4(t)$$

$$A_7^4(t) = M_{71}^4(t) + q_{78}(t) \odot A_8^4(t) + q_{77}^{(4)}(t) \odot A_7^4(t) + q_{76}^{(4,5)}(t) \odot A_6^4(t)$$

$$A_8^4(t) = M_{81}^4(t) + q_{81}(t) \odot A_1^4(t) + q_{88}^{(3)}(t) \odot A_8^4(t) + q_{87}^{(3,4)}(t) \odot A_7^4(t) + q_{86}^{(3,4,5)}(t) \odot A_6^4(t)$$

In steady state, the availability of the system is given by

$$A_0^4 = \lim_{s\to 0} s\,A_0^{4*}(s) = \frac{N_1(0)}{D_1'(0)} = \frac{N_{11}}{D_1}$$

$$N_{11} = \left(\left(1 - p_{11}^{(2)}\right)\mu_0 + k_7\right)p_{67}p_{78}p_{81} - \left(p_{81}\mu_1 - k_{11}\right)p_{67}p_{78}\left(p_{18}^{(2,3)} + p_{17}^{(2,3,4)} + p_{16}^{(2,3,4,5)}\right)$$
$$+ \mu_7\left(p_{81}p_{67}\left(p_{17}^{(2,3,4)} + p_{16}^{(2,3,4,5)}\right) + p_{67}\left(p_{16}^{(2,3,4,5)} + p_{17}^{(2,3,4)} + p_{18}^{(2,3)}\right)\left(p_{87}^{(3,4)} + p_{86}^{(3,4,5)}\right)\right)$$

$$D_1 = \left\{\left(p_{16}^{(2,3,4,5)} + p_{17}^{(2,3,4)} + p_{18}^{(2,3)}\right)\left(p_{67}p_{78} + p_{67}p_{87}^{(3,4)} + p_{67}p_{86}^{(3,4,5)} + p_{76}^{(4,5)}\left(1 - p_{88}^{(3)}\right) + p_{78}p_{86}^{(3,4,5)}\right)\right.$$

$$\left. + p_{67}p_{75}p_{81} + \left(p_{17}^{(2,3,4)} + p_{16}^{(2,3,4,5)}\right) + p_{81}\left(p_{16}^{(2,3,4,5)}p_{78} - p_{18}^{(2,3)}p_{76}^{(4,5)}\right)\right\}\mu_5 + p_{67}p_{78}p_{81}p_{10}\mu_4\mu_5$$

Availability at Reduced Capacity

Using the probabilistic arguments of the theory of regenerative processes, we have the following recursive relations for $AR_i^j(t)$

$$AR_0^4(t) = q_{01}(t)\textcircled{c}AR_1^4(t)$$

$$AR_1^4(t) = M_1^4(t) + q_{10}(t)\textcircled{c}AR_0^4(t) + q_{11}^{(2)}(t)\textcircled{c}AR_1^4(t) + q_{16}^{(2,3,4,5)}(t)\textcircled{c}AR_6^4(t) + q_{17}^{(2,3,4)}(t)\textcircled{c}AR_7^4(t) + q_{18}^{(2,3)}(t)\textcircled{c}AR_8^4(t)$$

$$AR_6^4(t) = M_6^4(t) + q_{67}(t)\textcircled{c}AR_7^4(t) + q_{66}^{(5)}(t)\textcircled{c}AR_6^4(t)$$

$$AR_7^4(t) = M_7^4(t) + q_{78}(t)\textcircled{c}AR_8^4(t) + q_{77}^{(4)}(t)\textcircled{c}AR_7^4(t) + q_{76}^{(4,5)}(t)\textcircled{c}AR_6^4(t)$$

$$AR_8^4(t) = M_8^4(t) + q_{81}(t)\textcircled{c}AR_1^4(t) + q_{88}^{(3)}(t)\textcircled{c}AR_8^4(t) + q_{87}^{(3,4)}(t)\textcircled{c}AR_7^4(t) + q_{86}^{(3,4,5)}(t)\textcircled{c}AR_6^4(t)$$

In steady state, the availability of the system is given by

$$AR_0^4 = \lim_{s\to 0} s\,AR_0^{4*}(s) = \frac{N_{1r}}{D_1}$$

$$\begin{aligned} N_{1r} = {} & k_8\left(p_{67}p_{78}p_{81}\right) + \mu_6\left\{p_{78}p_{81}p_{16}^{(2,3,4,5)} + p_{78}p_{86}^{(3,4,5)}\left(p_{16}^{(2,3,4,5)} + p_{17}^{(2,3,4)} + p_{18}^{(2,3)}\right)\right. \\ & \left. + p_{76}^{(4,5)}\left(p_{81} + p_{87}^{(3,4)} + p_{86}^{(3,4,5)}\right)\left(p_{16}^{(2,3,4,5)} + p_{17}^{(2,3,4)}\right) + p_{76}^{(4,5)}p_{18}^{(2,3)}p_{81}^{(3,4,5)} + p_{18}^{(2,3)}p_{87}^{(3,4)}p_{76}^{(3,4)}\right\} \\ & + k_9\left\{p_{67}\left(1 - p_{88}^{(3)}\right)\left(p_{16}^{(2,3,4,5)} + p_{17}^{(2,3,4)}\right) + p_{67}p_{18}^{(2,3)}\left(p_{87}^{(3,4)} + p_{86}^{(3,4,5)}\right)\right\} \\ & + k_{10}p_{67}p_{78}\left(p_{16}^{(2,3,4,5)} + p_{17}^{(2,3,4)} + p_{18}^{(2,3)}\right) \end{aligned}$$

D_1 is already defined.

Busy Period

By probabilistic arguments we have the following recursive relations for $B_i^j(t)$

$$B_0^4(t) = q_{01}(t) \textcircled{c} B_1^4(t)$$

$$B_1^4(t) = W_1^4(t) + q_{10}(t) \textcircled{c} B_0^4(t) + q_{11}^{(2)}(t) \textcircled{c} B_1^4(t) + q_{16}^{(2,3,4,5)}(t) \textcircled{c} B_6^4(t) + q_{17}^{(2,3,4)}(t) \textcircled{c} B_7^4(t) + q_{18}^{(2,3)}(t) \textcircled{c} B_8^4(t)$$

$$B_6^4(t) = W_6^4(t) + q_{67}(t) \textcircled{c} B_7^4(t) + q_{66}^{(5)}(t) \textcircled{c} B_6^4(t)$$

$$B_7^4(t) = W_7^4(t) + q_{78}(t) \textcircled{c} B_8^4(t) + q_{77}^{(4)}(t) \textcircled{c} B_7^4(t) + q_{76}^{(4,5)}(t) \textcircled{c} B_6^4(t)$$

$$B_8^4(t) = W_8^4(t) + q_{81}(t) \textcircled{c} B_1^4(t) + q_{88}^{(3)}(t) \textcircled{c} B_8^4(t) + q_{86}^{(3,4,5)}(t) \textcircled{c} B_6^4(t) + q_{87}^{(3,4)}(t) \textcircled{c} B_7^4(t)$$

In steady state, the total fractions of the time for which the system is under repair is given by

$$B_0^4 = \lim_{s \to 0} s B_0^{4*}(s) = \frac{N_2}{D_1}$$

$$\begin{aligned} N_2 = \mu_5 [& p_{67} p_{78} p_{81} - [-p_{16}^{(2,3,4,5)} \{ (p_{81} + p_{86}^{(2,4,5)})(p_{78} + p_{76}^{(4,5)}) + p_{76}^{(4,5)} p_{87}^{(3,4)} \} \\ & + p_{17}^{(2,3,4)} \{ -p_{86}^{(3,4,5)} (p_{78} + p_{76}^{(4,5)}) - p_{76}^{(4,5)} (p_{81} + p_{87}^{(3,4)}) \} - p_{18}^{(2,3)} \{ p_{76}^{(4,5)} p_{87}^{(3,4)} + p_{86}^{(3,4,5)} (p_{78} + p_{76}^{(4,5)})] \\ & + p_{67} (p_{16}^{(2,3,4,5)} + p_{17}^{(2,3,4)} + p_{18}^{(2,3)})(p_{87}^{(3,4)} + p_{86}^{(3,4,5)} + p_{78}) + p_{67} p_{81} (p_{16}^{(2,3,4,5)} + p_{17}^{(2,3,4)})] \end{aligned}$$

and D_1 is already defined.

Expected number of the visits of the repairman

By probabilistic arguments, we have the recursive relations for $V_i^j(t)$

$$V_0^4(t) = Q_{01}(t) \textcircled{s} \left[1 + V_1^4(t) \right]$$

$$V_1^4(t) = Q_{10}(t) \textcircled{s} V_0^4(t) + Q_{11}^{(2)}(t) \textcircled{s} V_1^4(t) + Q_{16}^{(2,3,5)}(t) \textcircled{s} V_6^4(t) + Q_{17}^{(2,3,4)}(t) \textcircled{s} V_7^4(t) + Q_{18}^{(2,3)}(t) \textcircled{s} V_8^4(t)$$

$$V_6^4(t) = Q_{67}(t) \textcircled{s} V_7^4(t) + Q_{66}^{(5)}(t) \textcircled{s} V_6^4(t)$$

$$V_7^4(t) = Q_{78}(t) \textcircled{s} V_8^4(t) + Q_{77}^{(4)}(t) \textcircled{s} V_7^4(t) + Q_{76}^{(4,5)}(t) \textcircled{s} V_6^4(t)$$

$$V_8^4(t) = Q_{81}(t) \textcircled{S} V_1^4(t) + Q_{86}^{(1)}(t) \textcircled{S} V_8^4(t) + Q_{86}^{(1,4,5)}(t) \textcircled{S} V_6^4(t) + Q_{87}^{(3,4)}(t) \textcircled{S} V_7^4(t)$$

For steady state, the expected No. of visits of the repairman is given by

$$V_0^4 = \lim_{s \to 0} s V_0^{4**}(s) = \frac{N_2}{D_1}$$

$$N_2 = p_{67} p_{78} p_{81} p_{10}$$

and D_1 is already defined.

Profit Analysis

At steady state, the expected total Profit (P_4) per unit time incurred to the system is given by

Profit (P_4) = $C_0 AC_0^4 - C_1 B_0^4 - C_2 V_0^4$-5IC

where

C_0 = Revenue per unit up time.

C_1 = Cost per unit up time for which the repairman is busy

C_2 = Cost per visit of the repairman

IC = Installation cost of a unit per unit time.

5.) Comparative Study among the Models

5.1 Comparative Analysis of the Profits with respect to Revenue per Unit up Time

a) Model 1 will be more or less or equally beneficial than Model 2 if according as

P_1-P_2 >0 or <0 or =0

i.e. if ($C_0 AC_0^1 - C_1 B_0^1 - C_2 V_0^1$-2*(IC$_0$))-($C_0 AC_0^2 - C_1 B_0^2 - C_2 V_0^2$-3*(IC$_0$)) >0 or <0 or =0

i.e. if $C_0(AC_0^1 - AC_0^2) - C_1(B_0^1 - B_0^2) - C_2(V_0^1 - V_0^2) + IC_0$ >0 or <0 or =0

i.e. if $C_0(AC_0^1 - AC_0^2)$ > or < or= $C_1(B_0^1 - B_0^2) + C_2(V_0^1 - V_0^2) - IC_0$

Hence, No Standby or One Standby may be used according as

$$\text{i.e. if } \begin{cases} C_0 > \text{or} < \text{or} = \dfrac{(C_1(B_0^1 - B_0^2) + C_2(V_0^1 - V_0^2) - IC_0)}{(AC_0^1 - AC_0^2)}, \text{for} AC_0^1 > AC_0^2 \\ C_0 < \text{or} > \text{or} = \dfrac{(C_1(B_0^1 - B_0^2) + C_2(V_0^1 - V_0^2) - IC_0)}{(AC_0^1 - AC_0^2)}, \text{for} AC_0^1 < AC_0^2 \end{cases}$$

b) Model 1 will be more or less or equally beneficial than Model 3 if according as

P_1-P_2 >0 or <0 or =0

i.e. if ($C_0 AC_0^1 - C_1 B_0^1 - C_2 V_0^1$-2*(IC$_0$))-($C_0 AC_0^3 - C_1 B_0^3 - C_2 V_0^3$-4*(IC$_0$)) >0 or <0 or =0

i.e. if $C_0(AC_0^1 - AC_0^1) - C_1(B_0^1 - B_0^3) - C_2(V_0^1 - V_0^3) + 2*(IC_0)$ >0 or <0 or =0

i.e. if $C_0(AC_0^1 - AC_0^3)$ > or < or= $C_1(B_0^1 - B_0^3) + C_2(V_0^1 - V_0^3)$-2*(IC$_0$)

Hence, No Standby or Two Standby may be used according as

$$\text{i.e. if } \begin{cases} C_0 > \text{or} < \text{or} = \dfrac{(C_1(B_0^1-B_0^3)+C_2(V_0^1-V_0^3)-2*(IC_0))}{(AC_0^1-AC_0^2)}, \text{for} AC_0^1 > AC_0^2 \\ C_0 < \text{or} > \text{or} = \dfrac{(C_1(B_0^1-B_0^3)+C_2(V_0^1-V_0^3)-2*(IC_0))}{(AC_0^1-AC_0^2)}, \text{for} AC_0^1 < AC_0^2 \end{cases}$$

c) Model 1 will be more or less or equally beneficial than Model 4 if according as

$P_1-P_4>0$ or <0 or $=0$

i.e. if $(C_0AC_0^1 - C_1B_0^1 - C_2V_0^1-2*(IC_0))-(C_0AC_0^4 - C_1B_0^4 - C_2V_0^4-5*(IC_0)) >0$ or <0 or $=0$

i.e. if $C_0(AC_0^1-AC_0^4)- C_1(B_0^1- B_0^4)- C_2(V_0^1- V_0^4)+ 3*(IC_0) >0$ or <0 or $=0$

i.e. if $C_0(AC_0^1-AC_0^4) >$ or $<$ or $= C_1(B_0^1- B_0^4)+ C_2(V_0^1- V_0^4)-3*(IC_0)$

Hence, No Standby or Three Standby may be used according as

$$\text{i.e. if } \begin{cases} C_0 > \text{or} < \text{or} = \dfrac{(C_1(B_0^1-B_0^4)+C_2(V_0^1-V_0^4)-3*(IC_0))}{(AC_0^1-AC_0^4)}, \text{for} AC_0^1 > AC_0^4 \\ C_0 < \text{or} > \text{or} = \dfrac{(C_1(B_0^1-B_0^4)+C_2(V_0^1-V_0^4)-3*(IC_0))}{(AC_0^1-AC_0^4)}, \text{for} AC_0^1 < AC_0^4 \end{cases}$$

d) Model 2 wiX be more or less or equally beneficial than Model 3 if according as

$P_2-P_3>0$ or <0 or $=0$

i.e. if $(C_0AC_0^2 - C_1B_0^2 - C_2V_0^2-3*(IC_0))-(C_0AC_0^3 - C_1B_0^3 - C_2V_0^3-4*(IC_0)) >0$ or <0 or $=0$

i.e. if $C_0(AC_0^2 - AC_0^3)-C_1(B_0^2- B_0^3)-C_2(V_0^2- V_0^3)+ IC_0>0$ or <0 or $=0$

i.e. if $C_0(AC_0^2 - AC_0^3) >$ or $<$ or $=C_1(B_0^2- B_0^3)+C_2(V_0^2- V_0^3)- IC_0$

Hence, One Standby or Two Standby may be used according as

$$\text{i.e. if } \begin{cases} C_0 > \text{or} < \text{or} = \dfrac{C_1(B_0^2 - B_0^3)+C_2(V_0^2 - V_0^3) - IC_0}{(AC_0^2 - AC_0^3)}, \text{for} AC_0^2 > AC_0^3 \\ C_0 < \text{or} > \text{or} = \dfrac{C_1(B_0^2 - B_0^3)+C_2(V_0^2 - V_0^3) - IC_0}{(AC_0^2 - AC_0^3)}, \text{for} AC_0^2 < AC_0^3 \end{cases}$$

e) Model 2 will be more or less or equally beneficial than Model 4 if according as

P_2-P_4 >0 or <0 or =0

i.e. if $(C_0AC_0^2 - C_1B_0^2 - C_2V_0^2\text{-}3*(IC_0))\text{-}(C_0AC_0^4 - C_1B_0^4 - C_2V_0^4\text{-}5*(IC_0)) > 0$ or < 0 or $= 0$

i.e. if $C_0(AC_0^2 - AC_0^4)\text{-}C_1(B_0^2 - B_0^4)\text{-}C_2(V_0^2 - V_0^4) + 2*(IC_0) > 0$ or < 0 or $= 0$

i.e. if $C_0(AC_0^2 - AC_0^4) >$ or $<$ or $= C_1(B_0^2 - B_0^4) + C_2(V_0^2 - V_0^4) - 2*(IC_0)$

Hence, One Standby or Three Standby may be used according as

$$\text{i.e. if} \begin{cases} C_0 > \text{or} < \text{or} = \dfrac{C_1\left(B_0^2 - B_0^4\right) + C_2\left(V_0^2 - V_0^4\right) - 2*(IC_0)}{\left(AC_0^2 - AC_0^4\right)}, \text{for} AC_0^2 > AC_0^4 \\ C_0 < \text{or} > \text{or} = \dfrac{C_1\left(B_0^2 - B_0^4\right) + C_2\left(V_0^2 - V_0^4\right) - 2*(IC_0)}{\left(AC_0^2 - AC_0^4\right)}, \text{for} AC_0^2 < AC_0^4 \end{cases}$$

f) Model 3 will be more or less or equally beneficial than Model 4 if according as

P_3-P_4 >0 or <0 or =0

i.e. if $(C_0AC_0^3 - C_1B_0^3 - C_2V_0^3\text{-}4*(IC_0))\text{-}(C_0AC_0^4 - C_1B_0^4 - C_2V_0^4\text{-}5*(IC_0)) > 0$ or < 0 or $= 0$

i.e. if $C_0(AC_0^3 - AC_0^4)\text{-}C_1(B_0^3 - B_0^4)\text{-}C_2(V_0^3 - V_0^4) + (IC_0) > 0$ or < 0 or $= 0$

i.e. if $C_0(AC_0^3 - AC_0^4) >$ or $<$ or $= C_1(B_0^3 - B_0^4) + C_2(V_0^3 - V_0^4) - (IC_0)$

Hence, Two Standby or No Standby may be used according as

$$\text{i.e. if} \begin{cases} C_0 > \text{or} < \text{or} = \dfrac{C_1(B_0^3 - B_0^4) + C_2(V_0^3 - V_0^4) - (IC_0)}{(AC_0^3 - AC_0^4)}, \text{for} AC_0^3 > AC_0^4 \\ C_0 < \text{or} > \text{or} = \dfrac{C_1(B_0^3 - B_0^4) + C_2(V_0^3 - V_0^4) - (IC_0)}{(AC_0^3 - AC_0^4)}, \text{for} AC_0^3 < AC_0^4 \end{cases}$$

Let us consider the following particular case to illustrate the comparative analysis with respect to revenue per unit up time. For the special case λ=0.1, β=0.2, C_1=500, C_2=300, IC_0=100.

a) P_1-P_2 >0 or < 0 or =0 if revenue per unit up time >944.1901 or <944.1901 or = 944.1901
b) P_1-P_3 >0 or < 0 or =0 if revenue per unit up time >1828.2596 or < 1828.2596 or = 1828.2596
c) P_1-P_4 >0 or < 0 or =0 if revenue per unit up time >437.4187 or < 437.4187 or = 437.4187
d) P_2-P_3 >0 or < 0 or =0 if revenue per unit up time > 9162.75 or < 9162.75 or = 9162.75
e) P_2-P_4 >0 or < 0 or =0 if revenue per unit up time >1483.5232 or < 1483.5232 or = 1483.5232
f) P_3-P_4>0 or < 0 or =0 if revenue per unit up time >2828.01 or < 2828.01or =2828.01.

5.2 Comparative Analysis of the Profits with respect to Installation Cost of a unit

a) Model 1 will be more or less or equally beneficial than Model 2 if according as

P_1-P_2 >0 or <0 or =0

i.e. if $(C_0AC_0^1 - C_1B_0^1 - C_2V_0^1 \cdot 2^*(IC_0))$-$(C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 \cdot 3^*(IC_0))$ >0 or <0 or =0

i.e. if $C_0(AC_0^1 - AC_0^2)$- $C_1(B_0^1 - B_0^2)$- $C_2(V_0^1 - V_0^2)$+ IC_0 >0 or <0 or =0

Hence, No Standby or One Standby may be used according as

i.e. if IC_0 > or < or= $-C_0(AC_0^1 - AC_0^2)+C_1(B_0^1 - B_0^2)+C_2(V_0^1 - V_0^2)$

b) Model 1 will be more or less or equally beneficial than Model 3 if according as

P_1-P_3 >0 or <0 or =0

i.e. if $(C_0AC_0^1 - C_1B_0^1 - C_2V_0^1 \cdot 2^*(IC_0))$-$(C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 \cdot 4^*(IC_0))$ >0 or <0 or =0

i.e. if $C_0(AC_0^1 - AC_0^3)$- $C_1(B_0^1 - B_0^3)$- $C_2(V_0^1 - V_0^3)$+ $2^*(IC_0)$ >0 or <0 or =0

Hence, No Standby or Two Standby may be used according as

i.e. if IC_0 > or < or= $\dfrac{-C_0\left(AC_0^1 - AC_0^3\right)+C_1(B_0^1 - B_0^3)+C_2(V_0^1 - V_0^3)}{2}$

c) Model 1 will be more or less or equally beneficial than Model 4 if according as

P_1-P_4 >0 or <0 or =0

i.e. if $(C_0AC_0^1 - C_1B_0^1 - C_2V_0^1 \cdot 2^*(IC_0))$-$(C_0AC_0^4 - C_1B_0^4 - C_2V_0^4 \cdot 5^*(IC_0))$ >0 or <0 or =0

i.e. if $C_0(AC_0^1 - AC_0^4)$- $C_1(B_0^1 - B_0^4)$- $C_2(V_0^1 - V_0^4)$+ $3^*(IC_0)$ >0 or <0 or =0

Hence, No Standby or Three Standby may be used according as

i.e. if IC_0 > or < or= $\dfrac{-C_0\left(AC_0^1 - AC_0^4\right)+C_1(B_0^1 - B_0^4)+C_2(V_0^1 - V_0^4)}{3}$

d) Model 2 will be more or less or equally beneficial than Model 3 if according as

P_2-P_3 >0 or <0 or =0

i.e. if $(C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 \cdot 3^*(IC_0))$-$(C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 \cdot 4^*(IC_0))$ >0 or <0 or =0

i.e. if $C_0(AC_0^2 - AC_0^3)$-$C_1(B_0^2 - B_0^3)$-$C_2(V_0^2 - V_0^3)$+ IC_0>0 or <0 or =0

Hence, One Standby or Two Standby may be used according as

i.e. if IC_0 > or < or = $-C_0(AC_0^2 - AC_0^3)+C_1(B_0^2 - B_0^3)+C_2(V_0^2 - V_0^3)$

e) Model 2 will be more or less or equally beneficial than Model 4 if according as

P_2-P_4 >0 or <0 or =0

i.e. if $(C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 \cdot 3^*(IC_0))$-$(C_0AC_0^4 - C_1B_0^4 - C_2V_0^4 \cdot 5^*(IC_0))$ >0 or <0 or =0

i.e. if $C_0(AC_0^2 - AC_0^4)$-$C_1(B_0^2 - B_0^4)$-$C_2(V_0^2 - V_0^4)$+ $2^*(IC_0)$ >0 or <0 or =0

Hence, One Standby or Two Standby may be used according as

$$\text{i.e. if } IC_0 > \text{or} < \text{or} = \frac{-C_0\left(AC_0^2-AC_0^4\right)+C_1(B_0^2-B_0^4)+C_2(V_0^2-V_0^4)}{2}$$

f) Model 3 will be more or less or equally beneficial than Model 4 if according as

$P_3-P_4>0$ or <0 or $=0$

i.e. if $(C_0AC_0^3 - C_1B_0^3 - C_2V_0^3-3*(IC_0))-(C_0AC_0^4 - C_1B_0^4 - C_2V_0^4-5*(IC_0))>0$ or <0 or $=0$

i.e. if $C_0(AC_0^3- AC_0^4)-C_1(B_0^3- B_0^4)-C_2(V_0^3- V_0^4)+2*(IC_0)>0$ or <0 or $=0$

i.e. if $2*(IC_0)>$ or $<$ or $= -C_0(AC_0^3- AC_0^4)+C_1(B_0^2- B_0^4)+C_2(V_0^3- V_0^4)$

Hence, Two Standby or Three Standby may be used according as

$$\text{i.e.if } IC_t > \text{ or} < \text{or} = \frac{-C_0(AC_0^3-AC_0^4)+C_1(B_0^3-B_0^4)+C_2(V_0^3-V_0^4)}{2}$$

Let us consider the following particular case to illustrate the comparative analysis with respect to installation cost of a unit. For the special case $\lambda=0.1$, $\beta=0.2$, $C_0=800$, $C_1=300$, $C_2=500$.

a) $P_1-P_2>0$ or <0 or $=0$ if installation cost of a unit >79.4679 or <79.4679 or $=79.4679$.
b) $P_1-P_3>0$ or <0 or $=0$ if installation cost of a unit >44.8977 or <44.8977 or $=44.897$.
c) $P_1-P_4>0$ or <0 or $=0$ if installation cost of a unit >78.2852 or <78.2852 or $=78.2852$.
d) $P_2-P_3>0$ or <0 or $=0$ if installation cost of a unit >10.3276 or <10.3276 or $=10.3276$.
e) $P_2-P_4>0$ or <0 or $=0$ if installation cost of a unit >86.0575 or <86.0575 or $=86.0575$.
f) $P_3-P_4>0$ or <0 or $=0$ if installation cost of a unit >175.5373 or <175.5373or $=175.5373$.

5.3 Comparative Analysis of the Profits with respect to Cost per visit of the repairman:

a) Model 1 will be more or less or equally beneficial than Model 2 if according as

$P_1-P_2>0$ or <0 or $=0$

i.e. if $(C_0AC_0^1 - C_1B_0^1 - C_2V_0^1-2*(IC_0))-(C_0AC_0^2 - C_1B_0^2 - C_2V_0^2-3*(IC_0))>0$ or <0 or $=0$

i.e. if $C_0(AC_0^1-AC_0^2)- C_1(B_0^1- B_0^2)- C_2(V_0^1- V_0^2)+ IC_0 >0$ or <0 or $=0$

i.e. if $C_2(V_0^1- V_0^2) <$ or $>$ or $= C_0(AC_0^1-AC_0^2) -C_1(B_0^1- B_0^2)+ IC_0$

Hence, No Standby or One Standby may be used according as

$$\text{i.e. if } \begin{cases} C_2 < \text{or} > \text{or} = \dfrac{(C_0\left(AC_0^1-AC_0^2\right)-C_1(B_0^1-B_0^2)+IC_0)}{\left(V_0^1-V_0^2\right)}, \text{for } V_0^1>V_0^2 \\ C_2 > \text{or} < \text{or} = \dfrac{(C_0\left(AC_0^1-AC_0^2\right)-C_1(B_0^1-B_0^2)+IC_0)}{\left(V_0^1-V_0^2\right)}, \text{for } V_0^1<V_0^2 \end{cases}$$

b) Model 1 will be more or less or equally beneficial than Model 3 if according as

$P_1-P_3>0$ or <0 or $=0$

i.e. if $(C_0AC_0^1 - C_1B_0^1 - C_2V_0^1-2*(IC_0))-(C_0AC_0^3 - C_1B_0^3 - C_2V_0^3-4*(IC_0))>0$ or <0 or $=0$

i.e. if $C_0(AC_0^1-AC_0^3)- C_1(B_0^1- B_0^3)- C_2(V_0^1- V_0^3)+ 2*(IC_0) >0$ or <0 or $=0$

i.e. if $C_2(V_0^1- V_0^3) <$ or $>$ or $= C_0(AC_0^1-AC_0^3) -C_1(B_0^1- B_0^3)+2*(IC_0)$

Hence, No Standby or Two Standby may be used according as

$$\text{i.e. if} \begin{cases} C_2 < \text{or} > \text{or} = \dfrac{(C_0(AC_0^1 - AC_0^3) - C_1(B_0^1 - B_0^3) + 2*(IC_0))}{(V_0^1 - V_0^3)}, \text{for } V_0^1 > V_0^3 \\ C_2 > \text{or} < \text{or} = \dfrac{(C_0(AC_0^1 - AC_0^3) - C_1(B_0^1 - B_0^3) + 2*(IC_0))}{(V_0^1 - V_0^3)}, \text{for } V_0^1 < V_0^3 \end{cases}$$

e) Model 1 will be more or less or equally beneficial than Model 4 if according as

$P_1 - P_4 > 0$ or < 0 or $= 0$

i.e. if $(C_0AC_0^1 - C_1B_0^1 - C_2V_0^1 - 2*(IC_0)) - (C_0AC_0^4 - C_1B_0^4 - C_2V_0^4 - 5*(IC_0)) > 0$ or < 0 or $= 0$

i.e. if $C_0(AC_0^1 - AC_0^4) - C_1(B_0^1 - B_0^4) - C_2(V_0^1 - V_0^4) + 3*(IC_0) > 0$ or < 0 or $= 0$

i.e. if $C_2(V_0^1 - V_0^4) < \text{or} > \text{or} = C_0(AC_0^1 - AC_0^4) - C_1(B_0^1 - B_0^4) + 3*(IC_0)$

Hence, No Standby or Three Standby may be used according as

$$\text{i.e. if} \begin{cases} C_2 < \text{or} > \text{or} = \dfrac{(C_0(AC_0^1 - AC_0^4) - C_1(B_0^1 - B_0^4) + 3*(IC_0))}{(V_0^1 - V_0^4)}, \text{for } V_0^1 > V_0^4 \\ C_2 > \text{or} < \text{or} = \dfrac{(C_0(AC_0^1 - AC_0^4) - C_1(B_0^1 - B_0^4) + 3*(IC_0))}{(V_0^1 - V_0^4)}, \text{for } V_0^1 < V_0^4 \end{cases}$$

d) Model 2 will be more or less or equally beneficial than Model 3 if according as

d) $P_2 - P_3 > 0$ or < 0 or $= 0$

i.e. if $(C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 - 3*(IC_0)) - (C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 - 4*(IC_0)) > 0$ or < 0 or $= 0$

i.e. if $C_0(AC_0^2 - AC_0^3) - C_1(B_0^2 - B_0^3) - C_2(V_0^2 - V_0^3) + IC_0 > 0$ or < 0 or $= 0$

i.e. if $C_2(V_0^2 - V_0^3) < \text{or} > \text{or} = C_0(AC_0^2 - AC_0^3) - C_1(B_0^2 - B_0^3) + IC_0$

Hence, One Standby or Two Standby may be used according as

$$\text{i.e. if} \begin{cases} C_2 < \text{or} > \text{or} = \dfrac{C_0(AC_0^2 - AC_0^3) - C_1(B_0^2 - B_0^3) + IC_0}{(V_0^2 - V_0^3)}, \text{for } V_0^2 > V_0^3 \\ C_2 > \text{or} < \text{or} = \dfrac{C_0(AC_0^2 - AC_0^3) - C_1(B_0^2 - B_0^3) + IC_0}{(V_0^2 - V_0^3)}, \text{for } V_0^2 < V_0^3 \end{cases}$$

e) Model 2 will be more or less or equally beneficial than Model 4 if according as

e) $P_2 - P_4 > 0$ or < 0 or $= 0$

i.e. if $(C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 - 3*(IC_0)) - (C_0AC_0^4 - C_1B_0^4 - C_2V_0^4 - 5*(IC_0)) > 0$ or < 0 or $= 0$

i.e. if $C_0(AC_0^2 - AC_0^4) - C_1(B_0^2 - B_0^4) - C_2(V_0^2 - V_0^4) + 2*(IC_0) > 0$ or < 0 or $= 0$

i.e. if $C_2(V_0^2 - V_0^4) < \text{or} > \text{or} = C_0(AC_0^2 - AC_0^4) - C_1(B_0^2 - B_0^4) + 2*(IC_0)$

Hence, One Standby or Three Standby may be used according as

$$\text{i.e. if } \left\{ \begin{array}{l} C_2 < \text{or} > \text{or} = \dfrac{C_0\left(AC_4^{\,2} - AC_0^{\,4}\right) - C_1\left(B_4^{\,2} - B_4^{\,4}\right) + 2*(IC_4)}{\left(V_0^{\,2} - V_0^{\,4}\right)}, \text{for } V_0^{\,2} > V_4^{\,4} \\ C_2 > \text{or} < \text{or} = \dfrac{C_4\left(AC_0^{\,2} - AC_4^{\,4}\right) - C_1\left(B_0^{\,2} - B_0^{\,4}\right) + 2*(IC_0)}{\left(V_4^{\,2} - V_4^{\,4}\right)}, \text{for } V_0^{\,2} < V_0^{\,4} \end{array} \right\}$$

f) Model 3 will be more or less or equally beneficial than Model 4 if according as

$P_3-P_4>0$ or <0 or $=0$

i.e. if $(C_0AC_0^{\,2} - C_1B_0^{\,2} - C_2V_0^{\,2} - 4*(IC_0)) - (C_0AC_0^{\,4} - C_1B_0^{\,4} - C_2V_0^{\,4} - 5*(IC_0)) > 0$ or <0 or $=0$

i.e. if $C_0(AC_0^{\,2} - AC_0^{\,4}) - C_1(B_0^{\,2} - B_0^{\,4}) - C_2(V_0^{\,2} - V_0^{\,4}) + (IC_0) > 0$ or <0 or $=0$

i.e. if $C_2(V_0^{\,2} - V_0^{\,4}) < \text{or} > \text{or} = C_0(AC_0^{\,2} - AC_0^{\,4}) - C_1(B_0^{\,2} - B_0^{\,4}) + IC_0$

$$\text{i.e. if } \left\{ \begin{array}{l} C_2 < \text{or} > \text{or} = \dfrac{C_0(AC_0^{\,3} - AC_0^{\,4}) - C_1(B_0^{\,3} - B_0^{\,4}) + (IC_0)}{(V_0^{\,3} - V_0^{\,4})}, \text{for } V_0^{\,3} > V_0^{\,4} \\ C_2 > \text{or} < \text{or} = \dfrac{C_0(AC_0^{\,3} - AC_0^{\,4}) - C_1(B_0^{\,3} - B_0^{\,4}) + (IC_0)}{(V_0^{\,3} - V_0^{\,4})}, \text{for } V_0^{\,3} < V_0^{\,4} \end{array} \right\}$$

Let us consider the following particular case to illustrate the comparative analysis with respect to cost per visit of the repairman. For the special case $\lambda=0.1$, $\beta=0.3$, $C_0=1000$, $C_1=600$, $IC_0=125$.

a) $P_1-P_3>0$ or <0 or $=0$ if cost per visit of the repairman >6328.7676 or <6328.7676 or $=6328.7676$.
b) $P_1-P_4>0$ or <0 or $=0$ if cost per visit of the repairman >3087.063 or <3087.063 or $=3087.063$
c) $P_2-P_3>0$ or <0 or $=0$ if cost per visit of the repairman>1982.5649 or <1982.5649 or $=1982.5649$.
d) $P_3-P_4>0$ or <0 or $=0$ if cost per visit of the repairman>318.985or <318.985 or $=318.985$.
e) $P_3-P_4>0$ or <0 or $=0$ if cost per visit of the repairman >18077.90 or <18077.90 or $=18077.90$.

5. Conclusion:

A system comprising two operative units and no/one/two/three standby units have been analyzed developing four models on the following situations:

i) When two unit is operative and no unit is standby initially
ii) When two unit is operative and one unit is standby initially
iii) When two unit is operative and two units are standby initially
iv) When two unit is operative and three units are standby initially

The number of standby units is optimized on the basis of profitability derived from various measures of system effectiveness. Comparative analysis among the models revealed as to how many number of

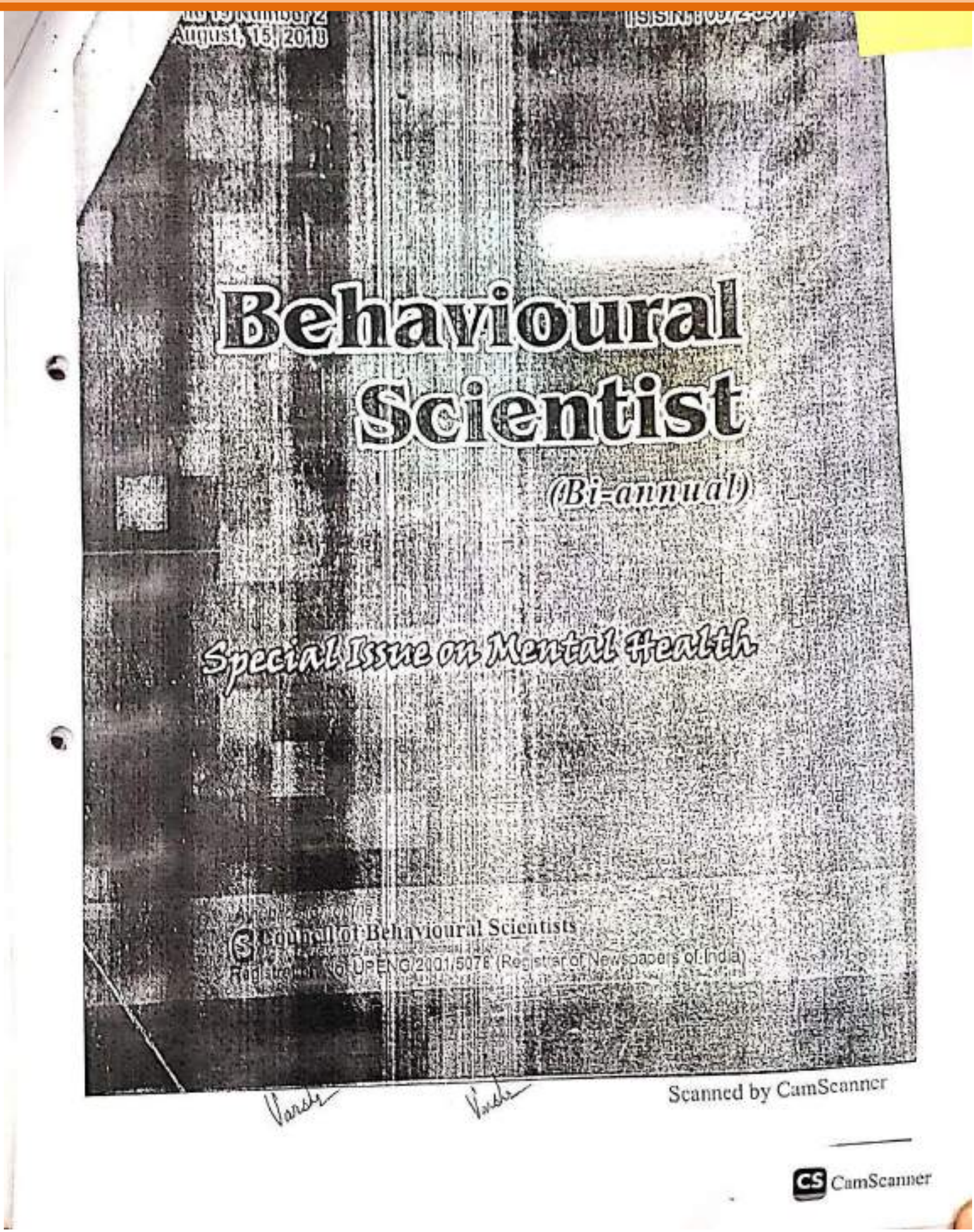
standby units should be there to get the maximum profit. The cut off points for the revenue per unit up time, intallation cost of a unit and cost per visit of the repairman have been obtained which enable us to decide as to when no or one or two or three standby units should be used in order to optimize the profit.

References

1. Yun W.,(1989), "Optimal Number of Redundant Units for a Standby System", Reliability Engineering and System Safety, 25.
2. Lim T. and Lie C.(2000), "Analysis of System Reliability with Dependent Repair Modes", *IEEE Transactions on Reliabilty*,49(2),153-162.
3. Badı'a F.G., Berrade M.D.,Campos C.A. (2002), "Optimal inspection and preventive maintenance of units with revealed and unrevealed failures", *Reliability Engineering and System Safety* ,78, 157–163.
4. Chen T. and Popova E. (2002) , "Maintenance Policies with Two-Dimensional Warranty", *Reliability Engineering and System Safety*, 77, 61-69.
5. Chandrasekhar P., Nataranjan R. and Yadavalli V.(2004), "A Study on a Two Unit Standby System with Erlangian Repair Time", *Asia-Pacific Journal of Operation Research*,21(3).
6. Nakagawa, T. (2005), "Maintenance Theory of Reliability, Springer. ISBN No. 1846282217.
7. El-Said K. and El-Sherbany M.(2005), "Profit Analysis of a Two Unit Cold Standby System with Preventive Maintenance and Random Change in the Units", *Journal of Mathematics and Statistics*,71-77.
8. Parasher B. and Taneja G.(2007), "Reliability and Profit Evaluation of a PLC Hot Standby System based on a Master Slave Concept and Two Types of Repair Facilities", *IEEE Transcations on Reliability*,56(3),534-539.
9. Mokaddis G., El-Sherbeny M. and Ayid M.(2009), "Stochastic Behaviours of a Two Unit Warm Standby System with Two Types of Repairmen and Patience Time" , *Journal of Mathematics and Statistics*,5(1),42-46.
10. Damcese M. and Temraz N.(2010), "Analysis of Availability for Reliability Parallel Systems with Different Rates", *Asian Journal of Information Technology*,9(4),231-237.
11. Eryilmaz S. And Tank F.,(2012),"On reliability analysis of a two-dependent-unit series system with a standby unit", *Applied Mathematics and Computation,218(15).*
12. Wang G. and Zhang Y. (2014), "Optimal replacement policy for a two-dissimilar-component cold standby system with different repair actions", *International Journal of System Science*, 47(5), 1021-1031.
13. Manocha A. and Taneja G.(2014), "Stochastic Analysis of Two-Unit Cold Standby System with Arbitrary Distribution for Life, Repair and Waiting Times",*International Journal Of Performability Engineering*,11(3),293-299.
14. Malhotra R. and Taneja G.(2015), "Comparative Study between a Sinle Unit System and a Two-Unit Cold Standby System with Varying Demand", *Springer Plus.*
15. Shengli Liao, Zhifu Li, Gang Li *, Jiayang Wang and Xinyu Wu (2016), "Modeling and Optimization of the Medium-Term Units Commitment of Thermal Power", *Energies*, 8, 12848-12864.

16. Sachdeva S. and Taneja G.(2016), " Availability and Profit Analysis of Unidirectional and Revertible 1:1 Protection Switching Scheme in Optical Communication Process", International Journal of Pure and Applied Mathematics,111(3),381-391.

04 Dr. Varsha Rani" WORK CENTRALITY, RESILIENCE AND HARDINESS IN RELATION TO WORK RELATED QUALITY OF LIFE AMONG PRIVATE SECTOR BANK EMPLOYEES" Year 2018



Behavioural Scientist

(Bi-Annual–Reffered Journal)

(U.G.C. Approved 40778)

2018 (August) Volume 19 Number 2

Editor : R. L. Bharadwaj

Guest Editor : Dr. U. Dhar

CONTENTS

Behavioural Scientist is abstracted and indexed in :

- Indian Psychological Abstracts and Reviews.
- Indian Educational Abstracts.
- Indian Science Abstracts (CSIR-NISCAIR) New Delhi.

Behavioural Scientist
2018, 19 (2), 95-104
© C.B.S.

WORK CENTRALITY, RESILIENCE AND HARDINESS IN RELATION TO WORK RELATED QUALITY OF LIFE AMONG PRIVATE SECTOR BANK EMPLOYEES

V. Rani* A. Malik** S. Kohli**

Key words : Work centrality, Resilience, Hardiness and Work related Quality of life.

The problem of the present research was to study work centrality, resilience and hardiness in relation to work related quality of life among private sector bank employees. A sample comprising of 100 private bank employees within the age range of 30-50 years with at least 5 years of experience from private banks were selected on the basis of availability and informed consent. The tools utilized were Work Centrality Scale (1994), Resilience Scale (1993) Hardiness Scale (1989) and Work Related Quality of Life Questionnaire (2007) (WRQoL). Results indicated that there was a significant positive correlation of work centrality, resilience and hardiness with work related quality of life. Results implicate that the employees can be offered workshops whereby they can be trained to develop and expand these positive psychological assets.

The concept of "work centrality" refers generally to the degree of importance of work plays in one's life (Paullay, Alliger, and Stone-Romero, 1994). Work centrality has been viewed as an important aspect of work ethic (Miller, Woehr, and Hudspeth, 2001), and as central to understanding work meaningfulness (MOW International Research Team, 1987). Work centrality also relates positively with work satisfaction and with organizational and occupational commitment (Herrbach, Mignonac, Vandenberghe, and Negrini, 2009; Schmidt and Lee, 2008). Work involvement, work-role centrality, and work centrality are all terms used to describe a phenomenon in which a person places high life importance on the activity of working.

Work centrality differs from the concept of job involvement where work centrality refers to the extent to which people perceive work as a main component of their life and job and work involvement refers to the extent to which people are immersed in their present job or work (Bal and Kooij, 2011). As such, work centrality is broader in scope than job or work involvement, because it reflects the importance of work in general, whereas the scope of job involvement

* Research Scholar, Department of Psychology, M.D. University, Rohtak-124001 Haryana.
** Professor, Department of Psychology, M.D. University, Rohtak-124001 Haryana.
*** Professor, Department of Psychology, M.D. University, Rohtak-124001 Haryana.

concerns the job that a person currently has (Bal, et.al., 2011). Hyman, Baldry, Scholarios, and Bunzel (2003) found that organizational pressures, combined with lack of work centrality, result in work intruding into non-work areas of employee lives. Wallis (2011) also reported positive correlation between work centrality and work life balance. The study reported that individuals who have high work centrality, *i.e.*, who give high priority to their work in life, keep their work above other pursuits, derive satisfaction in life from work and have personal work oriented life goals, tend to show less interference of work with personal life, are able to derive energy from work for personal life and exhibit high level of work life balance. Work-centrality has been shown to have an important influence on the development of organizational commitment (Mannheim, 1984). Resilience is also related to organizational commitment and quality of work life.

Resilience is also being explored in the context of the working population as it relates to how employees deal with the challenges of the business world (Badran and Kafafy, 2008; Caverley, 2005). A large number of studies have also considered different facets of resilience (personal resilience, trait resilience, psychological resilience, emotional resilience, career resilience, and ego resilience) in individual and organizational contexts (Bolton, 2004; Dulewicz, Higgs, and Slaski, 2003; Fredrickson and Tugade, 2003; Waugh, Fredrickson, and Taylor, 2008). In general, researchers agree that resilience is a capacity that reflects in behaviour, deals with change, relates to overcoming some unwanted situation (Paul and Garg 2012). Literature provides strong evidence that experiences of difficult situations, negative events or stressors at the workplace can lead to poor employee outcomes and may result in burnout (Maslach, Jackson, and Leiter, 2001). Resilience as a resource capacity may help employees bounce back from such situations.

Extant literature presents evidence that resilience has organizational outcomes. These include employee attitudes like organizational commitment (Shin, Taylor, and Seo, 2012; Youssef and Luthans, 2007), job satisfaction (Vohra and Goel, 2009), and flexibility (Siu, Hui, Phillips, Lin, Wong, and Shi, 2009); employee behaviours like organizational commitment behaviour (Toor and Ofori, 2010); employee performance and effectiveness (Luthans, Youssef, and Rawski, 2011); self-esteem (Ramlall, 2009), work happiness and well-being (Wilson, *et.al.*, 2005; Youssef *et.al.*, 2007), quality of life and work-life balance (Siu, *et.al.*, 2009); and, physical and psychological health (Siu, *et.al.*, 2009; Youssef and Luthans, 2012).

Resilient people are able to pursue new knowledge and experiences and get into deeper relationships with others (Luthans, *et.al.*, 2007). The sense of exploring new experiences motivates employees to build social relationships at the workplace and engage into activities which are beyond their defined job roles (Tugade, *et.al.*, 2004). Further, resilient individuals are more likely to experience positive emotions even in the midst of difficult situations. Literature suggests that positive emotions are linked to positive outcomes at the workplace (Fredrickson, 2001). Thus, it is expected that resilience at the workplace will encourage employees to engage in organizational commitment behaviour. Resilience is also related to hardiness. Hardiness has been put forward as the pathway to resilience under stress (Bonanno, 2004).

Hardiness was first identified by Kobasa as a resistance factor in the early 1980's. Preliminary findings revealed that individuals, who experience

high levels of stress, but remain healthy, had a different personality structure than individuals who experience high levels of stress and became sick. The central domain of this personality structure, labeled as hardiness, was subsequently defined as "the use of ego resources necessary to appraise, interpret and respond to healthy stressors". It was also defined as a personality structure comprising the three related general dispositions of commitment, control, and challenge that function as a resistance resource in encounters with stressful conditions (Kobasa, 1979; Kobasa, Maddi, and Kahn, 1982). The commitment disposition was defined as a tendency to involve oneself in activities in life and as having a genuine interest in and curiosity about the surrounding world (activities, things, other people). The control disposition was defined as a tendency to believe and act as if one can influence the events taking place around oneself through one's own efforts. Finally, the challenge disposition was defined as the belief that change, rather than stability, is the normal mode of life and constitutes motivating opportunities for personal growth rather than threats to security.

Hardiness can also be conceptualized as a general health promoting factor, which enables the individual to remain both psychologically and physically healthy despite being confronted by stressful situations or experiences (Maddi, Harvey, Khoshaba, Lu, Persico, and Brow, 2006). Employees who tend to possess high hardy attitudes show the active pattern of coping with stressful circumstances by facing them (rather than being in denial) and struggling to turn them from potential disaster into opportunities (rather than avoiding them or blaming others). Socially, the hardy employees were more involved in building patterns of interaction with the significant others that emphasized mutual assistance and encouragement (rather than undermining competition or over protection). The debilitating process such as mental health breakdown and performance inadequacies may arise due to exposure of threatening stressful situation may not affect much if the person has high level of hardiness. Moradi and Shaker (2015) found a meaningful relationship between psychological hardiness and its dimensions with quality of life. Slipkerl (2010) learnt that psychological hardiness and mental health have a meaningful relationship with life quality.

Quality of work life (QWL) can be defined as "the quality of relationship between employees and the total working environment". According to Rose, Beh, Uli, and Idris (2006) quality of work life is a philosophy or a set of principles, which holds that people are trustworthy, responsible and capable of making a valuable contribution to the organization. It also involves treating people with respect. The elements that are relevant to an individual's quality of work life include the task, the physical work environment, the social environment within the organization, administrative system and a relationship between life on the job and off the job (Rose, *et.al.*, 2006).

Improving the quality of work-life serves the aim of improving efficiency of employees, that results in making, profit and savings of the organization. Improving employees' efficiency gets through improving working conditions as well as employees' integrating themselves with the organization. Several studies reveal that the quality of work-life influences employees' organizational behaviors such as organizational identity, organizational commitment, job satisfaction and work performance (Huang, Lawler, and Lei, 2007; Roehling, Roehling, and Moen, 2001; Sirgy, Reily, Wu, and Efraty, 2008). Rethinam and Ismail (2008) study opined that quality of work life is associated with job satisfaction, job involvement, motivation,

productivity, health, safety and well-being, job security, competence development and balance between work and non work life. Chitra and Mahalakshmi (2012) study argues that quality of work life is directly related to job satisfaction. Parameswari and Kadhiravan (2014) showed that there are significant gender differences in two important aspects of quality of work life namely, control at work and working conditions. There are also significant gender differences in all the dispositions of hardiness that is, control, commitment and challenge. Also, it is found that certain factors of quality of work life and hardiness dispositions are significantly related to each other.

In the present scenario, banking sector is the most prevalent sub sector of the financial sector in India. The banking industry like many other financial service industries is facing a rapidly changing market, new technologies, economic uncertainties, fierce competition, and especially more demanding customers; and the changing climate has presented an unknown set of challenges. The intense competition in introducing innovative products and services and to satisfy the divergent customer needs has created more demand and pressures on employees thereby increasing vulnerability to stress. To deal with this stress and to enhance the quality of work life of employees, positive psychological characteristics like resilience, work centrality and hardiness play an important role. Lots of work has been done on these positive psychological strengths on different areas, but one area that has not been explored is the relationship of work centrality, resilience and hardiness with work related quality of life. Therefore, the present research and the following problem has been formulated- To study work centrality, resilience and hardiness in relation to work related quality of life among private sector bank employees.

Objectives

1. To assess the work centrality, resilience, hardiness and work related quality of life of private bank employees.
2. To study the relationship of work centrality, resilience and hardiness with work related quality of life among private sector bank employees.

Hypothesis

There would be a positive relationship of work centrality, resilience and hardiness with work related quality of life among private sector bank employees.

METHOD

Design

A correlational design was used for the present study.

Sample

For the purpose of the present study, a total sample comprising of 100 private bank employees within the age range of 30-50 years with at least 5 years of experience from private banks were selected. These employees were working in HDFC Bank, ICICI Bank, Federal Bank and AXIS Bank on the post of assistant managers and managers.

Tools

Work Centrality Scale

Work Centrality Scale has been developed by Paullay, Alliger, and Stone-Romero in 1994.

The measure of work centrality (WC) is used to assess the degree of importance that work plays in one's life. The WC measure has 12 items. All items are rated using a 6-point Likert scale (6 = strongly agree; 1 = strongly disagree). The

Work Centrality measure yielded an internal consistency reliability estimate i.e., .78. In terms of validity, statistically significant ($p<.05$) correlations were found between work centrality and job involvement ($r = .35$) and Protestant work ethic ($r = .31$).

Resilience Scale

The Resilience scale has been developed by Wagnild and Young in 1993 and comprises of 25 items. The respondents have to answer each item on a 7-point Likert-type scale ranging from 1 (strongly disagree) to 7 (strongly agree). The scale has good reliability (Cronbach's alpha coefficient was 0.87). In terms of validity, the correlation of Resilience Scale with Resilience Scale-14 ($r = 0.97$; $p = 0.000$), the HADS depression ($r = -0.28$; $p = 0.017$) and anxiety ($r = -0.26$; $p = 0.028$) subscales, were significant.

Hardiness Scale

Hardiness scale has been developed by Bartone, Ursano, Wright, and Ingraham in 1989. It consists of 30 items with four alternatives (*i.e.* 0= not at all true, 1= A little true, 2= Quite true, 3= Completely true). The Hardiness Scale is composed of three subscales : commitment, control, and challenge. These subscales/ dimensions function as a resistance resource in the encounter with stressful conditions. The scale has a good internal reliability (Cronbach's Coefficient alpha .82) and is highly correlated ($r = .93$) with Kobasa's original scale.

Work-Related Quality of Life Questionnaire (WRQoL)

The questionnaire has been developed by Van Laar, Edwards and Easton in 2007. There are 6 factors i.e. Job and Career Satisfaction (JCS), General Well-Being (GWB), Home-Work Interface (HWI), Stress at Work (SAW), Control at Work (CAW) and Working Conditions (WCS) which are based on responses to 23 items. A 24th item is usually included to provide an outcome variable for measuring the reliability and validity of the items. Respondents are required to answer the questions on a 5 point scale comprising of : 'Strongly Disagree, Disagree, Neutral, Agree,' and Strongly Agree. The data is coded such that Strongly Disagree = 1 and Strongly Agree = 5. The scale has good reliability ($r = .674$) and is highly correlated ($r = .832$) with Overall Warr Job Satisfaction Scale (WJSAT) which is an indication of excellent convergent validity.

Procedure

First of all, the purpose of study was explained to the subjects that helped to establish a proper rapport with the subject. After establishing rapport, all the scales were given to the subjects. Respondents were asked to fill the scales according to instructions, with the request to respond honestly. They were also assured that their responses would be kept confidential. Scoring was done as per the manuals. The scores were tabulated to compute the mean, SDs and Pearson product moment coefficient of correlation.

RESULTS AND DISCUSSION

The present investigation aimed to study the relationship of work centrality, resilience and hardiness with work related quality of life amongst private bank employees. Table-1 shows the descriptive statistics for the present sample which includes mean scores and standard deviations for variables under the present study *i.e.* work centrality, resilience, hardiness and work related quality of life. Table-2 shows the inter-correlation matrix for scores of work centrality, resilience and hardiness with work related quality of life.

From Table-2, it can be established that work centrality is significantly and positively related

(WC = .277, R = .335 and H = .267) with work related quality of life which means that employees with high work centrality tend to have better work related quality of life. Work centrality implies that work plays an important role in one's life. People with high work centrality report that they would continue to work even after becoming eligible for retirement, and would continue to work even if their financial situation would allow them to live comfortably without working (Arvey, Harpaz, and Liao, 2004; Miller, *et.al.*, 2001; Mannheim, 1975; MOW International Research Team, 1987).

Work centrality is also positively associated with the three factors of work related quality of life *i.e.* general wellbeing (.391); home work interface (.43) and control (.198) at work (Table-2). General wellbeing incorporates broader psychological wellbeing as well as general physical health aspects. The home work interface factor addresses work-life balance and reflects the extent to which the employer is perceived to support employees' home lives and the control at work (CAW) factor reflects the level at which an employee feels they can exercise what they consider to be an appropriate level of control within their work environment. All three factors are positively associated with work centrality and there are some empirical evidences that support the present findings. Sharma (2017) reported that work interference with personal life was found to be lowest among doctors with high work centrality. The other three factors of work related quality of life *i.e.* job and career satisfaction; working conditions and stress at work have found no significant relationship with work centrality.

Table-2 shows that there is a significant positive relationship of resilience and hardiness with work related quality of life and its two factors (*i.e.* general wellbeing (.308; .374) and home work interface (.430; .360)). It means that resilient and hardy employees have better work related quality of life, better psychological and physical wellbeing and have good work life balance. Further, resilient individuals are more likely to experience positive emotions even in the midst of difficult situations. Literature suggests that positive emotions are linked to positive outcomes at the workplace (Fredrickson, 2001). Research evidence shows that resilience is related with work happiness and well-being (Wilson, *et.al.*, 2005; Youssef *et.al.*, 2007). A research conducted by Rani and Malik (2016) also found resilience as a positive predictor of work related quality of life with the contribution of 15 per cent of variance.

Hardiness is also character strength. Hardy employees are more committed to their work, have better control and take stressful situations as a challenge and make it a growth opportunity. Previous research also supports the present findings. Moradi, *et.al.*, (2015) found a meaningful relationship between psychological hardiness and its dimensions with quality of life. Table-2 also depicts that resilience and hardiness have shown significant negative correlation (–.293; – .219 with one of the factors of work related quality of life *i.e.* stress at work. It shows that resilient and hardy employees feel less stress at work. Rush, Schoel, and Barnard (1995) found that there are some individuals who are resilient and actually become stronger under pressure. When resilient employees experience something upsetting, they identify actions they can begin doing immediately to minimize its impact. On the other hand, hardiness is considered to be a personal characteristic that functions as a source of resistance to stress. Various studies have shown that hardiness has a positive relationship with people's mental health (Maddi and Kobassa, 1994), decreases stress (Shapperand and Kashani, 1991) and that hardiness has a positive relationship with physical and mental health (Florian, Mikulincer, and Taubman, 1995). Rani and Malik (2017) reported that hardiness and work

related quality of life have a positive significant association with each other. Thus, a significant positive relationship of work centrality, resilience and hardiness has been found with work related quality of life. Therefore, the hypothesis of the study stands verified.

Work centrality, resilience and hardiness are positive characteristics that enhance work related quality of life. These character strengths are very useful at work place, employees having these positive strengths are better able to deal with stress.

However significant and negative relationship also exists between resilience and stress at work and also between hardiness and stress at work.

REFERENCES

Arvey, R.D.; Harpaz, I. & Liao, H. (2004) Workcentrality and post-award work behavior of lottery winners. *The Journal of Psychology, 138*, 404-420.

Badran, M. A. & Kafafy, J. H. (2008) The effect of job redesign on job satisfaction, resilience, commitment and flexibility : The case of an Egyptian public sector bank. *International Journal of Business Research, 8*, 27-41.

Bal, M. & Kooij, D. (2011) The relations between work centrality, psychological contracts, and job attitudes : The influence of age. *European Journal of Work and Organizational Psychology, 20*, 497-523.

Bolton, D. (2004) Change, coping and context in the resilient organization. *Irish Eliza Business Review, 7*, 57-66.

Bonanno, G. (2004) Loss, trauma, and human resilience : How we underestimated the human capacity to thrive after extremely aversive events. *American Psychologist, 51*, 72-82.

Caverley, N. (2006) Civil service resilience and coping. *International Journal of Public Sector Management, 19*, 410-413.

Chitra, D. & Mahalakshmi, V. (2012) A study on employees' perception on quality of work life and job satisfaction in manufacturing organization – An empirical study. *International Journal of Trade and Commerce- IIARTC, 1*, 175-184.

Dulewicz, V.; Higgs, M. J. & Slaski, M. (2003) Emotional Intelligence : Construct and concurrent validity. *Journal of Managerial Psychology, 18*, 405-420.

Florian, V.; Mikulincer, M. & Taubman, O. (1995) Does hardiness contribute to mental health during a stressful real-life situation ? The roles of appraisal and coping. *Journal of Personality and Social Psychology, 68*, 687-695.

Fredrickson, B. L. (2001) The role of positive emotions in positive psychology : The broaden-and-build theory of positive emotions. *American Psychologist, 56*, 218— 226.

Fredrickson, B. L. & Tugade, M. M. (2003) What good are positive emotions in crises ? A prospective study of resilience and emotions following the terrorist attacks on the United States on September 11th, 2001. *Journal of Personality and Social Psychology, 84*, 365-376.

Herrbach, O.; Mignonac, K.; Vandenberghe, C. & Negrini, A. (2009) Perceived HRM practices, organizational commitment, and voluntary early retirement among late-career managers. *Human Resource Management, 48*, 895-915.

Huang, T.C.; Lawler, J. & Lei, C.Y. (2007) The effects of quality of work life on commitment and turnover intention. *Social Behavior and Personality, 35*, 735-750.

Hyman, J.; Baldry, C.; Scholarios, D. & Bunzel, D. (2003) Work-life imbalance in the new service sector economy. *British Journal of Industrial Relations, 41*, 215-239.

Kobasa, S.C. (1979) Stressful life events, personality, and health : Inquiry into hardiness. *Journal of Personality and Social Psychology, 37*, 1-11.

Kobasa, S.C.; Maddi, S.R. & Khan, S. (1982) Hardiness and health : A prospective study. *Journal of Personality and Social Psychology, 42*, 168-177.

Kobasa, S.C. (1982) Commitment and coping in stress resistance among lawyers. *Journal of Personality and Social Psychology, 42*, 707-717.

Luthans, F.; Youssef, C. M. & Avolio, B. J. (2007) *Psychological Capital*. Oxford : Oxford University Press.

Luthans, F.; Youssef, C. M. & Rawski, S. L. (2011) A tale of two paradigms : The impact of psychological capital and reinforcing feedback on problem solving and innovation. *Journal of Organizational Behavior Management, 31*, 333-350.

Maddi, S. R. & Kobassa, S. C. (1994) Hardiness and mental health. *Journal of Personality Assessment, 63*, 265-274.

Maddi, S.R.; Harvey, R.H.; Khoshaba, D.M.; Lu, J.L.; Persico, M. & Brow, M. (2006) The personality construct of hardiness III : Relationships with repression, innovativeness, authoritarianism and performance. *Journal of Personality, 74*, 575-597.

Mannheim, B. (1975) A comparative study of work centrality, job rewards and satisfaction. *Sociology of Work and Occupations, 2*, 79-102.

Mannheim, B. (1984) Managerial orientations and workers' job responses in labor-owned and in private industrial plants in Israel. *Organization Studies, 5*, 23-42.

Maslach, C.; Jackson, S.E. & Leiter, M.P. (2001) Job burnout: *Annual Review of Psychology, 52*, 397-422.

Miller, M.; Woehr, D. J. & Hudspeth, N. (2001) The meaning and measurement of work ethic : Construction and initial validation of a multidimensional inventory. *Journal of Vocational Behavior, 59*, 1-39.

Moradi, B. & Dhaker, A. (2015) The relationship between psychological hardiness and quality of life among teachers of district one high schools of Urmia city. *Journal of Psychology & Behavioral Studies, 3*, 43-47.

MOW (Meaning of Working) International Research Team. (1987) *The meaning of working*. London : Academic Press.

Parameswari, J. & Kadhiravan, S. (2014) Quality of work life and hardiness of school teachers. *Indian Journal of Health and Wellbeing, 5*, 457-460.

Paul, H. & Garg, P. (2012) Mutualistic perspective of individual resilience and organizational commitment : A path analysis model. *International Journal of Management and Behavioural Sciences, 1*, 107-119.

Paullay, I. M.; Alliger, G. M. & Stone-Romero, E. F. (1994) Construct validation of two instruments designed to measure job involvement and work centrality. *Journal of Applied Psychology, 79*, 224-228.

Ramlall, S. J. (2009) Continuing the HR evolution : Building resilience in turbulent economic times. *International Journal of Global Management Studies, 1*, 19-28.

Rani, V. & Malik, A. (2016) Self-efficacy and resilience as predictors of work related quality of life. *Behavioural Scientist, 17*, 103-112.

Rani, V. & Malik, A. (2017) Hardiness and work related quality of life in private bank employees. *Behavioural Scientist, 18*, 9-17.

Rethinam, G.S. & Ismail, M. (2008) Constructs of quality of work life : A perspective of information and technology professionals. *European Journal of Social Sciences, 7*, 58.

Roehling P.V.; Roehling, M.V. & Moen P. (2001) The relationship between work-life policies and

practices and employment loyalty : A life course perspective. *Journal of Family and Economic Issues, 22,* 141-170.

Rose, R.; Beh, L.; Uli, J. & Idris, K. (2006) An analysis of quality of work life and career-related variables. *American Journal of Applied Sciences, 3,* 2151-2159.

Rush, M.C.; School, W.A. & Barnard, S.M. (1995) Psychological resiliency in the public sector : "Hardiness" and pressure for change. *Journal of Vocational Behavior, 46,* 17-39.

Schmidt, J. A. & Lee, K. (2008) Voluntary retirement and organizational turnover intentions : The differential associations with work and non-work commitment constructs. *Journal of Business Psychology, 22,* 297-309.

Shakeri Nia, I. (2010) Examining the relationship between the extent of recognizing voices, psychological hardiness, and mental health with life quality among residents of noisy areas of Rasht city. *Journal of Health and Environment, 4,* 475-484.

Sharma, S. (2017) Work centrality and its relationship to work life balance. *International Journal of Applied Business and Economic Research, 15,* 249-259.

Sheppard, J. A. & Kashani J. H (1991) The relationship of hardiness, gender and stress to health outcomes in adolescents. *Journal of Personality, 59,* 747-767.

Shin, J.; Taylor, M. S. & Seo, M. G. (2012) Resources for change : The relationships of organizational inducements and psychological resilience to employees' attitudes and behaviors toward organizational change. *Academy of Management Journal, 55,* 727-748.

Sirgy, M.J.; Reilly, N.; Wu, J. & Efraty, D. (2008) A work-life identity model of well-being : Towards a research agenda linking quality-of-work-life (QWL) programs with quality of life (QoL). *Applied Research in Quality of Life, 3,* 181-202.

Siu, O.; Hui, C. H.; Phillips, D. R.; Lin, L.; Wang, T. & Shi, K. (2009) A study of resiliency among Chinese health care workers : Capacity to cope with workplace stress. *Journal of Research in Personality, 43,* 770-776.

Toor, S. & Ofori, G. (2010) Positive psychological capital as a source of sustainable competitive advantage for organizations. *Journal of Construction Engineering and Management, 136,* 341-352.

Tugade, M. M.; Fredrickson, B. L. & Barrett, L. M. (2004) Psychological resilience and positive emotional granularity : Examining the benefits of positive emotions on coping and health. *Journal of Personality, 72,* 1161-1190.

Van Laar, D.L.; Edwards, J. & Easton, S. (2007) The work-related quality of life (WRQoL) scale for healthcare workers. *Journal of Advanced Nursing, 60,* 325-333.

Vohra, N. & Goel, A. (2009) Influence of positive characteristics on organizational commitment and job satisfaction of Indian middle managers (Working paper series WPS No. 63). Calcutta : Indian Institute of Management.

Wagnild, G. M. & Young, H. M. (1993) Development and psychometric evaluation of the resilience scale. *Journal of Nursing Measurement, 1,* 165-178.

Walia, P. (2011) *Work Life Balance of Working Professionals–A Study of IT and ITES Industry. (Doctoral Dissertation).* Patiala : Punjab University.

Waugh, C. E.; Fredrickson, B. L. & Taylor, S. F. (2008) Adapting to life's slings and arrows : Individual differences in resilience when recovering from an anticipated threat. *Journal of Research in Personality, 42,* 1031-1046.

Wilson, S. M. & Ferch, S. R. (2005) Enhancing resilience in the workplace through the practice of caring relationships. *Organization Development Journal, 23,* 45-60.

Youssef, C. M. & Luthans, F. (2007) Positive organizational behavior in the workplace : The impact of hope, optimism, and resilience. Journal of Management, 33, 774-800.

Youssef, C. M. & Luthans, F. (2012) Positive global leadership. *Journal of World Business*, 47, 539-547.

Table-1 : Descriptive Statistics for Work Centrality, Resilience, Hardiness and Work Related Quality of Life ($N = 100$)

Variables	Mean	*SD*
Work Centrality	55.68	9.27
Resilience	149.35	15.57
Hardiness	58.99	7.46
Work related Quality of life	77.49	8.16

Table-2 : Inter-Correlation Matrix for Scores of Work Centrality, Resilience and Hardiness with Work Related Quality of Life (N-100).

Variables	General Wellbeing	Home Work Interface	Job and Career Satisfaction	Control At Work	Working Conditions	Stress At Work	Work related Quality of Life
Work Centrality	.391**	.451**	–.049	.198	.015	–.119	.277**
Resilience	.308**	.430**	.143	.130	.162	–.293**	.335**
Hardiness	.374**	.361**	.119	.077	–.075	–.219*	.267**

*Significant at the 0.05 level

**Significant at the 0.01 level

05 Dr. Shilpi Batra" Reliability and Optimum Analysis for Number of Standby Units in a System Working with One Operative Unit" 2018

Int. J. Agricult. Stat. Sci. Vol. 14, No. 1, pp. ....-....., 2018 ISSN : 0973-1903

ORIGINAL ARTICLE

OPTIMIZATION OF NUMBER OF HOT STANDBY UNITS THROUGH RELIABILITY MODELS FOR A SYSTEM OPERATIVE WITH ONE UNIT

Shilpi Batra and Gulshan Taneja

Department of Mathematics, Maharshi Dayanand University, Rohtak, India.
E-mail: batrashilpi1989@gmail.com, drgtaneja@gmail.com

Abstract : Hot standby systems are being used by various companies/ industries/ plants in order to avoid losses. However, use of too many hot standby units may be costlier and use of very less number of hot standby unit(s) may cause major losses. Thus, the study for taking decision regarding number of hot standby unit(s) becomes important in order to have optimum profit and hence the present paper develops three models for a system comprising one operative unit and no /one / two hot standby unit(s). To achieve the goal of optimizing the profit, the three models are compared finding out the cut-off points with regard to revenue, cost of installation of hot standby unit(s) and cost per visit of the repairman. Semi-Markov processes and regenerative point technique along with Laplace / Laplace Stieltjes transforms have been used to find various measures of system effectiveness.

Key words : Operative unit, Hot standby unit(s), MTSF, Profit, Optimization.

1. Introduction

With advancement of technology and need of the present day society, a large number of industries/ plants/ companies are using sophisticated systems for which the shutting down/ failure/ interruption cannot be afforded even for a while and hence for such systems it becomes necessary to introduce redundancy by using hot standby unit(s). Literature of reliability contains good contribution on models for standby systems. Goel and Gupta (1983) discussed the analysis of a two-unit hot standby system with three modes. Christov and Stoytcheva (1991) dealt with the reliability and safety research of hot standby microcomputer signally systems. Rizwan *et al.* (2005) carried out the reliability analysis of a hot standby PLC system. Parashar and Taneja (2007) finds the reliability and profit evaluation of a PLC hot standby system based on master-slave concept and two types of repair facilities. Rizwan *et al.* (2010) gave the reliability analysis of a hot standby industrial system. Singh *et al.* (2013) dealt with the reliability and availability analysis of database system with standby unit provided by the system provider. Kumar and Baweja (2015) carried out the cost-benefit analysis of a cold standby system with preventive maintenance wherein the repairman takes some time to arrive at the system whenever required. Kumar and Kumari (2017) carried out the comparative study of two-unit hot standby hardware software systems with impact of imperfect fault coverage. Manocha *et al.* (2017) discussed the stochastic and cost-benefit analysis of two-unit hot standby database system. The study to optimize the number of cold standby units on the basis of profitability of the system is carried out by Batra and Taneja (2018).

A good number of reliability models have been developed on hot standby systems, but the optimization of number of hot standby units has not been taken into consideration in these models. Hot standby systems are used by a large number of companies/industries including steel industries, oil refineries, fertilizers industries, biscuit manufacturing companies, cement industries, optical fiber plants, casting plants, etc. However, increase in number of hot standby units increases the cost of installation for the system on one hand and decrease in the number of hot standby units may result into major losses on the other hand and hence the users of such systems want to optimize the number of hot standby units. Therefore, this aspect has been

**Author for correspondence* *Received* *Revised* *Accepted*

well taken into consideration in the present paper developing following three models :

i) One operative unit and no hot standby unit (Model 1)

ii) One operative unit and one hot standby unit (Model 2)

iii) One operative unit and two hot standby units (Model 3)

The models are compared in order to optimize the number of hot standby units to be used. Systems are analyzed by making use of semi-Markov processes and regenerative point technique and determining various measures of system effectiveness for Model 2 and Model 3. For the description and results for Model 1, one may refer to the paper by Batra and Taneja (2018).

2. Assumptions of the Models

1. The system is operative with one operating unit.
2. All random variables are independent.
3. Failures are assumed to follow exponential distribution, whereas the repair times have arbitrary distributions.
4. After repair the system becomes operative.
5. There is only one repairman available for the system as and when required.

Other assumptions are as usual.

3. Nomenclature

λ	Constant rate of failure
λ_1	Constant failure rate of hot standby unit
g(t),G(t)	p.d.f. and c.d.f. of the repair rate
Op	Operative unit
Cs	Standby unit
F_r	Failed unit under repair
F_{wr}	Failed unit is waiting for the repair
F_R	Repair of the failed unit is continuing from previous state
C_0	Revenue per unit up time
C_1	Cost per unit up time for which the repairman is busy
C_2	Cost per visit of the repairman
IC	Installation cost of an additional identical unit
P_i	Profit of model i; i = 1, 2, 3, 4
$\Phi t_i(t)$	C.d.f. of the first passage time from regenerative state i to a failed state
$q_{ij}(t)$, $Q_{ij}(t)$	Probability density function (p.d.f.), cumulative distribution function (c.d.f.) of the first passage time from regenerative state S_i to a regenerative state S_j
$AC_i^j(t)$	Probability that system is up and working in full capacity at the instant t given that system entered regenerative state S_i at t=0 for model j; j=1, 2, 3.
$B_i^j(t)$	Probability that the repairman is busy in repairing the failed unit at instant t given that the system started from regenerative state S_i at t=0 for model j; j=1, 2, 3.
$V_i^j(t)$	Expected number of visits of the repairman in (0, t]; given that the system entered regenerative state S_i at t=0 for model j; j=1, 2, 3.

4. Analysis of the Models

4.1 Model 1 : System having One Operative Unit and No Hot Standby Unit

In this model, we have considered a system wherein one unit is operative and there is no hot standby unit. Possible transitions from one state to other are given as follows :

From	S_0	S_1
To	**S_1**	**S_0**

Where, S_0 and S_1 are the states representing the system as operative and failed, respectively.

For description and analysis of this model, the paper by Batra and Taneja (2018) may be referred to.

4.2 Model 2: System having One Operative Unit and One Hot Standby Unit

In this model, we have considered a system wherein one unit is operative and one hot standby unit which takes place of the operative unit, if the latter gets failed. Possible transitions from one state to other one given as follows:

From	**S_0**	**S_1**	**S_3**	**S_1**	**S_2**
To	S_1	S_0	S_3	S_2	S_1
Via	...	...	**S_2**	...	...

Where,

S_0 = (Op, Hs), S_1 = (Fr, Op), S_2 = (F_R, F_{wr}).

States S_0 and S_1 are regenerative states whereas S_2 is a non-regenerative state.

4.2.1 Transition Probabilities and Mean Sojourn Times

The state transition probabilities $p_{ij} = \lim_{s\to 0} q_{ij}^{*}(s)$ can be obtained using the following:

$$q_{01}(t) = (\lambda + \lambda_1)e^{-(\lambda+\lambda_1)t},\ q_{10}(t) = e^{-\lambda t}g(t)dt,$$

$$q_{12}(t) = \lambda e^{-\lambda t}\overline{G}(t)dt,\ q_{11}^{(2)}(t) = \left(\lambda e^{-\lambda t} \circledcirc 1\right)g(t)dt$$

Mean sojourn times (μ_i) *i.e.* the expected time of stay in regenerative state *i* are given as

$$\mu_0 = \frac{1}{\lambda+\lambda_1},\ \mu_1 = \frac{1-g^{*}(\lambda_1)}{\lambda_1}$$

The unconditional mean time taken by the system to transit to any regenerative state j, when time is counted from the epoch of entrance into state i is mathematically stated as

$m_{ij} = \int_0^{\infty} t q_{ij}(t)dt = -q_{ij}^{**}(0)$ and thus, we have

$m_{01} = \mu_0,\ m_{10} + m_{12} = \mu_1,$

$$m_{10} + m_{11}^{(2)} = \int_0^{\infty} t g(t)dt = k_2 (say)$$

4.2.2 Measures of System Effectiveness

4.2.2.1 Mean Time to System Failure (MTSF)

To determine the mean time to system failure (MTSF) of the system, we regard the failed state as absorbing state. Thus,

$\phi_0(t) = Q_{01}(t) \circledcirc \phi_1(t)$

$\phi_1(t) = Q_{10}(t) \circledcirc \phi_0(t) + Q_{12}(t)$

Thus, $MTSF = \lim_{s\to 0} \frac{1-\phi_0^{**}(s)}{s} = \frac{N}{D}$,

Where, $N = \mu_0 + \mu_1$, $D = p_{12}$

4.2.2.2 Availability Analysis

The availability $AC_i(t)$ is seen to satisfy the following recursive relations

$$AC_0^2(t) = M_0(t) + q_{01}(t) \circledcirc AC_1^2(t)$$

$$AC_1^2(t) = M_1(t) + q_{10}(t) \circledcirc AC_0^2(t) + q_{11}^{(2)}(t) \circledcirc AC_1^{(2)}(t)$$

Taking Laplace Transforms and then solving the above equations for $AC_0^{2*}(s)$, the availability of the system, in steady state, is given by

$$AC_0^2 = \lim_{s\to 0} sAC_0^{2*}(s) = \frac{N_1}{D_1},$$

Where, $N_1 = p_{10}\mu_0 + \mu_1$, $D_1 = p_{10}\mu_0 + k_2$

4.2.2.3 Busy Period Analysis

By probabilistic arguments, we have the following recursive relation for $B_i(t)$

$$B_0^2(t) = q_{01}(t) \circledcirc B_1^2(t)$$

$$B_1^2(t) = W_1(t) + q_{10}(t) \circledcirc B_0^2(t) + q_{11}^{(2)} \circledcirc B_1^2(t)$$

Where, $W_1(t) = \overline{G}(t)$.

In steady state, the total fractions of the time for which the system is under repair is given by

$$B_0^2 = \lim_{s\to 0} sB_0^{2*}(s) = \lim_{s\to 0} \frac{sN_2(s)}{D_1(s)} = \frac{N_2}{D_1},$$

Where, $N_2 = k_2$ and D_1 is already specified.

4.2.2.4 Expected Number of the Visits of the Repairman

By probabilistic arguments, we have the following recursive relations for $V_i(t)$

$$V_0^2(t) = Q_{01}(t) \circledcirc \left[1 + V_1^2(t)\right]$$

$$V_1^2(t) = Q_{10}(t) \circledcirc V_0^2(t) + Q_{11}^{(2)}(t) \circledcirc \left[1 + V_1^2(t)\right]$$

In steady state, the expected no. of visits of the repairman is given by

$V_0^2 = \lim_{s\to 0} sV_0^{2**}(s) = \frac{N_3}{D_1}$, where $N_3 = 1$ and D_1 is already given.

4.2.3 Profit Analysis

In steady state, the expected profit (P_2) per unit time incurred to the system is given by

Profit $(P_2) = C_0 AC_0^2 - C_1 B_0^2 - C_2 V_0^2 - (IC_0)$

Where,

C_0 = Revenue per unit up time

C_1 = Cost per unit up time for which the repairman is busy

C_2 = Cost per visit of the repairman

IC_0 = Installation cost of a hot standby unit per unit time

4.3 Model 3 : System having One Operative Unit and Two Hot Standby Units

In this model, we have considered a system wherein one unit is operative and two hot standby units are there. Hot standby unit becomes operative as and when required. Possible transitions from one state to other one given as follows:

From	S_0	S_1	S_2	S_3	S_4	S_5	S_6
To	S_1	S_0	S_1	S_3	S_4	S_1	S_4
Via	...	...	S_2	S_2	S_2 and S_3	...	S_3

Where,

S_0 = (Op, Hs, Hs), S_1 = (Fr, Op, Hs), S_2 = (F_R, Fwr, Op), S_3 = (F_R, Fwr, Fwr), S_4 = (Op, Fr, Fwr). States S_0, S_1 and S_4 are regenerative states whereas S_2 and S_3 are non-regenerative states.

4.3.1 Transition Probabilities and Mean Sojourn Times

The transition probabilities $p_{ij} = \lim_{s\to 0} q_{ij}^*(s)$ for this model are obtained as

$$p_{01} = 1,\ p_{10} = g^*(\lambda_1 + \lambda),$$

$$p_{11}^{(2)} = \frac{\lambda_1 + \lambda_2}{\lambda_2}\left(g^*(\lambda_2) - g^*(\lambda_1 + \lambda)\right),$$

$$p_{13}^{(2)} = \frac{(\lambda_1 + \lambda)\lambda}{\lambda_1}\left(\overline{G^*}(\lambda) - \overline{G^*}(\lambda_1 + \lambda)\right),$$

$$p_{14}^{(2,3)} = \frac{1}{\lambda(\lambda_1 + \lambda)}g^*(0) - \frac{1}{\lambda_1\lambda}g^*(\lambda) + \frac{1}{(\lambda_1 + \lambda)\lambda_1}g^*(\lambda_1 + \lambda),$$

$$p_{41} = g^*(\lambda),\ p_{44}^{(3)} = g^*(0) - g^*(\lambda)$$

Mean Sojourn times (μ_i) for the model are

$$\mu_0 = \frac{1}{\lambda + 2\lambda_1},\ \mu_1 = \frac{1 - g^*(\lambda_1 + \lambda)}{\lambda + \lambda_1},\ \mu_4 = \frac{1 - g^*(\lambda)}{\lambda}$$

Sums of unconditional mean times taken by the system to transit to any regenerative state j, when time is counted from the epoch of entrance into state i are obtained as

$$m_{01} = \mu_0,\ m_{10} + m_{11}^{(2)} + m_{13}^{(2)} = \frac{1 - g^*(\lambda)}{\lambda} + \frac{1}{\lambda_1} = k_3 (say)$$

$$m_{10} + m_{11}^{(2)} + m_{14}^{(2,3)} = \int_0^\infty tg(t)dt = k_4 (say),$$

$$m_{41} + m_{44}^{(3)} = \int_0^\infty tg(t)dt = k_4 (say)$$

4.3.2 Measures of System Effectiveness

Proceeding in the similar fashion as done in Section 4.2.2, various measures of system effectiveness are obtained as follows:

Mean Time to System Failure (MTSF) = $\frac{N}{D}$

Steady State Availability $\left(AC_0^3\right) = \frac{N_1}{D_1}$

Expected fraction of time during which the repairman is busy $\left(B_0^3\right) = \frac{N_2}{D_1}$.

Expected Number of Visits $\left(V_0^3\right) = \frac{N_3}{D_1}$.

Where,

$N = k_3 + \mu_0\left(1 - p_{11}^{(2)}\right),\ D = p_{13}^{(2)}$,

$N_1 = p_{40}p_{10}\mu_0 + p_{41}k_3 + p_{14}^{(2,3)}\mu_4$,

$D_1 = p_{40}p_{10}\mu_0 + \left(p_{14}^{(2,3)} + p_{41}\right)k_4$

$N_2 = \left(p_{41} + p_{14}^{(2,3)}\right)k_4,\ N_3 = p_{41}\left(1 - p_{11}^{(2)} + p_{14}^{(2,3)}\right)(1 + p_{41})$

and $k_3 = \frac{-\lambda}{\lambda_1}\left(\frac{1 - g^*(\lambda_1 + \lambda)}{\lambda_1 + \lambda}\right) + \frac{\lambda_1 + \lambda}{\lambda_1}\left(\frac{1 - g^*(\lambda)}{\lambda}\right)$ (say)

4.4 Profit Analysis

The expected total Profit (P_3) per unit time incurred to the system for this model, in steady state, is given by

Profit (P_3) = $C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 - 2*(IC_0)$

Where,

C_0 = Revenue per unit up time

C_1 = Cost per unit up time for which the repairman is busy

C_2 = Cost per visit of the repairman

IC_0 = Installation cost of a hot standby unit per unit time

5. Comparative Study among the Models

5.1 Optimization of Number of Hot Standby Units with regard to Revenue per Unit up Time

a) On comparing the profits of models 1 and 2, we conclude that Model 1 is better or worse than Model 2 if $P_1 - P_2 > 0$ or < 0

i.e. if $(C_0AC_0^1 - C_1B_0^1 - C_2V_0^1) - (C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 - (IC_0)) > 0$ or < 0.

i.e. if $\begin{Bmatrix} C_0 > or > C_{01}^* \text{ for } AC_0^1 > AC_0^2 \\ C_0 < or > C_{01}^* \text{ for } AC_0^1 < AC_0^2 \end{Bmatrix}$

Both the models are equally good if $C_0 = C_{01}^*$,

where $C_{01}^* = \dfrac{\left(C_1\left(B_0^1 - B_0^2\right) + C_2\left(V_0^1 - V_0^2\right) - IC_0\right)}{\left(AC_0^1 - AC_0^2\right)}$

b) Comparison between models 2 and 3 reveals that Model 2 is better or worse than Model 3.

if $P_2 - P_3 > 0$ or < 0

i.e. if $(C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 - (IC_0)) - (C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 - 2*(IC_0)) > 0$ or < 0.

i.f. if $\begin{Bmatrix} C_0 > or > C_{02}^* \text{ for } AC_0^2 > AC_0^3 \\ C_0 < or > C_{02}^* \text{ for } AC_0^2 < AC_0^3 \end{Bmatrix}$

Both the equally good if $C_0 = C_{02}^*$,

where $C_{02}^* = \dfrac{C_1\left(B_0^2 - B_0^3\right) + C_2\left(V_0^2 - V_0^3\right) - IC_0}{\left(AC_0^2 - AC_0^3\right)}$

c) As far as the selection between model 3 and model 1 is concerned, one should adopt Model 3 in preference to Model 1

if $P_3 - P_1 > 0$ or < 0

i.e. if $(C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 - 2*(IC_0)) - (C_0AC_0^1 - C_1B_0^1 - C_2V_0^1) > 0$ or < 0

i.e. if $\begin{Bmatrix} C_0 > or > C_{03}^* \text{ for } AC_0^3 > AC_0^1 \\ C_0 < or > C_{03}^* \text{ for } AC_0^3 < AC_0^1 \end{Bmatrix}$

Both are equally good if $C_0 = C_{03}^*$,

where, $C_{03}^* = \dfrac{C_1\left(B_0^3 - B_0^1\right) + C_2\left(V_0^3 - V_0^1\right) + 2*(IC_0)}{\left(AC_0^3 - AC_0^1\right)}$

5.2 Optimization of Number of Hot Standby Units with regard to Cost of Installing a Hot Standby Unit

a) On comparing thr profits of model 1 and 2, we conclude that Model 1 is better or worse than Model 2

if $P_1 - P_2 > 0$ or < 0

i.e. if $(C_0AC_0^1 - C_1B_0^1 - C_2V_0^1 - IC_0) - (C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 - 2*(IC_0)) > 0$ or < 0

i.e. if $IC_0 > or < IC_{01}^*$

Both are equally good if $IC_0 = IC_{01}^*$, where

$IC_{01}^* = C_1\left(B_0^1 - B_0^2\right) + C_2\left(V_0^1 - V_0^2\right) - C_0\left(AC_0^1 - AC_0^2\right)$

b) Comparing between models 2 and 3 reveals that Model 2 is better or worse than Model 3

if $P_2 - P_3 > 0$ or < 0

i.e. if $(C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 - (IC_0)) - (C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 - 2*(IC_0)) > 0$ or < 0

i.e. if $IC_0 > or < IC_{02}^*$

Both are equally good if $IC_0 = IC_{02}^*$, where

$IC_{02}^* = C_1\left(B_0^2 - B_0^3\right) + C_2\left(V_0^2 - V_0^3\right) - C_0\left(AC_0^2 - AC_0^3\right)$

c) As far as the selection between model 3 and model 1 is concerned, one should adopt Model 3 in preference to Model 1

if $P_3 - P_1 > 0$ or < 0

i.e. if $(C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 - 2*(IC_0)) - (C_0AC_0^1 - C_1B_0^1 - C_2V_0^1) > 0$ or < 0

i.e. if $IC_0 >$ or $< IC_{03}^*$

Both are equally good if $IC_0 = IC_{03}^*$, where

$IC_{03}^* = \dfrac{C_0\left(AC_0^3 - AC_0^1\right) - C_1\left(B_0^3 - B_0^1\right) - C_2\left(V_0^3 - V_0^1\right)}{2}$

5.3 Optimization of Number of Hot Standby Units with regard to Cost per visit of the repairman

a) On comparing thr profits of model 1 and 2, we conclude that Model 1 is better or worse than Model 2

if $P_1 - P_2 > 0$ or < 0

i.e. if $(C_0AC_0^1 - C_1B_0^1 - C_2V_0^1) - (C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 - (IC_0)) > 0$ or < 0

i.e. if $\begin{Bmatrix} C_2 < or > C_{21}^* \text{ for } V_0^1 > V_0^2 \\ C_2 > or > C_{21}^* \text{ for } V_0^1 < V_0^2 \end{Bmatrix}$

Both are equally if $C_2 = C_{21}^*$, where

$C_{21}^* = \dfrac{\left(C_0\left(AC_0^1 - AC_0^2\right) - C_1\left(B_0^1 - B_0^2\right) + IC_0\right)}{\left(V_0^1 - V_0^2\right)}$

b) Comparing between models 2 and 3 reveals that

Model 2 is better or worse than Model 3

if $P_2 - P_3 > 0$ or < 0

i.e. if $(C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 - (IC_0)) - (C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 - 2*(IC_0)) > 0$ or < 0

i.e. if $\begin{Bmatrix} C_2 < or > C_{22}^* \text{ for } V_0^2 > V_0^3 \\ C_2 > or < C_{21}^* \text{ for } V_0^2 < V_0^3 \end{Bmatrix}$

Both are equally good if $C_2 = C_{22}^*$, where

$$C_{22}^* = \frac{C_0\left(AC_0^2 - AC_0^3\right) - C_1\left(B_0^2 - B_0^3\right) + IC_0}{\left(V_0^2 - V_0^3\right)}$$

c) As far as the selection between model 3 and model 1 is concerned, one should adopt Model 3 in preference to Model 1

if $P_3 - P_1 > 0$ or < 0

i.e. if $(C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 - 2*(IC_0)) - (C_0AC_0^1 - C_1B_0^1 - C_2V_0^1) > 0$ or < 0

i.e. if $\begin{Bmatrix} C_2 < or > C_{23}^* \text{ for } V_0^3 > V_0^1 \\ C_2 > or < C_{23}^* \text{ for } V_0^3 < V_0^1 \end{Bmatrix}$

Both are equally good if $C_2 = C_{23}^*$, where

$$C_{23}^* = \frac{C_0\left(AC_0^3 - AC_0^1\right) - C_1\left(B_0^3 - B_0^1\right) - 2*\left(IC_0\right)}{\left(V_0^3 - V_0^1\right)}$$

6. Conclusion

Three reliability models have been developed to arrive at a decision regarding number of hot standby units to be used for a system having one operative unit. The difference between profits have been obtained taking two models at a time with regard to parameter of interest such as revenue per unit up time, cost of installing a hot standby unit, cost per visit of the repairman or any other parameter which the user of such systems wishes to be considered. Cut-off points of such parameters reveal as to when and which model is more beneficial than the other and accordingly as to model should be adopted by the user. The company/ plant/ industry using such system(s) may apply the present study to achieve simulated results for the data on rates/ costs available with them for a particular situation existing therein.

References

Batra, S. and G Taneja (2018). Reliability and Optimum Analysis for Number of Standby Units in a System Working with One Operative Unit. *International Journal of Applied Engineering Research*, **13(5)**, 2791-2797.

Christov, C. and N. Stoytcheva (1991). Reliability and Safety Research of Hot Standby Microcomputer Signally Systems. *Periodica Polytechnica SER-TRANSP. ENG.*, **27(1-2)**, 17-28.

Goel, L. R. and P. Gupta (1983). Analysis of a Two-Unit Hot Standby System with Three Modes. *Microelectronics Reliability*, **23(6)**, 1029-1033.

Kumar, A. and S. Baweja (2015). Cost-Benefit Analysis of a Cold Standby System with Preventive Maintenance subject to Arrival Time of Server. *Int. J. Agricult. Stat. Sci.*, **11(2)**, 375-380.

Kumari, S. and R. Kumar (2017). Comparative Analysis of Two-Unit Hot Standby Hardware-Software Systems with Impact of Imperfect Fault Coverages. *International Journal of Statistics and Systems*, **12(4)**, 705-719.

Manocha, A., G Taneja and S. Singh (2017). Stochastic and Cost-Benefit Analysis of Two Unit Hot Standby Database System. *International Journal of Performability Engineering*, **13(1)**, 63-72.

Parashar, B. and G. Taneja (2007). Reliability and profit evaluation of a PLC hot standby system based on a master slave concept and two types of repair facilities. *IEEE Transactions on Reliability*, **56(3)**, 534-539.

Rizwan, S. M., V. Khurana and G Taneja (2005). Reliability modeling of a hot standby PLC system. *Proc. of International Conference on Communication, Computer and Power*. Sultan Qaboos University, Oman, 486–489.

Rizwan, S. M., V. Khurana and G Taneja (2010). Reliability analysis of a hot standby industrial system. *International Journal of Modelling and Simulation*, **30(3)**, 315-322.

Singh, S., R. Rishi, G Taneja and A. Manocha (2013). Reliability and Availability Analysis of Database System with Standby Unit Provided by the System Provider. *Interntional Journal of Soft Computing and Engineering*, **3(2)**, 235-237.

Cost Benefit Analysis :Local Saving Group Vs Bank

Jyoti Sharma, Assistant Professor Economics

Government College ,Meham

1. INTRODUCTION :

India is home to 21 percent of the world's unbanked adults and about two-thirds of South Asia's (Global Findex Database report 2014). Albeit, government also interfere to address flaws and disappointments in the regulated financial institutions. But subsidized government interventions also come out as a failure mainly due to inefficiency in execution and presence of asymmetry information. No doubt, that problem associated with informational asymmetries, moral hazard, and adverse selection is difficult to interpret for the design of specific policies and institutions. Thus, disappointment with the effectiveness of formal financial systems in fostering economic growth has diverted towards reevaluation of the role of informal financial institution as a medium of mobilization and allocation of resources.

2. REVIEW OF LITRATURE :

Bouman, F.JA. (1976) traces the indigenous saving and credit societies in the third world through various literatures available on it. It reveals that rotating credit association is a worldwide phenomenon, appearing in many parts of Africa, Asia both Americas, the Caribbean area, the middle east and even in early Europe. The paper provides the ingredients of ROSCAs success in diverse cultures and also identifies its multi dimension function. It was suggested that in order to build stronger institutions upon traditional form of savings and credit, an idea of traditionalizing modern institution must be cooperated with the idea of modernizing traditional institutions.

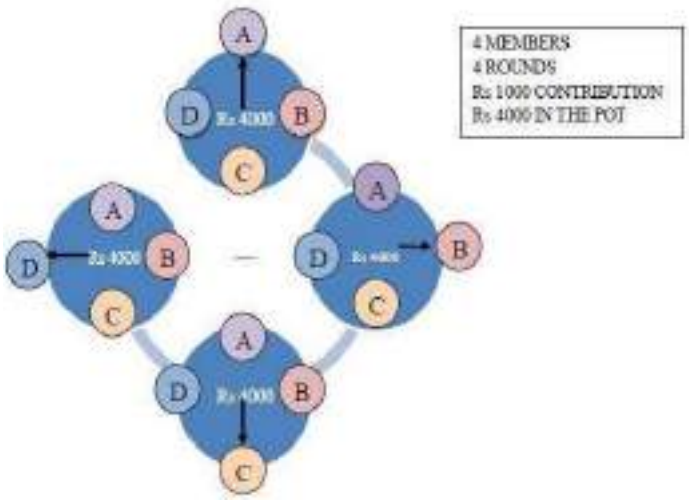
Low, Alaine (1995) conducted a biographical survey of ROSCAs. The major objective of the study was to provide

European Journal of Business & Social Sciences
Available at https://ejbss.org/
ISSN: 2235-767X
Volume 07 Issue 04
April 2019

systematic and up to date literature available on ROSCAs. This survey covers the wide range of literature on these associations regarding various aspects like – its definition, characteristics, geographical spread, membership advantage and so on. The findings of the study revealed that major literature was available in the form of case study, not in the general demise of ROSCAs.

3. ROTATING SAVING AND CREDIT ASSOCIATIONS (ROSCAs):

The term 'rotating credit and saving associations' was given by Geertz (1962) for institutions which have previously been called esusu (small rotating credit associations exist in Africa around the mid 19th century) or have been included in the wider groups of thrift, loan and benevolent associations. But the credit of making this term more famed and mirror image of various indigenous Savings and Credit societies over great part of that broadband of underdeveloped or semi developed countries stretching from Japan on the east through South East Asia and India to Africa, known by different local names[1] goes to Aderner (1964) . According to Aderner "The rotating credit association has been defined



as a group of participants who make regular contributions to a fund which is given, in whole or in part, to each member in turn."

In its simplest form, ROSCAs comprised of four participants, who regularly contribute a pre-agreed amount of Rs. 1000, to a saving pot[2] each month, will thus eventually receive amount of Rs. 4000 each. After, four months the cycle is closed (fig.1.2).

Working Process of ROSCAs :

The first collector receives an interest-free loan from all others. While the last in line is only saving money as he extends credit to his fellow members. The others alternate

ISSN: 2235-767X
Volume 07 Issue 04
April 2019

between debtor and creditor positions. A member saves until he receives the fund, after which he starts to repay a loan in installments. Thus, not only the credit rotates, the saving positions rotate too.

The procedure and methodology adopted from the word kameti and ROSCAs are used interchangeably in this chapter being the first used to refer an institution found in Haryana, and the second to similar institutions all over the world.

Evaluating Financial Benefits Or Losses Of Joining Kameti

In kameti a participant is predicted to contribute a fixed periodic contribution from the beginning to the end of the cycle. Assuming that the individual will win the last pot (about which the individual will also be 100% definite), s/he will come to be with a saving equal to what s/he'll make a contribution. This individual, nevertheless, have another hazard free and easy option to place or get monetary savings. That's depositing it right into a financial institution periodically. By doing so, he will also be able to get an interest income throughout the time that he hold the money within the bank. If he determined to contribute to kameti, the advantage might be calculated depending on what he's going to do with the pot money he won from the kameti. But, absolutely, a only financially prompted individual will have to calculate and compute the net amount of money that he can earn from both options and will decide whether to participate or not to participate.

There would be difference between the decision made by those who consider kameti as an saving mechanism and those recall it as a credit mechanism. In both cases, the individual should comprehend the point at which he'll be detached in order that he can come to a decision among the options that he has. Calculating the monetary part here will aid to understand the empirical findings higher. Calculating the financial aspect here will help to understand the empirical findings better.

Kameti as a saving mechanism

Now individual is available with two option that will help to generate earnings on the money whilst he's saving at the same time: both he's going to use bank or he's going to join kameti.

I. No involvement in kameti, put it aside in a bank periodically

This situation is viewed as a standard to evaluate the advantages or loses incurred with the aid of becoming a member of kameti, rather of using bank. As long as the

ISSN: 2235-767X
Volume 07 Issue 04
April 2019

individual keep on depositing the periodic repayments this alternative is risk free.

In this case, the total money that an individual will have at the end of the nth period can be calculated using the future value of annuity formula.

FVoa = PMT [((1 + i)n - 1) / i]

Where, FVoa is the future value of annuity PMT is value of the periodic payment,

i is the periodic interest rate (annual interest / number of periods) ,

n is the number of periods for annuity contribution

For our case we assume that the individual will save 8,000 Rs every month for 12 months or a year for all scenarios demonstrated below. Given a 6% annual interest rate (the prevailing bank saving interest rate in India), the monthly interest rate will be calculated as 6%/12. Thus the Fv of money accumulated at the end of the 12 month will be:

= 8000 [((1 + (6%/12))12 - 1)/ (6%/12)

= Rs. 99177.92

Of this value 96000 (calculated as 12 * 8000) is the principal, making the interest income Rs.3177.92. The formula can be modified to find only the interest income as follows:

Interest income from annuity = {PMT [((1 + i)n - 1) / i]} – (PMT*n)

The periodically accumulated interest is depicted in the following graph.

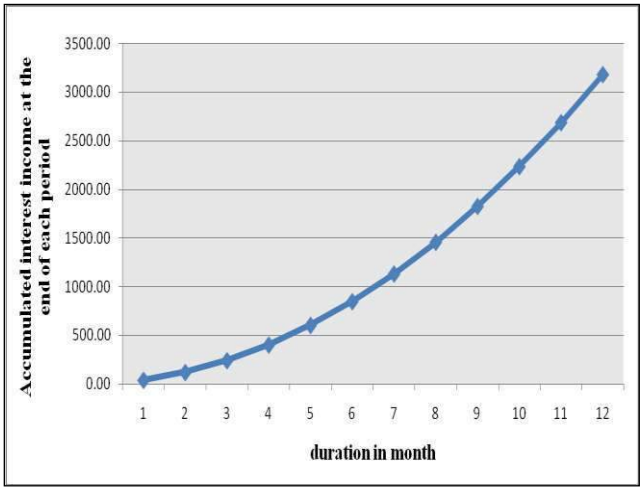


Fig 3.1.1.1 Accumulated Interest

As it is shown in the graph, the accumulated interest will rise at a lower rate at the beginning and rises at higher rate later as the principal as well as compounded interest increases. The accumulated interest income will stand at Rs. 3177.12 at the end of the period.

ii. Involvement in kameti

Having the same amount of money to contribute the same person can also join kameti. The person joins kameti as if he will get the last pot since that is the point where he can be 100% sure about getting the pot (assuming there is no default by members). Consequently, logically he can keep on

ISSN: 2235-767X
Volume 07 Issue 04
April 2019

contributing the Rs. 8000 periodic contributions regardless of when he will definitely get the pot. Nevertheless, he may get the pot at the first period however he still continue to make a contribution of the periodic payment without touching the pot money he gained. Now the question is what will he do with the pot money? The individual has a options to deposit it in a financial institution right away after he get the pot money at the bank interest rate– in our case 6%

a) Deposit it in a financial institution instantly after getting the pot:

here the individual makes use of both kameti and bank. S/he's going to bring the pot money to deposit in a bank. The interest rate the bank deposit interest rate. As soon as the individual deposited the cash it's assumed that he will not withdraw it until the end of the kameti cycle.

For instance, let us suppose that the kameti has 12 members in which monthly contribution is made. If the individual get the pot at the 3 period, he will deposit it right away and will not withdraw it until the end of the 12 month whilst keep on paying the contribution to the kameti.

This individual joins kameti instead of saving by his own in a bank. If order to calculate the financial benefit that the individual enjoys by joining kameti, we should know the period that he will get the pot money. The financial benefit (interest income) he enjoyed differs based on the period he gets the pot since the interest is dependent on the time that the money will keep within the bank.

At the beginning of the cycle, however, the individual do not know when he will get it. Therefore, we should calculate the interest income for every possible period. At 6% interest rate compounded monthly, the individual's interest income at the end of the 12 month period given the period where he get the pot money is depicted in the following graph.

As it can be seen clearly from figure, the individual gain will be high if s/he wins and deposits the pot money in a bank in early period. If s/he wins the 1st pot and deposits it immediately, the interest income will be Rs. 5760, while s/he will not have an interest if s/he wins the last pot.

European Journal of Business & Social Sciences
Available at https://ejbss.org/
ISSN: 2235-767X
Volume 07 Issue 04
April 2019

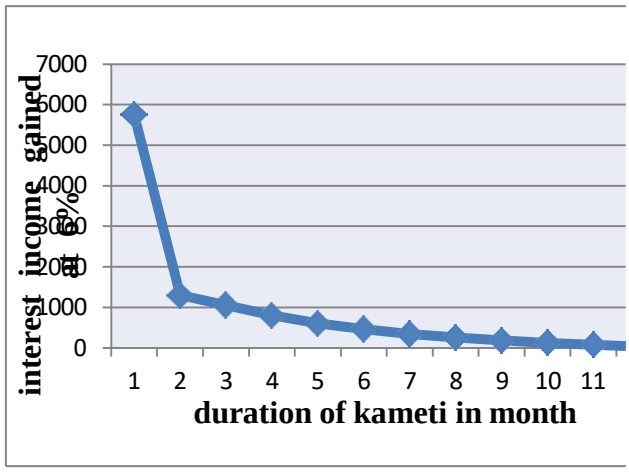


Fig 3.1.1.2 if s/he win the pot & deposit it into a bank account

Now we can compute when the individual will be better off financially if he joins kameti instead of using the bank. It is important to note here is that the gain from the bank if he don't involve in kameti is constant since his deposit is not affected by other parties involved.

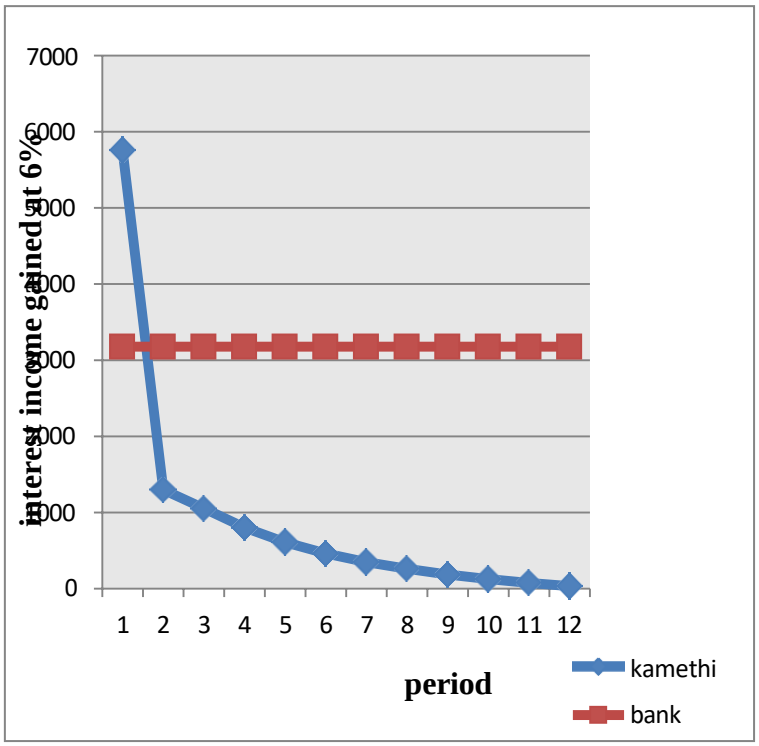


Fig 3.1.1.3 kameti participation vs using bank

from the above graph one can infer that a given kameti participant will be financially better off if and only if he can win the pot at beginning period of the cycle.

4. CONCLUDING THE FINANCIAL ANALYSIS :

The following concluding remark are drawn from the points discussed above :

If the individual is going to deposit the pot money s/he win in a bank at the average bank saving interest rate, the breakeven point is always before the middle. Thus if the individual win before half of the

ISSN: 2235-767X
Volume 07 Issue 04
April 2019

kameti cycle, s/he will be better off than making an ordinary annuity saving in a bank.

Implications:

1 For those who join kameti to be committed or for some other reason and want to take the last pot, the kameti is costing them a value equal to the interest they could have enjoyed by making an ordinary saving in a bank. Net payment to the service they intended toget from kameti, however is equal to:

= (the interest they forgo + the transaction cost they incur in kameti - the transaction cost had they use the bank)

Usually the transaction cost in formal institutions is higher than the informal and hence the net loss after calculating transaction cost will be lower than the interest they forgo.

2 For those who use the kameti as a credit mechanism and use the ordinary bank saving as a standard, the net gain they enjoy by joining kameti will be:

= the gain from the investment + the transaction cost in bank - transaction cost in kameti

3 For those who use the kameti as a credit mechanism and use bank lending rate as a standard, the net gain they enjoy by joining kameti will be:

= the interest expense they avoid + transaction cost in bank - transaction cost in kameti

By the same effect of the transaction cost, the net gain from joining kameti will be higher that the interest expense avoided

5. REFRENCES :

DBI. (2014). *Financial Inclusion in Asia Country Surveys*. *Asian Development Bank Institute*.

Ardener, S. (1964). The Comparative Study of Rotating Credit Associations. *The Journal of the Royal Anthropological Institute of Great Britain and Ireland*, *94*(2), 201-229. doi:10.2307/2844382

Anderson, S., & Baland, J.-M. (2002). The Economics of Roscas and Intrahousehold Resource Allocation. *Source: The Quarterly Journal of Economics*, *117*(3), 963–995. https://doi.org/10.1162/00335530276 0193931

Aniket, K. (2005). Self Help Groups : Use of modified ROSCAs in Microfinance. *Self*, (June).

Besley, T. (1993). The economics of rotating savings and credit associations. *American Economic Review*, *83*(4), 792–810.

Besley, T., Coate, S., & Loury, G. (1994). Rotating Savings and Credit Associations Credit Markets and

ISSN: 2235-767X
Volume 07 Issue 04
April 2019

Efficiency. *The Review of Economic Studies*. https://doi.org/10.2307/2297915

Biggart, N. W. (2001). Banking on Each Other: The Situational Logic of Rotating Savings and Credit Associations. *Advances in Qualitative Organization Research*.

07 Dr. Shilpi Batra" Relibability Modeling and optimization of the number of hot standby units in a system working with two operative unit" Year 2019

Available online at:https://ijact.in

Date of Submission	12/01/2019
Date of Acceptance	23/02/2019
Date of Publication	28/02/2019
Page numbers	3059-3068 (10 Pages)

ISSN:2320-0790

COMPUSOFT
An International Journal of Advanced Computer Technology

RELIABILITY MODELING AND OPTIMIZATION OF THE NUMBER OF HOT STANDBY UNITS IN A SYSTEM WORKING WITH TWO OPERATIVE UNITS

Shilpi Batra, Gulshan Taneja

Department of Mathematics, Maharshi Dayanand University, Rohtak, Haryana, India
batrashilpi1989@gmail.com, drgtaneja@gmail.com

Abstract: In the present paper, a reliability model is developed about the profit analysis and Optimization of number of hot standby units for a system working with two operative units. Hot standby works in a similar manner as operating unit means that when an operating unit fails, hot standby unit works with the same efficiency as the operating unit. The optimization of hot standby units is very important factor for any industry/unit/system for increasing the reliability redundancy and achieving the maximum profit. Thus, reliability models with no/one/two/three hot standby units in a system working with two operative units are developed. The cut-off points with regard to revenue, failure rate, etc. have been obtained to determine as to how many standby unit(s) should be there for the system. Comparative study has also been made to see which and when one of these models is better than the other as far as the profitability of the system is concerned. Semi-Markov processes and regenerative point technique have been used to obtain various performability measures.

Keywords: Two operative units, hot standby units, Regenerative point Technique, Profit analysis, Optimization

I. INTRODUCTION

Ranging from man to machine and in the present scenario also, technology has a great impact on every field of life. Due to increase in population and change in their tastes/ interests, demand of products is increasing continuously. To overcome this increasing demand, it is necessary to introduce the standby redundancy. Hot standby redundancy is that redundancy which is loaded with the same way as the operating unit when the operating unit fails. Many scholars have done a lot of work on hot standby units like Goel and Gupta (1983) discussed the analysis of a two-unit hot standby system with three modes. Christov and Stoytcheva (1999) dealt with the reliability and safety research of hot standby microcomputer signally systems. Rizwan et al. (2005) carried out the reliability analysis of a hot standby PLC system. Parashar and Taneja (2007) found the reliability and profit evaluation of a PLC hot standby system based on master-slave concept and two types of repair facilities. Rizwan et al. (2010) gave the reliability analysis of a hot standby industrial system. Kumar and Kumari (2017) carried out the comparative study of two-unit hot standby hardware software systems with impact of imperfect fault coverage. Manocha et al. (2017) discussed the stochastic and cost-benefit analysis of two-unit hot standby database system but the optimization of number of hot standby units for a system has not been taken into consideration by them. Batra and Taneja (2018) found a reliability model for the optimum number of hot standby

units in a system working with one operative unit. However, there are many systems where systems comprising operative and hot standby system may require two operative units to meet out the demand. For such a system, working with two operative units, there is need to study as to how many hot standby units should be kept in order to get the optimum profit. To answer this question, we, in the present paper, develop four reliability models for a system having two operative units and:

i. No hot standby unit (Model 1)
ii. Two operative and one hot standby unit (Model 2)
iii. Two operative and two hot standby units (Model 3)
iv. Two operative and three hot standby units (Model 4).

The models are compared in order to optimize the number of hot standby units to be used. Analysis is done using semi-Markov processes and regenerative point technique.

II. Nomenclature

λ	Failure rate of operative unit
$\lambda 1$	Failure rate of hot standby unit
g(t),G(t)	p.d.f. and c.d.f. of the repair time
Op	Operative unit
Hs	Standby unit
Fr	Failed unit under repair
Fwr	Failed unit is waiting for the repair
FR	Repair of the failed unit is continuing from previous state
C0	Revenue per unit up time
C1	Cost per unit up time for which the repairman is busy
C2	Cost per visit of the repairman
IC	Installation cost of an additional identical unit
Pi	Profit of model i; i=1,2,3,4
$\Phi_i(t)$	C.d.f. of the first passage time from regenerative state i to a failed state
qij(t), Qij(t)	pdf, cdf of the first passage time from regenerative state Si to a regenerative state Sj
$AC_i^j(t)$	Probability that system working in full capacity at the instant t given that it entered Si at t=0 in case of model j; j=1, 2, 3, 4.
$B_i^j(t)$	Probability that the system is under repair at t given that the system entered Si at t=0 in case of j=1, 2, 3, 4.
$V_i^j(t)$	Expected number of visits in (0, t]; given that the system entered regenerative state Si at t=0 in case of j; j=1, 2, 3, 4.

III. Analysis of the Models

3.1 Model 1: System Comprising Two Operative Units and No Hot Standby Unit

In this model, we have considered a system wherein two units are operative and there is no hot standby unit. Possible transitions from one state to other are given as follows:

From	S_0	S_1	S_1	S_1	S_2
To	S_1	S_0	S_1	S_2	S_1
Via	...	...	S_2	...	...

where $S_0 = (Op, Op)$, $S_1 = (Fr, Op)$, $S_2 = (F_R, F_{wr})$.
States S_0 and S_1 are regenerative states whereas S_2 is a non-regenerative state

3.1.1 Transition Probabilities and Mean Sojourn Times

The state transition probabilities $p_{ij} = \lim_{s\to 0} q_{ij}^*(s)$ can be obtained using the following: $q_{ii}(t) = (2\lambda)e^{-(2\lambda)t}dt$,

$q_{10}(t) = e^{-\lambda t}g(t)dt$, $q_{12}(t) = \lambda e^{-\lambda t}\bar{G}(t)dt$,

$q_{ii}^{(2)}(t) = (\lambda e^{-\lambda t}\bar{G}(t))g(t)dt$

Thus, we have

$p_{11}=1$, $p_{10}=g^*(\lambda)$, $p_{11}^{(2)}=g^*(0)-g^*(\lambda)$, $p_{12}=\lambda\bar{G}^*(\lambda)$

From these values, we have thefollowing relations

$p_{11}=1$

$p_{10}+p_{12}=1$

$p_{10}+p_{11}^{(2)}=1$

Mean sojourn times (μ_i) i.e. the expected time of stay in regenerative state i are given as

$\mu_0 = \frac{1}{2\lambda}$, $\mu_1 = \frac{1-g^*(\lambda)}{\lambda}$

Let $m_{ij} = \int_0^\infty tq_{ij}(t)dt = -q_{ij}^{*\prime}(0)$,

i.e., $m_{01}=\mu_0$, $m_{10}+m_{12}=\mu_1$,

$m_{11}+m_{11}^{(2)} = \int_0^\infty tg(t)dt = k_1$(say)

3.1.2 Measures of System Effectiveness

3.1.2.1 Mean Time to System Failure (MTSF)

To determine the mean time to system failure (MTSF) of the system, we regard the failed state as absorbing state. Thus,

$\phi_0(t) = Q_{01}(t) \textcircled{S} \phi_1(t)$

$\phi_1(t) = Q_{10}(t) \textcircled{S} \phi_0(t) + Q_{12}(t)$

Thus, $\text{MTSF} = \lim_{s\to 0} \frac{1-\phi_0^{**}(s)}{s} = \frac{N^1}{D^1}$, where

$N^1 = \mu_0 + \mu_1$, $D^1 = p_{12}$

3.1.2.2 *Availability*

The availability $AC_i(t)$ is seen to satisfy the following recursive relations:

$AC_0^1(t) = M_0^1(t) + q_{01}(t) \textcircled{C} AC_1^1(t)$

$AC_i^1(t) = M_i^1(t) + q_{10}(t) \textcircled{C} AC_0^1(t) + q_{11}^{(2)}(t) \textcircled{C} AC_i^1(t)$

$M_0^1(t) = e^{-2\lambda t}$

$M_i^1(t) = e^{-\lambda t}\overline{G(t)}$

Taking Laplace Transforms and then solving the above equations for $AC_0^{1*}(s)$, the availability of the system, in steady state, is given by

$$AC_0^1 = \lim_{s\to 0} sAC_0^{1*}(s) = \frac{N_1^1}{D_1^1},$$

where

$N_1^1 = p_{10}\mu_0 + \mu_1$, $D_1^1 = p_{10}\mu_0 + k_1$

Proceeding in the similar manner as done in the case of obtaining expressions:

3.1.2.3 *Expected fraction of time during which the repairman is busy*

$$(B_0^1) = \lim_{s\to 0} sB_0^{1*}(s) = \lim_{s\to 0} \frac{sN_2^1(s)}{D_1^1(s)} = \frac{N_2^1}{D_1^1}$$

3.1.2.4 *Expected Number of Visits*

$$(V_0^1) = \lim_{s\to 0} sV_0^{1**}(s) = \lim_{s\to 0} \frac{sN_3^1(s)}{D_1^1(s)} = \frac{N_3^1}{D_1^1}$$

where

$N_2^1 = k_1$ $\qquad$ $N_3^1 = 1$

3.1.3 Profit Analysis

Profit equation in steady state is given by

$\text{Profit } (P_1) = C_0 AC_0^1 - C_1 B_0^1 - C_2 V_0^1$

3.2 Model 2: System Comprising Two Operative Units and One Hot Standby Unit

In this model, system with two operative and one hot standby unit is considered. Possible transitions from one state to the other are shown as follows:

From	S_0	S_1	S_1	S_1	S_1	S_4	S_4
To	S_1	S_0	S_1	S_3	S_4	S_1	S_4
Via	...	...	S_2	S_2	S_2 and S_3	...	S_3

Where

$S_0 = (Op, Hs, Hs)$, $S_1 = (Fr, Op, Hs)$, $S_2 = (F_R, Fwr, Op)$, $S_3 = (F_R, Fwr, Fwr)$, $S_4 = (Op, Fr, Fwr)$

States S_0, S_1 and S_4 are regenerative states whereas S_2 and S_3 are non-regenerative states.

3.2.1 Transition Probabilities and Mean Sojourn Times

$q_{01}(t) = (2\lambda + \lambda_1)e^{-(2\lambda+\lambda_1)t}$, $q_{10}(t) = e^{-2\lambda t}g(t)$, $q_{11}^{(2)}(t) = (2\lambda e^{-2\lambda t} \textcircled{C} e^{-\lambda t})g(t)$, $q_{13}^{(2)}(t) = (2\lambda e^{-2\lambda t} \textcircled{C} \lambda e^{-\lambda t})\overline{G}(t)$,

$q_{14}^{(2,3)}(t) = (2\lambda e^{-2\lambda t} \textcircled{C} \lambda e^{-\lambda t} \textcircled{C} 1)g(t)$, $q_{41}(t) = e^{-\lambda t}g(t)dt$, $q_{44}^{(3)}(t) = (\lambda e^{-\lambda t} \textcircled{C} 1)g(t)$

The transition probabilities $p_{ij} = \lim_{s\to 0} q_{ij}^*(s)$ for this model are obtained as

$p_{01} = 1, p_{10} = g^*(2\lambda)$, $p_{11}^{(2)} = 2(g^*(\lambda) - g^*(2\lambda))$, $p_{13}^{(2)} = 2\lambda(\overline{G^*}(\lambda) - \overline{G^*}(2\lambda))$

$p_{14}^{(2,3)} = g^*(0) - 2g^*(\lambda) + g^*(2\lambda)$, $p_{41} = g^*(\lambda)$, $p_{44}^{(3)} = g^*(0) - g^*(\lambda)$

Thus, from these probabilities we conclude that

$p_{01} = 1$

$p_{10} + p_{11}^{(2)} + p_{13}^{(2)} = 1$

$p_{10} + p_{11}^{(2)} + p_{14}^{(2,3)} = 1$

$p_{41} + p_{44}^{(3)} = 1$

Mean Sojourn times (μ_i) for the model are:

$\mu_0 = \frac{1}{2\lambda + \lambda_1}$, $\mu_1 = \frac{1-g^*(2\lambda)}{2\lambda}$, $\mu_4 = \frac{1-g^*(\lambda)}{\lambda}$

Here,

$m_{01} = \mu_0$

$m_{10} + m_{11}^{(2)} + m_{13}^{(2)} = \int_0^\infty t(e^{-2\lambda t}g(t) + 2e^{-\lambda t}g(t) - 2e^{-2\lambda t}g(t) + 2\lambda e^{-\lambda t}\overline{G}(t) - 2\lambda e^{-2\lambda t}\overline{G}(t))dt = k_2$ (say)

$m_{10} + m_{11}^{(2)} + m_{14}^{(2,3)} = \int_0^\infty tg(t)dt = k_1$ (say), $\quad m_{41} + m_{44}^{(3)} = \int_0^\infty tg(t)dt = k_1$ (say)

3.2.2 Measures of System Effectiveness

3.2.2.1 Mean Time to System Failure (MTSF)

$\phi_0(t) = Q_{01}(t) \textcircled{S} \phi_1(t)$

$\phi_1(t) = Q_{10}(t) \textcircled{S} \phi_0(t) + Q_{11}^{(2)}(t) \textcircled{S} \phi_1(t) + Q_{13}^{(2)}(t)$

Thus, $MTSF = \lim_{s\to 0} \frac{1-\phi_0^{**}(s)}{s} = \frac{N^2}{D^2}$, where

$N^2 = \mu_0 (p_{10}+p_{13}^{(2)})+k_2$, $D^2 = p_{13}^{(2)}$

3.2.2.2 Availability at full Capacity

The availability $AC_i(t)$ is seen to satisfy the following recursive relations:

$ACF_0^2(t) = M_0^2(t) + q_{01}(t) \copyright ACF_1^2(t)$

$ACF_1^2(t) = M_{1f}^2(t) + q_{10}(t) \copyright ACF_0^2(t) + q_{11}^{(2)}(t) \copyright ACF_1^2(t) + q_{14}^{(2,3)}(t) \copyright ACF_4^2(t)$

$ACF_2^2(t) = q_{41}(t) \copyright ACF_1^2(t) + q_{44}^{(3)}(t) \copyright ACF_4^2(t)$

$M_0^1(t) = e^{-(2\lambda+\lambda_1)t}$

$M_{1f}^1(t) = e^{-2\lambda t}\overline{G(t)}$

Taking Laplace Transforms and then solving the above equations for $AC_0^{2*}(s)$, the availability of the system, in steady state, is given by

$$ACF_0^2 = \lim_{s\to 0} sACF_0^{2*}(s) = \frac{N_{1f}^2}{D_1^2},$$

Where,

$N_{1f}^2 = p_{41}p_{10}\mu_0 + p_{41}\mu_1$, $D_1^2 = p_{41}p_{10}\mu_0 + p_{14}^{(2,3)}\mu_3 + p_{41}k_2$

3.2.2.3 Availability at reduced Capacity

The availability $ACR_i(t)$ is seen to satisfy the following recursive relations:

$ACR_0^2(t) = q_{01}(t) \copyright ACR_1^2(t)$

$ACR_1^2(t) = M_{1r}^2(t) + q_{10}(t) \copyright ACR_0^2(t) + q_{11}^{(2)}(t) \copyright ACR_1^2(t) + q_{14}^{(2,3)}(t) \copyright ACR_4^2(t)$

$ACR_2^2(t) = M_4^2(t) + q_{41}(t) \copyright ACR_1^2(t) + q_{44}^{(3)}(t) \copyright ACR_4^2(t)$

$M_{1r}^2(t) = (2\lambda e^{-2\lambda t} \copyright e^{-\lambda t})\overline{G(t)} = k_3(say)$

$M_4^2(t) = e^{-\lambda t}\overline{G(t)}$

Taking Laplace Transforms and then solving the above equations for $ACR_0^{2*}(s)$, the availability of the system, in steady state, is given by

$$ACR_0^2 = \lim_{s\to 0} sACR_0^{2*}(s) = \frac{N_{1r}^2}{D_1^2}$$

, where

$N_{1r}^2 = p_{14}^{(2,3)}\mu_4 + p_{41}k_3$, $D_1^2 = p_{41}p_{10}\mu_0 + p_{14}^{(2,3)}\mu_3 + p_{41}k_2$

Proceeding in the similar manner as done in the case of obtaining expressions

3.2.2.4 Expected fraction of time during which the repairman is busy

$$(B_0^2) = \lim_{s\to 0} sB_0^{2*}(s) = \lim_{s\to 0} \frac{sN_2^2(s)}{D_1^2(s)} = \frac{N_2^2}{D_1^2}$$

3.2.2.5 Expected Number of Visits:

$$(V_0^2) = \lim_{s\to 0} sV_0^{2**}(s) = \lim_{s\to 0} \frac{sN_3^2(s)}{D_1^2(s)} = \frac{N_3^2}{D_1^2}$$

Where,

$N_2^2 = (p_{41} + p_{14}^{(2,3)})k_1$ and $N_3^2 = (1-p_{11}^{(2)})p_{41} + p_{14}^{(2,3)}(1+p_{41})$

3.2.3 Profit Analysis

Profit equation for standby unit in steady state is given by

Profit $(P_2) = C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 - (IC_0)$

IC_0 is the installation cost of a hot standby unit per unit time.

3.3 Model 3: System Comprising Two Operative Units and Two Hot Standby Units

In this model, a system with two operative and two hot standby units have been considered. Possible state transitions are shown in the following table:

From	S_0	S_1	S_1	S_1	S_1	S_1
To	S_1	S_0	S_1	S_4	S_5	S_6
Via	...	...	S_2	S_2 and S_3	S_2 and S_3	S_2, $S_3$and S_5
From	S_4	S_4	S_4	S_4	S_6	S_6
To	S_1	S_4	S_5	S_6	S_4	S_6
Via	...	S_3	S_3	S_3 and S_5		S_5

Where,

S_0 = (Op, Op, Hs, Hs), S_1= (Fr, Op, Op, Hs), S_2 = (F_R, Fwr, Op, Op), S_3 = (Op, F_R, Fwr, Fwr), S_4= (Op, Op, Fr, Fwr), S_5 = (F_R, Fwr, Fwr, Fwr), S_6= (Op, F_r, Fwr, Fwr)

States S_0, S_1, S_4 andS_6 are regenerative states whereas S_2, S_3 and S_5 are non-regenerative states.

3.3.1 Transition Probabilities and Mean Sojourn Times

The transition probabilities are:

$q_{01}(1) = (2\lambda + 2\lambda_1)e^{-(2\lambda+2\lambda_1)t}dt$,

$q_{10}(t) = e^{-(2\lambda+\lambda_1)t}g(t)dt$,

$q_{11}^{(2)}(t) = ((2\lambda + \lambda_1)\odot e^{-(2\lambda+\lambda_1)t} e^{-2\lambda t})g(t)dt$

$q_{14}^{(2,3)}(t) = ((2\lambda + \lambda_1)\odot e^{-(2\lambda+\lambda_1)t} 2\lambda e^{-2\lambda t}\odot e^{-\lambda t})g(t)dt$

$q_{15}^{(2,3)}(t) = ((2\lambda + \lambda_1)e^{-(2\lambda+\lambda_1)t}\odot 2\lambda e^{-2\lambda t}\odot e^{-\lambda t})\bar{G}(t)dt$

$q_{16}^{(2,5,5)}(t) = ((2\lambda + \lambda_1)e^{-(2\lambda+\lambda_1)t}\odot 2\lambda e^{-2\lambda t}\odot \lambda e^{-\lambda t}\odot 1)g(t)dt$

$q_{43}(t) = e^{-2\lambda t}g(t)dt$, $q_{44}^{(3)}(t) = (2\lambda e^{-2\lambda t}\odot e^{-\lambda t})g(t)dt$,

$q_{45}^{(3)}(t) = (2\lambda e^{-2\lambda t}\odot \lambda e^{-\lambda t})\bar{G}(t)dt$

$q_{46}^{(3,5)}(t) = (2\lambda e^{-2\lambda t}\odot \lambda e^{-\lambda t}\odot 1)g(t)dt$, $q_{56}(t) = e^{-\lambda t}g(t)dt$

$q_{66}^{(5)}(t) = (\lambda e^{-\lambda t}\odot 1)g(t)dt$

The transition probabilities are given as $p_{ij} = \lim_{s\to 0} q_{ij}^{*}(s)$

Here,

$p_{01} = 1$

$p_{10} + p_1^{(2)} + p_1^{(2,3)} + p_{15}^{(2,3)} = 1$

$p_{10} + p_{11}^{(2)} + p_{14}^{(2,3)} + p_{16}^{(2,5,5)} = 1$

$p_{41} + p_{43}^{(3)} + p_{45}^{(3)} = 1$

$p_{54} + p_{44}^{(3)} + p_{46}^{(3,5)} = 1$

$p_{64} + p_{66}^{(5)} = 1$

Mean Sojourn times (μ_i) for the model are:

$$\mu_0 = \frac{1}{2\lambda + 2\lambda_1},\ \mu_1 = \frac{1-g^{*}(2\lambda+\lambda_1)}{2\lambda+\lambda_1},\ \mu_4 = \frac{1-g^{*}(2\lambda)}{2\lambda},\ \mu_6 = \frac{1-g^{*}(\lambda)}{\lambda}$$

Thus,

$m_{01} = \mu_0$

$$m_{14} + m_{11}^{(2)} + m_{14}^{(2,3)} + m_{15}^{(2,3)} = \int_0^{\infty} t\left\{\frac{2\lambda^2(1-2\lambda\lambda_1)}{\lambda_1(\lambda+\lambda_1)}e^{-(2\lambda+\lambda_1)}g(t) + \frac{(4\lambda^2+2\lambda\lambda_1-\lambda_1-2\lambda)}{\lambda_1}e^{-2\lambda}g(t) + \frac{2(2\lambda+\lambda_1)(1-\lambda)}{(\lambda+\lambda_1)}e^{-\lambda}g(t)\right\}$$

$dt = K_5$ (say)

$$m_{10} + m_{11}^{(2)} + m_{14}^{(2,3)} + m_{16}^{(2,5,5)} = \int_0^{\infty} tg(t)dt = k_2(\text{say})$$

$$m_{43} + m_{44}^{(3)} + m_{46}^{(3)} = \int_0^{\infty} t\{(2\lambda-1)e^{-2\lambda t} + 2(1-\lambda)e^{-\lambda t}\}g(t)dt = k_6(\text{say})$$

$$m_{56} + m_{54}^{(3)} + m_{46}^{(3,5)} = \int_0^{\infty} tg(t)dt = k_7(\text{say})$$

3.3.2 Measures of System Effectiveness

3.3.2.1 *Mean Time to System Failure (MTSF)*

$Q_0(t) = Q_{01}(t)\overline{\odot}\ \phi_1(t)$

$Q_1(t) = Q_{10}(t)\overline{\odot}\ \phi_0(t) + Q_{11}^{(2)}(t)\overline{\odot}\ \phi_1(t) + Q_{14}^{(2,3)}(t)\overline{\odot}\ \phi_4(t) + Q_{15}^{(2,3)}(t)$

$Q_4(t) = Q_{41}(t)\overline{\odot}\ \phi_1(t) + Q_{44}^{(3)}(t)\overline{\odot}\ \phi_4(t) + Q_{42}^{(5)}(t)$

MTSF when system starts from the state '0' is

$$\text{MTSF} = \lim_{s\to 0}\frac{1-\phi_0^{**}(s)}{s} = \lim_{s\to 0}\frac{D(s)-N(s)}{sD(s)} = \frac{'0'}{0}\text{form} = \frac{D'(0)-N'(0)}{D(0)} = \frac{N^3}{D^3}$$

Where,

$D^3 = p_{14}^{(2,3)}p_{45}^{(3)} + p_{15}^{(2,3)}(1-p_{44}^{(3)})$

$N^3 = p_{14}^{(2,3)}(m_{43}+m_{46}^{(3)}+m_{45}^{(3)}) + (p_{43}(p_{10}+p_{15}^{(2,3)}) + p_{45}^{(3)}(1-p_{44}^{(3)}))m_{01} + (p_{43}+p_{45}^{(3)})(m_{14}+m_{11}^{(2)}+m_{15}^{(2,3)})$

$= p_{14}^{(2,3)}k_6 + (p_{43}(p_{10}+p_{15}^{(2,3)}) + p_{45}^{(3)}(1-p_{44}^{(3)}))\mu_0 + (p_{43}+p_{45}^{(3)})k_2$

3.3.2.2 Availability at full Capacity

The availability $ACF_0(t)$ is seen to satisfy the following recursive relations:

$ACF_0^3(t) = M_0^3(t) + q_{01}(t)\odot ACF_1^3(t)$

$ACF_1^3(t) = M_1^3(t) + q_{10}(t)\odot ACF_0^3(t) + q_{11}^{(2)}(t)\odot ACF_1^3(t) + q_{14}^{(2,3)}(t)\odot ACF_4^3(t) + q_{16}^{(2,5,5)}(t)\odot ACF_6^3(t)$

$ACF_4^3(t) = M_4^3(t) + q_{41}(t)\odot ACF_1^3(t) + q_{44}^{(3)}(t)\odot ACF_4^3(t) + q_{46}^{(3,5)}(t)\odot ACF_6^3(t)$

$ACF_6^3(t) = q_{64}(t)\odot ACF_4^3(t) + q_{66}^{(5)}\odot ACF_6^3(t)$

Where,

$M_0^3(t) = e^{-(2\lambda+\lambda_1)t}$

$M_1^3(t) = \frac{(2\lambda-\lambda_1)}{\lambda_1}e^{-2\lambda t}\bar{G}(t) - \frac{2\lambda}{\lambda_1}e^{-(2\lambda+\lambda_1)t}\bar{G}(t) = k_3(\text{say})$

$M_4^3(t) = e^{-2\lambda t}\bar{G}(t)$

Taking Laplace Transforms and then solving the above equations for $ACF_0^{3*}(s)$, the availability of the system, in steady state, is given by

$$ACF_0^3 = \lim_{s\to 0} sACF_0^3(t) = \lim_{s\to 0}\frac{sN_3(s)}{D_3(s)} = \frac{'0'}{0}\text{form} = \lim_{s\to 0}\frac{sN_3'(s)+N_3(s)}{D_3'(s)} = \frac{N_3'(0)}{D_3'(0)} = \frac{N_U^3}{D_3^3}$$

Where,

$N_U^3 = p_{64}p_{43}p_{10}\mu_0 + p_{64}(1-p_{10}-p_{11}^{(2)})\mu_4 + p_{64}p_{43}k_7$

$$D_1^2 = p_{64}p_{41}(m_{16} + m_{12}^{(3)} + m_{12}^{(2,3)} + m_{16}^{(2,3,5)}) + p_{65}(p_{12}^{(2,3)} + p_{16}^{(2,3,5)})(m_{21} + m_{26}^{(3)} + m_{26}^{(3,5)}) + p_{61}p_{12}p_{16}\mu_6 + \mu_5(p_{21}p_{16}^{(2,3,5)} + p_{16}^{(3,5)}(p_{12}^{(2,3)} + p_{16}^{(2,3,5)})$$

$$\Rightarrow p_{64}p_{41}p_{16}\mu_6 + [p_{61}(p_{16}^{(2,3,5)} + p_{66}) + (p_{66}^{(3,5)} + p_{66})(p_{12}^{(2,3)} + p_{16}^{(2,3,5)})]k_5$$

3.3.2.2 *Availability at reduced Capacity*

The availability $ACR_i(t)$ is seen to satisfy the following recursive relations:

$$ACR_0^1(t) = q_{01}(t) \odot ACR_1^1(t)$$

$$ACR_1^1(t) = M_1^1(t) + q_{10}(t) \odot ACR_0^1(t) + q_{11}^{(2)}(t) \odot ACR_1^1(t) + q_{14}^{(2,3)}(t) \odot ACR_4^1(t) + q_{16}^{(2,3,5)}(t) \odot ACR_6^1(t)$$

$$ACR_4^1(t) = M_4^1(t) + q_{41}(t) \odot ACR_1^1(t) + q_{44}^{(3)}(t) \odot ACR_4^1(t) + q_{46}^{(3,5)}(t) \odot ACR_6^1(t)$$

$$ACR_6^1(t) = M_6^1(t) + q_{61}(t) \odot ACR_1^1(t) + q_{66}^{(3)}(t) \odot ACR_6^1(t)$$

Where,

$$M_0^1(t) = \frac{2(2\lambda+\lambda_1)}{\lambda+2\lambda_1}e^{-\alpha t}\bar{G}(t) + \frac{2(2\lambda+\lambda_1)}{\lambda_1}e^{-\beta t}\bar{G}(t) - \frac{2(2\lambda+\lambda_1)(\lambda+2\lambda_1)}{\lambda_1(\lambda+\lambda_1)}e^{-(\alpha+\beta)t}\bar{G}(t) = k_0(say)$$

$$M_1^1(t) = 2e^{-\alpha t}\bar{G}(t) - 2e^{-\beta t}\bar{G}(t) = k_1(say)$$

$$M_4^1(t) = e^{-\beta t}\bar{G}(t)$$

Taking Laplace Transforms and then solving the above equations for $ACR_0^{1*}(s)$, the availability of the system, in steady state, is given by:

$$ACR_0^1 = \lim_{s\to 0} sACR_0^1(t) = \lim_{s\to 0}\frac{sN_1(s)}{D_1(s)} = \frac{'0'}{0}\text{form}$$

$$= \lim_{s\to 0}\frac{sN_1'(s) + N_1(s)}{D_1'(s)} = \frac{N_1^1(0)}{D_1^1(0)} = \frac{N_0^1}{D_0^1}$$

Where,

$$N_0^1 = p_{64}p_{41}k_6 + (p_{41}p_{16}^{(2,3,5)} + p_{16}^{(2,3)}(p_{12}^{(2,3)} + p_{16}^{(2,3,5)}))\mu_6 + p_{64}(p_{14}^{(2,3)} + p_{16}^{(2,3,5)})k_5 \text{ and } D_0^1 \text{ is already defined.}$$

Proceeding in the similar manner as done in the case of obtaining expressions

3.3.2.4 Expected fraction of time during which the repairman is busy

$$(B_0^1) = \lim_{s\to 0} sB_0^{1*}(s) = \lim_{s\to 0}\frac{sN_2^1(s)}{D_1'(s)} = \frac{N_2^1}{D_1^1}$$

3.3.2.5 Expected Number of Visits

$$(V_0^1) = \lim_{s\to 0} sV_0^{1**}(s) = \lim_{s\to 0}\frac{sN_3^1(s)}{D_1'(s)} = \frac{N_3^1}{D_1^1}$$

Where,

$$N_2^1 = (p_{61}(p_{12} + p_{16}^{(2,3,5)}) + (p_{16}^{(3,5)} + p_{66})(p_{14}^{(2,3)} + p_{16}^{(2,3,5)}))k_1 \text{ and}$$

$$N_3^1 = p_{64}p_{41}p_{16}$$

3.3.4 Profit Analysis

Profit equation for two standby units in steady state is given by:

Profit $(P_3) = C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 - 2(IC_6)$

3.4 Model 4: System having Two Operative Units and Three Hot Standby Units:

In this model, we have considered a system wherein two units are operative and three hot standby units which take place of the operative unit if the latter gets failed. Possible transitions from one state to other one given as follows:

From	S_0	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
To	S_1	S_0	S_1	S_5	S_7	S_8	S_8	S_7	S_8	S_9
Via	---	---	S_2	S_2, S_3 and S_4	S_2, S_3 and S_4	S_2 and S_3	S_2, S_3, S_4 and S_5	---	S_8	S_9
From	S_7	S_7	S_7	S_8	S_5	S_5	S_7	S_5	S_5	
To	S_8	S_6	S_5	S_5	S_8	S_7	S_5	S_5	S_6	
Via		S_4 and S_6	S_4		S_5	S_5 and S_7	S_4	S_5 and S_6	S_5, S_4 and S_6	

Where,

$S_0 = (Op, Op, Hs, Hs, Hs)$, $S_1 = (F_R, Op, Op, Hs, Hs)$, $S_2 = (F_R, F_{WR}, Hs, Op, Op)$, $S_3 = (Op, Op, F_R, F_{WR}, F_{WR})$, $S_4 = (Op, F_R, F_{WR}, F_{WR}, F_{WR})$, $S_5 = (F_R, F_{WR}, F_{WR}, F_{WR}, F_{WR})$, $S_6 = (Op, F_R, F_{WR}, F_{WR}, F_{WR})$, $S_7 = (Op, O_p, F_{WR}, F_{WR}, F_R)$, $S_8 = (Op, O_p, Hs, F_{WR}, F_R)$

States S_0, S_1, S_6, S_7 and S_8 are regenerative states whereas S_2, S_3, S_4 and S_5 are non-regenerative states.

3.4.1 Transition Probabilities and Mean Sojourn Times

The transition probabilities are:

$$q_{01}(t) = (2\lambda + 3\lambda_1)e^{-(2\lambda+3\lambda_1)t}dt \;,\; q_{21}(t) = e^{-(2\lambda+2\lambda_1)t}g(t)dt$$

$$q_{11}^{(2)}(t) = ((2\lambda + 2\lambda_1)e^{-(2\lambda+2\lambda_1)t} \odot e^{-(2\lambda+\lambda_1)t})g(t)dt$$

$$q_{41}^{(2,3,4)}(t) = ((2\lambda + 2\lambda_1)e^{-(2\lambda+2\lambda_1)t} \odot (2\lambda + \lambda_1)e^{-(2\lambda+\lambda_1)t} \odot 2\lambda e^{-2\lambda t} \odot \lambda e^{-\lambda t})\bar{G}(t)dt$$

$$q_{12}^{(2,3)}(t) = ((2\lambda + 2\lambda_1)e^{-(2\lambda+2\lambda_1)t} \odot (2\lambda + \lambda_1)e^{-(2\lambda+\lambda_1)t} \odot e^{-2\lambda t})g(t)dt$$

$$q_{17}^{(2,3,4)}(t) = ((2\lambda + 2\lambda_1)e^{-(2\lambda+2\lambda_1)t} \odot (2\lambda + \lambda_1)e^{-(2\lambda+\lambda_1)t} \odot 2\lambda e^{-2\lambda t} \odot e^{-\lambda t})g(t)dt$$

$$q_{16}^{(2,3,5)}(t) = ((2\lambda + 2\lambda_1)e^{-(2\lambda+2\lambda_1)t} \odot (2\lambda + \lambda_1)e^{-(2\lambda+\lambda_1)t} \odot 2\lambda e^{-2\lambda t} \odot e^{-\lambda t} \odot 1)g(t)dt$$

$q_{67}(t) = e^{-\lambda_1 t} g(t)dt$, $q_{66}^{(5)}(t) = (2\lambda e^{-\lambda_1 t} \odot 1) g(t)dt$,

$q_{78}(t) = e^{-2\lambda_1 t} g(t)dt$

$q_{77}^{(4)}(t) = (2\lambda e^{-2\lambda t} \odot e^{-\lambda t}) g(t)dt$,

$q_{76}^{(4,5)}(t) = (2\lambda e^{-2\lambda_1 t} \odot \lambda e^{-\lambda_1 t} \odot 1) g(t)dt$

$q_{81}(t) = e^{-2\lambda_1 t} g(t)dt$, $q_{88}^{(3)}(t) = (2\lambda e^{-2\lambda_1 t} \odot e^{-2\lambda_1 t}) g(t)dt$

$q_{87}^{(3,4)}(t) = (2\lambda e^{-2\lambda_1 t} \odot 2\lambda e^{-2\lambda_1 t} \odot e^{-\lambda_1 t}) g(t)dt$

$q_{86}^{(3,4,5)}(t) = (2\lambda e^{-2\lambda_1 t} \odot 2\lambda e^{-2\lambda_1 t} \odot \lambda e^{-\lambda_1 t} \odot 1) g(t)dt$

$q_{75}^{(4)}(t) = (2\lambda e^{-2\lambda_1 t} \odot \lambda e^{-\lambda_1 t}) \bar{G}(t)dt$

$q_{85}^{(3,4)}(t) = (2\lambda e^{-2\lambda_1 t} \odot 2\lambda e^{-2\lambda_1 t} \odot \lambda e^{-\lambda_1 t}) \bar{G}(t)dt$

It can be checked that

$p_{01} = 1$

$p_{10} + p_{11}^{(2)} + p_{15}^{(2,3,4)} + p_{18}^{(2,3)} + p_{17}^{(2,3,4)} = 1$

$p_{10} + p_{11}^{(2)} + p_{18}^{(2,3)} + p_{17}^{(2,3,4)} + p_{16}^{(2,3,4,5)} = 1$

$p_{64} + p_{66}^{(5)} = 1$

$p_{78} + p_{77}^{(4)} + p_{76}^{(4,5)} = 1$

$p_{78} + p_{77}^{(4)} + p_{75}^{(4)} = 1$

$p_{81} + p_{88}^{(3)} + p_{87}^{(3,4)} + p_{85}^{(3,4)} = 1$

$p_{81} + p_{88}^{(3)} + p_{87}^{(3,4)} + p_{86}^{(3,4,5)} = 1$

Mean Sojourn times (μ_i) for the model are:

$\mu_0 = \frac{1}{2\lambda + 3\lambda_1}$, $\mu_1 = \frac{1 - g^*(2\lambda + 2\lambda_1)}{2\lambda + 2\lambda_1}$, $\mu_6 = \frac{1 - g^*(\lambda)}{\lambda}$, $\mu_7 = \frac{1 - g^*(2\lambda)}{2\lambda} = \mu_8$

Here,

$m_{01} = \mu_0$

$$m_{10} + m_{11}^{(2)} + m_{18}^{(2,3)} + m_{17}^{(2,3,4)} + m_{15}^{(2,3,4)} = \int_0^\infty t\{e^{-(2\lambda+2\lambda_1)t} g_1(t) + \frac{2(\lambda+\lambda_1)}{\lambda_1}(e^{-(2\lambda+\lambda_1)t} - e^{-(2\lambda+2\lambda_1)t}) g(t)$$
$$+ \frac{(\lambda+\lambda_1)(2\lambda+\lambda_1)}{\lambda_1^2}(e^{-(2\lambda)t} - 2e^{-(2\lambda+\lambda_1)t} + e^{-(2\lambda+2\lambda_1)t}) g(t)$$
$$+ 4\lambda(\lambda+\lambda_1)(2\lambda+\lambda_1)\left(\frac{e^{-2\lambda t}}{\lambda(\lambda+\lambda_1)(2\lambda+\lambda_1)} - \frac{e^{-2\lambda t}}{2\lambda\lambda_1^2}\right.$$
$$\left. + \frac{e^{-(2\lambda+2\lambda_1)t}}{\lambda_1^2(\lambda+\lambda_1)} + \frac{e^{-(2\lambda+2\lambda_1)t}}{2\lambda_1^2(\lambda+2\lambda_1)}\right) g(t)$$
$$+ 4\lambda^2(\lambda+\lambda_1)(2\lambda+\lambda_1)\left(\frac{e^{-2\lambda t}}{\lambda(\lambda+\lambda_1)(2\lambda+\lambda_1)} - \frac{e^{-2\lambda t}}{2\lambda\lambda_1^2}\right.$$
$$\left. + \frac{e^{-(2\lambda+\lambda_1)t}}{\lambda_1^2(\lambda+\lambda_1)} + \frac{e^{-(2\lambda+2\lambda_1)t}}{2\lambda_1^2(\lambda+2\lambda_1)}\right) \bar{G}(t)]dt = k_{10} \text{(say)}$$

$$m_{10} + m_{11}^{(2)} + m_{15}^{(2,3)} + m_{16}^{(2,3,4,5)} + m_{17}^{(2,3,4)} = \int_0^\infty t g(t)dt = k_1 \text{(say)}$$

$$m_{67} + m_{66}^{(5)} = \int_0^\infty t g(t)dt = k_1$$

$$m_{78} + m_{77}^{(4)} + m_{75}^{(4)} = \int_0^\infty t\{e^{-2\lambda t} + 2(e^{-\lambda t} - e^{-2\lambda t}) + 2\lambda(e^{-\lambda t} - e^{-2\lambda t})\} g(t)dt = k_{11} \text{(say)}$$

$$m_{78} + m_{77}^{(4)} + m_{76}^{(4,5)} = \int_0^\infty t g(t)dt = k_1 \text{(say)}$$

$$m_{81} + m_{88}^{(3)} + m_{87}^{(3,4)} + m_{85}^{(3,4)} = \int_0^\infty t\{e^{-2\lambda t} + 2\lambda t e^{-2\lambda t} + 4(e^{-\lambda t} - e^{-2\lambda t} - \lambda t e^{-2\lambda t})\} g(t)dt + 4\lambda(e^{-\lambda t} - e^{-2\lambda t} - \lambda t e^{-2\lambda t})\bar{G}(t)dt = k_{12} \text{(say)}$$

$$m_{81} + m_{88}^{(3)} + m_{87}^{(3,4)} + m_{86}^{(3,4,5)} = \int_0^\infty t g(t)dt = k_1$$

4.4.2 Measures of System Effectiveness

3.4.2.1 Mean Time to System Failure (MTSF)

$\phi_0(t) - Q_{01}(t) \textcircled{s} \phi_1(t) = 0$

$Q_{10}^{(2)} \phi_0(t) - \phi_1(t)(1 - q_{11}^{(2)}) - q_{17}^{(2,3,4)}(t)\phi_7 - q_{18}^{(2,3)}\phi_8 = q_{15}^{(2,3,4)}$

$(1 - q_{77}^{(4)})\phi_7 - q_{78}\phi_8 = q_{75}^{(4)}$

$-q_{81}\phi_1 - q_{87}^{(3,4)}\phi_7 - q_{88}^{(3)}\phi_8 = q_{85}^{(3,4)}$

$$\text{MTSF} = \lim_{s \to 0} \frac{1 - \phi_0^{**}(s)}{s}$$

$$= \lim_{s \to 0} \frac{1 - \frac{N(s)}{D(s)}}{s} = \frac{D'(0) - N'(0)}{D(0)} = \frac{N^4}{D^4}$$

Where,

$$N^4 = \{p_{78}p_{17}^{(2,3,4)} + p_{18}^{(2,3)}(p_{78} + p_{75}^{(4)})\mu_5 + \{p_{17}^{(2,3,4)}(p_{81} + p_{85}^{(3,4)} + p_{87}^{(3,4)}) + p_{18}^{(2,3)}p_{87}^{(3,4)}\}k_1$$
$$+ (p_{78}p_{81} + p_{75}^{(4)}(p_{81} + p_{87}^{(3,4)} + p_{85}^{(3,4)})k_3$$
$$+ [\{p_{78}(p_{81}p_{85}^{(3,4)}) + p_{75}^{(4)}(p_{81} + p_{87}^{(3,4)})p_{85}^{(3,4)})\}(p_{01} + p_{15}^{(2,3,4)})]\mu_0$$

$$D^4 = (1 - p_{11}^{(2)} - p_{10})[(1 - p_{77}^{(4)})(1 - p_{88}^{(3)}) - p_{78}p_{87}^{(3,4)}]$$
$$- p_{81}[p_{78}p_{17}^{(2,3,4)} + p_{18}^{(2,3)}(1 - p_{77}^{(4)})]$$

3.4.2.2 Availability at full Capacity

The availability $ACF_i(t)$ is seen to satisfy the following recursive relations:

$ACF_0^4(t) = M_0^4(t) + q_{01}(t) \textcircled{c} ACF_1^4(t)$

$$ACF_1^4(t) = M_{1f}^4(t) + q_{10}(t) \textcircled{c} ACF_0^4(t) + q_{11}^{(2)}(t) \textcircled{c} ACF_1^4(t) + q_{16}^{(2,3,4,5)}(t) \textcircled{c} ACF_6^4(t)$$
$$+ q_{17}^{(2,3,4)}(t) \textcircled{c} ACF_7^4(t) + q_{18}^{(2,3)}(t) \textcircled{c} ACF_8^4(t)$$

$ACF_6^4(t) = q_{67}(t) \textcircled{c} ACF_7^4(t) + q_{66}^{(5)}(t) \textcircled{c} ACF_6^4(t)$

$ACF_8^4(t) = M_{8f}^4(t) + q_{81}(t) \textcircled{c} ACF_1^4(t) + q_{88}^{(3)}(t) \textcircled{c} ACF_8^4(t) + q_{87}^{(3,4)}(t) \textcircled{c} ACF_7^4(t) + q_{86}^{(3,4,5)}(t) \textcircled{c} ACF_6^4(t)$

Thus,

$$ACF_0^4 = \lim_{s \to 0} sACF_0^{4*}(s) = \frac{N_{1f}^4}{D_1^4}$$

$$N_{1f}^4 = p_{67}p_{78}p_{81}(1 - p_{11}^{(2)} + p_{10}k_{12})\mu_0 - (p_{81}\mu_0 - p_{01}k_{13})(p_{18}^{(2,3)} + p_{17}^{(2,3,4)} + p_{16}^{(2,3,4,5)})$$
$$+ p_{01}\mu_7\{(p_{81}p_{67})(p_{17}^{(2,3,4)} + p_{16}^{(2,3,4,5)}) + p_{67}(p_{16}^{(2,3,4,5)} + p_{17}^{(2,3,4)} + p_{18}^{(2,3)})(p_{87}^{(3,4)} + p_{86}^{(3,4,5)})\}$$

$$D_1^4 = [(p_{86}^{(2,3,4,5)} + p_{17}^{(2,3,4)} + p_{18}^{(2,3)})(p_{67}p_{78} + p_{67}p_{87}^{(3,4)} + p_{67}p_{86}^{(3,4,5)}p_{76}^{(4,5)}(1-p_{88}^{(2)}) + p_{78}p_{86}^{(3,4,5)}) + p_{67}p_{78}p_{81} + p_{67}p_{81}(p_{17}^{(2,3,4)} + p_{16}^{(2,3,4,5)}) + p_{81}(p_{16}^{(2,3,4,5)}p_{78} - p_{18}^{(2,3)}p_{76}^{(4,5)})]k_4 + p_{67}p_{78}p_{81}p_{10}\mu_0$$

3.4.2.3 Availability at reduced Capacity

The availability $ACR_i(t)$ is seen to satisfy the following recursive relations:

$$ACR_0^4(t) = M_0^4(t) + q_{01}(t) \copyright ACR_1^4(t)$$

$$ACR_1^4(t) = M_{11}^4(t) + q_{10}(t) \copyright ACR_0^4(t) + q_{11}^{(2)}(t) \copyright ACR_1^4(t) + q_{16}^{(2,3,4,5)}(t) \copyright ACR_6^4(t) + q_{17}^{(2,3,4)}(t) \copyright ACR_7^4(t) + q_{18}^{(2,3)}(t) \copyright ACR_8^4(t)$$

$$ACR_6^4(t) = q_{67}(t) \copyright ACR_7^4(t) + q_{65}^{(5)}(t) \copyright ACR_6^4(t)$$

$$ACR_8^4(t) = M_{81}^4(t) + q_{81}(t) \copyright ACR_1^4(t) + q_{88}^{(2)}(t) \copyright ACR_8^4(t) + q_{87}^{(3,4)}(t) \copyright ACR_7^4(t) + q_{86}^{(3,4,5)}(t) \copyright ACR_6^4(t)$$

Thus,

$$ACR_0^4 = \lim_{s\to 0} sACR_0^4 * (s) = \frac{N_{1f}^4}{D_1^4}$$

$$N_{1f}^4 = p_{67}p_{78}p_{81}k_{14} + \mu_4\{p_{78}p_{81}p_{16}^{(2,3,4,5)} + p_{78}p_{16}^{(3,4,5)}(p_{18}^{(2,3,4,5)} + p_{10} + p_{18}^{(2,3)}) + p_{76}^{(4,5)}(p_{81} + p_{87}^{(3,4)} + p_{86}^{(3,4,5)})(p_{16}^{(2,3,4,5)} + p_{18}^{(2,3)}) + p_{76}^{(4,5)}p_{18}^{(2,3)}p_{86}^{(3,4,5)} + p_{18}^{(2,3)}p_{87}^{(3,4)}p_{76}^{(4,5)}\} + k_{15}\{p_{67}(1-p_{88}^{(2)})(p_{17}^{(2,3,4)} + p_{18}^{(2,3)}) + p_{67}p_{18}^{(2,3)}(p_{87}^{(3,4)} + p_{86}^{(3,4,5)})\} + k_{16}p_{67}p_{78}(p_{16}^{(2,3,4,5)} + p_{18}^{(2,3)}) + p_{18}^{(2,3)})$$

Proceeding in the similar manner as done in the case of obtaining expressions:

3.4.2.4 Expected fraction of time during which the repairman is busy:

$$(B_0^4) = \lim_{s\to 0} sB_0^{4*}(s) = \lim_{s\to 0} \frac{sN_2^4(s)}{D_1^4(s)} = \frac{N_2^4}{D_1^4}$$

3.4.2.5 Expected Number of Visits

$$(V_0^4) = \lim_{s\to 0} sV_0^{4**}(s) = \lim_{s\to 0} \frac{sN_3^4(s)}{D_1^4(s)} = \frac{N_3^4}{D_1^4}$$

Where,

$$N_2^4 = [p_{67}p_{78}p_{81} + p_{16}^{(2,3,4,5)}((p_{81} + p_{86}^{(3,4,5)})(p_{78} + p_{76}^{(4,5)}) + p_{76}^{(4,5)}p_{87}^{(3,4)}) + p_{17}^{(2,3,4)}(-p_{86}^{(3,4,5)}(p_{76} + p_{76}^{(4,5)}) - p_{76}^{(4,5)}(p_{81} + p_{87}^{(3,4)})) - p_{18}^{(2,3)}(p_{76}^{(4,5)}p_{87}^{(3,4)} + p_{86}^{(3,4,5)}(p_{78} + p_{76}^{(4,5)})) + p_{67}(p_{87}^{(3,4)}\{p_{67}p_{78}(p_{16}^{(2,3,4,5)}) + p_{17}^{(2,3,4)} + p_{18}^{(2,3)}\} + (p_{86}^{(3,4,5)})(p_{16}^{(2,3,4,5)} + p_{17}^{(2,3,4)} + p_{18}^{(2,3)}) + p_{67}p_{81}(p_{16}^{(2,3,4,5)} + p_{17}^{(2,3,4)})]k_1$$

And $N_3^4 = p_{67}p_{78}p_{81}p_{10}$

3.4.3 Profit Analysis

Profit equation for three standby in steady state is given by

Profit $(P_4) = C_0AC_0^4 - C_1B_0^4 - C_2V_0^4 - 3(IC_0)$

IV. Comparative Study among the Models

4.1 Optimization of Number of Hot Standby Units with regard to Revenue per Unit up Time:

a) On comparing the profits of Models 1 and 2, we conclude that Model 1 is better or worse than Model 2

if $P_1 - P_2 > 0$ or < 0

i.e. if $(C_0AC_0^1 - C_1B_0^1 - C_2V_0^1) - (C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 - (IC_0)) > 0$ or < 0 i.e. if $\begin{cases} C_0 > \text{or} < C_{01}^* \text{ for } AC_0^1 > AC_0^2 \\ C_0 < \text{or} > C_{01}^* \text{ for } AC_0^1 < AC_0^2 \end{cases}$

Both the models are equally good if $C_0 = C_{01}^*$.

where $C_{01}^* = \frac{(C_1(B_0^1 - B_0^2) + C_2(V_0^1 - V_0^2) - IC_0)}{(AC_0^1 - AC_0^2)}$

b) Comparison between Models 2 and 3 reveals that Model 2 is better or worse than Model 3

if $P_2 - P_3 > 0$ or < 0

i.e. if $(C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 - (IC_0)) - (C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 - 2*(IC_0)) > 0$ or < 0

i.e. if $\begin{cases} C_0 > \text{or} < C_{02}^* \text{ for } AC_0^2 > AC_0^3 \\ C_0 < \text{or} > C_{02}^* \text{ for } AC_0^2 < AC_0^3 \end{cases}$

Both are equally good if $C_0 = C_{02}^*$.

where $C_{02}^* = \frac{C_1(B_0^2 - B_0^3) + C_2(V_0^2 - V_0^3) - IC_0}{(AC_0^2 - AC_0^3)}$

c) As far as the selection between Model 3 and 1 is concerned, one should adopt Model 3 in preference to Model 1:

if $P_3 - P_1 > 0$ or < 0

i.e. if $(C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 - 2*(IC_0)) - (C_0AC_0^1 - C_1B_0^1 - C_2V_0^1) > 0$ or < 0

i.e. if $\begin{cases} C_0 > \text{or} < C_{03}^*, \text{for } AC_0^3 > AC_0^1 \\ C_0 < \text{or} > C_{03}^*, \text{for } AC_0^3 < AC_0^1 \end{cases}$

Both are equally good if $C_0 = C_{03}^*$.

where $C_{03}^* = \frac{C_1(B_0^3 - B_0^1) + C_2(V_0^3 - V_0^1) + 2*(IC_0)}{(AC_0^3 - AC_0^1)}$

4.2 Optimization of Number of Hot Standby Units with regard to Cost of Installing a Hot Standby Unit:

a) On comparing thr profits of Model 1 and 2, we conclude that Model 1 is better or worse than Model 2

if $P_1 - P_2 > 0$ or < 0

i.e. if $(C_0AC_0^1 - C_1B_0^1 - C_2V_0^1 - IC_0) - (C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 - 2*(IC_0)) > 0$ or < 0

i.e. if $IC_0 >$ or $< IC_{01}^*$

Both are equally good if $IC_0 = IC_{01}^*$

Where, $IC^*_{01} = -C_0(AC_0^1 - AC_0^2) + C_1(B_0^1 - B_0^2) + C_2(V_0^1 - V_0^2)$ c)

b) Comparing between Model 2 and 3 reveals that Model 2 is better or worse than Model 3

if $P_2 - P_3 > 0$ or < 0

i.e. if $(C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 - (IC_0)) - (C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 - 2*(IC_0)) > 0$ or < 0

i.e. if $IC_0 >$ or $< IC^*_{02}$

Both are equally good if $IC_0 = IC^*_{02}$

Where, $IC^*_{02} = -C_0(AC_0^2 - AC_0^3) + C_1(B_0^2 - B_0^3) + C_2(V_0^2 - V_0^3)$

c) As far as the selection between **Model 3 and 1** is concerned, one should adopt **Model 3** in preference to **Model 1**

if $P_3 - P_1 > 0$ or < 0

i.e. if $(C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 - 2*(IC_0)) - (C_0AC_0^1 - C_1B_0^1 - C_2V_0^1) > 0$ or < 0

i.e. if $IC_0 >$ or $< IC^*_{03}$

Both are equally good if $IC_0 = IC^*_{01}$

Where, $IC^*_{03} = \dfrac{C_0(AC_0^3 - AC_0^1) - C_1(B_0^3 - B_0^1) - C_2(V_0^3 - V_0^1)}{2}$

4.3 Optimization of Number of Hot Standby Units with regard to Cost per visit of the repairman:

a) On comparing the profits of **Model 1 and 2**, we conclude that **Model 1** is better or worse than **Model 2**

if $P_1 - P_2 > 0$ or < 0

i.e. if $(C_0AC_0^1 - C_1B_0^1 - C_2V_0^1) - (C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 - (IC_0)) > 0$ or < 0

i.e. if $\begin{Bmatrix} C_2 < \text{ or } > C^*_{21} \text{ for } V_0^1 > V_0^2 \\ C_2 > \text{ or } < C^*_{21} \text{ for } V_0^1 < V_0^2 \end{Bmatrix}$

Both are equally good if $C_2 = C^*_{21}$

where $C^*_{21} = \dfrac{(C_0(AC_0^1 - AC_0^2) - C_1(B_0^1 - B_0^2) + IC_0)}{(V_0^1 - V_0^2)}$

b) Comparing between **Model 2 and 3** reveals that **Model 2** is better or worse than **Model 3**

if $P_2 - P_3 > 0$ or < 0

i.e. if $(C_0AC_0^2 - C_1B_0^2 - C_2V_0^2 - (IC_0)) - (C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 - 2*(IC_0)) > 0$ or < 0

i.e. if $\begin{Bmatrix} C_2 < \text{ or } > C^*_{22} \text{ for } V_0^2 > V_0^3 \\ C_2 > \text{ or } < C^*_{22} \text{ for } V_0^2 < V_0^3 \end{Bmatrix}$

Both are equally good if $C_2 = C^*_{22}$

where $C^*_{22} = \dfrac{C_0(AC_0^2 - AC_0^3) - C_1(B_0^2 - B_0^3) + IC_0}{(V_0^2 - V_0^3)}$

As far as the selection between Model 3 and 1 is concerned, one should adopt Model 3 in preference to Model 1

if $P_3 - P_1 > 0$ or < 0

i.e. if $(C_0AC_0^3 - C_1B_0^3 - C_2V_0^3 - 2*(IC_0)) - (C_0AC_0^1 - C_1B_0^1 - C_2V_0^1) > 0$ or < 0

i.e. if $\begin{Bmatrix} C_2 < \text{ or } > C^*_{23}, \text{ for } V_0^3 > V_0^1 \\ C_2 > \text{ or } < C^*_{23}, \text{ for } V_0^3 < V_0^1 \end{Bmatrix}$

Both are equally good if $C_2 = C^*_{23}$

where $C^*_{23} = \dfrac{C_0(AC_0^3 - AC_0^1) - C_1(B_0^3 - B_0^1) - 2*(IC_0)}{(V_0^3 - V_0^1)}$

V. Conclusion

Four reliability models have been developed to decide as to how many hot standby units should be there for a system working with two operative units. The decision may be taken by finding the difference between profits with regard to parameter of interest like revenue per unit up time, cost of installing a hot standby unit, cost per visit of the repairman or any other parameter which the user of such systems wishes to be considered. Cut-off points of some parameters have been obtained to reveal as to when and which model is more beneficial than the other. Cut-off points of some other parameters of interest may also be obtained to arrive at a decision of adopting one of the four discussed models.

VI. References

[1] Goel, L.R. and P. Gupta (1983). Analysis of a Two-Unit Hot Standby System with Three Modes. Microelectronics reliability, 23(6), 1029-1033.

[2] Christov, C. and N. Stoytcheva (1999). Reliability and Safety Research of Hot Standby Microcomputer Signally Systems. Periodica Polytechnica SER-TRANSP. ENG., 27(1-2), 17-28.

[3] Rizwan, S.M., V. Khurana and G. Taneja (2005). Reliability modeling of a hot standby PLC system. Proc. of International conference on communication, computer and power. Sultan Qaboos University, Oman, 486–489.

[4] Parashar, B. and G. Taneja (2007). Reliability and profit evaluation of a PLC hot standby system based on a master slave concept and two types of repair facilities. *IEEE Transactions on Reliability*, 56(3), 534-539.

[5] Rizwan, S.M., V. Khurana and G. Taneja(2010). Reliability analysis of a hot standby industrial system. International Journal of Modelling and Simulation, 30(3), 315-322.

[6] Kumari, S. and R. Kumar (2017). Comparative Analysis of Two-Unit Hot Standby Hardware-Software Systems with Impact of Imperfect Fault Coverages. International Journal of Statistics and Systems, **12**(4), 705-719.

[7] Manocha, A., G. Tanеja, S. and Singh (2017). Stochastic and Cost-Benefit Analysis of Two Unit Hot Standby Database System. International Journal of Performability Engineering, 13(1), 63-72.

[8] Batra, S. and G. Taneja (2018).Optimization of Number of Hot Standby Units through Reliability Models for a System Operative with One Unit. Int. j. Agricult. Stat. Sci., 14(1),365-370.

08 Dr Sunil Kumari"Gender Perception towards Spiritual Health Seekers Satisfaction and Service Quality at Yog Gram, Haridwar Year 2019

MANAGEMENT INSIGHT

The Journal of Incisive Analysers

INDEXED WITH

SMS VARANASI
SCHOOL OF MANAGEMENT SCIENCES
VARANASI

Available online at : myresearchjournals.com

MRI Publications

Gender Perception towards Spiritual Health Seekers Satisfaction and Service Quality at Yog Gram, Haridwar

Management Insight
15(1) 37 - 41
DOI: https://doi.org/10.21844/mijia.15.1.5

Sunil Kumari*

Correspondence Email: jiyasunil17@yahoo.com

Abstract

Present study is evaluating gender perception towards treatment and service quality at Yog Gram. Gender is Independent variables categorised in male and female. Dependent variables are patient satisfaction and service quality. Study is based on formative scale and data is collected on deliberate sampling. Analysis is performed using software JAMOVI for computing t-test. Findings include there is significant difference found in the perception of spiritual health seekers satisfaction and service quality at Yog Gram.

Key words: Health, Seeker, Spiritual, Treatment

Introduction

Health is not only attained by physiological aspect but also spirituality, psychology and other factors are related to it are concerned. That's why muskurana (Smiling) and shukrana (Be thankful) are the two ornaments given by Yog Gram for being healthy. Enjoy with the concerns you are blessed with as well as thankful to god and everybody and everything made by almighty God. Are these spiritual therapies are related to patient satisfaction for male and females present in Yog Gram, is the research question to be answered in this paper.

Literature Review

Chatterjee and Ramu (2017) in a survey segues into a round table discussion with a distinguished set of women entrepreneurs, academics and scientists on the challenges to the participation of women in Indian innovation and entrepreneurship and how it could be facilitated. Kuamr and Mehrotra (2006) studied the requirement of health study related to complementary and alternative medicine (CAM) and checked the effectiveness of self-care ad found significant. Hasan, etal(2001) also found high recurrence of self-awareness using CAM in Malaysian was significant. Choi(2017) etal found conventional medicine was managing parallel form and was important in treatment. Farooqui (2016) studied on tumor patients and found that using local herbs were found useful with the treatment as they were claiming cure of sarcoma. Wazaify(2011). studied in Jordon and found herbal use among patients was found commendable. Also Qureshi(2016) estimated the presence of CAM use provided affirmative insolence towards CAM. Kumar, Mamidala Jagadesh(2017) laid impact of happiness with technology advancement. In A

*Assistant Professor, Government College Meham, Rohtak, Haryana

survey, Sharma and Prajapati and Tripathi (2018) presented a state of art over diverse attitudes engaging PM-QPSK skills for accomplishment as well as development of several ophthalmic concert rebukes. Arora M (2018) observed two types of customers. Consequently different profiles have been described. The obtained cluster groups in users are labelled as techno shrewdness and nonengrossed. The above literature review shows that there is gap to study on Gender Perception towards spiritual health seekers satisfaction and service quality at Yog Gram, therefore present study is intended to fill the research gap.

Research Methodology:

Paper is descriptive. Data used is primary and secondary. Primary data from patients based on structured questionnaire from males and females. Based on selective sampling sample size of 54 is enough as it covers about 25 per cent of population of about 200 patients available. Data analysis is done using open software JAMOVI. Cronbach alpha for internal consistency in statement, Mean, Standard deviation for analysis and t-test is used for validity of results at 5 per cent and 1 per cent level of significance.

Results and Discussions:

Cronbach's α results for patient satisfaction are .815 which shows internal consistency for statement is justified being >.60. also Cronbach's α for service quality is .860 calculated using JAMOVI also > .60.

Scale Reliability Statistics for Constructs

Constructs/Latent variable	Cronbach's α
Patient Satisfaction	0.815 (4 items)
Service quality	0.860 (4 items)

Subsequent table shows descriptive related patient satisfaction (PS), service quality (SQ) and Spiritual therapy (Spi).

Descriptives for patient satisfaction, service quality and Spiritual Treatment

	Gender	PS	SQ	Spi
N	Male	28	28	28
	Female	26	26	26
Mean	Male	4.15	3.94	4.25
	Female	4.09	3.88	4.28
Standard deviation	Male	0.853	0.436	0.658
	Female	0.840	0.668	0.676

From above table it is clear that male feels more patient satisfaction (Mean=4.15, SD=.853) than female respondents (Mean=4.09, SD=.840) , male feels more service quality at yog gram (Mean=3.94, SD=.436) than female respondents (Mean=3.88, SD=.668). But that female feels more spiritual treatment (Mean=4.28, SD=.676) than male respondents (Mean=4.25, SD=.658)

Patient satisfaction

Ps1:	I intend to continue coming to yog gram
PS2:	I have confidence in recommending yog gram to friends and relatives
PS3:	I resist influences for me to switch to other naturopathy centres
PS4:	Loyalty programmes will make me strongly connected to the yog gram

Descriptive for Patient satisfaction

	Gender	Ps1	Ps2	PS3	
Ps4					
Mean	Male	4.59	4.56	3.93	3.85
	Female	4.32	4.12	3.88	4.28
Standard deviation	Male	0.636	0.751	1.14	1.03
	Female	1.03	1.33	1.27	0

Independent Samples T-Test for Patient satisfaction

		statistic	df	p
Iintendtocontinuecomingtoyoggram	Student's t	1.158 [a]	52.0	0.252
Ihaveconfidenceinrecommendingyoggramtofriendsandrelati	Student's t	1.466 [a]	52.0	0.149
Iresistinfluencesformetoswitchtoothernaturopathycentre	Student's t	0.137	52.0	0.891
Loyaltyprogrammeswillmakemestronglyconnectedtotheyoggr	Student's t	-1.600	52.0	0.116

[a] Levene's test is significant ($p < .05$), suggesting a violation of the assumption of equal variances

Service Quality

My concerns are highly valued by yog gram
My treatment experiences with yog gram has exceeded my expectations
Environment at yog gram temperature, light were virtuous
The level of ICT applications in customer service at the yog gram are comprehensive

Independent Samples T-Test for Service Quality

		statistic	df	p
ThelevelofICTapplicationsincustomerserviceattheyoggra	Student's t	0.110	52.0	0.913
Environmentatyoggramtemperaturelightwerevirtuous	Student's t	-0.319	52.0	0.751
Mytreatmentexperienceswithyoggramhasexceededmyexpectat	Student's t	1.555	52.0	0.126
Myconcernsarehighlyvaluedbyyoggram	Student's t	1.050 [a]	52.0	0.299

[a] Levene's test is significant (p < .05), suggesting a violation of the assumption of equal variances

The independent sample t-test for service quality shows that there is no significant difference between opinion of male and female regarding the concerns are highly valued by Yog gram (p=.299), treatment experiences with Yog gram has exceeded the expectations(p=.751), Environment at Yog gram temperature, light were virtuous (p=.751) and The level of ICT applications in customer service at the Yog gram are comprehensive (p=.913) at 5 per cent level of significance therefore null hypothesis is accepted.

Correlation Matrix of spiritual treatment, overall transformation, patients satisfaction and service quality

		Overall	PS	SQ	Spi	Gender
	Overall Pearson's r	—	0.706 ***	0.187	0.757 ***	0.043

Correlation Matrix of spiritual treatment, overall transformation, patients satisfaction and service quality

		Overall	PS	SQ	Spi	Gender
	p-value	—	< .001	0.142	< .001	0.758
PS	Pearson's r		—	0.093	0.646 ***	-0.035
	p-value		—	0.467	< .001	0.800
SQ	Pearson's r			—	0.243	-0.055
	p-value			—	0.055	0.692
Spi	Pearson's r				—	0.016
	p-value				—	0.906
Gender	Pearson's r					—
	p-value					—

Note. * p < .05, ** p < .01, *** p < .001

Correlation matrix shows there is correlation between overall transformation and patient satisfaction which shows higher the patient satisfaction, higher will be overall transformation.

Also higher is the spiritual treatment, higher is the overall transformation. Results are also significant at 5 per cent and 1 per cent level.

Findings and Recommendations:

Male feels more patient satisfaction than female respondents, male feels more service quality at yog gram than female respondents but that female feels more spiritual treatment than male respondents. High degree of correlation is found between overall transformation and patient satisfaction which shows higher the patient satisfaction, higher will be overall transformation.

Also higher is the spiritual treatment, higher is the overall transformation. It is recommended that more patient satisfaction will lead to more overall transformation of health seekers so efforts should be made to know the satisfaction level of patients.

References

D.Kumar[a], S.Bajaj[a] R.MehrotraC Knowledge, attitude and practice of complementary and alternative medicines for diabetes, Public Health, Volume 120, Issue 8, , Pages 705-11, August 2006

http://yoggram.divyayoga.com/ accessed on 05-01-2019

https://www.who.int/news-room/detail/05-07-2018-low-quality-healthcare-isincreasing-the-burden-of-illness-and-health-costs-globally accessed on 05-01-2019

Kumar, Mamidala Jagadesh, Happiness and Technological Advances: Where are we heading? IETE Technical Review, Taylor & Francis, Vol 34, issue 6, pp 591-92, Nov 2017

Maryam Farooqui, Mohamed Azmi Hassali, Aishah Knight Abdul Shatar, Muhammad Aslam Farooqui, Fahad Saleem, Noman ulHaq Che NoriahOthman Use of complementary and alternative medicines among Malaysian cancer patients: A descriptive study Journal of Traditional and Complementary Medicine Volume 6, Issue 4, October 2016, Pages 321-326

Mayyada Wazaify, Fatma U.Afifi, MohammadEl-Khateeb, KamelAjloun, Complementary and alternative medicine use among Jordanian patients with diabetes, Complementary Therapies in Clinical Practice, Volume 17, Issue 2, May 2011, Pages 71-75

Sharma and Prajapati and Tripathi , Success Journey of Coherent PM-QPSK Technique With Its Variants: A Survey, IETE Technical Review, Taylor & Francis, Vol 1, Issue 20, Dec 2018, https://doi.org/10.1080/02564602.2018.1557569

Sulaiman Al-Eidi ab Salwa Tayel, Fatima Al-Slail, Naseem Akhtar Qureshi, Imen Sohaibani, Mohamed Khalil, Abdullah Mohammad Al-Bedah, Knowledge, attitude and practice of patients with type 2 diabetes mellitus towards complementary and alternative medicine, Journal of Integrative Medicine, Volume 14, Issue 3, May 2016, Pages 187-196

Chirantan Chatterjee ,, Swapnika Ramu (2017) Gender and its rising role in modern Indian innovation and entrepreneurship, IIMB Management Review (2018) 30, 62–72

Arora M (2018) Use of Digital Wallets- Cluster Analysis for Expectation and Voice Of The Customers, "Vimarsh - An Endeavour to Share Knowledge" Volume 9/Issue 2 July-December 2018.

ByungheeChoi, DongwoonHan, SeonsamNa, ByungmookLim Factors related to the parallel use of complementary and alternative medicine with conventional medicine among patients with chronic conditions in South Korea, Integrative Medicine Research Volume 6, Issue 2, June 2017, Pages 223-29

Syed ShahzadHasanSyed ImranAhmedNadeem IrfanBukhariWilliam Cheah WeiLoon, Use of complementary and alternative medicine among patients with chronic diseases at outpatient clinics,, Complementary Therapies in Clinical Practice Volume 15, Issue 3, August 2009, Pages 152-157

Farmers Attitude towards New Crop Insurance Scheme (PMFBY) [A Study of Sanghi Village of Rohtak District in Haryana, India]

Dr. Sunil Kumari, Assistant Professor, Govt. College Meham, Rohtak

Abstract

Present study aims at finding the effectiveness of new crop insurance scheme launched by Government in India, particularly at a village Sanghi in Rohtak district of Haryana. Success of any program depends upon the active participation of all stakeholders therein but how the Indian farmers take it, is ambiguous. Hence, the present study is an attempt to explore the perceptions and attitude of people engaged in agri business. Study is descriptive in nature which went through primary data collection via getting the questionnaire filled up from 100 households chosen on the basis of purposive sampling, making the content analysis using mean value index and testing the validity of results with the help of F-values to ensure the generalization of outcome. Study finds the majority of people aware of this scheme and thinking upon it rationally but their policy buying decisions are affected by multiple factors of which peer's influence is significant one.

Key Words: Agriculture, Risk, Crop Insurance, Farmers.

INTRODUCTION

The field of agriculture has been full of uncertainties in terms of yield as well as price volatility where a single natural calamity puts the farmers in a pitiable condition **(O Brien et al, 2004)** but announcement of PMFBY by Finance Minister Arun Jeitely in his budget speech (2016-17) seems to be a big changer for the life of Indian farmers. No doubt agriculture is a very risky venture and practically, a larger insurance premium would cover more risks. But, it is necessary to opt for optimum insurance **(Bastian, 1999).** It is a biggest attempt of Govt of India taken ever in de-risking this sector but it strikes the minds of researchers and throws a big question – could it be effectively implemented at ground level? Need of answer this question initiates the researcher to make a study on this topic. No doubt it is being taken a big move of Government to mitigate a big part of agri-risk, Agri minister Radha Mohan has called it a "Amrit Yojna" which also covers the post-harvest and localised crop losses like hailstones.

As we know that a major part of Haryana is a rural economy based on agriculture and village Sanghi of Rohtak district has always been active participatory in various fields such as politics, education, social issues etc. Thus researcher finds it interesting to know the attitude of the people residing in this village towards new crop

insurance scheme named Pradhan Mantri Fasal Bima Yojna. PMFBY mitigates the yield risk against the natural calamity which is attempt to transfer the anticipatory loss of agriculturists with the least premium offer (2% for kharif crops and 1.5% for ruby crops and 5% for horticulture & commercial crops) of all earlier crop insurance plans or programmes. It is also notable that today around 23% area of crops is insured under either of NAIS or MNAIS whereas new crop insurance plan targets to reach the level of 50%. **LITERATURE REVIEW**

Vast literature is available on insurance but on crop insurance it is limited of which few studies are as under:

Mamata Swain (2014) made a study on crop insurance for adoption to climate change in India analyzing the performance of NAIS and WBCIS on the basis of secondary data in the state of Odisha the climate change hot spot of India and revealed the WBCIS as a better plan than NIAS but it covers only losses of climate uncertainities.

Sabina Yasmin & C. Hazarika (2015) stated in his study that people of Kamrup village of Assam are very illiterate and not much aware of crop insurance scheme named Modified National Agricultural Insurance Scheme (MNAIS) which mark the scheme failed.

Mukesh. H.V (2015) revealed that the factors like access to loan, education, off-farm income, and region (based on nature of irrigation) in which a farmer is located have significantly influenced the adoption of crop insurance. Moreover, landholding-size, whether insured or non-insured, has depicted a positive influence on the income of farmers.

Tao Ye & Yangbin Liu (2016) carried out a survey of data for paddy rice farmers in Hunan Province, China. It shows that the sampled farmers' crop insurance perception was surprisingly low despite years of pilot programs and tens of billions of expenditure in government subsidies. The result of simultaneous equations model indicates that crop insurance perception and participation are simultaneously determined and mutually improving.

Being the agriculture a low profit potential has been unable to find attention from business point of view that's why only few studies have been made thereon and further different scholars with different outcome could not provide a uniform solution to reduce or transfer the risk involved therein which provides the scope to choose this subject for the purpose of study and bridges the gap lying in the literature.

OBJECTIVES OF THE STUDY

Present study focuses on analyzing the new crop insurance plan (PMFBY) in terms of farmers' view, perception and reaction.

RESEARCH METHODOLOGY

Target Population: Total number of 1705 families with the population of 9108 of which 4889 are males and 4229 are females as per census 2011 are living in the Sanghi village.

Sampling: 100 households have been chosen for the purpose of study where a household represents the collective opinion of a family determined on the basis of majority of the members thereof. Survey contains respondents' demographic as well as agricultural information, risk perceptions & management and rating to PMFBM.

Parameters of the Study: Five factors/ variables i.e. Education, Risk Management, Buying Decision, Perceived Premium and Perceived Value have been taken as parameters of the study to determine attitude of farmers towards PMFBY which further have been classified into different statements to get them rated by respondents at five point rating scale i.e. Strongly Agree, Agree, Indifferent, Disagree and Strongly Disagree. Further weights have also been given to each statement to include the subjective assessment of the researcher and reach the more concrete results.**Table I: Parameters of the stated variables**

Variables	Code	Statements
Education/ Awareness	E_1	I know about the Pradhan Mantri Fasal Bima Yojna.
	E_2	Government campaign for raising the awareness of new crop insurance plan is satisfactory.
	E_3	I am skilled in managing yield risk of my crop.
	E_4	I disseminate my view on new crop insurance plan to others.
Perceived Risk	PR_1	Agri-business is very risky and Agriculturists are risk averse.
	PR_2	Probability of variation in personal yield from country yield is high.
	PR_3	There is a lack of risk management tools available in India. NAIS, MNAIS, WBCIS and all other previous crop plans were not proved good.
	PR_4	PMFBY is able to mitigate the yield risk absolutely.
Perceived Influence	PI_1	I take my policy decision at my own rationality.
	PI_2	I prefer the advice of my friends and peers on purchasing the policy.
	PI_3	Premium is major concern in buying the policy.
	PI_4	I prefer to follow the advice of experts to invest in Risky Market Instrument.
Perceived Premium	PP_1	Premium to be charged under new crop plan is reasonable.
	PP_2	Variation in premium of different kinds of crops is justified.
	PP_3	Time interval of premium is appropriate
	PP_4	More premium covers more risk.
Perceived Value	PV_1	PMFBY indemnifies the fair value of loss to farmers.
	PV_2	New plan provides the ease of getting claim.
	PV_3	Claim settlement process is transparent.
	PV_4	Probability of recovery of compensation is fast.

Tools & Model Framework

Farmers' attitude has been measured in terms of their preference and factors affecting their perceptions which have been analyzed at two levels:

- **Ascertaining the level of effectiveness for individual parameters**.

The scores for the parameter are derived by multiplying the number of respondents with the respective score and its subsequent summing. Effectiveness index was calculated by applying the formula:

Actual scores obtained for the statement x 100

Maximum obtainable score for the statement

- **The overall effectiveness Index is calculated by using the formula:**

Top scores obtained for the seven parameters x 100

Sum of maximum scores obtainable for seven parameters

Overall index is taken as benchmark

Hypotheses: Following null hypotheses have been set regarding all stated variables:

H_1: Awareness has no impact on farmers' attitude towards PMFBY.

H_2: Perceived Risk has no impact on farmers' attitude towards PMFBY.

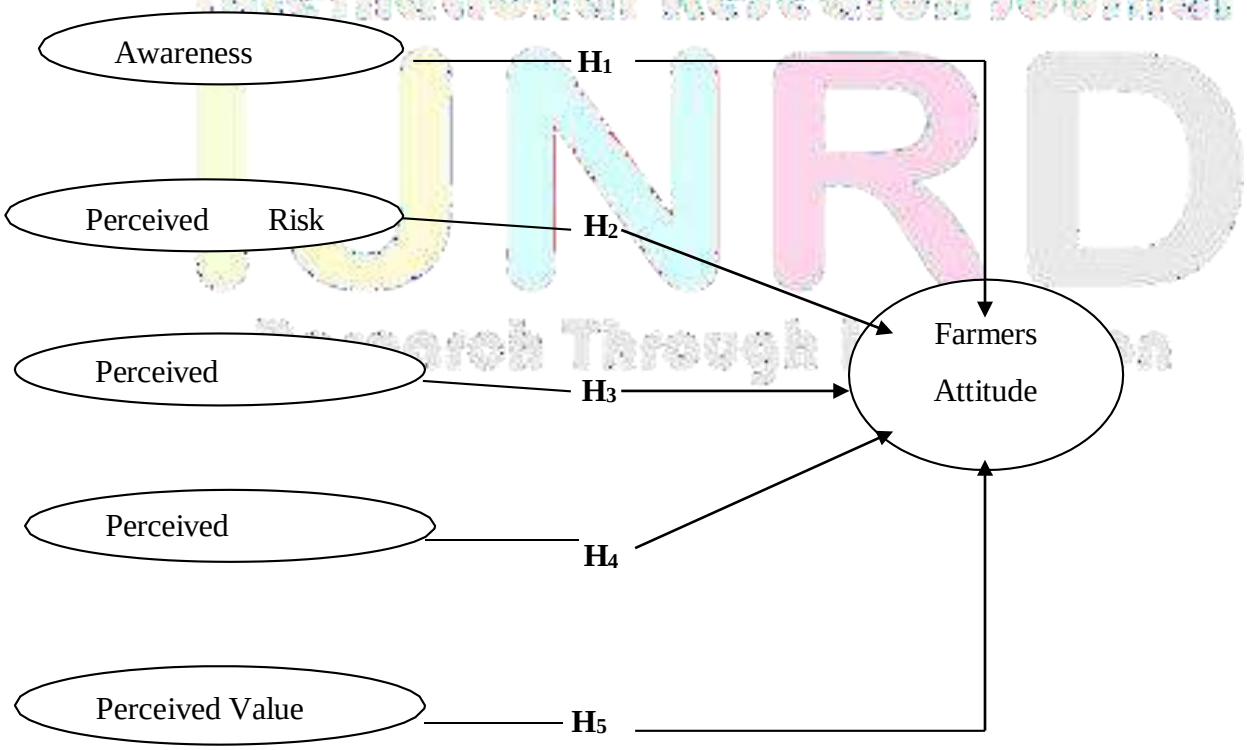
H_3: Perceived Influence has no impact on farmers' attitude towards PMFBY

H_4: Perceived Risk has no impact on farmers' attitude towards PMFBY.

H_5: Perceived Value has no impact on farmers' attitude towards PMFBY.

Following research model given in figure 1, has been developed to achieve the objectives of the study:-

Figure 1: Research Model



Where; Farmers Attitude is a dependent variable and Education, perceived Risk, Buying Decision, Perceived Premium and Perceived Value are independent variables. These five independent variables have been taken as determinants of intension to adopt the Pradhan Mantri Fasal Bima Yojna.

RESULTS & DISCUSSIONS

Results are to be discussed into two parts:

1. Parameter wise Analysis
2. Overall Analysis
3. Hypothesis Testing

1. **Parameter wise Analysis:** As selection of crop insurance scheme depends upon the various factors but here major 5 factors have been taken into account, in which so many other sub factors have been comprised of. Scores were gathered through survey at point rating scale and has been analyzed in table 2

Table 2: Parameter wise Farmers' Attitude

SN	Factors/ Variables	Strongly Agree	Agree	Not Agree	Disagree	Strongly Disagree	Mean Scores	Mean Index
1	Education/ Awareness	29	32	26	5	8	456	81
2	Perceived Risk	35	27	25	7	6	479	86
3	Perceived Influence	33	25	27	8	7	453	81
4	Perceived Premium	32	24	27	10	7	451	81
5	Perceived Value	33	30	22	10	3	470	84
	Overall Mean Index						2758	83

Table2 highlights that mean indices of two factors i.e. perceived risk and perceived value are 86 and 84 respectively that indicates that these are most influential factors in farmers attitude to PMFBY whereas other factors have almost similar scores in mean index that indicates their less consideration in adoption of crop insurance plan. This doesn't mean that except of two major factors don't affect the farmers' perceptions, as overall mean index is 83 and all variables' mean indices are near about this value, so they also have the impact on farmers' attitude. So all stated variables are determinants of farmers attitude of Sanghi village at Rohtak District in Haryana.

2. Overall Analysis (Correlation Analysis):

Table 3 shows the Pearson Correlation Analysis among all stated variables. Most of the correlations are significant.

Table 3: Pearson Correlation between Latent Variable

	EA	PR	PE	PP	PV
EA	1	0.109	0.035	0.187*	0.385**
PR	0.109	1	0.274**	0.004	-0.145
PE	0.035	0.275**	1	0.177*	0.191
PP	0.187*	0.004	0.177*	1	0.289**
PV	0.385**	0.125	0.191*	0.289**	1

*: Correlation is significant at the 0.05 level (2-tailed).

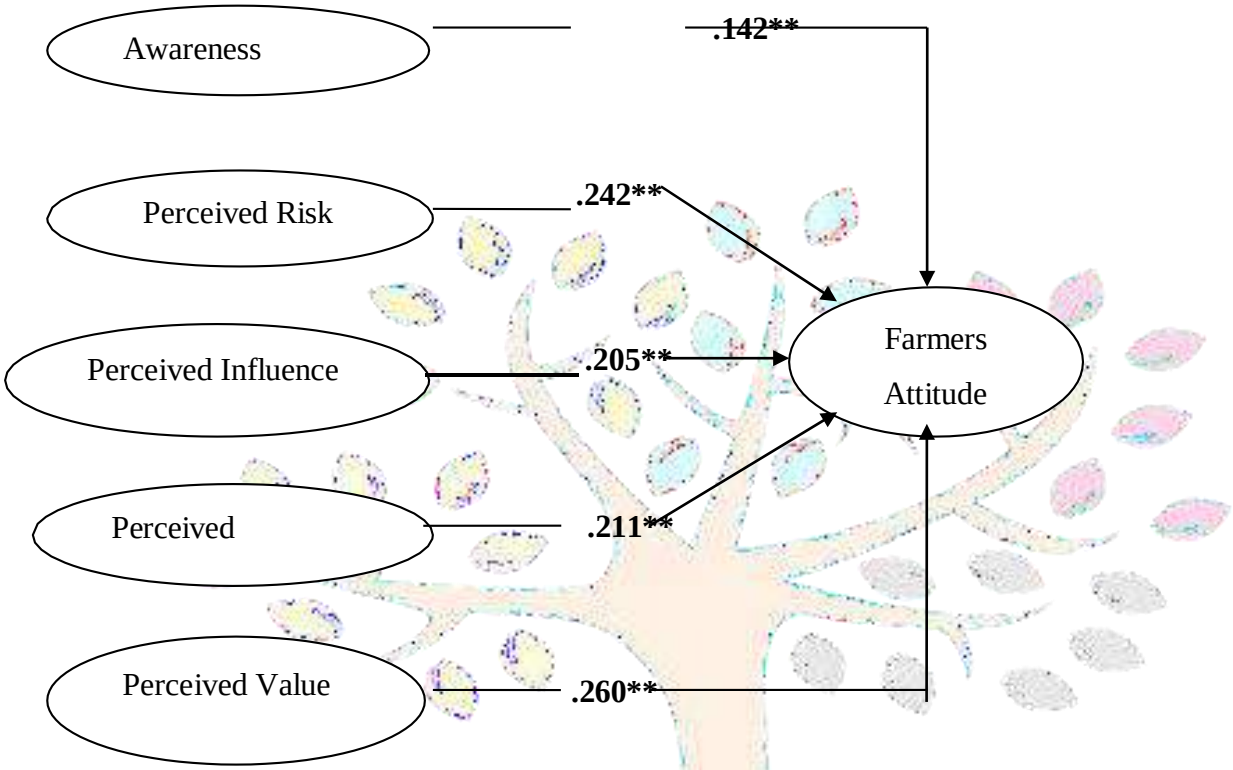
**: Correlation is significant at the 0.01 level (2-tailed).

With the integration of finance and psychological theories, it has been found that most of the stated variables i.e. awareness, perceived risk, perceived influence, perceived premium and perceived value are significantly correlated. Furthermore degree of correlation between awareness and perceived value of PMFBY is highest i.e. 0.385 whereas awareness and perceived risk are not found significantly correlated. Between risk and premium least amount of correlation has been traced.

Hypotheses Testing

Hypotheses have been tested with the help of regression results as shown in following figure;

Figure 2: Results of Hypotheses Tests (H1 to H5)



The values shown in figure2 are regression coefficients of stated variables which all are significant at 0.01 as well as .05 level which confirms that farmers attitude towards PMFBY is dependent on awareness, risk, others actions & decisions, premium and value creation of policy.

CONCLUSION

Study found the crop insurance to absorb the production risk effectively, encouraging the farmers to concentrate on a fewer number of profitable crops instead of spreading their resources and energy across many crops. In this way, it has acted as an incentive for specialization in agriculture. The crop insurance scheme has led to the use of high-value inputs like seed, fertilizer and plant protection chemicals. The insured farmers have realized more returns than their non-insured counterparts.

Farmers face constraints like tedious and time consuming procedure, non-availability of crop loan, lack of motivation and information from officials, etc. On the other hand, the agencies implementing crop insurance expressed that lack of staff, lack of coordination among them and hindrance to their routine functions were the major constraints.

Moreover, empirical evidence indicates that the impact of crop insurance participation on perception is slightly stronger than that of perception on participation, and thus provides weak evidence of a 'learning-by-doing' stage

in China at present. Together with evidence of substantial local disparities in perception, implications for the Chinese government in further cultivating the crop and rural insurance market are discussed.

References

1. Mamta Swain (2014); "Crop Insurance for Adaptation to Climate Change in India", Working Paper, LSE Asia Research Centre, Retrieved from http://www.lse.ac.uk/asiaResearchCentre/_files/ARCWP61-Swain.pdf
2. Yasmin Sabina & Hazarika C. (2015); "Status Awareness and Adaptability of Crop Insurance: A Case Study of Kamrup (Rural) District of Assam", International Journal of Humanities & Social Science Studies (IJHSSS), ISSN: 2349-6959 (Online), ISSN: 2349-6711 (Print), Volume-II, Issue-I, July 2015, Page No.316-321. Retrieved from https://www.ijhsss.com/files/Sabina-Yasmin.pdf
3. Mukesh. H.V (2015); "Impact of Crop Insurance on Indian Agriculture", GJRA - Global Journal For Research Analysis, Volume-4, Issue-4, April-2015 • ISSN No 2277 – 8160. Retrieved from https://www.worldwidejournals.com/global-journal-for-research-analysis-GJRA/file.php?val=April_2015_1429596999_136.pdf
4. Tao Ye, Yangbin Liu, et al (2016); "Farmers' crop insurance perception and participation decisions: empirical evidence from Hunan, China", Journal of Risk Research. Retrieved from http://dx.doi.org/10.1080/13669877.2015.1118151
5. Bhushan, C., & Kumar, V. (2017); Pradhan mantri fasal bima yojana: An assessment. Centre for Science and Environment, New Delhi.

ABBREVIATIONS

PMFBY: Pradhan Mantri Fasal Bima Yojna

NAIS: National Agricultural Insurance Scheme

MNAIS: Modified National Agricultural Insurance Scheme

WBCIS: Weather Based Crop Insurance Scheme

10. Dr Sunil Kumar" Corporate financial behavior towards global recession" Year 2018

20-12-18 **Ref No: ROGE-2019-1041**

Sunil Kumari
Assistant Professor, Govt. College, Meham (Rohtak), Haryana, India
Sanjay Nandal
Assistant Professor, IMSAR, MD University, Rohtak, Haryana, India

Re: 9th International Conference on Restructuring of the Global Economy (ROGE)
University of Oxford, UK
8th - 9th July 2019

Dear Author**,**
Your paper titled **''Corporate Financial Behavior towards Global Recession''** submitted for consideration for oral presentation at The **International Conference on Restructuring of the Global Economy (ROGE)** has been accepted for oral presentation based on the recommendation of the conference chair and external reviewers. **ROGE** utilizes a double-blind reviewing process for all papers and proposals. Your paper also will be published in the conference proceedings titled "**the Business and Management Review**", ISSN No-2047-2854.

Congratulations on your successful research efforts and thank you for making **ROGE** a platform for your research interests. Please note the following details:

1. **Conference venue**: **Saïd Business School, University of Oxford, Park End Street, Oxford, OX1 1HP.**
2. **Duration of the conference:** 8th - 9th July 2019 (2 days).
3. **Conference proceedings:** All accepted and registered full text papers will be included in the conference proceedings in both online and printed version while all abstracts will be included in the printed version. Conference proceedings is indexed by ProQuest & EBSCO Host.
4. **Conference registration fee**: £350 (registration as a single author).

If you have travel restrain and need special dates and times for your presentation, please let us know your preferred date and we will be happy to accommodate you. Conference details will be sent 2 weeks prior to the conference.

Please fill in the publication form and send it to us along with the registration fees within 10 working days after receiving the confirmation letter.

Yours faithfully,

Executive Chair
Academy of Business and Retail Management (ABRM)

Corporate financial behavior towards global recession

Sunil Kumari
Govt. Collge Meham (Rohtak), Haryana, India

Sanjay Nandal
IMSAR, MD University, Rohtak, Haryana, India

Keywords
CAPM, Stocks, Risk Analysis, Investment Decisions, Bayes Theorem

Abstract
Present study identifies the corporate financial behavior towards the global recession. Study explores how financial markets reacted to the economic downturn. Study reveals that old financial theories and models could not predict the worldwide recessionary conditions and were replaced by new financial concepts like behavioral finance, multi-factor & agent based modeling and non-trival probability etc. Financial mix was also redefined as per changing the priorities of investors during the global financial crisis. (G10, G11, G12, G13, G14, G15, G17 7 G18)

Introduction

In the history of human beings the kind of events, global financial recessions have been witnessed time to time and have a significant effect on the economic systems but generally we fail to predict them apparently and when they happen then we throw away our orthodox and move towards the new ways and approaches [Rudd Kevin, 2009]. Recently world has faced severe economic crisis during the year 2008-09 where even AAA rated securities didn't follow the Efficient Market Hypothesis and were found crashed [Jeremy J. Siegel, 2010]. Aftermath of various economic crises at global level, the term "Herd" is again on the edge of disapproval in financial literature [Bikhchandani, S. & Sharma, 2000]. Traditional financial theories have again been questioned during the period of global recession which needs to be incorporated the behavioral finance with the integration of various disciplines. Efficient market hypothesis gained a lot of dominance in 1970s but during the 1980s it couldn't predict the financial market behavior significantly. During 1990s the behavioral finance emerged as a research concept and various feedback theories were developed. Models of assessment of impact of smart money on investors were also designed in this era [Robert J. Shiller, 2003]. The global crisis in subprime mortgage bank loans in US, could have been better managed with the involvement of all stakeholders, investment fund managers, rating agencies, regulatory and monitoring authorities of financial and banking markets [Pezzuto, Ivo, 2008]. The fourth quarter which is the peak point of the global financial crisis, 2008 declined the rate of new loans to big borrowers by 47% in comparison to previous quarters in US [Victoria Ivashina, 2008]. Despite the innovative financial strategies of leveraging and funding, the banks couldn't reduce the systematic risks and financial instability in 2008 and they were titled as 'Old Wine in New Bottle' [Mah-Hui, Michael Lim, 2008]. Many of the financial firms which took rescue operations during the economic crisis became insolvent. This financial crisis is not last, it will happen again but in some other sort [Alan Greespan, 2009].

As we know, traditional financial theories have again been questioned during the period of global recession occurred in 2008. These theories have been failed to predict and address recent global financial crisis which has pushed to financial professionals and economists to rethink about financial theories to make their disciplines compatible with changing present scenario. No one can deny that there is a gap between theory and practice or there is a fundamental problem in finance theory itself. Even if the problems are only with the practice and not with the theory, finance academicians must revisit how financial theories can be renowned so that these problems do not reoccur. If there are problems in finance theory itself, then finance academics must reflect on the directions that finance research should take to redress these problems.

Now question arises what kind of change is required in finance mix/ theory to make it compatible with global economic slowdown. Need to answer this question initiated the researcher to make the study on this topic. This paper focuses on how finance theory needs to change to cope with global economic meltdown.

Literature review

Present study reviews the following previous studies made on global recession occurred at different time intervals.

Author, Year	Title of Research	Findings
John H. Cochrane, 1999	New Facts in Finance	CAPM explains the cause of variation in average returns of different stocks, assets, portfolios and funds etc. but not all investment options. So multi-factor models have been superseded to CAPM to explain it further in adequate manner. To infer the market expectations, price variables are used by the firms. Rewards for risk of recession, financial distress along with the risk of market fluctuations, are also offered by the financial marketers.
Burton G. Malkiel, 2003	The Efficient Market hypothesis and its critics	Stock markets are efficient and cannot be predicted precisely and accurately.
Ian M. McDonald, 2009	The Global Financial Crisis and Behavioral Economics	Traditional economics which is based on home-economics was not found enough to explain the financial crisis 2008-09. Behavioral finance has emerged as a predictor of market movements. Free market, self-interest approach based on rationality
J. Doyne Farmer & Duncan Foley, 2009	The economy needs agent-based modelling	Financial behavioral patterns are changing at global level. In micro-structure theories, agent-based modeling has been emerged as a necessity of the economies to enable them to predict the market behavior.
Jeremy J. Siegel, 2010	Efficient Market Theory and the Recent Financial Crisis	Efficient market hypothesis didn't work in the economic crisis 2008-09. This recession was not because of EMH. Efficient market hypothesis doesn't mean the prices are right and risk is none. EMH cannot be made responsible for this meltdown.
Schwaab, Bernd and Koopman, Siem et. Al, 2011	Systemic Risk Diagnostics: Coincident Indicators and Early Warning Signals	Study formulated a model to assess the financial system risk and with the help of this framework conterminous measures and predictors based on underlying macro-economic and credit risk constituents for the whole world were constructed. Study revealed that credit risk conditions can be segregated from macro financial fundamentals significantly in a continuous manner which can function as an alarming signal for wise macro- economic policy.
Andrew K. Rosea & Mark M. Spiegel, 2011	Cross-country causes and consequences of the 2008 crisis: Early warning	Study is based on cross sectional analysis of 107 countries. No common cause was found to the incidence of such severe economic downturn across the countries. Such negative findings disappointed the researcher.
Nicola Cetorellia & Linda S. Goldberg, 2012	Liquidity management of U.S. global banks: Internal capital markets in the great recession	Location wise pecking order theory was adopted by the parent banks to reallocate the liquidity in case of financing shock arisen in global economic downturn. From revenue point of view, more valuable affiliates to parent banks were prioritized in protection.
Eamon Duede and Victor Zhorin, 2016	Convergence of Economic Growth and the Great Recession as Seen from a Celestial Observatory	Study evidenced that the mechanisms driving the σ convergence couldn't work properly and recession started at global level. Macro-economic theories had massive effect on domestic as well as worldwide economic and social policies.
Troy Davig, & Aron Smalter Hall, 2017	Recession Forecasting using Bayesian Classification	Study uses the Naïve Bayes model which is closely connected to Markov's switching models and logistic regression with some significant differences as well, to predict the recession. It revealed that a very large asymptotic error rate was found in naïve Bayes Model, but it merges this error quicker than the logistic regression.

The available literature on global recessionary conditions and interpretations thereof, provides the scope to researchers to make a consolidated view of all studies to determine a new roadmap to predict and prevent such economic slowdown. The present study is purely based on the literature evidences and opinions of financial experts.

Objectives of the study

Present study aims at knowing the corporate behavioral change towards global recessionary conditions. It also examines the practical implications of financial models/ theories in worldwide economic crisis to explore the substitutes of traditional financial mix.

Research methodology

Present study is descriptive in nature which describes the implications of financial models applicable to the recessionary conditions. Study went through the review of various studies made on global meltdown along with the personal interviews of financial experts engaged in financial consultancy to the corporate; to draw some concrete results regarding to failure of prediction about the worldwide recession occurred. Study is based on following assumptions:

Preferences: It implies the risk preference. Generally, investors are found risk averse, but it is to be found whether it is time invariant or it varies with market conditions or trade cycles.

Probabilities: It implies the uncertainty in returns in terms of cash on investments which depends on the investors' prediction with precision and accuracy. Investors may have homogenous expectations or subjectively heterogeneous.

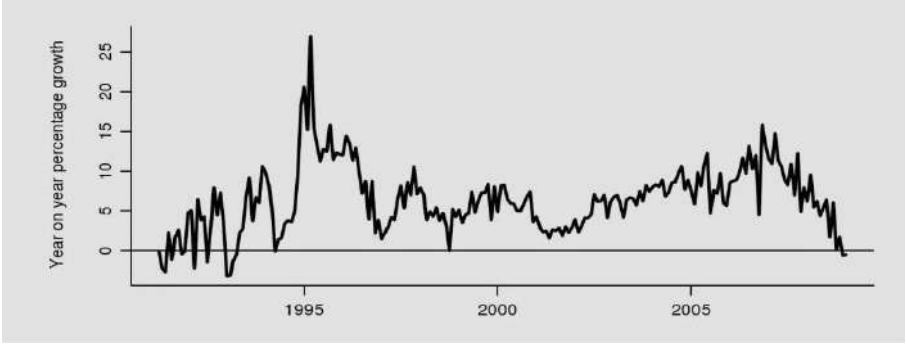
Prices: It implies the investment options with investors. Being the reaction of quotes and orders a very complex process, it is not necessary the price to be in equilibrium at every point of time.

Global recession in India & UK

A recession is a downward state of trade cycle which is officially declared by the National Bureau of Economic Research (NBER) for any economy. Economic activities in terms of real GDP, employment, income, industrial production and sales turnover (retail and wholesale both) get declined significantly. International Monetary Fund (IMF) which is global nodal agency of management of finance defines the global recession considering many aspects as if any of the economies keeps its growth rate equivalent or less than 3%, will be taken in global recessionary condition. As per this specified measurement here time periods i.e. 1990-93, 1998 and 2001-02 have been qualified as global economic slowdown.

Most of the countries have been got influenced by the global economic crisis stringently. America, Europe, and Japan faced a severe crises of liquidity as well as credit during the recessionary periods but India has not been insulated as much of it, Being the India a developing and rural based economy with a large untapped markets, running on cautious reforms, it has not been found much affected but it could not completely isolated itself from the recessionary impacts.

Figure 1: Economic downturn of Indian Economy



Source: http://www.nipfp.org.in

Table 1: Volatility of UK Macro Economics Variables during the Great Moderation Compared with 150-years Average

Variable	Volatility (1998-2007)	Volatility (1857-2007)
GDP growth (%)	0.6	2.7
Earnings growth (%)	0.5	6.4
Inflation (%)	0.9	5.9
Unemployment (%)	0.6	3.4

Source: Haldane (2009)

Results & discussion

On the basis of review of the various studies and opinions of financial analysts, it has been found that conventional financial theories could not indicate the early warning signal of the global meltdown in 2008 but the enterprises which adopted the behavioral finance models and new theories to cope with changing patterns of the markets were found least affected by such worldwide recession. Results of the study have been presented in following table:

Table 2: Move of Financial theory during Global Recession

	Aspects of Finance Theory	Move during Global Recession	Substitution in Global Recession
	Efficient Market Hypothesis	Irrational investment decisions	Behavioral Finance
	Factor Models	Inadequacy of CAPM	Multi-Factor Model
	Liquidity	Micro has become macro!	Systemic Risk- non diversifiable risk
	Risk Free Rate	Mere a useful approximation	Overnight Index Swap
	Microstructure theories	Heterogeneous Players	Agent–based Modeling
	Tail Risk – Real Risk	Non-linear dependence	Quantitative models based on non-Gaussian fat-tailed distributions
	Econometrics	Several possible regimes	Non-trivial Probability

Global recession has opposed the two aspects of Efficient Market Hypothesis (EMH). Burton G. Malkiel (2003) clearly stated that first aspect is that there is no free lunch means it is not possible to beat the market in risk adjusted terms. During recession low-risk, high return investments turned out to be high-risk that failed the EMH. Second aspect is that prices are "right" in the sense that they reflect fundamentals. The economic slowdown has also denied this claim. Many prices were clearly not right.

Global Recession has proved that CAPM should be substituted by Fama-French three-factor model and it should be taken as core financial model in prediction of market behavior. Further finance analyst should go beyond even to reflect liquidity as an overt risk aspect.

Most of the studies depicted that during the global meltdown, liquidity risk has been identified as a systematic risk that cannot be diversified. The second important aspect is that there is key relationship between funding liquidity and market liquidity, both were found deeply connected. As it is well known that market liquidity is related to microstructure of markets whereas funding liquidity is associated with macroeconomics. It shows that how suddenly micro has turned to macro.

After worldwide economic downturn Overnight Index Swap (OIS) has been regarded as a thing very closely associated to the risk-free rate of return. It is supposed that high credit rated entities have very low (negligible) probability of being defaulter over a one-day time span. Its front runs to a very popular two curve discounting model. Hence the usefulness of risk-free rate of return should be taken only in approximation.

Financial behavioral patterns are changing at global level. In micro-structure theories, agent-based modeling has been emerged as a necessity of the economies to enable them to predict the market behavior. Agent based modeling permit arbitrary number of heterogeneous market players having diverse information sets, dealing approaches, and purposes. If it is taken correct that microstructure theories are capable to understand the portents at macro stage, then it becomes essential to adopt agent-based modeling in finance theories.

Financial move in recessionary conditions have also explored that a large amount of tail risk doesn't depend on tail risks of assets individually but on ordinary jump and other conditions of non- linear dependency. Quantitative models which depend on non-gussian fat tailed distributions based on nonlinear structure have been suggested to apply. These models are hard but technical sound.

Risk models having Gaussian probability distributions along with linear correlation are now no longer defendable after witnessing the facts related thereto during global recession.

Before occurrence of this global meltdown, Great moderation had been accepted as a perpetual structural change in the global economy which signified permanently reduced volatility but this global crisis 2008-09 has compelled to review the statistical procedures in wholesomeness of probability of various policy regimes. Hence it should be taken that nontrivial probability of moving to a separate regime exits.

Conclusion

The global economic slowdown has caused the serious problems with the rejection of implications of traditional finance mix and theories. It seems that finance courses have not coped with the developments in finance theories in the last decade or more. Since late 1990s, finance theory had shifted to new multifactor Network models that are used in modern finance. In other words, change in finance teaching is required, a lot in comparison to change in finance theory itself. Interpretation of the various studies states that home-economics actions were found inconsistent with the prediction of the global crisis. This is the era of a large amount of innovations in financial markets and products where free markets and self-interest approach are taking place. Study also reveals that there are some aspects of finance which are required to be espoused in mainstream of new models in better manner. However, finance theory itself is upgrading with the incorporation behavioral finance which integrates the new ideas and insights from several other disciplines and models, but the this worldwide economic meltdown has depicted that sociological factors have significant impact on many financial phenomena. To achieve the optimized point of finance theory, not only sociology but finance professionals must incorporate newly evolved biology, neurosciences, financial antiquity, and the multidisciplinary arenas of network theory in finance. At the end, it can be said that in globalization and increasing complex world, finance theory must be converged with sophisticated mathematical models and statistical tools.

References

Bikhchandani, S. & Sharma, S. *IMF Econ Rev* (2000) 47: 279. https://doi.org/10.2307/3867650

Malkiel, Burton, G. 2003. The Efficient Market Hypothesis and Its Critics. *Journal of Economic Perspectives,* 17 (1): 59-82.

Jeremy J. Siegel (2010). Efficient Markets and the Financial Crisis. *Wall Street Journa*l, Oct. 28, 2009, p. A23.

Shiller, Robert, J. 2003. From Efficient Markets Theory to Behavioral Finance. *Journal of Economic Perspectives*, 17 (1): 83-104.

Pezzuto, Ivo, Miraculous Financial Engineering or Toxic Finance? The Genesis of the U.S. Subprime Mortgage Loans Crisis and its Consequences on the Global Financial Markets and Real Economy (October 7, 2008). *Journal of Governance and Regulation,* Volume 1, Issue 3, 2012. Available at SSRN: https://ssrn.com/abstract=2196577

Victoria Ivashina (2008). Bank lending during the financial crisis of 2008, *Journal of Financial Economics,* Volume 97, Issue 3, September 2010, Pages 319-338

Mah-Hui, Michael Lim (2008). Old Wine in New Bottles: Subprime Mortgage Crisis - Causes and Consequences (July 30, 2008). *Journal of Applied Research in Accounting and Finance (JARAF),* Vol. 3, No. 1, pp. 3-13, 2008. Available at SSRN: https://ssrn.com/abstract=1263280

Reinhart, Carmen M. and Kenneth S. Rogoff. 2009. The Aftermath of Financial Crises. *American Economic Review*, 99(2):466-72.

Schularick, Moritz and Alan M. Taylor. 2012. Credit Booms Gone Bust: Monetary Policy, Leverage Cycles, and Financial Crises, 1870-2008. *American Economic Review,* 102(2):1029-61

Eamon Duede and Victor Zhorin (2016). Convergence of Economic Growth and the Great Recession as Seen from a Celestial Observatory. Available at https://arxiv.org/pdf/1604.04312.pdf

Obstfeld, Maurice, Jay C. Shambaugh, and Alan M. Taylor (2009). Financial Instability, Reserves, and Central Bank Swap Lines in the Panic of 2008. *American Economic Review*, 99 (2): 480-86.

Berq, Nathan and Gigerenzer, Gerg (2010). As-if Behavioral Economics: Neoclassical Economics in Disguise? MPRA Paper No. 26586.

Beshouri (2006). A grassroot Approach to emerging- market consumers. *Mackinsey Quarterly 2006.* No. 4.

Buss, David M (2009). How can Evolutionary Psychology Successfully Explain Personality and Individual Differences? *Perspectives on Psychological Sciences,* 4(4), 359-366.

Jayanth R Verma (2011). Finance Teaching and Research after Global Financial Crisis. *Vikalpa. -The Journal for Decision Makers*, Volume 36, Number-4, Oct.-Dec. 2011, pg. no. 61-16.

Khan, Saeed Ahmed (2009). Recession and India - Impact on Indian IT Industry (November 16, 2009). Available at SSRN: https://ssrn.com/abstract=1506961 or http://dx.doi.org/10.2139/ssrn.1506961

Troy Davig, & Aron Smalter Hall (2017): Federal Reserve Bank of Kanas City; Research Working Papers; Recession Forecasting using Bayesian Classification, ISSN 1936-5330, August 2016; Revised February 2017, RWP 16-06, https://dx.doi.org/10.18651/RWP2016-06

Rudd, Kevin. The Global Financial Crisis [online]. Monthly, *The Feb 2009*: 20-29. Availability: <https://search.informit.com.au/documentSummary;dn=610838417780601;res=IELAPA> ISSN: 1832-3421. [cited 10 Feb 19].

John H. Cochrane (1999). New Facts in Finance. NBER Working Paper No. 7169

Ian M. McDonald (2009). The Global Financial Crisis and Behavioral Economics. *Economic Papers*, Volume28, Issue3, September 2009, Pages 249-254

Andrew K. Rosea & Mark M. Spiegel (2011). Cross-country causes and consequences of the 2008 crisis: Early warning. *Japan and the World Economy,* Volume 24, Issue 1, January 2012, Pages 1-16

Nicola Cetorellia & Linda S. Goldberg 2012 Liquidity Management of U.S. global banks: Internal capital markets in the great recession. *Journal of International Economics,* Volume 88, Issue 2, November 2012, Pages 299-311

J. Doyne Farmer & Duncan Foley (2009). The economy needs agent-based modeling. *Nature,* volume 460, pages 685–686 (06 August 2009)

Schwaab, Bernd and Koopman, Siem Jan, Systemic Risk Diagnostics: Coincident Indicators and Early Warning Signals (April 4, 2011). *ECB Working Paper No. 1327*. Available at SSRN: https://ssrn.com/abstract=1802346

Kashyap Pradeep & Raut (2005). *Rural Marketing Book*. Biztantra Publication, New Delhi.

Langnau, Alex (2010). *A Dynamic Model for Correlation. Risk*, April, 74-78.

Ravindranath V. Badi & Naranyansa V. Badi (2004). Rural Marketing", Himalaya Publishing.

The Indian Economy Blog

http://en.wikipedia.org/wiki/Global_recession

http://www.oppapers.com/essays/Rural-Marketing/273291

http://business.mapsofindia.com/rural-economy/state-development/marketing.html

11. Dr.Bhupender Singh "Development of Nuclear Energy in India -An Analytical study" Year 2019

Certificate of Publication

is awarded to

भुपेन्द्र सिंह

for the paper titled

भारत में परमाणु ऊर्जा का विकास: —एक विश्लेषणात्मक अध्ययन

Published in अक्सर Vol-13, Issue-04 Year 2019 ISSN: 22782338

International Refereed and Indexed Journal for Research Publication

With Impact Factor 5.2 UGC APPROVED journal Sr No. 41061

Index Copernicus Value (ICV) 100 & Indexed in Thomson Reuters

अक्सर (Akshar)
Available at www.aksharjournal.com
ISSN: 2278-2338
Volume 13 Issue 03
March 2019

भारत में परमाणु ऊर्जा का विकासः–एक विश्लेषणात्मक अध्ययन

भुपेन्द्र सिंह
सहायक प्राध्यापक (रक्षा अध्ययन विभाग)
राजकीय महाविद्यालय, महम,रोहतक (हरियाणा)

आज कृषि से लेकर यातायात तक के हर क्षेत्र में ऊर्जा खपत की असीम संभावना है। आज ऊर्जा खपत इतनी अधिकबढ़ गई है कि ऊर्जा प्रदान करने वाले संसाधन कम प्रतीत होने लगे हैं।आज जिस देश के पास जितने अधिक ऊर्जा संसाधन है वह उतना ही अधिक सम्पन्न है। ऊर्जा संसाधन की प्रचुरता देश के आर्थिक विकास में भी सहायक है, क्योंकिऊर्जा, उद्योग जगत की भी धुरी है। आज के वैश्विक युग में एक देश दूसरे देश को ऊर्जा स्थानांतरण कर अधिक मात्रा में धन अर्जित करते हैं। इसी तरह विदेशी मुद्रा अर्जन का भी यह एक साधन है। ऐसे में परमाणु ऊर्जा उत्पादन की तकनीक बहुत ही कारगर सिद्ध हो रही है। क्योंकि परमाणु संलयन व विखंडन की प्रकिया को नियंत्रित ढ़ंग से कराने पर अधिक मात्रा में ऊर्जा की प्राप्ति होती है।प्रस्तुत शोध–पत्र में भारत में परमाणु ऊर्जा संयंत्रों पर प्रकाश डाला गया है। इस शोध–पत्र का उददेश्य भारत में बिजली उत्पादन के क्षेत्र में परमाणु ऊर्जा के योगदान, निर्माण को दर्शाने का प्रयास किया गया है। प्रस्तुत शोध–पत्र में द्वितीय स्त्रोतों का प्रयोग करते हुए ऐतिहासिक तथा विश्लेषणात्मक शोध पद्धतियों का उपयोग किया गया है।

भारत में परमाणु युग के जनक सुप्रसिद्ध वैज्ञानिक डॉ0 होमी जहांगीर भाभा थे। 10 अगस्त, 1948 को भाभा की अध्यक्षता में परमाणु ऊर्जा आयोग कि स्थापना कि गई जिसका उददेश्य भारत में परमाणु ऊर्जा के क्षेत्र में अनुसंधान, विकास तथा अनुप्रयोग कार्यों का विकास करना था।परमाणु ऊर्जा के महत्व को ध्यान में रखकर भारतीय संविधान सभा में अगस्त 1947 को दिये गये भाषण में नेहरु जी ने कहा था– "हमें एटम बम तथा अनेक प्रकार की ऊर्जा शक्ति के बारे में बहुत कुछ सुना है....परमाणु बम और मानवता की भावना– इन दो बातों में आज संघर्ष विद्यमान है।मुझ आशा है कि भारत सभी भौतिक क्षेत्रों में निःसंदेह एक बड़ी भूमिका निभाएगा, वह सदैव मानवता की भावना पर ही बल देगा।" शान्तिपूर्ण परमाणु कार्यक्रम किस प्रकार विश्व में सामाजिक

ISSN: 2278-2338
Volume 13 Issue 03
March 2019

च आर्थिक रूप से लाभ पहुचा सकता है। इसकी व्याख्या अमेरिका के शस्त्र नियंत्राण एवं निःशस्त्रीकरण एजेन्सी ने निम्न शब्दों में की – परमाणु शक्ति का सबसे महत्त्वपूर्ण उपयोग मानव समाज के विकास के लिए ऊर्जा का उत्पादन करने में किया जा सकता है। भारतीय नाभिकीय विद्युत कार्यक्रम की शुरूआत 1960 के दशक में अमेरिका की सहायता से दो उबलते पानी रिएक्टरों की स्थापना के साथ हुई। यह एक तरह से भारतीय वैज्ञानिकों तथा प्रौद्योगविदों के इस क्षेत्र में तकनीकी एवं व्यावसायिक अनुभव दिलाने में महत्वपूर्ण सिद्ध हुआ। देश में उपलब्ध यूरेनियम तथा थोरियम के भंडारों के आधार पर भारतीय नाभिकीय विद्युत कार्यक्रम को त्रिचरणीय स्वरूप दिया गया है। इसके अन्तर्गत प्रचालित रिएक्टर क्षमता 6780 मेगावाट एवं निर्माणधीन, रिएक्टर क्षमता 6700 मेगावाट, जबकी 41800 मेगावाट के रिएक्टरों के लिए योजना बनाई गई है। 31 दिसंबर, 1947 में विद्युत उत्पादन की कुल स्थापित क्षमता 1362 मेगावाट थी जो अब बढ़कर 31 मार्च 2019 में 356100 मेगावाट हो गयी। प्रारम्भ में ही दीर्घ कालिन योजना के अंतर्गत डॉ. होमी भाभा ने तीन चरणों के भारतीय नाभिकीय विद्युत कार्यक्रम का साहसिक कार्य प्रारंभ किया, जिसके अंतर्गत यूरेनियम के सीमित एवं थोरियम के विशाल भंडारों का न्याय संगत उपयोग, दाबित भारी पानी रिएक्टर (PHWR) एवं तीव्र प्रजनक रिएक्टरों (FBR) के ईंधन चक्रों को संयुक्त करने के कार्य में किया गया। इस कार्यक्रम का महत्व दीर्घकालीन उद्देश्यों के लिए थोरियम का उपयोग एवं देश को स्वावलंबी बनाना था। नाभिकीय विद्युत कार्यक्रम के निम्न तीन चरण है:–

प्रथम चरण– दाबित भारी पानी रिएक्टर का निर्माण, जिसमें प्राकृतिक यूरेनियम का उपयोग ईंधन के रूप में तथा भारी पानी का उपयोग मंदक एवं शीतलक के रूप में करते है। इन रिएक्टरों में इस्तेमाल हुए ईंधन की पुनः प्रकिया कर प्लूटोनियम की प्राप्ति की जाती है।

द्वितीय चरण– द्रुत प्रजनक रिएक्टरों का निर्माण, जिसमें चरण–1 से उत्पन्न प्लूटोनियम का उत्पादन का उपयोग ईंधन के रूप में करते हैं। इन रिएक्टरों में थोरियम द्वारा यूरेनियम–233 का प्रजनन भी होता है।

तृतीय चरण– इन रिएक्टरों में यूरेनियम–233 एवं थोरियम का उपयोग ईंधन के रूप में करते हैं।

इन कार्यक्रमों पर आधारित, प्रचालित, निर्माणाधीन तथा स्वीकृति की प्रतीक्षा वाले रिएक्टरों से सम्बंधित जानकारी नीचे तालिका 1, 2 और 3 में दी गयी है:–

1. देश में परमाणु ऊर्जा के उत्पादन में कार्यरत् संयंत्रों का उल्लेख इस प्रकार है।

संयंत्र का नाम	इकाई	प्रकार	क्षमता	व्यवसायिक उत्पादन की तिथि
तारापुर नाभिकीय विद्युत संयंत्र,	01	BWR	160	28 अक्टूबर, 1969

ISSN: 2278-2338
Volume 13 Issue 03
March 2019

महाराष्ट्र				
तारापुर नाभिकीय विद्युत संयंत्र, महाराष्ट्र	2	BWR	160	28 अक्टूबर, 1969
तारापुर नाभिकीय विद्युत संयंत्र, महाराष्ट्र	3	PHWR	540	18 अगस्त, 2006
तारापुर नाभिकीय विद्युत संयंत्र, महाराष्ट्र	4	PHWR	540	12 सितंबर, 2005
राजस्थान नाभिकीय विद्युत संयंत्र, राजस्थान	1	PHWR	100	16 दिसंबर, 1973
राजस्थान नाभिकीय विद्युत संयंत्र, राजस्थान	2	PHWR	200	1 अप्रैल, 1981
राजस्थान नाभिकीय विद्युत संयंत्र, राजस्थान	3	PHWR	220	1 जून, 2000
राजस्थान नाभिकीय विद्युत संयंत्र, राजस्थान	4	PHWR	220	23 दिसंबर, 200
राजस्थान नाभिकीय विद्युत संयंत्र, राजस्थान	5	PHWR	220	4 फरवरी, 2010

ISSN: 2278-2338
Volume 13 Issue 03
March 2019

राजस्थान नाभिकीय विद्युत संयंत्र, राजस्थान	6	PHWR	220	31 मार्च, 2010
मद्रास नाभिकीय विद्युत संयंत्र, तमिलनाडु	1	PHWR	220	27 जनवरी, 1984
मद्रास नाभिकीय विद्युत संयंत्र, तमिलनाडु	2	PHWR	220	21 मार्च, 1986
कैगा नाभिकीय विद्युत संयंत्र, कर्नाटक	1	PHWR	220	16 नवंबर,2000
कैगा नाभिकीय विद्युत संयंत्र, कर्नाटक	2	PHWR	220	16 मार्च, 2000
कैगा नाभिकीय विद्युत संयंत्र, कर्नाटक	3	PHWR	220	6 मई, 2007
कैगा नाभिकीय विद्युत संयंत्र, कर्नाटक	4	PHWR	220	20 जनवरी, 2011
कुडनकुलम नाभिकीय विद्युत संयंत्र, तमिलनाडु	1	VVER-1000(PWR)	1000	31 दिसंबर, 2014
कुडनकुलम नाभिकीय विद्युत संयंत्र, तमिलनाडु	2	VVER-1000(PWR)	1000	31 मार्च, 2017
नरौरा नाभिकीय विद्युत संयंत्र, उत्तर प्रदेश	1	PHWR	220	1 जनवरी, 1991
नरौरा नाभिकीय विद्युत संयंत्र, उत्तर प्रदेश	2	PHWR	220	1 जुलाई, 1992
काकरापार नाभिकीय विद्युत	1	PHWR	220	6 मई, 1993

ISSN: 2278-2338
Volume 13 Issue 03
March 2019

संयंत्र, गुजरात				
काकरापार नाभिकीय विद्युत संयंत्र, गुजरात	2	PHWR	220	1 सितम्बर, 1995
कुल			6780 मेगावाट	

2. निर्माणधीन परमाणु ऊर्जा संयंत्रः–

संयंत्र का नाम	इकाई	प्रकार	क्षमता	अनुमानित व्यवसायिक उत्पादन की तिथि
मद्रास नाभिकीय विद्युत संयंत्र, भाविनि, तमिलनाडु	1	PHWR	500	2020
काकरापार नाभिकीय विद्युत संयंत्र, गुजरात	3 व 4	PHWR	1400	2022
गोरखपुर नाभिकीय विद्युत संयंत्र, हरियाणा	1 व 2	PHWR	1400	2022
राजस्थान नाभिकीय विद्युत संयंत्र, राजस्थान	7 व 8	PHWR	1400	2022
कुडनकुलम नाभिकीय विद्युत संयंत्र, तमिलनाडु	3 व 4	VVER-1000	2000	2026
कुल			6700 मेगावाट	

3. भारत में परमाणु ऊर्जा संयंत्रों की योजना (Under Planning):–

अक्सर (Akshar)
Available at www.aksharjournal.com
ISSN: 2278-2338
Volume 13 Issue 03
March 2019

संयंत्र का नाम	राज्य	इकाई	प्रकार	क्षमता
जैतापुर	महाराष्ट्र	1650*6	EPR	9900
कोव्वाडा	आंध्र प्रदेश	1100*6	AP1000	6600
केवली	आंध्र प्रदेश	1000*6	VVER	6000
गोरखपुर	हरियाणा	700*2	PHWR	1400
भीमपुर	मध्य प्रदेश	700*4	PHWR	2800
माही बासवाडा	राजस्थान	700*4	PHWR	2800
कैगा	कर्नाटक	700*2	PHWR	1400
चुटका	मध्य प्रदेश	700*2	PHWR	1400
कुडनकुलम	तमिलनाडु	1000*2	VVER	2000
मद्रास	तमिलनाडु	600*2	FBR	1200
तारापुर	महाराष्ट्र	300*1	AHWR	300
कुल				41800 मेगावाट

इस क्षेत्र में दीर्घकालीन आत्मनिर्भरता की प्राप्ति हेतु परमाणु ऊर्जा विभाग ने ईंधन की संरचना, जिरकोनिम मिश्रित अवयवों, रिएक्टर के परिशुद्ध अवयवों के उत्पादन एवं भारी पानी के उत्पादन के लिए सुविधाओं की स्थापना की। अंतर्राष्ट्रीय नाभिकीय मानकों के अनुसार विभिन्न उपसर्गों एवं अवयवों की पूर्ति एवं निर्माण के लिए उत्पादकों के विकास के लिए महत्वपुर्ण प्रयास किये गये।

भारतीय नाभिकीय विद्युत कार्यक्रम ने जनता से संबंधित हर क्षेत्र में दक्षता प्राप्त कर ली है जिसमें मुख्य सुरक्षा संबंधी एवं उच्च स्तरीय दीर्घ जीवन रेडियो सक्रिय अपशिष्ट का प्रबंधन है। नाभिकीय संस्थानों में उच्च सुरक्षा मानकों का अनुसरण किया जाता है, जो सामान्यतः अंतर्राष्ट्रीय संहिता के अनुरूप होते है। अपशिष्टों के व्यवहार से संबंधित सभी तकनीकी विषयों में दक्षता प्राप्त कर ली है। इन संयंत्रों के प्रचालन में अनेक कठीन अनुरक्षण गतिविधियों को भी स्वदेशी तकनीकी के जरिए सफलतापूर्वक पूरा किया गया।

हमारे स्वदेशी कार्यक्रम को बिना प्रभावित किये हुए नाभिकीय विद्युत के योगदान में वृद्धि

ISSN: 2278-2338
Volume 13 Issue 03
March 2019

की दृष्टि से विभाग ने विदेशी तकनीकी एवं लागत से नाभिकीय संयंत्रों की स्थापना के लिए भी प्रयास किया है। इसके अनुसार रूस की सहायता से 1000 मेगावाट की दो इकाईयों वी. वी. ई. आर. (VVER) प्रकार के रिएक्टरों ने 31 दिसंबर, 2014 व 31 मार्च, 2017 को व्यवसायिक उत्पादन शुरू कर दिया है। हमें वी. वी. ई. आर.–1000 (VVER-1000) की जो तकनीकी प्राप्त हुई है, वह अति आधुनिक तीसरी पीढ़ी की तकनीकी है, जो सिद्धांतों, लक्षणों एवं निर्माण में पश्चिमी अभिकल्पना के समरूप है। संयंत्र की अभिकल्पना सुरक्षा प्रणालियों के संदर्भ में अंतर्राष्ट्रीय व्यावहारिक प्रमाणकों के अनुरूप है। नाभिकीय विद्युत कार्बन डाई आक्साइड (CO_2) नाइट्रोजन डाई आक्साइड (NO_2) और सल्फर डाई आक्साइड (SO_2) नहीं छोड़ते है, जिससे ग्रीन हाउस प्रभाव अर्थात् पृथ्वी के तापमान में वृद्धि तथा अम्लीय वर्षा से पर्यावरण की रक्षा होती है।

भारत विवरण प्रदान करने की अंतर्राष्ट्रीय प्रणाली, अंतर्राष्ट्रीय नाभिकीय घटना परिमाण (INES) का पालन करता है और भारत का नाभिकीय ऊर्जा कार्यक्रम सुरक्षित एवं सस्ते पर्याय के रूप में न केवल देश की ऊर्जा मांग की पूर्ति के लिए परिपक्व है बल्कि तकनीकी के साहसिक निर्यात एवं विकास की त्वरित गति की तकनीकी सहायता भी प्रदान करने के लिए पूर्णतया तैयार है।

भारत के संदर्भ में भविष्य की ऊर्जा मांग बहुत अधिक है इसलिए ऊर्जा के विभिन्न स्त्रोतों के विकास की आवश्यकता है। लंबी अवधी के ऊर्जा प्रबंधन में नाभिकीय विद्युत को महत्वपूर्ण भूमिका अदा करनी होगी और 2050 तक कुल स्थापित क्षमता में कम से कम 25प्रतिशत भाग नाभिकीय विद्युत का होने का अनुमान है।

संदर्भ

1. डॉ0 प्रदीप कुमार यादव,"नाभिकीय शक्ति सम्पन्न भारत," राधा पब्लिकेशन्स, अंसारी रोड, दरियागंज, नई दिल्ली, 2014
2. डॉ0 विनोद कुमार पाल,"परमाणु सम्पन्न भारत," डिस्कवरी पब्लिशिंग हाऊस प्राइवेट लिमिटेड, अंसारी रोड, दरियागंज, नई दिल्ली, 2010
3. वैज्ञानिक पत्रिका, भाभा परमाणु अनुसंधान केंद्र के सौजन्य से प्रकाशित, जुलाई–सितंबर 1999, वर्ष: 24, अंक: 3

ISSN: 2278-2338
Volume 13 Issue 03
March 2019

4. वैज्ञानिक पत्रिका, भाभा परमाणु अनुसंधान केंद्र के सौजन्य से प्रकाशित, जनवरी–मार्च 1993, वर्ष: 24, अंक: 1
5. वैज्ञानिक पत्रिका, भाभा परमाणु अनुसंधान केंद्र के सौजन्य से प्रकाशित, जुलाई–सितंबर 1999, वर्ष: 31, अंक: 3
6. आउटलुक पत्रिका, नई दिल्ली, 19 जुलाई,2004, पृष्ठ–44
7. रंजीत कुमार, परमाणु बम रक्षा एवं राजनीति , किताब घर प्रकाशन, नई दिल्ली, 2000, पृष्ठ–104
8. http://www.tifr.res.in
9. http://www.vecc.gov.in/writeraddata/upload/files/grover_vecc_%20june2018pdf
10. http://en.wikipedia.org/wiki/nuclear_power_in_india
11. https://en.wikipedia.org/wiki/Electricity_sector_in_India
12. https://www.npcil.nic.in/content/Hindi/380_1_StatusOfProjectsUnderConstruction.aspx
13. https://www.npcil.nic.in/Content/Hindi/index.aspx
14. https://www.npcil.nic.in/content/Hindi/365_1_AllPlants.aspx

STUDENTS' PERCEPTION ON DIGITAL LEARNING DURING LOCKDOWN PERIOD IN INDIA: AN EMPIRICAL STUDY OF RURAL AND URBAN COMMUNITY

Miklesh Prasad Yadav
Assistant Professor, ACCF, Amity University Noida

Madhu Arora
Associate Professor, RDIAS, Delhi-110085

Sunil Kumari
Assistant Professor, Govt. College Meham, Rohtak, India

Sanjay Nandal
Assistant Professor, IMSAR, MDU Rohtak, India

ABSTRACT

The digital journey of learning has been of different perception to different community. We study the perception of students regarding online learning during lockdown period in three different communities of India i.e. rural, urban and metropolitan on the basis of survey of 411 students during lockdown period. Ten problem statements have been considered to be rated at Likert's Five Scale. To check the reliability, Cronbach's α, to analyze the data- mean & standard deviation and to validate the results t-test and Post Hoc Test have been used. It is concluded that majority of students have smart phones in urban and metropolitan but neutral to learning while rural students prefer the conventional leaning. This study contributes to the new theory of the efficacy of digital learning as mode of learning in and after lock down period that will bring the attention of educational agencies, faculty members as well as policy makers towards the problems faced by the students in digital learning.

Key words: Digital, Learning, Online, Teaching, Students, Lockdown.

INTRODUCTION

Education is inevitable thing which changes the world into something better. Everyone in this globe wants a good education to develop in them a perspective of looking at life. There are innumerable ways to get education and bring it in the learning process like physical presence (attending class in School/College/Institute) and online learning (remote). Majority of the students prefer physical presence in the classroom but this COVID-19 outbreak has now entrapped the whole world and compelled students to go through online mode of learning. But due to the less availability online facilities, students have not been able to grasp knowledge properly.

The online journey of learning has been of different perception to different community. The students of rural community have different opinion whereas the students of urban community have different perception.

As per world meter around 200 countries have got influenced by it. Corona havoc is rising day by day very speedily; consequently most of the affected countries even the territories therein, have announced the locked down. Economies are getting stagnant being stopped the all kinds of activities and movements. No doubt, digital media is emerging in a vital role in different modes in handling such lock down period of facing pandemic COVID-19 (Sachdeva, P., & Tripathi, D, 2019; Kabha, R., Kamel, A., Elbahi, M., & Narula, S., 2019 & Singh, P., 2019). Target vectors and educational technology are being affected by digital transformation of the economies in present scenario (Zakharova Nadezhda, Polyakov Kirill et.al.2019). Different states have started to ride on digital media to provide the online services. Every nation is trying to protect its primary and core field i.e. education from the effects of locked down. Hence, it has become the necessity of time to address the educational work stoppage due to corona crisis (Hindustan Times, 2020).

DOI: 10.31620/JCCC.12.20/10

However, majority of the nations haven't adopted a country wide school or college closure policies, it rests with local authorities. In context of India, the State Governments have declared the closure on extension basis (UNESCO, 2020).

During this critical condition, digital learning is evolving as a solution to the problem. Digital learning may be in various forms like Mobile Assisted Learning (MAL), Computer Assisted Learning (CAL), Technology Enhanced Learning (TEL), Computer Mediated Communication (CMC) etc. To pursue the distance teaching-learning process in digital form, India has announced a list of digital channels which could enable the students, teachers as well as researchers, an online learning platform in lock down, which includes SWAYAM, MOOCS, E-Pathshala, CEC-UGC U-tube Channels, Shodh Ganga, Vidwan, E-Shodh Sindhu etc. (MINISTRY OF EDUCATION, Govt. of India, 2020). Various apps are also being offered to be installed to access, upload or retrieve the e-content, of which "Zoom" is getting very popular to conduct the online classes via cloud technology. Further social networking systems like whatsapp, facebook, twitters, skype, U-tube etc. are also playing an eminent role in setting up the interactions between teachers and students. Virtual labs, digital library inflibnet, Google classrooms, Google forms and spoken tutorials etc. are also being recognized as effective means of knowledge transmission in digital mode. But how effectively these means are in tackling the present situation is researchable.

India, like many developing countries across the globe, is badly equipped to deal with what's to come. Having understood the insufficiency of digital faculty and in light of the many challenges being reported by parents and students across the country, the Ministry of Human Resources and Development launched a *"Bharat Padhe Online"* campaign on April 12, 2020 for crowd sourcing of ideas to improve the online education flora and fauna of India. However, it remains unclear as to which ideas will see light of day as the urban-rural education gap further widens amidst the looming COVID-19 crisis. This paper attempts to answer the question "Is there any significant difference in the perception of students residing in rural, urban and metropolitan area regarding online learning during lockdown period?"

The paper is categorized into five different sections including the present one. Section 2 discusses review of literature, section 3 presents research methodology, results and discussion and conclusion are provided in section 4 and section 5 respectively.

LITERATURE REVIEW

Rainie & Horrigan (2005) quoted that in all income groups whether it is low income or high, computers and internet access at high speed seem now everywhere in US ménages. Petri Nokelainen (2006) presented the pedagogical usability criteria and stated that theoretical aspect of how to design the digital learning content should also be considered equally important as technical one. To test the results of study, two samples- one of 66 students of 5th standard and second one of 74 students of 6th standards of elementary education, were taken under which students were given to evaluate one LMS and four LMs with PMLQ. Study found that the PMLQ was capable to apprehend the differences in the instructional usability profiles of the learning modules. Warschauer (2007) stated that curricular and pedagogic methodologies to educational technology, occur which can stand-in to improve the digital learning for all. Hidaayatullaah et.al. (2020) found the entire global educational arena including Indonesia, significantly influenced by COVID-19. Conventional learning has been shifted to digital mode of learning. Digital learning is not new one but it had gained the importance before this corona crisis to keep the pace with industrialization 4.0 and community 5.0. Mahalakshmi and Radha (2020) stated in their study that COVID-19 has accelerated the pace of "Digital India", an initiative of Govt. of India launched recently. The lockdown has collapsed the traditional teaching and learning system. However corona is worsening the entire globe but in spite of that it's a positive thing that it has promoted digital learning marvelously.

Crawford, Joseph, Butler-Henderson, et al. (2020) collected higher education responses on COVID 19, particularly of universities of 20 countries across the globe. On the basis of 172 secondary sources of information and found that all developed countries except US are

running online classes and have not declared the semester break. Majority of the developing nations are not in the position to run online classes due to lack of IT infrastructure, remote reach, skillsets, content availability etc. Moreover, the focus of organizations being closed, is shifting to online pedagogy. Revees et.al. (2020) stated that to assist the students in learning, business players can provide the online educational services partnered with the ministry of education through opening of the nationwide digital cloud classrooms.

Further, Eisenstein in 1979, Ong in 1982, Harvard Discussions in 1991, Winston and Attewell in 200, Chengyi Lin in Harvard Business Review 2020 and so many other studies or scholars have quoted the importance of digital learning and literacy earlier, whereas in present scenario, digital learning is gaining much more importance and seems the necessity of the hour. No previous study has focused on problems faced by the students on account of sudden adoption of digital learning. Hence the present study fills the research gap existing in the field of education with reference to present critical period of lock down. Referring the above detailed review of literature and research gap, following hypotheses are formulated:

H0: There is no significant difference in perception of students about online digital learning in Rural and Urban Area during lock down period.

H1: There is significant difference in perception of students about online digital learning in rural and urban area during lockdown period.

Research Methodology

Present study is descriptive in nature. Responses of a sample of 411 students selected from two states (Delhi, Haryana) through snow ball sampling technique were recorded by imparting structured questionnaire. got filled up in Google Form from focus group i.e. 411 students residing in two states -Haryana and Delhi during the lockdown period, selected on the basis of snow ball sampling. Ten problem statements have been taken to be rated at Likert's Five Scale. Reliability of data has been checked terms of Cronbach's α. Mean, Standard deviation, T-test and Post Hoc Test have been used to analyze the data. Jamovi software has been used for statistical computation and validation of results.

Results & Discussions

Reliability Analysis: This analysis checks the internal consistency of responses or data collected. The rule given by George and Mallery (2003) has been followed to interpret internal consistency output.

Table 1.1 Scale Reliability Statistics

	Mean	SD	Cronbach's α
Scale	2.91	.901	.837

Source: Authors' Calculations

Value of Cronbach's alpha is 0.837 with mean 2.91 and standard deviation 2.91 which shows statements have internal consistency as value of 0.70 or higher is considered good.

Table 1.2 Item Reliability Statistics

	if item dropped
Statement	Cronbach's α
I face problem in digital learning in lock down period as it is not user friendly	0.824
I face problem in digital learning in lock down period as difficult to learn than conventional offline learning	0.825
I face problem in digital learning in lock down period as it is difficult to understand	0.822
I do not have smartphone/laptop or device for digital learning	0.825
I do not have access to internet	0.819
I can't afford data package for digital learning	0.814
lack of Electricity/regular power supply is problem in digital learning	0.822
I feel problems in digital learning as I do not have smart phone	0.822
I feel problems in digital learning as it takes more time than traditional lecture	0.824
I feel problems in digital learning as I do not have knowledge how to use	0.826

Source: Authors' Calculations

Table 1.2 demonstrates the impact on internal consistency on statements if one item is dropped. It is obvious that all values are more than 0.70, so no single statement have extreme impact, all statements are normal.

Opinion of Students of Rural Area (N=208) states that they feel very few problems in digital learning due to not having smart phone (Mean=2.09, Standard Deviation=1.399, Standard Error=0.0970). Also students of

Table 2.1 Group Descriptive about Perception of Students in Digital Learning during Lock down Period

	Residence	N	Mean	SD	SE
I face problem in digital learning in lock down period as it is not user friendly	Rural	208	3.40	1.551	0.1075
	Urban	138	3.52	1.314	0.1118
	Metropolitan	65	3.37	1.219	0.1512
I face problem in digital learning in lock down period as difficult to learn than conventional offline learning	Rural	208	3.88	1.362	0.0944
	Urban	138	3.76	1.241	0.1057
	Metropolitan	65	3.86	1.236	0.1533
I face problem in digital learning in lock down period as it is difficult to understand	Rural	208	3.92	1.363	0.0945
	Urban	138	3.56	1.351	0.1150
	Metropolitan	65	3.46	1.324	0.1642
I do not have smartphone/laptop or device for digital learning	Rural	208	2.28	1.478	0.1025
	Urban	138	1.87	1.317	0.1121
	Metropolitan	65	1.54	0.969	0.1202
I do not have access to internet	Rural	208	2.51	1.516	0.1051
	Urban	138	2.09	1.293	0.1100
	Metropolitan	65	1.86	1.210	0.1501
I can't afford data package for digital learning	Rural	208	3.10	1.601	0.1110
	Urban	138	3.06	1.584	0.1348
	Metropolitan	65	2.12	1.386	0.1720
lack of Electricity/regular power supply is problem in digital learning	Rural	208	2.88	1.589	0.1102
	Urban	138	2.57	1.499	0.1276
	Metropolitan	65	2.29	1.331	0.1651
I feel problems in digital learning as I do not have smart phone	Rural	208	2.09	1.399	0.0970
	Urban	138	1.68	1.101	0.0937
	Metropolitan	65	1.62	0.963	0.1195
I feel problems in digital learning as it takes more time to understand than traditional lecture	Rural	208	3.71	1.426	0.0988
	Urban	138	3.57	1.323	0.1126
	Metropolitan	65	3.22	1.420	0.1761
I feel problems in digital learning as I do not have knowledge how to use	Rural	208	3.07	1.416	0.0982
	Urban	138	2.57	1.361	0.1159
	Metropolitan	65	1.85	1.228	0.1523

Source: Authors' Calculations

Observation states that Students of Rural Area (N=208) feel very few problems in digital learning in lock down period as it is not user friendly (Mean=3.40, Standard Deviation=1.551, Standard Error=0.1075). Also students of Urban Area have less problems of having smart phone (N=138), (Mean=3.52, Standard Deviation=1.1314, Standard Error=0.1118) and students of Metropolitan Area (N=65) feel very less problems in digital learning in lock down period as it is not user friendly (Mean=3.37, Standard Deviation=1.219, Standard Error=0.1512).

Urban Area have less problems of having smart phone (N=138), (Mean=1.68, Standard Deviation=1.101, Standard Error=0.0937) and students of Metropolitan Area (N=65) feel very less problems in digital learning due to? (Mean=1.62, Standard Deviation=0.963, Standard Error=0.1195). As in three cases mean is less than 3, it is observed that lack of smart phone is not an issue in any location now. Also Students of Rural Area (N=208) feel more problems in digital learning as takes more time to understand than traditional lecture (Mean=3.71, Standard Deviation=1.426,

Standard Error=0.0988) than students of Urban Area (N=138), (Mean=3.57, Standard Deviation=1.323, Standard Error=0.1126) and students of Metropolitan Area (N=65) feel less problems in digital learning (Mean=3.22, Standard Deviation=1.420, Standard Error=0.1761).

the perception of students in rural, urban and metropolitan location about problem in digital learning in lock down period as difficult to learn as conventional offline learning (F=.372, p value= .690) at 5 percent level of significance. Hence Null hypothesis (H0) is accepted. Also there is a significant difference in the perception of students in rural, urban

Table 2.2 One-Way ANOVA (Welch's) and empirical results about perception of students in digital learning during lock down period

Statements	F	P value	Decision Rule	Significant association
I face problem in digital learning in lock down period as it is not user friendly	0.448	0.640	H0 Accepted	No
I face problem in digital learning in lock down period as difficult to learn than conventional offline learning	0.372	0.690	H0 Accepted	No
I face problem in digital learning in lock down period as it is difficult to understand	4.520	0.012	H0 Rejected	Yes
I do not have smartphone/laptop or device for digital learning	11.356	<.001	H0 Rejected	Yes
I do not have access to internet	7.475	<.001	H0 Rejected	Yes
I can't afford data package for digital learning	12.480	<.001	H0 Rejected	Yes
Lack of Electricity/regular power supply is problem in digital learning	4.634	0.011	H0 Rejected	Yes
I feel problems in digital learning as I do not have smart phone	6.451	0.002	H0 Rejected	Yes
I feel problems in digital learning as it takes more time than traditional lecture	3.025	0.051	H0 Rejected	Yes
I feel problems in digital learning as I do not have knowledge how to use ?	23.136	<.001	H0 Rejected	Yes

Source: Authors' computations

About feeling more problems in digital learning Students of Rural Area (N=208) opine that they do not have knowledge how to use (Mean=3.07, Standard Deviation=1.416, Standard Error=0.0982) than students of Urban Area (N=138), (Mean=2.57, Standard Deviation=1.361, Standard Error=0.1159) and students of Metropolitan Area (N=65) feel less problems in digital learning (Mean=1.85, Standard Deviation=1.228, Standard Error=0.1523).

As table 2.2 states that there is no significant association in the perception of students in rural, urban and metropolitan location about problem in digital learning in lock down period as it is not user friendly (F=.448, p value= .640) at 5 percent level of significance. Hence Null hypothesis (H0) is accepted. Similarly there is no significant association in

and metropolitan location about problems in digital learning as they do not have do not have smart phone (F=6.451, p value< .002) at 5 percent level of significance. Hence Null hypothesis (H0) is rejected. Also there is a significant difference in the perception of students in rural, urban and metropolitan location about problems in digital learning as they it takes more time to understand the concept than traditional lecture (F=3.025, p value = 0.051) at 5 percent level of significance. Hence Null hypothesis (H0) is rejected. As a contrary there is a significant difference in the perception of students in rural, urban and metropolitan location about problems in digital learning as they do not have knowledge how to use (F=23.136, p value< .001) at 5 percent level of significance. Hence Null hypothesis (H0) is rejected.

Tukey Post-Hoc Test is a test to check the significant difference if categories are more than two. Hence three categories are students of rural area, urban area and metropolitan area. This test will show the results of rural area with urban area as well as rural area with metro Politian area. Decision rule is just like as earlier that accept the null hypothesis if not found significant and reject the null hypothesis if found significant.

Table 3.1 indicates that there is significant difference in perception of students about ? it is difficult to understand in rural area with metropolitan area As Mean difference is .364 in urban and .4615 in metropolitan respectively. T- Value is 2.46 in urban area and rural with in metropolitan area is 2.40. Hence value is more than 2 so significant difference is visible as p value is 0.038 with rural and Urban as well as p=0.044 in rural vs. metropolitan. Decision rule says null hypothesis is rejected. But looking at observation of Urban Vs. Metropolitan area there is no significant difference in perception of students about impact of online learning about it is difficult to understand as p value is 0.884. Null hypothesis is accepted.

Table 3.2 indicates that there is significant difference in perception of students about smartphone/laptop or device for digital learning with metropolitan area As Mean difference is .414 in urban and .745 in metropolitan respectively. T- Value is 2.78 in urban area and rural with in metropolitan area is 3.87. Hence value is more than 2 so significant difference is visible as p value is

Table 3.1 Tukey Post-Hoc Test – I face problem in digital learning in lock down period as it is difficult to understand

Residence	Statistics	Rural	Urban	Metropolitan	
Rural	Mean difference	–	0.365	0.4615	*
	t-value	–	2.46	2.400	
	df	–	408	408	
	p-value	–	0.038	0.044	
Urban	Mean difference		–	0.0964	
	t-value		–	0.474	
	df		–	408	
	p-value		–	0.884	
Metropolitan	Mean difference			–	
	t-value			–	
	df			–	
	p-value			–	
Significant level at 1 percent and 5 percent Note. * p < .05, ** p < .01, *** p < .001					

Source: Authors' Calculations

Table 3.2 Tukey Post-Hoc Test – I do not have smartphone/laptop or device for digital learning

Residence	Statistics	Rural	Urban	Metropolitan	
Rural	Mean difference	–	0.414	0.745	***
	t-value	–	2.78	3.87	
	df	–	408	408	
	p-value	–	0.016	<.001	
Urban	Mean difference		–	0.331	
	t-value		–	1.62	
	df		–	408	
	p-value		–	0.237	
Metropolitan	Mean difference			–	
	t-value			–	
	df			–	
	p-value			–	
Note. * p < .05, ** p < .01, *** p < .001					

Source: Authors' Calculations

0.016 with rural and Urban as well as p=0.001 in rural vs. metropolitan. Decision rule says null hypothesis is rejected. But looking at observation of Urban Vs. Metropolitan area there is no significant difference in perception of students about impact of online learning about smartphone/laptop or device for digital learning as p value is 0.237. Null hypothesis is accepted.

Table 3.3 indicates that there is significant difference in perception of students about do not have access to internet for digital learning with metropolitan area As Mean difference is .427 in urban and .653 in metropolitan respectively. T- Value is 2.78 in urban area and rural with in metropolitan area is 3.28. Hence value is more than 2 so significant difference is visible as p value is 0.016 with rural and Urban as well as p=0.003 in rural vs. metropolitan. Decision rule says null hypothesis is rejected. But looking at observation of Urban Vs. Metropolitan area there is no significant difference in perception of students about do not have access to internet for digital learning as p value is 0.533. Null hypothesis is accepted.

Table 3.4 indicates that there is no significant difference in perception of students about access to internet for digital learning with rural and urban area as Mean difference is .0430 in urban and .978 in metropolitan respectively. T- Value is .250 in urban area and. Hence value is less than 2 so no significant difference is visible as p value is 0.966 with rural and Urban and decision rule says null hypothesis is accepted but rural with in metropolitan area is t value is 4.40 as well as p=0.003 in rural vs. metropolitan. Decision

Table 3.3 Tukey Post-Hoc Test – I do not have access to internet

		Rural	Urban	Metropolitan	
Rural	Mean difference	–	0.427	0.653	**
	t-value	–	2.78	3.28	
	Df	–	408	408	
	p-value	–	0.016	0.003	
Urban	Mean difference		–	0.225	
	t-value		–	1.07	
	Df		–	408	
	p-value		–	0.533	
Metropolitan	Mean difference			–	
	t-value			–	
	Df			–	
	p-value			–	

Note. * p < .05, ** p < .01, *** p < .001

Source: Authors' Calculations

Table 3.4 Tukey Post-Hoc Test – I cant afford data package for digital learning

Residence	Statistics	Rural	Urban	Metropolitan	
Rural	Mean difference	–	0.0430	0.978	***
	t-value	–	0.250	4.40	
	Df	–	408	408	
	p-value	–	0.966	<.001	
Urban	Mean difference		–	0.935	***
	t-value		–	3.97	
	Df		–	408	
	p-value		–	<.001	
Metropolitan	Mean difference			–	
	t-value			–	
	Df			–	
	p-value			–	

Note. * p < .05, ** p < .01, *** p < .001

Source: Authors' Calculations

rule says null hypothesis is rejected. But looking at observation of Urban Vs. Metropolitan area there is a significant difference in perception of students about do not have access to internet for digital learning as p value is 0.001. Null hypothesis is rejected.

Table 3.5 indicates that there is no significant difference in perception of students about lack of Electricity/regular power supply is problem in digital learning with rural and urban area As Mean difference is .310 in urban and .583 in metropolitan respectively. T- Value is 1.85 in urban area and. Hence value is less than 2 so no significant difference is visible as p value is 0.153 with rural and Urban and decision rule says null hypothesis is accepted but rural with in metropolitan area is t value is 2.70 as well as p=0.020 in rural vs. metropolitan. Decision rule says null hypothesis is rejected. But looking at observation of Urban Vs. Metropolitan area there is a significant difference in perception of students about lack of Electricity/regular power supply is problem in digital learning as p value is 0.458. Null hypothesis is accepted.

Table 3.6 indicates that there is no significant difference in perception of students about problems in digital learning as it takes more time than traditional lecture with rural and urban area As Mean difference is .146 in urban and .496 in metropolitan respectively. T- Value is .958 in urban area and. Hence value is less than 2 so no significant difference is visible as p value is 0.604 with rural and Urban and decision rule says null hypothesis is accepted but rural with in metropolitan area is t value is

Table 3.5 Tukey Post-Hoc Test – lack of Electricity/regular power supply is problem in digital learning

Residence	Statistics	Rural	Urban	Metropolitan	
Rural	Mean difference	–	0.310	0.583	*
	t-value	–	1.85	2.70	
	Df	–	408	408	
	p-value	–	0.153	0.020	
Urban	Mean difference		–	0.273	
	t-value		–	1.19	
	Df		–	408	
	p-value		–	0.458	
Metropolitan	Mean difference			–	
	t-value			–	
	Df			–	
	p-value			–	

Note. * p < .05, ** p < .01, *** p < .001

Source: Authors' Calculations

Table 3.6 Tukey Post-Hoc Test – I feel problems in digital learning as it takes more time than traditional lecture

Residence	Statistics	Rural	Urban	Metropolitan	
Rural	Mean difference	–	0.146	0.496	*
	t-value	–	0.958	2.51	
	Df	–	408	408	
	p-value	–	0.604	0.033	
Urban	Mean difference		–	0.350	
	t-value		–	1.67	
	Df		–	408	
	p-value		–	0.217	
Metropolitan	Mean difference			–	
	t-value			–	
	Df			–	
	p-value			–	

Note. * p < .05, ** p < .01, *** p < .001

Source: Authors' Calculations

2.51 as well as p=0.033 in rural vs. metropolitan. Decision rule says null hypothesis is rejected. But looking at observation of Urban Vs. Metropolitan area there is a significant difference in perception of students about problems in digital learning as it takes more time than traditional lecture as p value is 0.217. Null hypothesis is accepted.

Table 3.7 indicates that there is a significant difference in feel problems in digital learning as I do not have knowledge how to use as it takes more time than traditional lecture with rural and urban area As Mean difference is .146 in urban and .496 in metropolitan respectively. T- Value is 3.34 in urban area and. Hence value is less than 2 so significant difference is visible as p value is .003 with rural and Urban and decision rule says null hypothesis is accepted also rural with in metropolitan area is t value is 6.27 as well as p< .001 in rural vs. metropolitan. Decision rule says null hypothesis is rejected. Again looking at observation of Urban vs. Metropolitan area there is significant difference in perception of students about feel problems in digital learning as I do not have knowledge how to use as p value is 0.002. Null hypothesis is rejected

major issue of digital learning mode but in case of understanding, rural students are more comfortable with traditional lectures as compared to urban and metropolitan students who are already in habit of getting digital lectures so earlier. Thus efforts are required to make the online content compatible to them. Similar results were found about the knowledge of how to use the smartphone or other digital media to access, retrieve and store the content. Hence it is also recommended that rural students should be made aware of how to use the digital media. Further, there is no significant association in the perception of students in rural, urban and metropolitan location about problem in digital learning in lock down period. Overall it can be concluded that more problems are being faced by rural area students in using digital media as a tool of learning as compared to the urban area and metropolitan area students. So, efforts should be made to enhance the efficacy of digital media as a tool of learning by providing practical exposure to the students about this media.

Limitations of the study and future scope

Data being collected via Google Form; the study could cover only those students who

Table 3.7 Tukey Post-Hoc Test - I feel problems in digital learning as I do not have knowledge how to use

Residence	Statistics	Rural	Urban	Metropolitan	
Rural	Mean difference	–	0.502	1.221	***
	t-value	–	3.34	6.27	
	Df	–	408	408	
	p-value	–	0.003	<.001	
Urban	Mean difference		–	0.719	**
	t-value		–	3.49	
	Df		–	408	
	p-value		–	0.002	
Metropolitan	Mean difference			–	
	t-value			–	
	Df			–	
	p-value			–	

Note. * p < .05, ** p < .01, *** p < .001

Source: Authors' Calculations

CONCLUSION

Many students have been found friendly to use of digital media of learning. Further there is no significant difference in this regard among the different groups i.e. rural, urban and metropolitan. Almost same results were found regarding to availability of smart phone. Hence the smart phone is also not a

were having smart phones and internet connectivity. This study examines the efficacy of digital learning as mode of learning in lock down period that will bring the attention of educational agencies, faculty members as well as policy makers towards the problems faced by the students in digital learning. Hence the findings of the study would be useful for the

students, faculty members, educational institutions and government as well. As now India has entered in lockdown phase 4.0, so in future, researchers may study the perceptions of other stakeholders like faculty members, management, parents and government etc. to add the value in existing literature in this regard.

REFERENCES

Abdul Razzak, N.(2020). Paulo Freire"s critical and dialogic pedagogy and its implications for the Bahraini educational context. Educational Philosophy and Theory (Article in Press). Retrieved from: https://doi.org/10.1080/00131857.2020.1716731

Abidah, A., Hidayatullaah, H. N., Simamora, R. M., Fehabutar, D., & Mutakinati, L. (2020). The Impact of Covid-19 to Indonesian Education and Its Relation to the Philosophy of "Merdeka Belajar". Studies in Philosophy of Science and Education, 1(1), 38-49. Retrieved from https://scie-journal.com/index.php/SiPoSE/article/view/9

Chengyi L. (2020). Coronavirus and Business: The Insights You Need from Harvard Business Review. Retrieved from file:///C:/Users/user/Downloads/HBR-corona.pdf

Chinmi, Maichel, Marta, RF., Haryono, CG., Fernando, J., Goswami, JK. (2020). Exploring Online News As Comparative Study Between Vendatu at India and Ruan Guru from Indonesia in Covid 19. Journal of Content, Community & Communication Amity School of Communication, 11(6), 167-176

Coronavirus: MINISTRY OF EDUCATION promotes digital platforms for students and teachers. Hindustan times. Retrieved from https://www.hindustantimes.com/education/coronavirus-outbreak-Ministry of Education-promotes-digital-platforms-for-students-and-teachers/story-oNsHUsNV7mUZpVKNIxgXXL.html.

Kabha, R., Kamel, A., Elbahi, M., & Narula, S. (2019). Comparison Study between the UAE , the UK , and India in Dealing with WhatsApp Fake News. Journal of Content, Community and Communication, 10, 176-186.https://doi.org/10.31620/JCCC.12.19/18

Mahalakshmi, K. & Radha R. (2020). COVID 19: A massive exposure towards web based learning. Journal of Xidian University. ISSN No.: 1001-2400. Volume 14, Issue 4, 2020, pg 2405-2411. https://doi.org/10.37896/jxu14.4/266

Michael Carrier, Ryan M. Damerow, Kathleen M. Bailey (2017). Digital Language Learning and Teaching: Research, Theory, and Practice. ISBN 9781138696815. Routledge, Oxfordshire, USA.

Nokelainen, P. (2006). An empirical assessment of pedagogical usability criteria for digital learning material with elementary school students. Interoperability of Educational Systems. Journal of Educational Technology & Society (April, 2006). Vol. 9, No. 2, pp. 178-197. Retrieved from https://www.jstor.org/stable/jeductechsoci.9.2.178

Sachdeva, P., & Tripathi, D. (2019). A Critical Education for 21st Century: A Study on Youth and Media literacy. Journal of Content, Community and Communication, 10(9). https://doi.org/10.31620/jccc.12.19/07

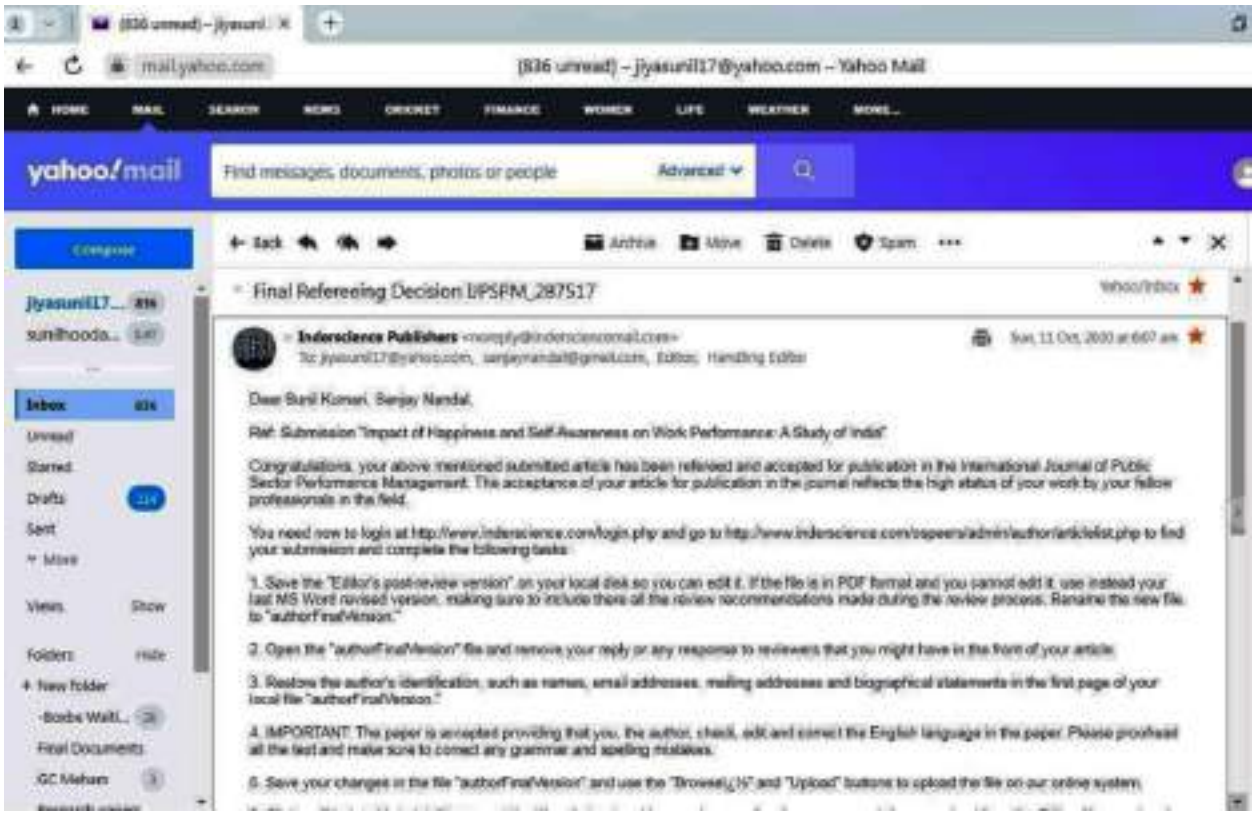
Singh, P. (2019). New Media as a Change Agent of Indian Television and Cinema: A study of over the top Platforms. Journal of Content, Community and Communication, 9(2019), 131-137. https://doi.org/10.31620/JCCC.06.19/18

The Jamovi Project (2019). Jamovi. (Version 1.0) [Computer Software]. Retrieved from https://www.jamovi.org.

Warschauer, M. (2007). The Paradoxical Future of Digital Learning. Learn Inq 1, 41–49. Retrieved from https://doi.org/10.1007/s11519-007-0001-5

Zakharova Nadezhda, Polyakov Kirill et.al. (2019). Developing key competencies in the digital economy for students in higher education. SPBPU IDE '19: Proceedings of the 2019 International SPBPU Scientific Conference on Innovations in Digital Economy. October 2019 Article No.: 2 Pages 1-6. Retrieved from: https://doi.org/10.1145/3372177.3372208

13. Dr. Sunil Kumari" Impact of Self Awareness and Happiness on Performance" Year 2020



Submission

Title: **Impact of Happiness and Self-Awareness on Work Performance: A Study of India**

Author(s): Sunil Kumari, e-mail: jiyasunil17@yahoo.com
Sanjay Nandal, e-mail: sanjaynandal@gmail.com

Paper submitted for the : International Journal of Public Sector Performance Management

Supplementary Files: None Add Supplementary File

Accepted Paper - Make sure to complete the following tasks:

Editor: Bhajneet Kaur <bhajneet.kaur@rdias.ac.in>

Editor/Author Comments <- Use this link to communicate with the Editor

Required Files and Tasks	Filename	Upload Date	Completed
Author's original submission	on-2020-287517.pdf	05/Apr/20	✓
Author's latest revised version	on-2020-287517-AV.pdf	04/Jul/20	✓
Editor's accepted version	on-2020-287517-EV.pdf	11/Oct/20	✓
Author's final version	on-2020-287517-CV.pdf	27/Jan/21	✓
Copyright Agreement(s)	on-2020-287517-CAF.zip	27/Jan/21	✓

Congratulations! You have completed all requested tasks. Now, your paper has been sent to copyediting, proofreading and typesetting, which are the final steps in this editorial process and are intended to catch and correct minor errors only, and to produce the final publishable PDF version of your paper.
If you have questions about the publishing progress of your article, contact your Journal Manager: Jenny Key < jkey@ielan.com >

14. Dr.Bhupender Singh "India's Security Challenges In Changing Globle Strategic Environment" Year 2020

India's Security Challenges in Changing Globle Strategic Environment-
Dr. Satish Kumar

1st Edition In India

ISBN - 978-93-89990-93-5

Published by
The Readers Paradise
103, 4787/23, Ansari Road,
Darya Ganj, New Delhi - 110002
09654444181
thereadersparadisesales@gmail.com

Price - 495.00
Pages - 138 | Paper - 80gsm | Size - 5.5x8.5

Typesetting by
Shri Sai Printographers

Cover Design by
Kamini, Daryaganj, New Delhi 110059

Printed in India
Balaji Offset, Naveen Shahadara, Delhi

INDIA'S SECURITY CHALLENGES IN CHANGING GLOBLE STRATEGIC ENVIRONMENT

Dr. Satish Kumar
Assistatt Professor, Defence Studies,
Govt. PG College,
Hisar

The Readers Paradise
New Delhi - 110002

5

India's Capability of Strategic Nuclear Triad

DR. BHUPENDER SINGH
Assistant Professor Govt. College,
Meham (Rohtak)

ABSTRACT

India and China fought a brutal short war in 1962. Nuclear power China is big threat to India's territorial integrity. China claims entire state of Arunachal Pradesh. Both India and China have developed their nuclear weapons at par with super powers in terms of destruction each of them can inflict. Pakistan with Chinese assistance still maintains decent quantity of nuclear delivery systems. India is not a signatory of the Non Nuclear proliferation Treaty as it believes that it could entrench the status quo of the existing nuclear weapons states. China too follows the same code of conduct when it comes to the nuclear weapons usage. But Pakistan's nuclear policy revolves around first use of nuke to protect itself from massive Indian Armed Force columns. So with its versatile nuclear neighbors Indian has to preserve its nuclear weapons from getting destroyed by enemy's first strike. Strategic Nuclear Triad is the ability of the country to launch nuclear weapons from Air, Land and Sea.

Keywords: Nuclear Doctrine, Nuclear Weapons, Nuclear Triad India-China Relations, Non Nuclear proliferation Treaty, Nuclear Explosion, Deterrence, Nuclear Triad

INTRODUCTION

India aspired to be a nuclear state after 1962 conflict with China, particularity after China conducted its first nuclear test in 1964. India carried out its first nuclear detonation a "peaceful nuclear explosion," on May 18, 1974. Since then this test has been mostly known as Pokhran-1 and it had demonstrated a yield of perhaps 12 Kilo Tons (kT). On May 11, 1998, India tested three devices at the Pokhran underground testing site, followed by two more tests on May 13, 1998. These tests include fission device with a yield of about 12 kT, a thermonuclear device with a yield of about 43 KT, and a sub-kiloton device.

India as a nuclear weapon state desires to hold 'minimum credible deterrence'. India has adopted a 'No First Use' (NFU) policy after the 1998 (Pokhran II) nuclear tests. Even though there will be no first-use of nuclear weapons by India as per the 1999 draft nuclear doctrine (a) any threat of use of nuclear weapons against India shall invoke measures to counter the threat and (b) any nuclear attack on India and its forces shall result in punitive retaliation with nuclear weapons to inflict damage unacceptable to the aggressor.

Nuclear Triad essentially has three major components the strategic bombers, Inter Continental Ballistic Missiles (ICBMs) and Submarine Launched Ballistic Missiles (SLBMs) for the purpose of delivering a nuclear weapon. The reason for having such three branched capability is to significantly reduce the possibility of the destruction of the entire nuclear architecture of the state in the first nuclear strike by the enemy itself. The triad provides the potency to the country which has been under the nuclear attack to respond swiftly by nuclear means. Such system essentially increases the deterrence potential of the state's nuclear forces. This triad fundamentally represents the three basic deliveries platform for nuclear weapons, such as system like Vertical Launch Systems (VLS), Transporter Erector Launcher (TEL), Rail-mobile launcher etc. for land based fighters and strategic bombers for air based and under water submarines for sea based US and Soviet Union understood the importance of an effective deterrent that could survive a surprise nuclear attack. This demanded the requirement of designing and developing accurate delivery systems which could be dispersed easily in case of an imminent attack or the one which could remain deployed in the high seas. Above discussion could be viewed as a backdrop for the foundation of a nuclear triad, essentially a structure to assure the massive second-strike capability and provide more 'teeth' to the deterrence.

STRATEGIC NUCLEAR TRIAD OF INDIA

India completed its nuclear triad with the commissioning of INS Arihant in August 2016. INS Arihant is a nuclear-powered ballistic missile submarine armed with 12 K-15 missiles with a range of 750 km, which will later be upgraded K-4 missiles with an extended range of 3500 km. In November 2017, it tested the BrahMos missile from the Sukhoi-30 MKI platform. India maintains a no first use nuclear policy and has been developing a nuclear triad capability as a part of its credible minimum deterrence doctrine. India's nuclear-weapons program possesses surface-to-surface missiles such as the Agni III and Agni IV. In addition, the 5,000–8000 km range Agni-V ICBM was also successfully tested beginning 19 April 2012 and is expected to enter service by 2019. India has nuclear-capable fighter aircraft such as the Dassault Mirage 2000H, Dassault Rafale, Sukhoi Su-30 MKI, MIG-29 and SEPECAT Jaguar. Land and air strike capabilities are under the control of Strategic Forces Command which is a part of Nuclear Command Authority.

1. Air Launched Nuclear Delivery System

The only nuclear weapon ever used during any war was dropped by using a bomber aircraft by the US Air Force against Japan. The Combat Fixed-Wing Aircraft are the second leg of 'Nuclear Triad' which is used for delivering nuclear weapon. In any theater of war, Aircraft offers immense flexibility to deliver conventional as well as nuclear weapons on the target. Ability of Aerial platforms to be reused for longer period of time and modern day avionics offers a variety of advantages for weapon delivery. The chief attributes for any aircraft to successfully deliver nuclear weapon on the target could be

1. Most reliable delivery of the weapon with nil margins for any form of error
2. Ability to penetrate defence and capability to engage

alternative targets, if required

3. All-weather, day and night capability

For the purposes of deploying a nuclear weapon it's enviable that the normal fighter bomber be able to cater for technological huddlers in terms of initial power and power-conditioning, method of weapon integration, and operational control and security. Essentially nuclear weapons are required to have specific attributes for aerial delivery on the target Weapon control systems desired to have inbuilt interlocks to formulate a system which could be made failsafe. Weapon release system should be designed in such a way that only after the code entry and corresponding to specific parameter the weapon is released on the target Additionally, modern aircraft which are capable of delivering nuclear weapon are equipped with fire arm systems which shield the avionics of aircraft from Electromagnetic pulse (EMP) generated by nuclear detonation. For detonation of a nuclear weapon considerable amount of electronic power is required which could be made obtainable with the munitions itself or by the aerial platform. Any nuclear weapon state would try to induct aircrafts offering following traits:

1. Air craft with the capability to increase its range
2. Accuracy of weapon delivery (modern day PGMs/JDAMs have inbuilt systems for this purpose and are guided by satellites)
3. Methods to mask or otherwise disguise flight signatures to detection networks (additional aircrafts would be part of nuclear attack mission employed in various roles like EW, ECM, ECCM etc)
4. Stealth capability and ability to undertake day and night tasks in all-weather condition situations.

India in collaboration with Russia is on the verge of coming up with 5th generation stealth fighter to be called as T-50 PAK-

FA. From all open sources from India and Russia, it has [illegible] indicated that India to shares 25 percent contribution [illegible] development of design. Being a 5th generation fighter, it [illegible] anticipated that aircraft will be able to deliver tactical nuclear weapon. Russia intends to operate at least 200 PAK-FAs, India 250 of the Indian 5th Generation Fighter Aircraft (FGFA) variant. Although, the avionics system provide all weather operating capability and day and night ability but system requires further up gradation. Apart from Su30s, the other Indian aircrafts which could deliver nuclear weapons include Mirage-2000H/TH (Vajra), Mig29K and Mig-27 (Bhadur). While Mig-27 is a vintage aircraft, others are under up gradation plans to next generation increasing its effectiveness and reliability. The Indian Air Force (IAF) successfully test-fired the BrahMos-A supersonic cruise missile from a Sukhoi Su-30MKI multirole fighter jet on November 22, 2017.

BrahMos was a joint venture between India's Defense Research and Development Organization (DRDO) and Russia's NPO Mashinostroyenia (NPOM). According to the India's Press Information Bureau (PIB), the successful test of the air-launched cruise missile "completes the tactical cruise missile triad," noting that the missile can now be launched from ground, sea, and air-based platforms. India's army and navy are already operating ground- and sea-launched variants, and the IAF is likely to receive the first deliveries of the air-launched version in next year's.

From the present indications, the IAF is unlikely to reach its target of 42 combat squadrons in the foreseeable future, for that would translate into about 900 fighters and is unlikely to be achieved, even if all ongoing procurement programmes reach their fruition on schedule. With a maximum of 272 Su-30MKIs, 126 and possibly 200 Rafales, 150 LCA Tejas', and all other combat aircraft that are available in 2015, the IAF cannot hope to get 900 modern fighters, as more than 30 per cent or

oximately 300 (MiG-21s and MiG-27s) of these would be hased out well before 2030.

2. Land Based Nuclear Delivery System

The main agencies responsible for development of this programme were India's Defence research Development Organization (DRDO) and Ordinance Factories. The purpose of the project was to develop strategic missiles into various categories. IGMDP has developed five missiles and their variants: Prithvi, Agni, Akash, Trishul, and Nag. On January 8, 2008 the DRDO has formally announced the successful completion of the IGMDP.

India in its early days were faced with many failures when it comes to Missile technologies. But today there are around 68 nuclear warheads which will be fitted on top of ballistic missiles. These are controlled by Indian Army units. Indian Missiles can be launched from missile silos and large vehicles. India's first nuclear capable missile was Prithvi. But it was much needed in its western war theatres against Pakistan. Today India posses world class Agni series missiles ranging from 750 kilometers to 5500 kms. India also developing a true intercontinental ballistic missile Agni-6. Which are expected to have range of over 8000 km to 10,000 km. With Agni-5 missiles India can target any part of China and with Agni-6 India's nuclear ambition will take shape as a major power in global politics. And these missile are to be fitted with MIRV. These Maneuverable Reentry warheads can target several targets with a single missile or multiple warheads targeting single city to nullify SAM systems and anti ballistic missiles systems. India and Russia developed Brahmos missiles which are considered as the world's most dangerous missile with the speed of mach 3 and accuracy of few cm these missiles can be used on enemy weapons industries or nuclear storage area. India after signing Missile Technology Control Regime (MTCR) has planed to increase the range of Brahmos from 300 km to

850 km. China voiced its concern over capabilities of this ... systems.

On November 7, the Indian Ministry of Defense announced that its Defense Research and Development Organization successfully test-fired the Nirbhay, an indigenous land-attack cruise missile. The Nirbhay was fired from the Integrated Test Range on Abdul Kalam Island off the coast of the southeastern province of Odisha. "The missile majestically cruised for a total time duration of 50 minutes, achieving the range of 647 km," the MoD said. The Nirbhay is capable of loitering, cruises at Mach 0.9, and is reported to have a range between 800 and 1,000 km. It carries a 300-450 kg conventional payload (high explosive, submunitions), but can also be fitted with a small nuclear warhead (<12 kT). The missile has previously been compared to the US RGM-109 Tomahawk and Russian SS-N-27 Klub cruise missiles. Following table provides some useful details in this regard.

Table 1: Source: See References No.7

Designation	Class	Payload	Range	Status
Agni-1	SRBM	Single warhead 1,000-2,500 kg	700-900 km	Operational
Agni-2	MRBM	Single warhead 15-250 kt	2,000-3,500 km	Operational
Agni-3	IRBM	Single warhead 2,000-2,500 kg	3,000-5,000 km	Operational
Agni-4	IRBM	Single warhead 15-250 kt	3,500-4,000 km	Operational
Agni-5	ICBM	1,500 kg	5,000-8,000 km	In Development
Prithvi 1	SRBM	Single warhead 1,000 kg	150 km	Operational
Prithvi 2	SRBM	Single warhead 500 kg	250-350 km	Operational

Prithvi 3	SRBM	Single warhead 1,000 kg	350-600 km	Operational
Sagarika / Shaurya	SLBM /Cruise Missile	Single warhead 2,500kg/1,000kg	700 km/3,500km	In Development
Dhanush	SRBM	Single warhead 1000-250 kg	350-750 km	Operational
BrahMos	Cruise Missile	Single warhead 200-300 kg	450-600 km	Operational
Nirbhay	Cruise Missile	Single warhead 200-300kg	1,000-1,500km	Operational

3. Sea Based Nuclear delivery system

Submarines carrying nuclear-armed ballistic missiles present a credible deterrent. Because of its stealth character, most of the world's military forces have a great difficulty in locating or destroying a quiet submarine. Ballistic missile submarines equipped with nuclear warheads, which are also called Submarine Launch Ballistic Missiles (SLBM), serve as the third and most important leg of the nuclear triad. The invisibility, mobility and flexibility of submarines offer both a reliable means of survival against an attack, and a first-strike capability – particular5rdxly given the type of the weapons they carry. The era of SSBN started during Cold War, when survival against nuclear attack for second strike was found crucial. Today, with most of the states following NFU status the need for the second strike capability is obvious hence SSBN form an important part of modern day nuclear dynamics. India is among the few countries who operates SSBM. A nuclear powered submarine which can launch ballistic missiles. Due to weapon restrictions on these game changing nuclear submarines India developed its own version of Ballistic missile submarines. The lead ship of India's Arihant missile submarines, the INS Arihant is a 6,000 ton vessel launched on July 26, 2009. Commissioned in August

2016, the INS Arihant has four vertical launch tube, which can carry 12 smaller K-15 missile or four larger K-4 missile. It has a submerged speed of 24 knots. Basically aimed at Chinese heart land. India also planning to build next class of SSBN which are considered to have larger nuclear power stations and will carry much longer ranged missiles in the K series family. Namely K-5. These missiles are expected to have range of more than 5000 km and can launch multiple warheads to target different cities on a single mission.

CONCLUSION

Modern day warfare is multidimensional warfare essentially fought by using weapon systems on land, sea and air. For a peninsular state like India which shares its boundaries with neighbors with nuclear-weapons complex, it is essential to remain prepared to fight a multidimensional war. India's nuclear deterrence mechanism should have strategic delivery platforms capable of mounting an attack using land, sea, and air systems. India is yet to possess a fully operational nuclear triad capability. However, above analysis indicates that India is making significant amount of efforts towards that direction and shortly should have its nuclear triad operational.

The weapon delivery platforms available with India's neighbors in some cases are bit superior while in some cases Indian platforms are better. It is important to note that for a nuclear weapon state more than the quantity and types of platform having a correct mix of platforms is very essential. It is important to have platforms which can match your adversary but, at the same time particularly in the context of nuclear weapons it is important to develop a system which matches with your doctrine. Nature of strategic targets envisaged and the nature and type of weapons the country is capable of producing would also dictate the states investments in the triad. It is also important to note that nuclear strategy can never be static and triad should

not be viewed as an end itself. Space is finding increasing acceptance as an additional dimension of warfare. It could be premature to talk of orbital weapons now but it is difficult to predict the future. There are laws to restrict any use of space for using WMDs; however that does not fully guarantee that strategic nuclear strike missions in future would not have a space based platform.

REFERENCES

1. "India's Nuclear Weapons Program - Smiling Buddha: 1974" Nuclear Weapon Archive.
2. Nuclear weapon In India, [www.fas.org], (Accessed on Dec.10, 2017)
3. https://en.wikipedia.org/wiki/Nuclear_triad#India
4. http://www. Nuclear security project.org/uploads/ publications/Indias_Nuclear_Doctrine.pdf, (Accessed Dec.10,2017)
5. WMD411 - Case Studies: "The New Triad Nuclear Threat Initiative". 2010-04-06, (Accessed Dec. 7, 2017)
6. MIT Paper "US Nuclear weapon safety and control" [www.web.mit.edu/gelliott/ Public/sts.072/paper.pdf], (Accessed Dec. 12, 2017)
7. Accessing Sukhoi PAK-FA,(http://www.ausairpower.net/APA-2010-01.html#7),(Accessed Dec.12, 2017)
8. https://en.wikipedia.org/wiki/List_of_missiles_by_country #India
9. "China copies Su-27 fighter may compete with Russia" - paper. RIA Novosti.
10. "Evolution of India's Missile development Programme", Complete development history can be read in this part of case study, by Wg. Cdr. Ajey Lele ,Vinod kumar and Gunjan singh (unpublished)
11. http://brahmos.com/content.php?id=10&sid=25, (Accessed December 12, 2017)

12. BALLISTIC MISSILES (http://missilethreat.com/missiles-of-the-world/), (Accessed December 10, 2012)

13. https://www.defencenet.in/indians-nuclear-weapons-delivery-systems-review/

14. https://defence.pk/pdf/threads/the-risks-of-pakistans-sea-based-nuclear-weapons.523353/

15. Perkovich, George, India's Nuclear Bomb : The Impact on Global Proliferation, (University of California Press, CA. 1999), p. 248-249.

16. Scott D. Sagan, "The Commitment Trap: Why the United States Should Not Use Nuclear Threats to Deter Biological and Chemical Weapons Attacks," International Security, vol. 24, no. 4 (Spring 2000), pp. 85 – 115.

17. Deter Biological and Chemical Weapons Attacks," International Security, vol. 24, no. 4 (Spring 2000), pp. 85 – 115.

18. Rajesh Rajagopalan, "Assured Retaliation: The Logic of India's Nuclear Strategy," in Muthiah

19. Alagappa, ed., The Long Shadow: Nuclear Weapons and Security in 21st Century Asia (Stanford, CA: Stanford University Press, 2008), pp. 188 – 214.

20. Air Chief Marshal N.A.K. Browne in an interview to a defence journal on October 7, 2013 at http://indiastrategic.in/topstories3054_IAF_transformation_happening_but_delay_on_MMRCA_is_worrying.htm (Accessed November 2, 2017).

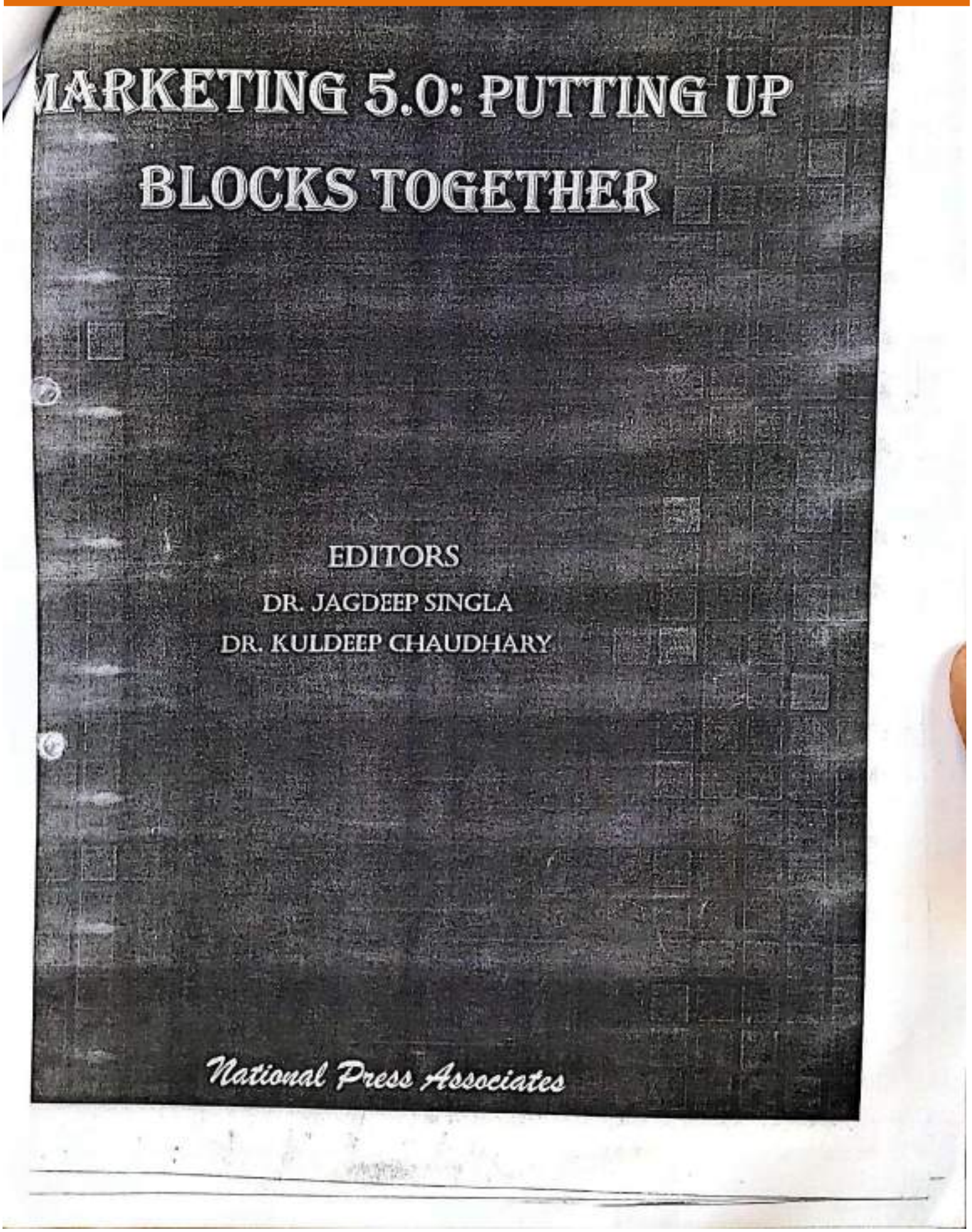
21. Hue Williams, Jane's International Defence Review, 43, June 2010, pp. 82-87.

22. http://idrw.org/india-militarys-most-powerful-weapons-that-make-it-a-force-to-reckon-with/ (Published August 15, 2017 Source: IBTIME)

23. https://missilethreat.csis.org/india-successfully-tests-brahmos-air-launched-cruise-missile/

24. https://missilethreat.csis.org/India-tests-nirbhay-cruise-missile/

15. Dr. Priyanka "Marketing 5.0: putting up blocks together" 2020



USTOMER ENGAGEMENT AND MARKETING STRATEGIES

*Dr. Karamvir Sheokand, **Priyanka
*Assistant Professor, IMSAR, M.D.U. Rohtak
**Assistant Professor, GC Meham

IER ENGAGEMENT

ing practice, customer is a person or a company who buy the products or service for consumption and it's ship of consumers with suppliers and clients. Customer engagement is connection between brand image of and

ers and it's a unique for businesses. For customer engagement, firstly acquire or attract the customer then em with product/ services after that retain or manage these customers with the brand; Netflix, Wendy's ocie Tilbury' are the best examples of the customer engagement. Loyal customers play impectant role in ner engagement. Loyal customers are those customers who buy the same brand products continuously other brands.Customer engagement is all about those activities which connect the customers with your t's a plan to increase the customer satisfaction by having repeatedly and positive way of communication customers and it can be possible by any way of connection like, emailing, repeated phone calls, social versation.

m has set a benchmark for customer engagement which attempt to fulfill the customer expectation and hem great values. Customer engagement improves the loyalty of consumers by delivering excellent services and personalized the experiences of customers in brand creation. When a business starts to invest ier engagement process and thought it reflects in the boost revenues, high level of customer satisfaction y in competitive environment it helps company to create business discrimination, attract more and more s. In deeper sense, customer engagement strategy implementation is not possible without a brand and its s totally based upon the base foundation of each and every organization.

superiority of your customer relation is also impact how your current user recommend the product to their ember, friends & other peer groups. WOM is an essential source for reference for small and medium Management of customer engagement is become necessity of today's digital business environment; to hese thing marketers have to adopt some strategy like,

Marketers should personalize the communication with each and every customer,
Customer's previous experiences,
Brand's humanization,
Get feisty on social media,
To know the line where your product stands,
Provide useful content and value
Listen carefully what people talking about your brand

gement and creation of interest of the buyer's marketers need to understand the marketing mix in this way buyer as well as marketers are aware about the solution of the problems of buyer, cost, convenience and ication. All these things can be possible with the help of marketing strategies; **Marketing strategy**refers to activities which are requires attracting or connecting the prospective consumer and turning them into loyal a. It focuses on the brand value of the company, customer's demographics and other elements.

O TRACK CUSTOMER ENGAGEMENT

e some strategies which work for customer engagement, it's depends upon marketers that which one is used

International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958,Volume-10 Issue-4, April 2021

Stochastic Model on Three-Similar Units Three-Phased Mission System with FCFS Repairs Pattern

Sudesh Kumari, Rajeev Kumar

Abstract. ***The paper allocates a stochastic model on three-similar units three-phased mission system. The developed system consists of units working in parallel, series and parallel configurations respectively. Initially, the three similar units are operational. Each component has only three states: good, degraded and failed. In this case, the single repair facility that repairs the units in first come first serve (FCFS)pattern has been thought of. Using Semi-Markov Process and regenerative point techniques, various measures of the system performance at each phase are obtained. The system has been analyzed graphically taking a particular case. Various conclusions are made regarding the reliability and cost consideration of the system at each phase as well as for the whole system(as combined Phase I, Phase II, Phase III).***

Keywords: Three Phased Mission System, Parallel Configuration, Series Configuration, Reliability, Profit.

I. INTRODUCTION

A phased mission system is a system that performs a sequence of various tasks in different time periods undergoing different environmental conditions and success criteria. Compared to a single phased system, it consists of multiple, consecutive and non-over lapping phases (time periods) of operations, during which the system's configuration, the phase duration, system performance, components' behavior, the parameters like failure rates, repair rates of the components may vary from one phase to alternative phase.If each phase completes successfully the task, then phased mission system obtains an overall mission success. By failing of any of these phases, the mission may fail. The phased mission system must be evaluated to obtain the reliability of each phase. As an application, an aircraft mission has many phases including taxing, take-off, cruising, descending and landing phases [6].

In the recent years, the modeling on phased mission systems that involves single or multi-phases with several components [1] has been widely investigated and many different approaches appear in the literature to evaluate the reliability of the phased mission system. Theresearchers [1]-[7] have focused on the problem of phase independence, mainly using Fault Tree Analysis, Boolean algebra and Petri Nets. But with the growing number of the system construction, it is more difficult to be applied to these systems.

Manuscript received on March 22, 2021.
Revised Manuscript received on March 30, 2021.
Manuscript published on April 30, 2021.
* Correspondence Author
Sudesh Kumari*, Research Scholar, Department of Mathematics, M.D. University, Rohtak-124001, Haryana, India
Rajeev Kumar, Professor & Head, Department of Mathematics, M.D. University, Rohtak-124001, Haryana, India

Retrieval Number:
100.1/ijeat.D23460410421
DOI:10.35940/ijeat.D2346.0410421

Keeping this view, thepaper allocates a stochastic model on a three-similar units three-phased mission system with relation to its reliability and cost consideration.

II. MODEL DESCRIPTION

In this paper, a stochastic model is developed with three similar units working in parallel, series and parallel configurations respectively. The model is based on separate phased modeling. The duration of each phase is fixed and in all phases, units are initially considered to be operative. Each unit has only three states: good, degraded and failed. In this case, the single repair facility that repairs the units in first come first serve (FCFS) pattern has been thought of.If any one of unit fails, the system goes for repair to the repairman. The system slowly works and goes to degradation state. It is assumed that the failure rate and hence repair rate in successive phases varies, however within the phase the rates remain constant. If all the units fail, the system stopped and goes to completely failed state. As operating life of the system consists of a series of separate time intervals/phases, the reliability of whole phased mission is taken as combined reliabilities of these phases. The phase III is assumed as phase I but rates are taken different. Using Semi-Markov Process and regenerative point techniques, various measures of the system performance at each phase have been obtained. The system has been analyzed graphically taking a particular case using exponential distribution. Various conclusions have been made regarding reliability of the system at each phase as well as for the whole system.

Other essential assumptions made in formulation of model are:

1. The system is as good as new after each repair.
2. Time to failures of a unit is exponentially distributed whereas other time distributions are general.
3. The transition times between the consecutive phases are instantaneous.
4. Switching is perfect and instantaneous.
5. All random variables are mutually independent.

Table-1: Notations used in Description of the Model.

Notation	Description
$q_{ij\varphi j}(t)/Q_{ij\varphi j}(t)$	Probability density function (P.d.f.)/Cumulative distribution function (C.d.f.) of the first passage time from a regenerative state i to a regenerative state j or to a failed state j without visiting to any other regenerative state in (0,t].

Published By:
Blue Eyes Intelligence Engineering

$q_{ij\varphi j}^{(k)}(t)$/ $Q_{ij\varphi j}^{(k)}(t)$	P.d.f./ C.d.f. of the first passage time from a regenerative state i to a regenerative state j or to a failed state j visiting state k only once in (0,t].
$p_{ij\varphi j}(t)$/ $p_{ij\varphi j}^{(k)}(t)$	Transition probability from regenerative state i to a regenerative state j without visiting any other state/and that of visiting state k once in (0,t] respectively.
$\mu_{i\varphi j}$	Mean sojourn time in regenerative state i before transiting to any other state. If T_i denote the sojourn time in state i, then mean sojourn time in state i is $\cdot_i(t) = \int_0^\infty P(T_i > t)\, dt$
$m_{ij\varphi j}$/ $m_{ij\varphi j}^{(k)}$	Contribution to mean sojourn time in regenerative state i before transiting to regenerative state j / visiting state k only once.
$\Phi_{i\varphi j}(t)$	C.d.f. of the first passage time from regenerative state i to a failed state.
$UT_i(t)$	Probability that the system is in up-state at instant t given that the system entered regenerative state i at time t = 0.
$DT_{i\varphi j}(t)$	Probability that the system is in degraded state at instant t given that the system entered regenerative state i at time t = 0.
$BR_{i\varphi j}(t)$	Probability that a repairman is busy in repairing the failed unit at instant t, given that the system started from the regenerative state i at t = 0.
$VR_{i\varphi j}(t)$	Expected number of visits by the repairman at instant t, given that the system started from the regenerative state i at t = 0.
$Mu_{i\varphi j}(t)$	Probability that the system is up initially in regenerative state i without passing through any regenerative state or returning to itself through one or more non- regenerative states.
$Md_{i\varphi j}(t)$	Probability that the system is down initially in regenerative state i without passing through any regenerative state or returning to itself through one or more non- regenerative states.
$W_{i\varphi j}(t)$	Probability that the repairman is busy with the system initially in regenerative state i at time t without passing through any regenerative state or returning to itself through one or more non-regenerative states.
*	Symbol for Laplace Transformation, e.g. $f^*(s) = \int_0^\infty e^{-st} f(t)\, dt = \int_0^\infty e^{-st}\, dF(t)$
**	Symbol for Laplace-Stieltjes transformation, e.g. $F^{**}(s) = \int_0^\infty e^{-st}\, dF(t) = \int_0^\infty e^{-st} f(t)\, dt.$
©	Symbol for Laplace Convolution, e.g. $a(t) © b(t) = \int_0^t a(u)\, b(t-u)\, du$
Ⓢ	Symbol for Stieltjes Convolution, e.g. $a(t) Ⓢ B(t) = \int_0^t A(u)\, B(t-u)\, du$

L.T.	Laplace Transform
L.S.T.	Laplace-Stieltjes Transform

III STATE TRANSITIONS DIAGRAM

Fig.1.depicts several transitions states of the system. Initially the system is in working where all the phases are operative. The epochs of entry into the states 0, 1 and 4 in phase I, states 5, 6 in phase II and states 7, 8, 11 in phase III are regenerative points and hence these are taken as regenerative states. The states 1, 2, 4 and 8, 9, 11 are degraded. State 3 in phase I, state 6 in phase II and state 10 in phase III are failed.

Table-II: Notations used in Developed Model

Notation	Description
$\phi_j(t)$	Time duration of j^{th} phase (j = 1, 2, 3)
O	Operative Unit
F_r	Unit is failed and is under repair (i = 1,2,3) resp.
F_R	Failed unit is repair continuing from previous state
F_w	Unit is failed and waiting for repair resp.
λ_1/ λ_2/ λ_3	Failure rate of failed unit in j^{th} phase (j = 1, 2, 3) resp.
α_1/ α_2/ α_3	Repair rate of repaired unit in j^{th} phase (j = 1, 2, 3) resp.
$g_1(t)$/ $g_2(t)$/ $g_3(t)$	Pdf of time for repair of unit in j^{th} phase (j = 1, 2, 3) resp.
$G_1(t)$/$G_2(t)$/$G_3(t)$	Cdf of time for repair of unit in j^{th} phase (j = 1, 2, 3) resp.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

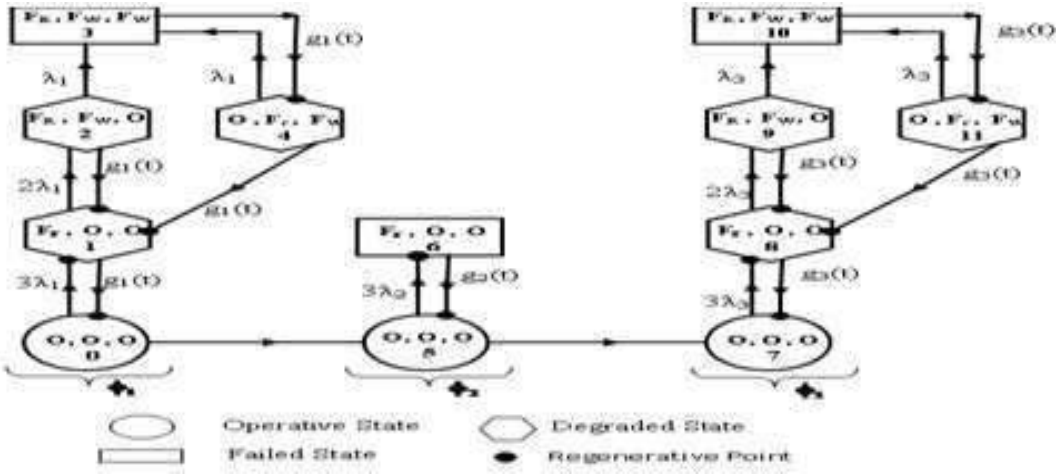


Fig.1. Three-Phased Mission System having Three-Similar Units with Parallel-Series-Parallel Configurations based on FCFS Repairs Pattern

IV. TRANSITION PROBABILITIES AND MEAN SOJOURN TIME

A. Transition Probabilities

Various Transition Probabilities for each phase in steady state are obtained as:

$$p_{ij\phi_1} = \lim_{s\to 0} q^{*}_{ij\phi_1}(s) = \lim_{s\to 0} Q^{**}_{ij\phi_1}(s)$$

Phase I

$$p_{01\phi_1} = 1 \;;$$
$$p_{10\phi_1} + p^{(2)}_{11\phi_1} + p^{(2)}_{13\phi_1} = 1 \;;$$
$$p_{10\phi_1} + p^{(2)}_{11\phi_1} + p^{(2,3)}_{14\phi_1} = 1;$$
$$p_{41\phi_1} + p_{43\phi_1} = 1 \;;$$
$$p_{41\phi_1} + p^{(3)}_{44\phi_1} = 1$$

Phase II

$$p_{56\phi_2} = p_{65\phi_2} = 1$$

Phase III

$$p_{78\phi_3} = 1 \;;$$
$$p_{87\phi_3} + p^{(9)}_{88\phi_3} + p^{(9)}_{8,10\phi_3} = 1 \;;$$
$$p_{87\phi_3} + p^{(9)}_{88\phi_3} + p^{(9,10)}_{8,11\phi_3} = 1 \;;$$
$$p_{11,8\phi_3} + p_{11,10\phi_3} = 1;$$
$$p_{11,8\phi_3} + p^{(10)}_{11,11\phi_3} = 1 \qquad (1-11)$$

B. Mean Sojourn Time

Mean sojourn time and unconditional mean time for each phase are given by:

Phase I

$$m_{01\phi_1} = \mu_{0\phi_1} \;;$$
$$m_{10\phi_1} + m^{(2)}_{11\phi_1} + m^{(2,3)}_{14\phi_1} = m_{41\phi_1} + m^{(3)}_{44\phi_1} = \mu_{3\phi_1} \;;$$
$$m_{41\phi_1} + m_{43\phi_1} = \mu_{4\phi_1} \;;$$
$$m_{10\phi_1} + m^{(2)}_{11\phi_1} + m^{(2)}_{13\phi_1} = k_1$$

Phase II

$$m_{56\phi_2} = \mu_{5\phi_2} \;;$$
$$m_{65\phi_2} = \mu_{6\phi_2}$$

Phase III

$$m_{78\phi_3} = \mu_{7\phi_3} \;;$$
$$m_{87\phi_3} + m^{(9)}_{88\phi_3} + m^{(9,10)}_{8,11\phi_3} = m_{11,8\phi_3} + m^{(10)}_{11,11\phi_3} = \mu_{10\phi_3} \;;$$
$$m_{11,8\phi_3} + m_{11,10\phi_3} = \mu_{11\phi_3} \;;$$
$$m_{87\phi_3} + m^{(9)}_{88\phi_3} + m^{(9)}_{8,10\phi_3} = k_2 \qquad (12-21)$$

V. MEASURES OF SYSTEM PERFORMANCE

Considering failed state as absorbing state, we obtain the recursive relation for mean time to system failure. Other measures of system performance as mean up time, mean degradation time, total fraction of time for which the repairman is busy, expected number of visits by the repairman are obtained. The steady state solutions for each phase and for the whole system are obtained as:

Phase I Mean Time to System Failure: $T_{0\phi_1} = \dfrac{N_{1\phi_1}}{D_{1\phi_1}}$

Mean Up Time: $UT_{0\phi_1} = \dfrac{N_{2\phi_1}}{D_{2\phi_1}}$

Mean Degradation Time: $DT_{0\phi_1} = \dfrac{N_{3\phi_1}}{D_{2\phi_1}}$ Busy Period of the Repairman: $BR_{0\phi_1} = \dfrac{N_{4\phi_1}}{D_{2\phi_1}}$

Expected Number of Visits by the Repairman: $VR_{0\phi_1} = \dfrac{N_{5\phi_1}}{D_{2\phi_1}}$

where

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

$$N_{1\phi_1} = \mu_{0\phi_1}(1-p^{(2)}_{11\phi_1}) + k_1 ;$$
$$N_{2\phi_1} = \mu_{0\phi_1} p_{10\phi_1} p_{41\phi_1} ;$$
$$N_{3\phi_1} = \mu_{1\phi_1} p_{41\phi_1} + \mu_{2\phi_1} p^{(2,3)}_{14\phi_1} ;$$
$$N_{4\phi_1} = (1+\mu_{1\phi_1}) p_{41\phi_1} + (1+\mu_{4\phi_1}) p^{(2,3)}_{14\phi_1} ;$$
$$N_{5\phi_1} = p_{10\phi_1} p_{41\phi_1} ;$$
$$D_{1\phi_1} = p^{(2)}_{13\phi_1} ;$$
$$D_{2\phi_1} = \mu_{0\phi_1} p_{10\phi_1} p_{41\phi_1} + \mu_{3\phi_1}(p_{41\phi_1} + p^{(2,3)}_{14\phi_1}) \quad (22-28)$$

Phase II Mean Time to System Failure: $T_{2\phi_2} = \frac{N_{1\phi}}{D_{1\phi_2}}$

Mean Up Time: $UT_{2\phi_2} = \frac{N_{2\phi_2}}{D_{2\phi_2}}$

Mean Degradation Time: $DT_{2\phi_2} = \frac{N_{3\phi_2}}{D_{2\phi_2}}$

Busy Period of the Repairman: $BR_{2\phi_2} = \frac{N_{4\phi_2}}{D_{2\phi_2}}$

Visits by the Repairman: $VR_{0\phi_2} = \frac{N_{5\phi_2}}{D_{2\phi_2}}$

where

$$N_{1\phi_2} = \mu_{5\phi_2} ; \quad N_{2\phi_2} = \mu_{5\phi_2} ;$$
$$N_{3\phi_2} = 0 ; \quad N_{4\phi_2} = 1+\mu_{6\phi_2} ;$$
$$N_{5\phi_2} = 1 ; \quad D_{1\phi_2} = 1 ;$$
$$D_{2\phi_2} = \mu_{5\phi_2} + \mu_{6\phi_2} \quad (29-35)$$

Phase III Mean Time to System Failure: $T_{7\phi_3} = \frac{N_{1\phi_3}}{D_{1\phi_3}}$

Mean Up Time: $UT_{7\phi_3} = \frac{N_{2\phi_3}}{D_{2\phi_3}}$

Mean Degradation Time: $DT_{7\phi_3} = \frac{N_{3\phi_3}}{D_{2\phi_3}}$

Busy Period of the Repairman: $BR_{7\phi_3} = \frac{N_{4\phi_3}}{D_{2\phi_3}}$

Expected Number of Visits by the Repairman: $VR_{7\phi_3} = \frac{N_{5\phi_3}}{D_{2\phi_3}}$

where

$$N_{1\phi_3} = \mu_{7\phi_3}(1-p^{(9)}_{88\phi_3}) + k_2 ;$$
$$N_{2\phi_3} = \mu_{7\phi_3} p_{87\phi_3} p_{11,8\phi_3} ;$$
$$N_{3\phi_3} = \mu_{8\phi_3} p_{11,8\phi_3} + \mu_{9\phi_3} p^{(9,10)}_{8,11\phi_3} ;$$
$$N_{4\phi_3} = (1+\mu_{8\phi_3}) p_{11,8\phi_3} + (1+\mu_{11\phi_3}) p^{(9,10)}_{8,11\phi_3} ;$$
$$N_{5\phi_3} = p_{87\phi_3} p_{11,8\phi_3} ;$$
$$D_{1\phi_3} = p^{(9)}_{8,10\phi_3} ;$$
$$D_{2\phi_3} = \mu_{7\phi_3} p_{87\phi_3} p_{11,8\phi_3} + \mu_{10\phi_3}(p_{11,8\phi_3} + p^{(9,10)}_{8,11\phi_3}) \quad (36-41)$$

Using the results of above three phases, combined result of the whole system is:

Combined Phase Result

Mean Time to System Failure: $T_0 = \frac{N_1}{D_1}$

Mean Up Time: $UT_0 = \frac{N_2}{D_2}$

Mean Degradation Time: $DT_0 = \frac{N_3}{D_2}$

Busy Period of the Repairman: $BR_0 = \frac{N_4}{D_2}$

Expected Number of Visits by the Repairman: $VR_0 = \frac{N_5}{D_2}$

where

$$N_1 = \mu_{5\phi_2}[\mu_{0\phi_1}(1-p^{(2)}_{11\phi_1}) + k_1][\mu_{7\phi_3}(1-p^{(9)}_{88\phi_3}) + k_2]$$
$$N_2 = \mu_{0\phi_1}\mu_{5\phi_2}\mu_{7\phi_3} p_{10\phi_1} p_{41\phi_1} p_{87\phi_3} p_{11,8\phi_3} ;$$
$$N_3 = 0$$
$$N_4 = (1+\mu_{6\phi_2})[(1+\mu_{1\phi_1}) p_{41\phi_1} + (1+\mu_{4\phi_1}) p^{(2,3)}_{14\phi_1}]$$
$$[(1+\mu_{1\phi_3}) p_{41\phi_3} + (1+\mu_{4\phi_3}) p^{(2,3)}_{14\phi_3}]$$
$$N_5 = p_{10\phi_1} p_{41\phi_1} p_{87\phi_3} p_{11,8\phi_3}$$
$$D_1 = p^{(2)}_{13\phi_1}\mu_{5\phi_2}[\mu_{7\phi_3}(1-p^{(9)}_{88\phi_3}) + k_2] + [\mu_{0\phi_1}(1-p^{(2)}_{11\phi_1}) + k_1]$$
$$[\mu_{7\phi_3}(1-p^{(9)}_{88\phi_3}) + k_2] + p^{(9)}_{8,10\phi_3}\mu_{5\phi_2}[\mu_{0\phi_1}(1-p^{(2)}_{11\phi_1}) + k_1]$$
$$D_2 = [\mu_{0\phi_1} p_{10\phi_1} p_{41\phi_1} + \mu_{3\phi_1}(p_{41\phi_1} + p^{(2,3)}_{14\phi_1})][\mu_{5\phi_2} + \mu_{6\phi_2}]$$
$$[\mu_{7\phi_3} p_{87\phi_3} p_{11,8\phi_3} + \mu_{10\phi_3}(p_{11,8\phi_3} + p^{(9,10)}_{8,11\phi_3})] \quad (42-48)$$

VI. PROFIT INCURRED TO THE SYSTEM

The expected total profit (P_0) incurred to the system in steady state is given by

$P_0 = C_0 UT_0 + C_1 DT_0 - C_2 BR_0 - C_3 VR_0 - C_4$,

where

C_0 = revenue per unit up time of the system.

C_1= revenue per unit degradation time of the system.

C_2 = cost per unit of busy period of the repairman.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

C_3 = cost per visit of the repairman.
C_4 = installation cost

VII. NUMERICAL COMPUTATION AND GRAPHICAL ANALYSIS

The following particular case and values of parameters are considered for graphical purpose:

$$g_i(t) = \alpha_i e^{-\alpha_i t} \quad \text{where } i=1,2,3$$

For the analysis purpose, various graphs have been plotted for mean time to system failure(T_0), mean up time(UT_0) and profit (P_0) of the system with respect to various estimated and assumed values of the failure rates(λ_1 , λ_2 , λ_3) and repair rates(α_1, α_2 , α_3) and various costs is studied by plotting various graphs. The following interpretations and conclusions have been drawn from the graphs:

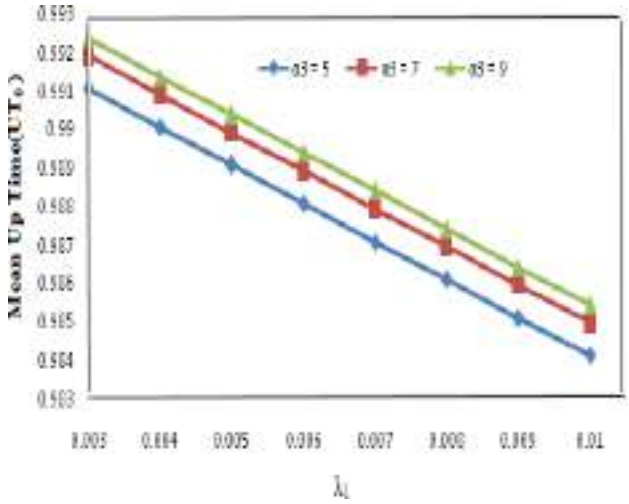


Fig.2. Mean up time of the system versus failure rate for phase I(λ_1) for different values of repair rate for phase III (α_3).

Assumed values of other parameters: failure rate for phase II (λ_2) = 0.004, failure rate for phase III (λ_3) = 0.005, repair rate for phase I (α_1)= 3, repair rate for phase II (α_2) = 4.

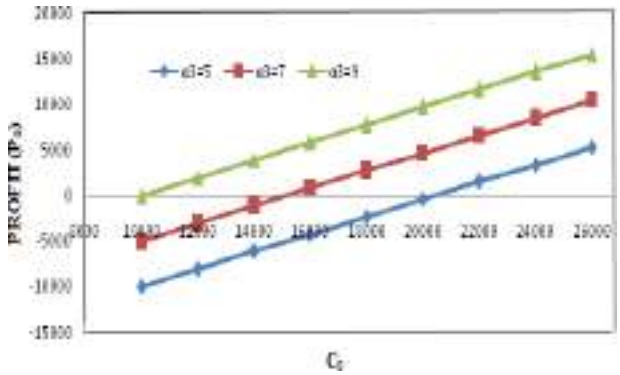


Fig.3. Profit incurred to the system versus revenue per unit uptime (C_0) of the system for different values of repair rate for phase III (α_3)

Assumed values of other parameters: failure rate for phase I (λ_1) = 0.003, failure rate for phase II (λ_2) = 0.004, failure rate for phase III (λ_3) = 0.005, repair rate for phase I (α_1)= 3, repair rate for phase II (α_2) = 4, C_1 = 30,000, C_2 = 1000, C_3 = 800, C_4 = 20000

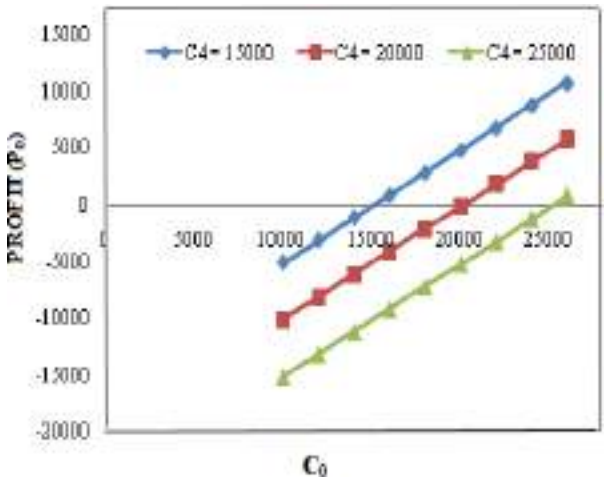


Fig.4. Profit incurred to the system versus revenue per unit uptime (C_0) of the system for different values of installation cost (C_4).

The assumed values of other parameters: failure rate for phase I (λ_1) = 0.003, failure rate for phase II(λ_2) = 0.004, failure rate for phase III (λ_3) = 0.005, repair rate for phase I (α_1)= 3, repair rate for phase II (α_2) = 4, repair rate for phase III (α_3) = 5, C_1 = Rs.30,000, C_2 = Rs.1000, C_3 = Rs.800.

VIII. CONCLUSION

We have explained three phases separately and have drawn some graphs related to mean up time and profit of the entire system w.r.t. failure rates for increasing values of repair rates. From the graphs, it can be interpreted as:

From fig. 2., it is clear that Mean up time (UT_0) of the system declines with increment in values of the failure rate for phase I (λ_1) and inclines with higher values of repair rate for phase III (α_3).

Fig.3 declares that Profit incurred to the system inclines with increment in the values of revenue per unit uptime (C_0) of the system and also inclines with incrementsin values of repair rate (α_3). Also

(i) when α_3 = 5, Profit incurred to the system inclines for C_0> Rs. 20430.3163,declines for C_0< Rs.20430.3163, remains unchanged for C_0 = Rs. 20430.3163 and hence to attain Profit, revenue per unit uptime(C_0) of the system should be greater than Rs. 20430.3163.

(ii) when α_3 = 7, Profit incurred to the system inclines for C_0> Rs. 15200.0196,declines for C_0< Rs. 15200.0196, remains unchanged for C_0 = Rs. 15200.0196 and hence to attain Profit, revenue per unit uptime(C_0) of the system should be greater than Rs. 15200.0196.

(iii) when α_3 = 9, Profit incurred to the system inclines for C_0> Rs. 10090.3677,declines for C_0< Rs. 10090.3677, remains unchanged for C_0 = Rs. 10090.3677 and hence to attain Profit, revenue per unit uptime(C_0) of the system should be greater than Rs. 10090.3677.

Fig.4 shows that Profit incurred to the system inclines with increment in the values of revenue per unit uptime (C_0) of the system and declines with higher values of installation cost (C_4). Also

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

(i) when C_4 = 15,000. Profit incurred to the system inclines for C_0> Rs.15135.5850,declines for C_0< Rs.15135.5850, remains unchanged for C_0 = Rs.15135.5850 and hence to attain Profit, revenue per unit uptime (C_0) of the system should be greater than Rs.15135.5850.

(ii) when C_4 = 20,000. Profit incurred to the system inclines for C_0 > Rs. 20180.7824,declines for C_0 < Rs. 20180.7824, remains unchanged for C_0 = Rs. 20180.7824 and hence to attain Profit, revenue per unit uptime (C_0) of the system should be greater than Rs. 20180.7824.

(iii) when C_4 = 25,000. Profit incurred to the system inclines for C_0> Rs. 25225.9796, declines for C_0< Rs. 25225.9796, remains unchanged for C_0 = Rs. 25225.9796 and hence to attain Profit, revenue per unit uptime (C_0) of the system should be greater than Rs. 25225.9796.

Further, the model discussed can be fitted by the designers/users to the real situations. While fitting this model, one can take estimated values of the parameters so that one can improve the reliability of the system. The limits of failure/repair rates are/can be obtained for the system to give higher reliability, mean up time and profit that is quite useful for both the system designer and the system user.

REFERENCES

1. Dugan, J. B.,"Automated Analysis of Phased-Mission Reliability,"IEEE Trans. on Reliability,Vol.40(1), 1991,pp. 45–52.
2. Esary, J.D. and Ziehms, H.,"Reliability Analysis of Phased Missions, Reliability and Fault Tree Analysis," Proceeding of the Conference: Society for Industrial Applied Mathematics, Philadelphia, Pennsylvania, 1975, pp.213-236.
3. Huang, X., Coolen, Frank P.A., Coolen-Maturi, T., Zhang,Y.,"A New Study on Reliability Importance Analysis of Phased Mission Systems," IEEE Transactions on Reliability,Vol. 69(2), 2019, pp. 522–532
4. Liu, C., Zhou, J. and Wang, H., "Reliability Analysis of Non-repairable Phased-mission System by Proposed Sequence-enforcing Fault Tree Combined with Monte Carlo Simulation," Proceedings of the 2020 4th International Conference on Management Engineering, Software Engineering and Service Sciences, 2020, pp. 265-270.
5. Nowakowski, T., "Problems of Reliability Modelling of Multiple-Phased Systems," Wroclaw University of Technology Publishing House, 2011, pp. 79-84
6. Tang,Z. and Dugan,J.B., "BDD-Based Reliability Analysis of Phased-Mission Systems with Multimode Failures," IEEE Transactions on Reliability,Vol. 55(2), 2006, pp. 350-360.
7. Yan Hua, Gao Li, Qi Lei, Wan Ping., "Simplified Markov Model for Reliability Analysis of Phased-Mission System Using States Merging Method,"Journal of Shanghai Jiaotong University (Science)Vol. 23(3), 2018, pp.418–422.

AUTHORS PROFILE

Sudesh Kumari, has completed her Master of Science (M.Sc.) in the year of 2010 and Master of Philosophy (M.Phil.) degree in subject of Mathematics in the year of 2012 from Department of Mathematics, Maharshi Dayanand University, Rohtak. She is gold medalist. She is pursuing her Ph.D. degree under the supervision of Prof. Rajeev Kumar, Head, Department of Mathematics, Maharshi Dayanand University, Rohtak. Now she is working also as an Assistant Professor in Govt. College Meham, Maharshi Dayanand University, Rohtak, Haryana India. She has published 6 research papers in various international journals and presented 15 research papers in different conferences/seminars. Her areas of interest are statistics and reliability modeling.

Dr. Rajeev Kumar, is presently working as Professor and Head, Department of Mathematics, Maharshi Dayanand University Rohtak. He is/ has been Chairman/ members of various academic/ research bodies. He has served as a Director, Department of Alumni Relations and Directorat Maharshi Dayanand University Rohtak from 2016 to 2020. He has completed his Ph.D. from Maharshi Dayanand University Rohtak in 1995. He has about 70 research publications in various National/ International journals of repute to his credit. His areas of interest are reliability modeling, information theory, operations research, bio-mathematics and statistical estimation. He has guided about 20 Ph.D./ M.Phil. Students for their theses/ dissertations work.

Advances and Applications in Mathematical Sciences
Volume 20, Issue 12, October 2021, Pages 3113-3128

RELIABILITY ANALYSIS OF A STOCHASTIC MODEL IN THREE SIMILAR UNITS THREE-PHASED MISSION SYSTEM WITH LCFS REPAIR PATTERN

SUDESH KUMARI and RAJEEV KUMAR

Department of Mathematics
M.D. University, Rohtak-124001, India
E-mail: sudeshmdu@gmail.com

Abstract

This paper deals with a three similar units stochastic model with a three-phased mission system. The system is considered parallel, series and parallel configuration in three consecutive phases respectively. Initially, the three similar units are operational. Each component has only three states: good, degraded and failed. In this case, the repair priority is given to the failed unit in the developed model, that is, the Last Come First Serve (LCFS) repair model is followed for the failed unit. Using the Semi-Markov process and regenerative point techniques, the different measurements of the system are obtained for each phase. The system is graphically analyzed starting from a particular case and various conclusions are drawn about the reliability of the system in each phase as well as for the whole system (as combined Phase I, Phase II, Phase III).

I. Introduction

A phased mission system is a system that performs a sequence of various activities over different time periods under different environmental conditions and success criteria. Compared to a single-phase system, it consists of multiple, consecutive and non-overlapping operating phases (time periods), during which the system configuration, phase duration, system performance, component behavior, parameters such as rates of failure, component repair rates may vary from phase to phase. A number of practical systems that operate in this sequential manner, such as: electronic power transformers, nuclear power plants, air travel, aerospace and distributed computing systems. Electronic power transformers have three similar units

2010 Mathematics Subject Classification: 91B70.
Keywords: Three-Phase Mission System Parallel configuration Serial configuration Semi-Markov Regenerative point techniques.
Received October 14, 2020; Accepted November 11, 2020

to maximize efficiency, reliability and availability of electrical power. Another application, the mission of an airplane, has many phases, including taxation, take-off, cruise, descent and landing phases [8], [9]. If each phase successfully completes the task, the phased mission system marks the overall success of the mission. Failure in any of these phases can cause the mission to fail. The phased mission system should be evaluated to obtain the reliability of each phase. In recent years, phased mission system modeling involving single or multiple phases with various components has been extensively studied, and many different approaches to assessing the reliability of phased mission system appear in the literature, including [1-7], [10].

In the literature, researchers have focused on the phase mission system problem, mainly using fault tree analysis, Boolean algebra and Petri nets. All of these techniques are limited by the size of the problem. But with the increasing number of system builds, it is more difficult to apply to these systems. When configuring system reliability is complicated and the number of components is large, especially when it is necessary to evaluate system reliability from multiple mission cycles, the use of these techniques will not be easy or straightforward. These techniques are suitable when modeling is non-repairable phased mission systems. These techniques avoid blowing up state space. The Markov model is a powerful tool in reliability engineering. The Markov model analyzes the system by identifying all the different states in which the system is able to produce accurate measures of system reliability by assigning transition rates between states. Markov-based approaches capture functional dependencies between components and the required order of failures. It is the Markov Reliability analysis of the phased mission system that provides a numerical result of the phased mission system with graphical interpretation. With this in mind, the paper deals with the analysis of a stochastic model in a three-phased mission system of three similar units in relation to its reliability, availability and cost consideration.

II. Model Description

We developed a similar three-units stochastic model with a three-phased mission system. The model is based on independent phase models. The system is considered parallel, series and parallel configuration in three consecutive phases respectively. The duration of each phase is fixed and in all

phases, initially, all similar units are considered operational. Each unit has only three states: good, degraded and failed. It was considered that single repair facility that repairs units under the LCFS (last-come, first-serve) scheme. If one of the units fails, the repairman repairs it. The system works slowly and goes into a degradation state. It is assumed that the failure rate and repair rate in successive phases vary, however, within the phase, the rates remain constant. If all units fail, the system shuts down and goes to the completely failed state. Since the operational life of the system consists of a series of separate time intervals / phases, the reliability of the full phase mission is considered as the combined reliability of these phases. Phase III is assumed to be Phase I but rates are taken differently. Using the semi-Markov process and regenerative point techniques, different measurements of the system performance were obtained at each stage. The system was analyzed graphically by taking a particular case for exponential distribution. Different conclusions were drawn about the reliability of the system at each stage, as well as for the whole system.

Other essential assumptions made in formulating the model are:

1. Failure rates and repair rates for a particular phase are constant, but can change in an individual phase.

2. The system is as good as new after every repair.

3. The time to failure of a unit is distributed exponentially, while the other time distributions are general.

4. The transition times between consecutive phases are instantaneous.

5. Switching is perfect and instant.

6. All random variables are mutually independent.

Table 1. Notations used in developed model and description of the model.

Notation	Description
$\lambda_1 / \lambda_2 / \lambda_3$	Failure rate of unit in j^{th} phase $(j = 1, 2, 3)$ resp.
$\beta_1 / \beta_2 / \beta_3$	Repair rate of unit in j^{th} phase $(j = 1, 2, 3)$ resp.
$q_{ij\varphi j}(t) / Q_{ij\varphi j}(t)$	Probability density function (P.d.f.)/Cumulative distribution function (C.d.f.) of the first passage time from a regenerative state i to a regenerative state j or to a failed state j without visiting to any other regenerative state in $(0, t]$.
$p_{ij\varphi j}(t) / p_{ij\varphi j}^{(k)}(t)$	Transition probability from regenerative state i to a regenerative state j without visiting any other state/and that of visiting state k once in $(0, t]$. respectively.
$\mu_{i\varphi j}$	Mean sojourn time in regenerative state i before transiting to any other state. If T_i denote the sojourn time in state i, then mean sojourn time in state i is $\mu_i(t) = \int_0^\infty P(T_i > t)dt$
$UT_i(t)$	Probability that the system is in up-state at instant t given that the system entered regenerative state i at time $t = 0$.
$DT_{i\varphi j}(t)$	Probability that the system is in degraded state at instant t given that the system entered regenerative state i at time $t = 0$.

$BR_{i\varphi j}(t)$	Probability that a repairman is busy in repairing the failed unit at instant *t*, given that the system started from the regenerative state *i* at $t = 0$.
$VR_{i\varphi j}(t)$	Expected number of visits by the repairman at instant *t*, given that the system started from the regenerative state *i* at $t = 0$.
$Mu_{i\varphi j}(t)$	Probability that the system is up initially in regenerative state *i* without passing through any regenerative state or returning to itself through one or more non- regenerative states.
$Md_{i\varphi j}(t)$	Probability that the system is down initially in regenerative state *i* without passing through any regenerative state or returning to itself through one or more non- regenerative states.
$W_{i\varphi j}(t)$	Probability that the repairman is busy with the system initially in regenerative state *i* at time *t* without passing through any regenerative state or returning to itself through one or more non-regenerative states.
$g_1(t)$ / $g_2(t)$ / $g_3(t)$	P.d.f. of time for repair of unit in j^{th} phase $(j = 1, 2, 3)$ resp.
$G_1(t)$ / $G_2(t)$ / $G_3(t)$	C.d.f. of time for repair of unit in j^{th} phase $(j = 1, 2, 3)$ resp.
$\phi_j(t)$	Time duration of j^{th} phase $(j = 1, 2, 3)$
$*$	Symbol for Laplace Transform e.g.

	$f^*(s) = \int_0^\infty e^{-st} f(t)dt = \int_0^\infty e^{st} dF(t)$
* *	Symbol for Laplace-Stieltjes Transform e.g. $F^{**}(s) = \int_0^\infty e^{-st} dF(t) = \int_0^\infty e^{-st} f(t)$
©	$a(t) © b(t) = \int_0^t a(u)b(t-u)du$
□	$a(t)□ B(t) = \int_0^\infty A(u)B(t - u)du$

States of Statistical Model	
O	Operative Unit
F_r	Unit is failed and is under repair
F_w	Unit is failed and is waiting for repair

III. State Transition Diagram

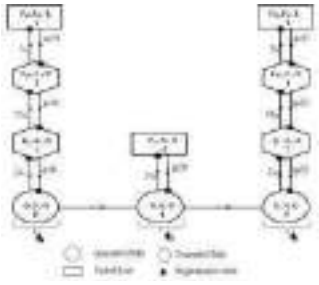


Figure 1. Three-phased mission system having three-similar units with parallel-series-parallel configurations based on LCFS repair pattern.

IV. Transition Probabilities and Mean Sojourn Time

Various transition probabilities from one state to other for each phase are obtained as:

Phase I

$$dQ_{01\phi_1}(t) = 3\lambda_1 e^{-3\lambda_1 t}dt; \qquad dQ_{10\phi_1}(t) = g_1(t)e^{-2\lambda_1 t}dt;$$
$$dQ_{12\phi_1}(t) = 2\lambda_1 e^{-2\lambda_1 t}\overline{G_1(t)}dt; \qquad dQ_{21\phi_1}(t) = g_1(t)e^{-\lambda_1 t}dt;$$
$$dQ_{23\phi_1}(t) = \lambda_1 e^{-\lambda_1 t}\overline{G_1(t)}dt; \qquad dQ_{32\phi_1}(t) = g_1(t)dt$$

Phase II

$$dQ_{45\phi_2}(t) = 3\lambda_2 e^{-3\lambda_2 t}dt; \quad dQ_{54\phi_2}(t)g_2(t)dt$$

Phase III

$$dQ_{67\phi_3}(t) = 3\lambda_3 e^{-3\lambda_3 t}dt; \qquad dQ_{76\phi_3}(t) = g_3(t)e^{-2\lambda_3 t}dt;$$
$$dQ_{78\phi_3}(t) = 2\lambda_3 e^{-2\lambda_3 t}\overline{G_3(t)}dt; \qquad dQ_{87\phi_3}(t) = g_3(t)e^{-\lambda_3 t}dt;$$
$$dQ_{89\phi_3}(t) = \lambda_3 e^{-\lambda_1 t}\overline{G_3(t)}dt; \qquad dQ_{98\phi_3}(t) = g_3(t)dt$$

Taking Laplace Stieltjes Transforms of above derivations, we get the non-zero element $p_{ij\phi_1}$ are given by:

$$p_{ij\phi_1} = \lim_{s\to 0} q^*_{ij\phi_1}(s) = \lim_{s\to 0} Q^{**}_{ij\phi_1}$$

Various transition probabilities in steady state for each phase are obtained as:

Phase I

$$p_{01\phi_1} = 1; \quad p_{10\phi_1} = g_1^*(2\lambda_1); \quad p_{12\phi_1} = 1 - g_1^*(2\lambda_1);$$

$$p_{21\phi_1} = g_1^*(\lambda_1); \quad p_{23\phi_1} = 1 - g_1^*(\lambda_1); \quad p_{32\phi_1} = 1$$

By these transition probabilities, it can be established that

$$p_{01\phi_1} = 1; \quad p_{10\phi_1} + p_{12\phi_1} = 1; \quad p_{21\phi_1} + p_{23\phi_1} = 1; \quad p_{32\phi_1} = 1$$

Phase II

$p_{45\phi_2} = p_{54\phi_2} = 1$

Phase III

$p_{67\phi} = 1; \quad p_{76\phi} = g^*(2\lambda_3); \quad p_{78\phi} 1 - g^*(2\lambda_3);$

$p_{87\phi_3}^{3} = g^*(\lambda_3)^3; \quad p_{89\phi_3}^{3} = 1^3 - g^*(\lambda_3)^3; \quad p_{98\phi_3}^{3} = 1^3$

By these transition probabilities, it can be established that

$p_{67\phi_3} = 1; \quad p_{76\phi_3} + p_{78\phi_3} = 1; \quad p_{87\phi_3} + p_{89\phi_3} = 1; \quad p_{98\phi_3} = 1$

Mean Sojourn Time and Unconditional Mean Time for each phase are obtained as:

Phase I

$m_{01\phi_1} = \mu_{0\phi_1}; \quad m_{10\phi_1} + m_{12\phi_1} = \mu_{1\phi_1};$

$m_{21\phi_1} + m_{23\phi_1} = \mu_{2\phi_1}; \quad m_{32\phi_1} = \mu_{3\phi_1}$

Phase II

$m_{45\phi_2} = \mu_{4\phi_2}; \quad m_{54\phi_2} = \mu_{5\phi_2}$

Phase III

$m_{67\phi_3} = \mu_{6\phi_3}; \quad m_{76\phi_3} + m_{78\phi_3} = \mu_{7\phi_3};$

$m_{87\varphi_3} + m_{89\phi_3} = \mu_{3\varphi_3}; \quad m_{98\phi_3} = \mu_{9\phi_3}$

V. Measures of System Performance

To calculate the mean time to system failure (MTSF), the failure state is considered as an absorbing state. Using probabilistic arguments, we obtain the following recursive relations for each phase for:

Phase I

$\Phi_{0\phi_1}(t) = Q_{01\phi_1}(t) \square \Phi_{1\phi_1}(t)$

$\Phi_{1\phi_1}(t) = (t) \square \Phi_{0\phi_1}(t) + Q_{12\phi_1}(t) \square \Phi_{2\phi_1}(t)$

$$\Phi_{2\phi}{}_{1}(t) = Q_{21\phi}{}_{1}(t)^{\square}\Phi_{1\phi}{}_{1}(t) + Q_{23\phi}{}_{1}(t)$$

Taking L.S.T of these equations and using L'Hospital's rule, we get

$$T_{0\phi_1} = \frac{N_{1\phi_1}}{D_{1\phi_1}}$$

where

$$N_{1\phi_1} = \mu_{0\phi_1}(p_{10\phi_1}p_{21\phi_1} + p_{23\phi_1}) + \mu_{1\phi_1} + \mu_{2\phi_1}p_{12\phi_1} \text{ and } D_{1\phi_1} = p_{12\phi_1}p_{23\phi_1}$$

Similarly, other system performance measures such as average uptime, average degradation time, total fraction of time the repairman is engaged, the expected number of repairman visits is achieved this way. The stationary solutions for each phase and for the whole system are obtained as:

Phase I Mean Up Time:

$$UT_{0\phi_1} = \frac{N_{2\phi_1}}{D_{2\phi_1}}.$$

Mean Degradation Time:

$$DT_{0\phi_1} = \frac{N_{3\phi_1}}{D_{2\phi_1}}.$$

Busy Period of the Repairman:

$$BR_{0\phi_1} = \frac{N_{4\phi_1}}{D_{2\phi_1}}.$$

Expected Number of Visits by the Repairman: 1

$$VR_{0\phi_1} = \frac{N_{5\phi_1}}{D_{2\phi_1}}.$$

where

$$N_{1\phi_1} = \mu_{0\phi_1}(p_{10\phi_1}p_{21\phi_1} + p_{23\phi_1}) + \mu_{2\phi_1} + \mu_{2\phi_1}p_{12\phi_1};$$

$$N_{2\phi_1} = \mu_{0\phi_1}p_{10\phi_1}p_{21\phi_1}; N_{3\phi_1} = \mu_{1\phi_1}p_{21\phi_1} + \mu_{2\phi_1}p_{12\phi_1};$$

$N_{4\phi_1} = 1 - p_{10\phi_1}p_{23\phi_1} + p_{12\phi_1}\mu_{1\varphi_1} + p_{12\phi_1}\mu_{2\phi_1} + p_{12\phi_1}p_{23\phi_1}\mu_{3\phi_1}$;

$N_{5\phi_1} = p_{10\phi_1}p_{21\phi_1}$; $D_{1\phi_1} = p_{12\phi_1}p_{23\phi_1}$;

$D_{2\phi_1} = \mu_{0\phi_1}p_{10\phi_1}p_{21\phi_1} + \mu_{1\phi_1} + p_{21\phi_1} + \mu_{2\phi_1} + \mu_{3\phi_1}p_{12\phi} + \mu_{3\phi_1}p_{12\phi_1}p_{23\phi_1}$;

Phase II Mean Time to System Failure:

$$T_{2_{\phi_2}} = \frac{N_{1\phi_2}}{D_{1\phi_2}}.$$

Mean Up Time:

$$UT_{2\phi_2} = \frac{N_{2\phi_2}}{D_{2\phi_2}}.$$

Mean Degradation Time:

$$DT_{2\phi_2} = \frac{N_{3\phi_2}}{D_{2\phi_2}}.$$

Busy Period of the Repairman:

$$BR_{2\phi_2} = \frac{N_{4\phi_2}}{D_{2\phi_2}}.$$

Expected Number of Visits by the Repairman:

$$VR_{2\phi_2} = \frac{N_{5\phi_2}}{D_{2\phi_2}}.$$

where

$N_{1\phi_2} = \mu_{4\phi_2}$; $N_{2\phi_2} = \mu_{4\phi_2}$; $N_{3\phi_2} = 0$; $N_{4\phi_2} = 1 + \mu_{5\phi_1}$; $N_{5\phi_2} = 1$;

$D_{1\phi_2} = 1$; $D_{2\phi_2} = \mu_{4\phi_2} + \mu_{5\phi_2}$

Phase III Mean Time to System Failure:

$$T_{7\phi_3} = \frac{N_{1\phi_3}}{D_{1\phi_3}}.$$

Mean Up Time:

$$UT_{7\phi_3} = \frac{N_{2\phi_3}}{D_{2\phi_3}}.$$

Mean Degradation Time:

$$DT_{7\phi_3} = \frac{N_{3\phi_3}}{D_{2\phi_3}}.$$

Busy Period of the Repairman:

$$BR_{7\phi_3} = \frac{N_{4\phi_3}}{D_{2\phi_3}}.$$

Expected Number of Visits by the Repairman:

$$VR_{7\phi_3} = \frac{N_{5\phi_3}}{D_{2\phi_3}}.$$

where

$N_{1\phi_3} = \mu_{6\phi_3}(p_{76\phi_3}p_{87\phi_3} + p_{89\phi_3})$; $N_{2\phi_3} = \mu_{6\phi_3}p_{76\phi_3}p_{87\phi_3}$;

$N_{3\phi_3} = \mu_{7\phi_3}p_{78\phi_3} + \mu_{8\phi_3}p_{78\phi_3}$; $N_{4\phi_3} = 1 - p_{76\phi_3}p_{89\phi_3} + p_{87\phi_3}$

$+p_{78\phi_3}\mu_{8\phi_3} + p_{78\phi_3}p_{89\phi_3}\mu_{9\phi_3}$;

$N_{5\phi_3} = p_{76\phi_3}p_{87\phi_3}$; $D_{1\phi} = p_{78\phi_3}p_{89\phi_3}$;

$D_{2\phi_3} = \mu_{6\phi_3}p_{76\phi_3}p_{87\phi_3} + \mu_{7\phi_3}p_{87\phi_3} + \mu_{8\phi_3}p_{78\phi_3} + \mu_{9\phi_3}p_{78\phi_3}p_{89\phi_3}$

Using the results of above three phases, combined result of the whole system is:

Mean Time to System Failure:

$$T_0 = \frac{N_1}{D_1}.$$

Mean Up Time:

$$UT_0 = \frac{N_2}{D_2}.$$

Mean Degradation Time:

$$DT_0 = \frac{N_3}{D_2}.$$

Busy Period of the Repairman:

$$BR_0 = \frac{N_4}{D_2}.$$

Expected Number of Visits by the Repairman: 5

$$VR_0 = \frac{N_5}{D_2}.$$

where

$N_1 = \mu_{4\phi_2}[\mu_{0\phi_1}(p_{10\phi_1}p_{21\phi_1} + p_{23\phi_1}) + \mu_{1\phi_1} + \mu_{2\phi_1}p_{12\phi_1}]$

$[\mu_{6\phi_3}(p_{76\phi_3}p_{87\phi_3} + p_{89\phi_3}) + \mu_{7\phi_3} + \mu_{8\phi_3}p_{78\phi_3}];$

$N_2 = \mu_{0\phi_1}\mu_{4\phi_2}\mu_{6\phi_3}p_{10\phi_1}p_{21\phi_1}p_{76\phi_3}p_{87\phi_3};\ N_3 = 0;$

$N_4 = [1 + \mu_{5\phi_2}][1 - p_{10\phi_1}p_{23\phi_1} + p_{21\phi_1}\mu_{1\phi_1} + p_{12\phi_1} + \mu_{2\phi_1} + p_{12\phi_1}p_{23\phi_1}\mu_{3\phi_1}]$

$[1 - p_{76\phi_3}p_{89\phi_3} + p_{87\phi_3}\mu_{7\phi_3} + p_{78\phi_3}\mu_{8\phi_3} + p_{78\phi_3}p_{89\phi_3}\mu_{9\phi_3}];$

$N_5 = p_{10\phi_1}p_{21\phi_1}p_{76\phi_1}p_{87\phi_3}$

and

$D_1 = p_{12\phi_1}p_{23\phi_1}\mu_{4\phi_2}[\mu_{6\phi_3}(p_{76\phi_3}p_{87\phi_3}p_{89\phi_3}) + \mu_{7\phi_3} + \mu_{8\phi_3}p_{78\phi_3}]$

$+ [\mu_{0\phi_1}(p_{10\phi_1}p_{21\phi_1} + p_{23\phi_1}) + \mu_{1\phi_1} + \mu_{2\phi_1}p_{12\phi_1}]$

$[\mu_{6\phi_3}(p_{76\phi_3}p_{87\phi_3} + p_{89\phi_3}) + \mu_{7\phi_3} + \mu_{8\phi_3}p_{78\phi_3}] + p_{78\phi_3}p_{89\phi_3}\mu_{4\phi_2}$

$[\mu_{0\phi_1}(p_{10\phi_1}p_{21\phi_1} + p_{23\phi_1}) + \mu_{1\phi_1} + \mu_{2\phi_1}p_{12\phi_1}$

$D_2 = (\mu_{4\phi_2} + \mu_{5\phi_2})[\mu_{0\phi_1}p_{10\phi_1}p_{21\phi_1} + \mu_{1\phi_1}p_{21\phi_1} + \mu_{2\phi_1}p_{12\phi_1}$

$+\mu_{3\phi_1} p_{12\phi_1} p_{23\phi_1}]$

$[\mu_{6\phi_3} p_{76\phi_3} p_{87\phi_3} + \mu_{7\phi_3} p_{87\phi_3} + \mu_{8\phi_3} + p_{78\phi_3} + \mu_{9\phi_3} p_{78\phi_3} p_{89\phi_3}]$

VI. Profit Incurred To The System

The expected total profit (P_0) incurred to the system in steady state is given by

$$P_0 = C_0 UT_0 + C_1 DT_0 - C_2 BR_0 - C_3 VR_0 - C_4,$$

where

$C_0 =$ revenue per unit up time of the system.

$C_1 =$ revenue per unit degradation time of the system.

$C_2 =$ cost per unit of busy period of the repairman.

$C_3 =$ cost per visit of the repairman.

$C_4 =$ installation cost

VII. Numerical Computation and Graphical Analysis

The following particular case and values of parameters are considered for graphical purpose:

$$g_i(t) = \alpha_i e^{-\alpha_i t} \text{ where } i = 1, 2, 3$$

For the analysis purpose, various graphs have been plotted for mean time to system failure (T_0), mean up time (UT_0) and profit (P_0) of the system with respect to various estimated and assumed values of the failure rates $(\lambda_1, \lambda_2, \lambda_3)$ and repair rates $(\alpha_1, \alpha_2, \alpha_3)$ and various costs is studied by plotting various graphs.

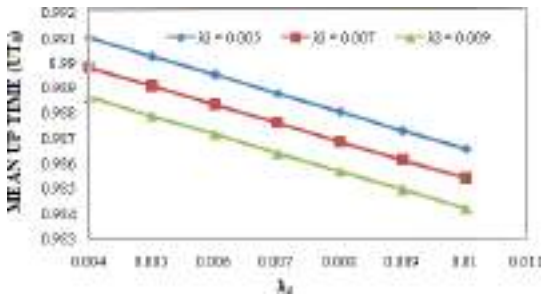


Figure 2. Mean up time of the system versus failure rate for phase II (λ_2) for different values of failure rate for phase III (λ_3).

Taking assumed values of other parameters: failure rate for phase $I(\lambda_1) = 0.003$, repair rate for phase $I(a_1) = 3$, repair rate for phase $II(a_2) = 4$, repair rate for phase $III(a_3) = 5$.

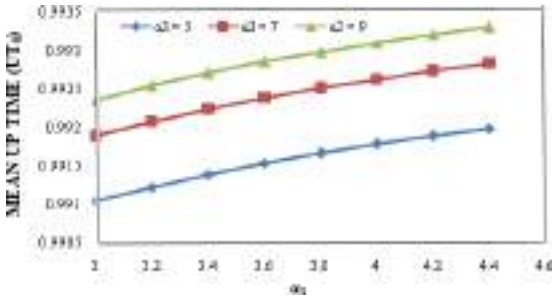


Figure 3. Mean up time of the system versus repair rate for phase I(a_1) for different values of repair rate for phase III(a_3).

Taking assumed values of other parameters: failure rate for phase $I(\lambda_1) = 0.003$, failure rate for phase $II(\lambda_2) = 0.004$, failure rate for phase $III(\lambda_3) = 0.005$, repair rate for phase $II(\alpha_2) = 4$.

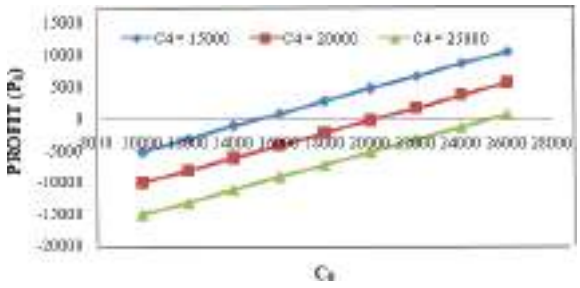


Figure 4. Profit incurred to the system versus revenue per unit uptime (C_0) of the system for different values of installation cost (C_4).

The assumed values of other parameters: failure rate for phase $I(\lambda_1) = 0.003$, failure rate for phase $\text{II}(\lambda_2) = 0.004$, failure rate for phase $\text{III}(\lambda_3) = 0.005$, repair rate for phase $\text{I}(a_1) = 3$, repair rate for phase $\text{II}(a_2) = 4$, repair rate for phase $\text{III}(a_3) = 5$, $C_1 = Rs.30,000$, $C_2 = Rs.1000$, $C_3 = Rs.800$.

VIII. Conclusion

The conclusion derived from Figure 2 to Figure 4 are as under:

Figure 2. Mean up time (UT_0) of the system declines with increment in values of the failure rate for phase $\text{II}(\lambda_2)$ and also declines with higher values of failure rate for phase $\text{III}(\lambda_3)$.

Figure 3. Mean up time (UT_0) of the system inclines with increment in values of the repair rate for phase $\text{I}(a_1)$ and inclines with higher values of repair rate for phase $\text{III}(a_3)$.

Figure 4. Profit incurred to the system inclines with increment in the values of revenue per unit uptime (C_0) of the system and declines with higher values of installation cost (C_4). Also

Table 2. Revenue per unit uptime V/S installation cost.

	$C_4 = 15{,}000$	$C_4 = 20{,}000$	$C_4 = 20{,}000$
C_0	> or < or = Rs.15135.5919	> or < or = Rs. 20180.7866	> or < or = Rs. 25225.9824

References

[1] M. Alam and U. M. Al-Saggaf, Quantitative Reliability Evaluation of Repairable Phased-Mission Systems using Markov Approach, IEEE Trans. on Reliability 35(1986), 498-503.

[2] M. Bouissou, Y. Dutuit and S. Maillard, Reliability Analysis of a Dynamic Phased Mission System Comparison of two Approaches, Modern Statistical and Mathematical Methods in Reliability 2(2005), 87-104.

[3] J. B. Dugan, Automated Analysis of Phased-Mission Reliability, IEEE Trans. on Reliability 40(1) (1991), 45-52.

[4] J. D. Esary and H. Ziehms, Reliability Analysis of Phased Missions, Reliability and Fault Tree Analysis, in Proceeding of the Conference Society for Industrial Applied Mathematics, Philadelphia, Pennsylvania (1975), 213-236.

[5] X. Huang, P. A. Coolen, T. Frank, Coolen-Maturi and Y. Zhang, A New Study on Reliability Importance Analysis of Phased Mission Systems, IEEE Transactions on Reliability 69(2) (2019), 522-532.

[6] C. Liu, J. Zhou, and H. Wang, Reliability Analysis of Non-repairable Phased-mission System by Proposed Sequence-enforcing Fault Tree Combined with Monte Carlo Simulation, in Proceedings of the 2020 4th International Conference on Management Engineering, Software Engineering and Service Sciences (2020), 265-270.

[7] T. Nowakowski, Problems of Reliability Modeling of Multiple-Phased Systems, Wroclaw University of Technology Publishing House (2011), 79-84.

[8] M. Singh, M. D. Jaybhaye and S. K. Basu, Degraded Performance Analysis of Phased Mission System, 5th International and 26th All India Manufacturing Technology, Design and Research Conference, IIT, Guwahati, Assam, India (2014), 278-1-278-6.

[9] Z. Tang and J. B. Dugan, BDD-Based Reliability Analysis of Phased-Mission Systems with Multimode Failures, IEEE Transactions on Reliability 55(2) (2006), 350-360.

[10] Hua. Yan Li. Gao, Qi. Lei and Wan Ping, Simplified Markov Model for Reliability Analysis of Phased-Mission System Using States Merging Method, Journal of Shanghai Jiaotong University Science 23(3) (2018), 418-422.

Cost-benefit Analysis of a Stochastic Model on Three-Dissimilar Units Three Phased Mission System

Sudesh Kumari[1], Rajeev Kumar[2]

[1,2]Department of Mathematics, M.D. University (Rohtak), Haryana, INDIA

****

ABSTRACT

The present paper deals with cost-benefit analysis of a stochastic model on three-dissimilar units three phased mission system in which the system carries out different tasks at different phases. Therefore the system configuration varies depending upon the requirement at the phases. The unit's configuration in the system is considered as parallel, series and parallel respectively in three consecutive phases. Initially, the three dissimilar units are operational. Each component has only three states: good, degraded and failed. In this case, the repair priority is given to the failed unit in the developed model, that is, the Last Come First Serve (LCFS) repair pattern is followed for the failed unit. Using Semi-Markov Process and regenerative point techniques, various measures of the system at each phase are obtained. As operating life of the system consists of series of time intervals at different phase, the reliability of the whole phased mission system is also evaluated. The system is analyzed plotting various graphs and various conclusions regarding the reliability of the system at each phase as well as for the whole system (as combined Phase I, Phase II, Phase III). The reliability of a phased mission system is the probability that the mission successfully achieve the entire submission objective in each phase.

Keywords: Three phased mission system, series configuration, profit, Semi-Markov and regenerative point techniques.

INTRODUCTION

A phased mission system is a system that performs a sequence of different tasks in different time periods. This is a complex system whose mission (task) is divided into a number of consecutive time periods (phases). It consists of multiple, consecutive and non-over lapping phases (time periods) of operations, in which the system's configuration, the phase duration, system performance, components' behavior, the parameters such as failure rates, repair rates etc. of the components may be different. As the failure of the PMS can be hazardous, the reliability evaluation of a PMS is essential before it is putted into operation. The reliability of a phased mission system is the probability that the mission successfully achieve the entire submission objective in each phase.

An example of a phased-mission system is a modern aircraft flight [1] that has to take passengers from one airport to another. This system includes several phases as taxiing to the runway, take-off, and ascent (Climb), Cruise (level flight), descent, landing and taxiing to the terminal. Each phase of the aircraft flight has a different configuration, reliability requirement and behavior. The dynamic structure and configuration of aircraft flight (PMS) usually requires distinct model for each phase. Other systems of the phased are flight systems in space, communication systems, water supply systems, boiling water reactor systems [2,4] etc and the reliability evaluation of PMS has attracted many researchers. Many efficient kinds of reliability evaluation methods and techniques have proposed such as analytical methods (binary decision diagrams, fault tree), Markov (State-Space) method, Petri-Nets and Simulation method, etc. As research continues, more literature has addressed the reliability analysis of PMS with more complicated cases, such as with repairable component, imperfect fault coverage, common cause failures. Several reliability models for analyzing such systems using synthetic modeling and separate phase modeling have been developed and reported in the literature including [1]-[15]. But work in the direction of stochastic modelling of Phased Mission System remains unattended in the literature. With this in mind, the paper deals with the analysis of a stochastic model in a three-phased mission system of three dissimilar units in relation to its reliability, availability and cost consideration.

MODEL DESCRIPTION

In the present paper, a three phased-mission system is analyzed through the stochastic separate phase modeling. In the model, three dissimilar units are considered in parallel, series and parallel configurations respectively in three consecutive

phases. Initially, the three units in a phase are assumed to be operative. If any one of unit fails, it goes for repair to the single repair facility. The system gradually degrades. It is assumed therefore, that the failure rate and hence repair rate in successive phases varies, however within the phase remains constant. It is assumed that the failed later is repaired first ie. the Last Come First Serve (LCFS) repair pattern is followed for the failed unit.. If all the units fail, the system goes to completely failed state. As operating life of the system consists of a series of separate time intervals and hence phases, the reliability of whole phased mission system is taken as the combined reliabilities of these phases. The phase III is assumed as phase I but rates are taken different. Various measures of system performance are obtained by using Semi-Markov Process and regenerative points technique and the model is analyzed graphically.

Other essential assumptions made in formulating the model are:

1. Failure rates and repair rates for a particular phase are constant, but can change in an individual phase.
2. The system is as good as new after every repair.
3. The time to failure of a unit is distributed exponentially, while the other time distributions are general.
4. The transition times between consecutive phases are instantaneous.
5. Switching is perfect and instant.
6. All random variables are mutually independent.

Table: 1. Notations Used In Developed Model and Description of the Model

Notation	Description
λ_{ij}	Failure rate of i^{th} unit in the j^{th} phase (i = 1,2,3 & $j=\phi_1,\phi_2,\phi_3$)
β_{ij}	Repair rate of i^{th} unit in the j^{th} phase (i = 1,2,3 & $j=\phi_1,\phi_2,\phi_3$)
F_{ir}	i^{th} unit is failed and is under repair
F_{iw}	i^{th} unit is failed and waiting for repair
$g_{ij}(t)$	Pdf of time for repair of i^{th} unit in j^{th} phase (i = 1,2,3 & $j=\phi_1,\phi_2,\phi_3$)
$G_{ij}(t)$	Cdf of time for repair of i^{th} unit in j^{th} phase (i = 1,2,3 & $j=\phi_1,\phi_2,\phi_3$)
$q_{ij\varphi j}(t)/Q_{ij\varphi j}(t)$	Probability density function (P.d.f.)/Cumulative distribution function (C.d.f.) of the first passage time from a regenerative state i to a regenerative state j or to a failed state j without visiting to any other regenerative state in (0,t].
$p_{ij\varphi j}(t)/ p_{ij\varphi j}^{(k)}(t)$	Transition probability from regenerative state i to a regenerative state j without visiting any other state/and that of visiting state k once in (0,t] respectively.
$\mu_{i\varphi j}$	Mean sojourn time in regenerative state i before transiting to any other state. If T_i denote the sojourn time in state i, then mean sojourn time in state i is $\mu_i(t) = \int_0^\infty P(T_i > t)\,dt$
$UT_i(t)$	Probability that the system is in up-state at instant t given that the system entered regenerative state i at time t = 0.
$DT_{i\varphi j}(t)$	Probability that the system is in degraded state at instant t given that the system entered regenerative state i at time t = 0.
$BR_{i\varphi j}(t)$	Probability that a repairman is busy in repairing the failed unit at instant t, given that the system started from the regenerative state i at t = 0.
$VR_{i\varphi j}(t)$	Expected number of visits by the repairman at instant t, given that the system started from the regenerative state i at t = 0.
$Mu_{i\varphi j}(t)$	Probability that the system is up initially in regenerative state i without passing through any regenerative state or returning to itself through one or more non- regenerative states.
$Md_{i\varphi j}(t)$	Probability that the system is down initially in regenerative state i without passing through any regenerative state or returning to itself through one or more non- regenerative states.
$W_{i\varphi j}(t)$	Probability that the repairman is busy with the system initially in regenerative state i at time t without passing through any regenerative state or returning to itself through one or more non-regenerative states.
$g_1(t)/ g_2(t)/ g_3(t)$	Pdf of time for repair of unit in j^{th} phase ($j=\phi_1,\phi_2,\phi_3$) resp.

International Journal of All Research Education and Scientific Methods (IJARESM), ISSN: 2455-6211
Volume 9, Issue 3, March -2021, Impact Factor: 7.429, Available online at: www.ijaresm.com

$G_1(t)$/ $G_2(t)$/ $G_3(t)$ Cdf of time for repair of unit in j^{th} phase ($j=\phi_1,\phi_2,\phi_3$) resp.

$\phi_i(t)$ Time duration of i^{th} phase (i = 1, 2, 3)

* Symbol for Laplace Transform e.g.

$$f^*(s) = \int_0^\infty e^{-st} f(t)\, dt = \int_0^\infty e^{-st}\, dF(t)$$

** Symbol for Laplace-Stieltjes Transform e.g.

$$F^{**}(s) = \int_0^\infty e^{-st}\, dF(t) = \int_0^\infty e^{-st}\, f(t)$$

© Symbol for Laplace Convolution, e.g.

$$a(t) \copyright b(t) = \int_0^t a(u)\, b(t-u)\, du$$

Ⓢ Symbol for Stieltjes Convolution, e.g.

$$a(t) \circledS B(t) = \int_0^t A(u)\, B(t-u)\, du$$

States of Statistical Model

O Operative Unit

F_r Unit is failed and is under repair

F_w Unit is failed and is waiting for repair

STATE TRANSITION DIAGRAM

The transition diagram consists of three phases viz phase I, phase II, phase III, depicting the various states of the system is shown in the fig. 1. Initially the system is in working where all the phases are operative. The initial states 0, 10 & 14 are operative. The epochs of entry into all the states in three phases are regenerative points and hence all these are taken as regenerative states. The states 1, 2, 3, 4, 5, 6, 15, 16, 17, 18, 19 and 20 are degraded. States 7, 8, 9 in phase I, states 11, 12, 13 in phase II and states 21, 22, 23 in phase III are failed.

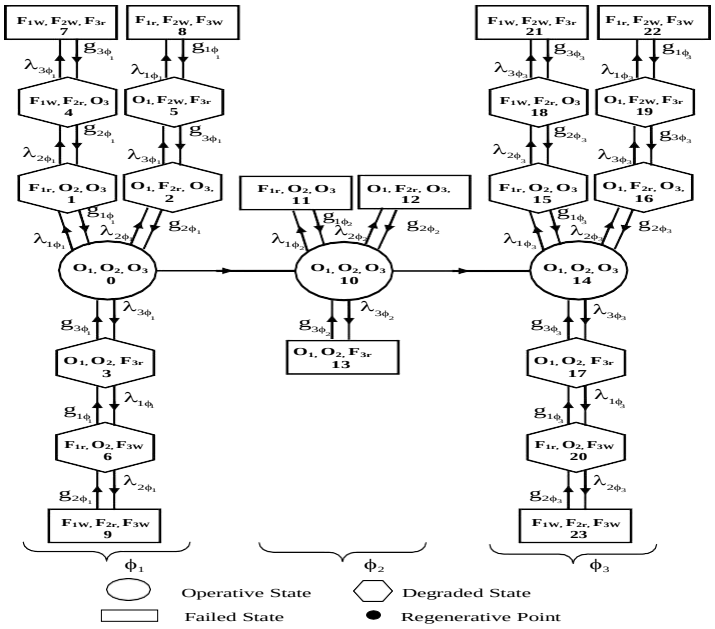


Fig. 1:Three-phased mission system having three-dissimilar units with parallel-series-parallel configurations based on LCFS repair pattern

International Journal of All Research Education and Scientific Methods (IJARESM), ISSN: 2455-6211
Volume 9, Issue 3, March -2021, Impact Factor: 7.429, Available online at: www.ijaresm.com

TRANSITION PROBABILITIES AND MEAN SOJOURN TIME

Various transition probabilities in steady state for each phase are obtained as:

Phase I

$$p_{01\phi_1} = \frac{\lambda_{1\phi_1}}{\lambda_{1\phi_1}+\lambda_{2\phi_1}+\lambda_{3\phi_1}} \quad ; \qquad p_{02\phi_1} = \frac{\lambda_{2\phi_1}}{\lambda_{1\phi_1}+\lambda_{2\phi_1}+\lambda_{3\phi_1}} \quad ;$$

$$p_{03\phi_1} = \frac{\lambda_{3\phi_1}}{\lambda_{1\phi_1}+\lambda_{2\phi_1}+\lambda_{3\phi_1}} \quad ; \qquad p_{10\phi_1} = p_{63\phi_1} = g^*_{1\phi_1}(\lambda_{2\phi_1}) \quad ;$$

$$p_{14\phi_1} = p_{69\phi_1} = 1 - g^*_{1\phi_1}(\lambda_{2\phi_1}) \; ; \qquad p_{20\phi_1} = p_{41\phi_1} = g^*_{2\phi_1}(\lambda_{3\phi_1}) \quad ;$$

$$p_{25\phi_1} = p_{47\phi_1} = 1 - g^*_{2\phi_1}(\lambda_{3\phi_1}) \; ; \qquad p_{30\phi_1} = p_{52\phi_1} = g^*_{3\phi_1}(\lambda_{1\phi_1}) \quad ;$$

$$p_{36\phi_1} = p_{58\phi_1} = 1 - g^*_{3\phi_1}(\lambda_{1\phi_1})$$

By these transition probabilities, it can be established that

$$p_{01\phi_1} + p_{02\phi_1} + p_{03\phi_1} = 1 \; ; \qquad p_{10\phi_1} + p_{14\phi_1} = 1 \; ;$$

$$p_{20\phi_1} + p_{25\phi_1} = 1 \; ; \qquad p_{30\phi_1} + p_{36\phi_1} = 1 \; ;$$

$$p_{41\phi_1} + p_{47\phi_1} = 1 \; ; \qquad p_{52\phi_1} + p_{58\phi_1} = 1 \; ;$$

$$p_{63\phi_1} + p_{69\phi_1} = 1 \; ; \qquad p_{74\phi_1} = p_{85\phi_1} = p_{96\phi_1} = 1$$

Phase II

$$p_{10,11\phi_2} = \frac{\lambda_{1\phi_2}}{\lambda_{1\phi_2}+\lambda_{2\phi_2}+\lambda_{3\phi_2}} \quad ; \qquad p_{10,12\phi_2} = \frac{\lambda_{2\phi_2}}{\lambda_{1\phi_2}+\lambda_{2\phi_2}+\lambda_{3\phi_2}} \quad ;$$

$$p_{10,13\phi_2} = \frac{\lambda_{3\phi_2}}{\lambda_{1\phi_2}+\lambda_{2\phi_2}+\lambda_{3\phi_2}} \quad ; \qquad p_{11,10\phi_2} = g^*_{1\phi_2}(0) \quad ;$$

$$p_{12,10\phi_2} = g^*_{2\phi_2}(0) \quad ; \qquad p_{13,10\phi_2} = g^*_{3\phi_2}(0)$$

By these transition probabilities, it can be established that

$$p_{10,11\phi_2} + p_{10,12\phi_2} + p_{10,13\phi_2} = 1 \; ; \qquad p_{11,10\phi_2} = p_{12,10\phi_2} = p_{13,10\phi_2} = 1$$

Phase III

$$p_{14,15\phi_3} = \frac{\lambda_{1\phi_3}}{\lambda_{1\phi_3}+\lambda_{2\phi_3}+\lambda_{3\phi_3}} \quad ; \qquad p_{14,16\phi_3} = \frac{\lambda_{2\phi_3}}{\lambda_{1\phi_3}+\lambda_{2\phi_3}+\lambda_{3\phi_3}} \quad ;$$

$$p_{14,17\phi_3} = \frac{\lambda_{3\phi_3}}{\lambda_{1\phi_3}+\lambda_{2\phi_3}+\lambda_{3\phi_3}} \quad ; \qquad p_{15,14\phi_3} = p_{20,17\phi_3} = g^*_{1\phi_3}(\lambda_{2\phi_3}) \; ;$$

$$p_{15,18\phi_3} = p_{20,23\phi_3} = 1 - g^*_{1\phi_3}(\lambda_{2\phi_3}) \; ; \qquad p_{16,14\phi_3} = p_{18,15\phi_3} = g^*_{2\phi_3}(\lambda_{3\phi_3}) \; ;$$

$$p_{16,19\phi_3} = p_{18,21\phi_3} = 1 - g^*_{2\phi_3}(\lambda_{3\phi_3}) \; ; \qquad p_{17,14\phi_3} = p_{19,16\phi_3} = g^*_{3\phi_3}(\lambda_{1\phi_3}) \; ;$$

$$p_{17,20\phi_3} = p_{19,22\phi_3} = 1 - g^*_{3\phi_3}(\lambda_{1\phi_3})$$

By these transition probabilities, it can be established that

$$p_{14,15\phi_3} + p_{14,16\phi_3} + p_{14,17\phi_3} = 1; \qquad p_{15,14\phi_3} + p_{15,18\phi_3} = 1;$$
$$p_{16,14\phi_3} + p_{16,19\phi_3} = 1; \qquad p_{17,14\phi_3} + p_{17,20\phi_3} = 1;$$
$$p_{18,15\phi_3} + p_{18,21\phi_3} = 1; \qquad p_{19,16\phi_3} + p_{19,22\phi_3} = 1;$$
$$p_{20,17\phi_3} + p_{20,23\phi_3} = 1; \qquad p_{21,18\phi_3} = p_{22,19\phi_3} = p_{23,20\phi_3} = 1$$

Mean Sojourn Time and Unconditional Mean Time for each phase are obtained as:

Phase I
$$m_{01\phi_1} + m_{02\phi_1} + m_{03\phi_1} = \mu_{0\phi_1}; \qquad m_{10\phi_1} + m_{14\phi_1} = \mu_{1\phi_1};$$
$$m_{20\phi_1} + m_{25\phi_1} = \mu_{2\phi_1}; \qquad m_{30\phi_1} + m_{36\phi_1} = \mu_{3\phi_1};$$
$$m_{41\phi_1} + m_{47\phi_1} = \mu_{4\phi_1}; \qquad m_{52\phi_1} + m_{58\phi_1} = \mu_{5\phi_1};$$
$$m_{63\phi_1} + m_{69\phi_1} = \mu_{6\phi_1}; \qquad m_{74\phi_1} = \mu_{7\phi_1};$$
$$m_{85\phi_1} = \mu_{8\phi_1}; \qquad m_{96\phi_1} = \mu_{9\phi_1}$$

Phase II
$$m_{10,11\phi_2} + m_{10,12\phi_2} + m_{10,13\phi_2} = \mu_{10\phi_2}; \qquad m_{11,10\phi_2} = \mu_{11\phi_2};$$
$$m_{12,10\phi_2} = \mu_{12\phi_2}; \qquad m_{13,10\phi_2} = \mu_{13\phi_2}$$

Phase III
$$m_{14,15\phi_3} + m_{14,16\phi_3} + m_{14,17\phi_3} = \mu_{14\phi_3}; \qquad m_{15,14\phi_3} + m_{15,18\phi_3} = \mu_{15\phi_3};$$
$$m_{16,14\phi_3} + m_{16,19\phi_3} = \mu_{16\phi_3}; \qquad m_{17,14\phi_3} + m_{17,20\phi_3} = \mu_{17\phi_3};$$
$$m_{18,15\phi_3} + m_{18,21\phi_3} = \mu_{18\phi_3}; \qquad m_{19,16\phi_3} + m_{19,22\phi_3} = \mu_{19\phi_3};$$
$$m_{20,17\phi_3} + m_{20,23\phi_3} = \mu_{20\phi_3}; \qquad m_{21,18\phi_3} = \mu_{21\phi_3};$$
$$m_{22,19\phi_3} = \mu_{22\phi_3}; \qquad m_{23,20\phi_3} = \mu_{23\phi_3}$$

MEASURES OF SYSTEM PERFORMANCE

A. Mean Time to System Failure

To calculate the mean time to system failure (MTSF), the failure state is considered as an absorbing state. Using probabilistic arguments, we obtain the following recursive relations for each phase for:

Phase I
$$\Phi_{0\phi_1}(t) = Q_{01\phi_1}(t) \textcircled{S} \Phi_{1\phi_1}(t) + Q_{02\phi_1}(t) \textcircled{S} \Phi_{2\phi_1}(t) + Q_{03\phi_1}(t) \textcircled{S} \Phi_{3\phi_1}(t)$$
$$\Phi_{1\phi_1}(t) = Q_{10\phi_1}(t) \textcircled{S} \Phi_{0\phi_1}(t) + Q_{14\phi_1}(t) \textcircled{S} \Phi_{4\phi_1}(t)$$
$$\Phi_{2\phi_1}(t) = Q_{20\phi_1}(t) \textcircled{S} \Phi_{0\phi_1}(t) + Q_{25\phi_1}(t) \textcircled{S} \Phi_{5\phi_1}(t)$$
$$\Phi_{3\phi_1}(t) = Q_{30\phi_1}(t) \textcircled{S} \Phi_{0\phi_1}(t) + Q_{36\phi_1}(t) \textcircled{S} \Phi_{6\phi_1}(t)$$
$$\Phi_{4\phi_1}(t) = Q_{41\phi_1}(t) \textcircled{S} \Phi_{1\phi_1}(t) + Q_{47\phi_1}(t)$$
$$\Phi_{5\phi_1}(t) = Q_{52\phi_1}(t) \textcircled{S} \Phi_{2\phi_1}(t) + Q_{58\phi_1}(t)$$
$$\Phi_{6\phi_1}(t) = Q_{63\phi_1}(t) \textcircled{S} \Phi_{3\phi_1}(t) + Q_{69\phi_1}(t)$$

Taking L.S.T of these equations and using L'Hospital's rule, we get

$$T_{0\phi_1} = \frac{N_{1\phi_1}}{D_{1\phi_1}}$$

where

$$N_{1\phi_1} = \mu_{0\phi}(1-p_{14\phi}p_{41\phi})(1-p_{25\phi}p_{52\phi})(1-p_{36\phi}p_{63\phi}) + p_{01\phi}(\mu_{1\phi}+\mu_{4\phi}p_{14\phi})(1-p_{25\phi}p_{52\phi})(1-p_{36\phi}p_{63\phi}) + p_{02\phi}(\mu_{2\phi}+\mu_{5\phi}p_{25\phi})(1-p_{14\phi}p_{41\phi})(1-p_{36\phi}p_{63\phi}) + p_{03\phi}(\mu_{3\phi}+\mu_{6\phi}p_{36\phi})(1-p_{14\phi}p_{41\phi})(1-p_{25\phi}p_{52\phi})$$

and

$$D_{1\phi_1} = (1-p_{14\phi}p_{41\phi})(1-p_{25\phi}p_{52\phi})(1-p_{36\phi}p_{63\phi}) - p_{01\phi}p_{10\phi}(1-p_{25\phi}p_{52\phi})(1-p_{36\phi_1}p_{63\phi_1}) - p_{02\phi_1}p_{20\phi_1}(1-p_{14\phi_1}p_{41\phi_1})(1-p_{36\phi_1}p_{63\phi_1}) - p_{03\phi_1}p_{30\phi_1}(1-p_{14\phi_1}p_{41\phi_1})(1-p_{25\phi_1}p_{52\phi_1})$$

Similarly, other system performance measures such as average uptime, average degradation time, total fraction of time the repairman is engaged, the expected number of repairman visits is achieved this way. The stationary solutions for each phase and for the whole system are obtained as:

Phase I

Mean Up Time: $$UT_{0\phi_1} = \frac{N_{2\phi_1}}{D_{2\phi_1}}$$

Mean Degradation Time: $$DT_{0\phi_1} = \frac{N_{3\phi_1}}{D_{2\phi_1}}$$

Busy Period of the Repairman: $$BR_{0\phi_1} = \frac{N_{4\phi_1}}{D_{2\phi_1}}$$

Expected Number of Visits by the Repairman: $$VR_{0\phi_1} = \frac{N_{5\phi_1}}{D_{2\phi_1}}$$

Where

$$N_{2\phi_1} = \mu_{0\phi}p_{10\phi}p_{20\phi}p_{30\phi}p_{41\phi}p_{52\phi}q_{63\phi};$$

$$N_{3\phi_1} = p_{10\phi_1}p_{41\phi_1}\{(\mu_{6\phi_1}+p_{63\phi_1}\mu_{3\phi_1})p_{03\phi_1}p_{20\phi_1}p_{36\phi_1}p_{52\phi_1} + (\mu_{5\phi_1}+p_{52\phi_1}\mu_{2\phi_1})p_{02\phi_1}p_{25\phi_1}p_{30\phi_1}p_{63\phi_1}\} + p_{20\phi}p_{52\phi}p_{30\phi}p_{63\phi}\{(p_{01\phi}\mu_{1\phi}+p_{02\phi}\mu_{2\phi}+p_{03\phi}\mu_{3\phi})p_{10\phi}p_{41\phi} + p_{01\phi}p_{14\phi}(\mu_{4\phi}+p_{41\phi}\mu_{1\phi})\};$$

$$N_{4\phi} = p_{10\phi}p_{20\phi}p_{30\phi}p_{41\phi}p_{52\phi}p_{63\phi} \{(p_{01\phi_1}\mu_{1\phi_1}+p_{02\phi_1}\mu_{2\phi_1}+p_{03\phi_1}\mu_{3\phi_1}) + p_{01\phi_1}p_{14\phi_1}(\mu_{4\phi_1}+p_{41\phi_1}\mu_{1\phi_1}+p_{47\phi_1}\mu_{7\phi_1})\} + p_{10\phi_1}p_{41\phi_1}\{p_{02\phi_1}p_{30\phi_1}p_{25\phi_1}p_{63\phi_1}(\mu_{5\phi_1}+p_{52\phi_1}\mu_{2\phi_1}+p_{58\phi_1}\mu_{8\phi_1}) + p_{03\phi_1}p_{20\phi_1}p_{36\phi_1}p_{52\phi_1}(\mu_{6\phi_1}+p_{63\phi_1}\mu_{3\phi_1}+p_{69\phi_1}\mu_{9\phi_1})\};$$

$$N_{5\phi} = p_{10\phi}p_{20\phi}p_{30\phi}p_{41\phi}p_{52\phi}p_{63\phi};$$

$$D_{2\phi} = p_{41\phi}p_{52\phi}p_{63\phi}(\mu_{0\phi}p_{10\phi}p_{20\phi}p_{30\phi}+\mu_{1\phi}p_{01\phi}p_{20\phi}p_{30\phi}+\mu_{2\phi}p_{02\phi}p_{10\phi}p_{30\phi}+\mu_{3\phi}p_{03\phi}p_{10\phi}p_{20\phi}) + p_{01\phi}p_{14\phi}p_{20\phi}p_{30\phi}p_{52\phi}p_{63\phi}(\mu_{4\phi}+\mu_{7\phi}p_{47\phi}) + p_{02\phi}p_{10\phi}p_{25\phi}p_{30\phi}p_{41\phi}p_{63\phi}(\mu_{5\phi}+\mu_{8\phi}p_{58\phi}) + p_{03\phi}p_{10\phi}p_{20\phi}p_{36\phi}p_{41\phi}p_{52\phi}(\mu_{6\phi}+\mu_{9\phi}p_{69\phi})$$

Phase II

Mean Time to System Failure: $T_{10\phi_2} = \frac{N_{1\phi_2}}{D_{1\phi_2}}$

Mean Up Time: $UT_{10\phi_2} = \frac{N_{2\phi_2}}{D_{2\phi_2}}$

Mean Degradation Time: $DT_{10\phi_2} = \frac{N_{3\phi_2}}{D_{2\phi_2}}$

Busy Period of the Repairman: $BR_{10\phi_2} = \frac{N_{4\phi_2}}{D_{2\phi_2}}$

Expected Number of Visits by the Repairman: $VR_{10\phi_2} = \frac{N_{5\phi_2}}{D_{2\phi_2}}$

where

$N_{1\phi_2} = \mu_{10\phi_2}$; $N_{2\phi_2} = \mu_{10\phi_2}$; $N_{3\phi_2} = 0$;

$N_{4\phi_2} = p_{10,11\phi_2}\mu_{11\phi_2} + p_{10,12\phi_2}\mu_{12\phi_2} + p_{10,13\phi_2}\mu_{13\phi_2}$;

$N_{5\phi_2} = 1$; $D_{1\phi_2} = 1$;

$D_{2\phi_2} = \mu_{10\phi_2} + p_{10,11\phi_2}\mu_{11\phi_2} + p_{10,12\phi_2}\mu_{12\phi_2} + p_{10,13\phi_2}\mu_{13\phi_2}$

Phase III

Mean Time to System Failure: $T_{14\phi_3} = \frac{N_{1\phi_3}}{D_{1\phi_3}}$

Mean Up Time: $UT_{14\phi_3} = \frac{N_{2\phi_3}}{D_{2\phi_3}}$

Mean Degradation Time: $DT_{14\phi_3} = \frac{N_{3\phi_3}}{D_{2\phi_3}}$

Busy Period of the Repairman: $BR_{14\phi_3} = \frac{N_{4\phi_3}}{D_{2\phi_3}}$

Expected Number of Visits by the Repairman: $VR_{14\phi_3} = \frac{N_{5\phi_3}}{D_{2\phi_3}}$

where

$$N_{1\phi_3} = \mu_{14\phi_3}(1-p_{15,18\phi_3}p_{18,15\phi_3})(1-p_{16,19\phi_3}p_{19,16\phi_3})(1-p_{17,20\phi_3}p_{20,17\phi_3}) + p_{14,15\phi_3}(\mu_{15\phi_3}+\mu_{18\phi_3}p_{15,18\phi_3})_3$$
$$(1-p_{16,19\phi_3}p_{19,16\phi_3})(1-p_{17,20\phi_3}p_{20,17\phi_3}) + p_{14,16\phi_3}(\mu_{16\phi_3}+\mu_{19\phi_3}p_{16,19\phi_3})(1-p_{15,18\phi_3}p_{18,15\phi_3})$$
$$(1-p_{17,20\phi_3}p_{20,17\phi_3}) + p_{14,17\phi_3}(\mu_{17\phi_3}+\mu_{20\phi_3}p_{17,20\phi_3})(1-p_{15,18\phi_3}p_{18,15\phi_3})(1-p_{16,19\phi_3}p_{19,16\phi_3})$$

$$N_{2\phi_3} = \mu_{14\phi_3}p_{15,14\phi_3}p_{16,14\phi_3}p_{17,14\phi_3}p_{18,15\phi_3}p_{19,16\phi_3}q_{20,17\phi_3}$$

$$N_{3\phi_3} = p_{15,14\phi_3}p_{18,15\phi_3}\{(\mu_{20\phi_3}+p_{20,17\phi_3}\mu_{17\phi_3}p)_{4,17\phi_3}p_{16,14\phi_3}p_{17,20\phi_3}p_{19,16\phi_3} + \mu_{19\phi_3}+p_{19,16\phi_3}\mu_{16\phi_3}$$
$$p_{14,16\phi_3}p_{16,19\phi_3}p_{17,14\phi_3}p_{20,17\phi_3}\} + p_{16,14\phi_3}p_{19,16\phi_3}p_{17,14\phi_3}p_{20,17\phi_3}$$
$$\{(p_{14,15\phi_3}\mu_{15\phi_3} + p_{14,16\phi_3}\mu_{16\phi_3} + p_{14,17\phi_3}\mu_{17\phi_3})p_{15,14\phi_3}p_{18,15\phi_3} + p_{14,15\phi_3}p_{15,18\phi_3}(\mu_{18\phi_3} + p_{18,15\phi_3}\mu_{15\phi_3})\}$$

$$N_{4\phi_3} = p_{15,14\phi_3}\, p_{16,14\phi_3}\, p_{17,14\phi_3}\, p_{18,15\phi_3}\, p_{19,16\phi_3}\, p_{20,17\phi_3}$$
$$\{(p_{14,15\phi_3}\mu_{15\phi_3} + p_{14,16\phi_3}\mu_{16\phi_3} + p_{14,17\phi_3}\mu_{17\phi_3}) + p_{14,15\phi_3}p_{15,18\phi_3}(\mu_{18\phi_3} + p_{18,15\phi_3}\mu_{15\phi_3} + p_{18,21\phi_3}\mu_{21\phi_3})\}$$
$$+ p_{15,14\phi_3}p_{18,15\phi_3}\{p_{14,16\phi_3}p_{17,14\phi_3}p_{16,19\phi_3}p_{20,17\phi_3}(\mu_{19\phi_3} + p_{19,16\phi_3}\mu_{16\phi_3} + p_{19,22\phi_3}\mu_{22\phi_3})$$
$$+ p_{14,17\phi_3}p_{16,14\phi_3}p_{17,20\phi_3}p_{19,16\phi_3}(\mu_{20\phi_3} + p_{20,17\phi_3}\mu_{17\phi_3} + p_{20,23\phi_3}\mu_{23\phi_3})\}$$

$$N_{5\phi_3} = p_{15,14\phi_3}\, p_{16,14\phi_3}\, p_{17,14\phi_3}\, p_{18,15\phi_3}\, p_{19,16\phi_3}\, p_{20,17\phi_3}$$

$$D_{1\phi_3} = (1-p_{15,18\phi_3}p_{18,15\phi_3})(1-p_{16,19\phi_3}p_{19,16\phi_3})(1-p_{17,20\phi_3}p_{20,17\phi_3}) - p_{14,15\phi_3}p_{15,14\phi_3}(1-p_{16,19\phi_3}p_{19,16\phi_3})$$
$$(1-p_{17,20\phi_3}p_{20,17\phi_3}) - p_{14,16\phi_3}p_{16,14\phi_3}(1-p_{15,18\phi_3}p_{18,15\phi_3})(1-p_{17,20\phi_3}p_{20,17\phi_3}) - p_{14,17\phi_3}p_{17,14\phi_3}$$
$$(1-p_{15,18\phi_3}p_{18,15\phi_3})(1-p_{16,19\phi_3}p_{19,16\phi_3})$$

$$D_{2\phi_3} = p_{18,15\phi_3}p_{19,16\phi_3}p_{20,17\phi_3}(\mu_{14\phi_3}p_{15,14\phi_3}p_{16,14\phi_3}p_{17,14\phi_3} + \mu_{15\phi_3}p_{14,15\phi_3}p_{16,14\phi_3}p_{17,14\phi_3} + \mu_{16\phi_3}p_{14,16\phi_3}p_{15,14\phi_3}p_{17,14\phi_3}$$
$$+ \mu_{17\phi_3}p_{14,17\phi_3}p_{15,14\phi_3}p_{16,14\phi_3}) + p_{14,15\phi_3}p_{15,18\phi_3}p_{16,14\phi_3}p_{17,14\phi_3}p_{19,16\phi_3}p_{20,17\phi_3}(\mu_{18\phi_3} + \mu_{21\phi_3}p_{18,21\phi_3})$$
$$+ p_{14,16\phi_3}p_{15,14\phi_3}p_{16,19\phi_3}p_{17,14\phi_3}p_{18,15\phi_3}p_{20,17\phi_3}(\mu_{19\phi_3} + \mu_{22\phi_3}p_{19,22\phi_3})$$
$$+ p_{14,17\phi_3}p_{15,14\phi_3}p_{16,14\phi_3}p_{17,20\phi_3}p_{18,15\phi_3}p_{19,16\phi_3}(\mu_{20\phi_3} + \mu_{23\phi_3}p_{20,23\phi_3})$$

Using the results of above three phases, combined result of the whole system is:

Mean Time to System Failure: $T_0 = \frac{N_1}{D_1}$

Mean Up Time: $UT_0 = \frac{N_2}{D_2}$

Mean Degradation Time: $DT_0 = \frac{N_3}{D_2}$

Busy Period of the Repairman: $BR_0 = \frac{N_4}{D_2}$

Expected Number of Visits by the Repairman: $VR_0 = \frac{N_5}{D_2}$

where

$$N_1 = \mu_{10\phi_2}[\mu_{0\phi_1}(1-p_{14\phi_1}p_{41\phi_1})(1-p_{25\phi_1}p_{52\phi_1})(1-p_{36\phi_1}p_{63\phi_1}) + p_{01\phi_1}(\mu_{1\phi_1} + \mu_{4\phi_1}p_{14\phi_1})(1-p_{25\phi_1}p_{52\phi_1})$$
$$(1-p_{36\phi_1}p_{63\phi_1}) + p_{02\phi_1}(\mu_{2\phi_1} + \mu_{5\phi_1}p_{25\phi_1})(1-p_{14\phi_1}p_{41\phi_1})(1-p_{36\phi_1}p_{63\phi_1}) + p_{03\phi_1}(\mu_{3\phi_1} + \mu_{6\phi_1}p_{36\phi_1})$$
$$(1-p_{14\phi_1}p_{41\phi_1})(1-p_{25\phi_1}p_{52\phi_1})][\mu_{14\phi_3}(1-p_{15,18\phi_3}p_{18,15\phi_3})(1-p_{16,19\phi_3}p_{19,16\phi_3})(1-p_{17,20\phi_3}p_{20,17\phi_3})$$
$$+ p_{14,15\phi_3}(\mu_{15\phi_3} + \mu_{18\phi_3}p_{15,18\phi_3})(1-p_{16,19\phi_3}p_{19,16\phi_3})(1-p_{17,20\phi_3}p_{20,17\phi_3}) + p_{14,16\phi_3}(\mu_{16\phi_3} + \mu_{19\phi_3}p_{16,19\phi_3})$$
$$(1-p_{15,18\phi_3}p_{18,15\phi_3})(1-p_{17,20\phi_3}p_{20,17\phi_3}) + p_{14,17\phi_3}(\mu_{17\phi_3} + \mu_{20\phi_3}p_{17,20\phi_3})(1-p_{15,18\phi_3}p_{18,15\phi_3})$$
$$(1-p_{16,19\phi_3}p_{19,16\phi_3})]$$

$$N_2 = [\mu_{10\phi_2}][\mu_{0\phi_1}p_{10\phi_1}p_{20\phi_1}p_{30\phi_1}p_{41\phi_1}p_{52\phi_1}q_{63\phi_1}][\mu_{14\phi_3}p_{15,14\phi_3}p_{16,14\phi_3}p_{17,14\phi_3}p_{18,15\phi_3}p_{19,16\phi_3}q_{20,17\phi_3}]$$

$$N_3 = 0$$

$$N_4 = [p_{10\phi}\,p_{20\phi}\,p_{30\phi}\,p_{41\phi}\,p_{52\phi}\,p_{63\phi}\{(p_{01\phi}\,\mu_{1\phi} + p_{02\phi}\,\mu_{2\phi} + p_{03\phi}\,\mu_{3\phi}) + p_{01\phi}\,p_{14\phi}\,(\mu_{4\phi} + p_{41\phi}\,\mu_{1\phi} + p_{47\phi}\,\mu_{7\phi})$$
$$+ p_{10\phi}\,p_{41\phi}\{p_{02\phi}\,p_{30\phi}\,p_{25\phi}\,p_{63\phi}\,(\mu_{5\phi} + p_{52\phi}\,\mu_{2\phi} + p_{58\phi}\,\mu_{8\phi})$$
$$+ p_{03\phi}\,p_{20\phi}\,p_{36\phi}\,p_{52\phi}\,(\mu_{6\phi} + p_{63\phi}\,\mu_{3\phi} + p_{69\phi}\,\mu_{9\phi})\}][p_{10,11\phi}\,\mu_{11\phi} + p_{10,12\phi}\,\mu_{12\phi} + p_{10,13\phi}\,\mu_{13\phi}]$$
$$[p_{15,14\phi}\,p_{16,14\phi}\,p_{17,14\phi}\,p_{18,15\phi}\,p_{19,16\phi}\,p_{20,17\phi}\{(p_{14,15\phi}\,\mu_{15\phi} + p_{14,16\phi}\,\mu_{16\phi} + p_{14,17\phi}\,\mu_{17\phi})$$
$$+ p_{14,15\phi}\,p_{15,18\phi}\,(\mu_{18\phi} + p_{18,15\phi}\,\mu_{15\phi} + p_{18,21\phi}\,\mu_{21\phi})\}$$
$$+ p_{15,14\phi_3}\,p_{18,15\phi_3}\{p_{14,16\phi_3}\,p_{17,14\phi_3}\,p_{16,19\phi_3}\,p_{20,17\phi_3}\,(\mu_{19\phi_3} + p_{19,16\phi_3}\,\mu_{16\phi_3} + p_{19,22\phi_3}\,\mu_{22\phi_3})$$
$$+ p_{14,17\phi_3}\,p_{16,14\phi_3}\,p_{17,20\phi_3}\,p_{19,16\phi_3}\,(\mu_{20\phi_3} + p_{20,17\phi_3}\,\mu_{17\phi_3} + p_{20,23\phi_3}\,\mu_{23\phi_3})\}]$$

$$N_5 = p_{10\phi_1}\,p_{20\phi_1}\,p_{30\phi_1}\,p_{41\phi}\,p_{52\phi}\,p_{63\phi}\,p_{15,14\phi_3}\,p_{16,14\phi_3}\,p_{17,14\phi_3}\,p_{18,15\phi_3}\,p_{19,16\phi_3}\,p_{20,17\phi_3}$$

$$D_2 = [p_{41\phi}\,p_{52\phi}\,p_{63\phi}\,(\mu_{0\phi}\,p_{10\phi}\,p_{20\phi}\,p_{30\phi} + \mu_{1\phi}\,p_{01\phi}\,p_{20\phi}\,p_{30\phi} + \mu_{2\phi}\,p_{02\phi}\,p_{10\phi}\,p_{30\phi} + \mu_3\,p_{03\phi}\,p_{10\phi}\,p_{20\phi})$$
$$+ p_{01\phi}\,p_{14\phi}\,p_{20\phi}\,p_{30\phi}\,p_{52\phi}\,p_{63\phi}\,(\mu_{4\phi} + \mu_{7\phi}\,p_{47\phi}) + p_{02\phi}\,p_{10\phi}\,p_{25\phi}\,p_{30\phi}\,p_{41\phi}\,p_{63\phi}\,(\mu_{5\phi} + \mu_{8\phi}\,p_{58\phi})$$
$$+ p_{03\phi}\,p_{10\phi}\,p_{20\phi}\,p_{36\phi}\,p_{41\phi}\,p_{52\phi}\,(\mu_{6\phi} + \mu_{9\phi}\,p_{69\phi})][\mu_{10\phi} + p_{10,11\phi}\,\mu_{11\phi} + p_{10,12\phi}\,\mu_{12\phi} + p_{10,13\phi}\,\mu_{13\phi}]$$
$$[p_{18,15\phi}\,p_{19,16\phi}\,p_{20,17\phi}(\mu_{14\phi}\,p_{15,14\phi}\,p_{16,14\phi}\,p_{17,14\phi} + \mu_{15\phi}\,p_{14,15\phi}\,p_{16,14\phi}\,p_{17,14\phi} + \mu_{16\phi}\,p_{14,16\phi}\,p_{15,14\phi}\,p_{17,14\phi}$$
$$+ \mu_{17\phi}\,p_{14,17\phi}\,p_{15,14\phi}\,p_{16,14\phi}) + p_{14,15\phi}\,p_{15,18\phi}\,p_{16,14\phi}\,p_{17,14\phi}\,p_{19,16\phi}\,p_{20,17\phi}\,(\mu_{18\phi} + \mu_{21\phi}\,p_{18,21\phi})$$
$$+ p_{14,16\phi}\,p_{15,14\phi}\,p_{16,19\phi}\,p_{17,14\phi}\,p_{18,15\phi}\,p_{20,17\phi}\,(\mu_{19\phi} + \mu_{22\phi}\,p_{19,22\phi})$$
$$+ p_{14,17\phi}\,p_{15,14\phi}\,p_{16,14\phi}\,p_{17,20\phi}\,p_{18,15\phi}\,p_{19,16\phi}(\mu_{20\phi} + \mu_{23\phi}\,p_{20,23\phi})]$$

$$D_1 = \mu_{10\phi_2}[(1-p_{14\phi}\,p_{41\phi_1})(1-p_{25\phi}\,p_{52\phi_1})(1-p_{36\phi}\,p_{63\phi}) - p_{01\phi}\,p_{10\phi_1}(1-p_{25\phi}\,p_{52\phi_1})(1-p_{36\phi}\,p_{63\phi})$$
$$- p_{02\phi_1}p_{20\phi_1}(1-p_{14\phi}\,p_{41\phi_1})(1-p_{36\phi}\,p_{63\phi}) - p_{03\phi}\,p_{30\phi_1}(1-p_{14\phi}\,p_{41\phi})(1-p_{25\phi}\,p_{52\phi})]$$
$$[\mu_{14\phi}(1-p_{15,18\phi}\,p_{18,15\phi})(1-p_{16,19\phi}\,p_{19,16\phi})(1-p_{17,20\phi}\,p_{20,17\phi}) + p_{14,15\phi}(\mu_{15\phi} + \mu_{18\phi}\,p_{15,18\phi})$$
$$(1-p_{16,19\phi}\,p_{19,16\phi})(1-p_{17,20\phi}\,p_{20,17\phi}) + p_{14,16\phi}(\mu_{16\phi} + \mu_{19\phi}\,p_{16,19\phi})(1-p_{15,18\phi}\,p_{18,15\phi})$$
$$(1-p_{17,20\phi}\,p_{20,17\phi}) + p_{14,17\phi}(\mu_{17\phi} + \mu_{20\phi}\,p_{17,20\phi})(1-p_{15,18\phi}\,p_{18,15\phi})(1-p_{16,19\phi}\,p_{19,16\phi})]$$
$$+[\mu_{0\phi}(1-p_{14\phi}\,p_{41\phi})(1-p_{25\phi}\,p_{52\phi})(1-p_{36\phi}\,p_{63\phi}) + p_{01\phi}(\mu_{1\phi} + \mu_{4\phi}\,p_{14\phi})(1-p_{25\phi}\,p_{52\phi})$$
$$(1-p_{36\phi}\,p_{63\phi}) + p_{02\phi}(\mu_{2\phi} + \mu_{5\phi}\,p_{25\phi})(1-p_{14\phi}\,p_{41\phi})(1-p_{36\phi}\,p_{63\phi}) + p_{03\phi}(\mu_{3\phi} + \mu_{6\phi}\,p_{36\phi})$$
$$(1-p_{14\phi_1}p_{41\phi_1})(1-p_{25\phi_1}p_{52\phi_1})][\mu_{14\phi_3}(1-p_{15,18\phi_3}p_{18,15\phi_3})(1-p_{16,19\phi_3}p_{19,16\phi_3})(1-p_{17,20\phi_3}p_{20,17\phi_3})$$
$$+ p_{14,15\phi}(\mu_{15\phi} + \mu_{18\phi}\,p_{15,18\phi})(1-p_{16,19\phi}\,p_{19,16\phi})(1-p_{17,20\phi}\,p_{20,17\phi}) + p_{14,16\phi}(\mu_{16\phi} + \mu_{19\phi}\,p_{16,19\phi})$$
$$(1-p_{15,18\phi}\,p_{18,15\phi})(1-p_{17,20\phi}\,p_{20,17\phi}) + p_{14,17\phi}(\mu_{17\phi} + \mu_{20\phi}\,p_{17,20\phi})(1-p_{15,18\phi}\,p_{18,15\phi})$$
$$(1-p_{16,19\phi_3}p_{19,16\phi_3})] + \mu_{10\phi}[(1-p_{15,18\phi}\,p_{18,15\phi})(1-p_{16,19\phi}\,p_{19,16\phi})(1-p_{17,20\phi}\,p_{20,17\phi})$$
$$- p_{14,15\phi}\,p_{15,14\phi}(1-p_{16,19\phi}\,p_{19,16\phi})(1-p_{17,20\phi}\,p_{20,17\phi}) - p_{14,16\phi}\,p_{16,14\phi}(1-p_{15,18\phi}\,p_{18,15\phi})$$
$$(1-p_{17,20\phi_3}p_{20,17\phi_3}) - p_{14,17\phi}\,p_{17,14\phi}(1-p_{15,18\phi}\,p_{18,15\phi})(1-p_{16,19\phi}\,p_{19,16\phi})][\mu_{0\phi}(1-p_{14\phi}\,p_{41\phi})$$
$$(1-p_{25\phi}\,p_{52\phi})(1-p_{36\phi}\,p_{63\phi}) + p_{01\phi}(\mu_{1\phi} + \mu_{4\phi}\,p_{14\phi})(1-p_{25\phi}\,p_{52\phi})(1-p_{36\phi}\,p_{63\phi})$$
$$+ p_{02\phi}(\mu_{2\phi} + \mu_{5\phi}\,p_{25\phi})(1-p_{14\phi}\,p_{41\phi})(1-p_{36\phi}\,p_{63\phi}) + p_{03\phi}(\mu_{3\phi} + \mu_{6\phi}\,p_{36\phi})(1-p_{14\phi}\,p_{41\phi})$$
$$(1-p_{25\phi_1}p_{52\phi_1})]$$

International Journal of All Research Education and Scientific Methods (IJARESM), ISSN: 2455-6211
Volume 9, Issue 3, March -2021, Impact Factor: 7.429, Available online at: www.ijaresm.com

COST-BENEFIT ANALYSIS OF THE SYSTEM

The expected total profit (P_0) incurred to the system in steady state is given by

$$P_0 = C_0 UT_0 + C_1 DT_0 - C_2 BR_0 - C_3 VR_0 - C_4 ,$$

where

C_0 = revenue per unit up time of the system.
C_1 = revenue per unit degradation time of the system.
C_2 = cost per unit of busy period of the repairman.
C_3 = cost per visit of the repairman.
C_4 = installation cost

NUMERICAL COMPUTATION AND GRAPHICAL ANALYSIS

The following particular case and values of parameters are considered for graphical purpose:

$g_{ij}(t) = \alpha_{ij} e^{-\alpha_{ij} t}$ where $i = 1,2,3 \& j = \phi_1, \phi_2, \phi_3$; –

Taking assumed values of parameters:
failure rate for phase I (λ_1) = 0.003,
failure rate for phase II (λ_2) = 0.004,
failure rate for phase III (λ_3) = 0.005,
repair rate for phase I (α_1) = 3,
repair rate for phase II (α_2) = 4,
repair rate for phase III (α_3) = 5,
Various Costs : C_0 = 30,000, C_1 = 30,000, C_2 = 1000, C_3 = 800, C_4 = 20000.

Using the above particular case and the estimated values of various parameters, the values of measures of system performance have been computed as:

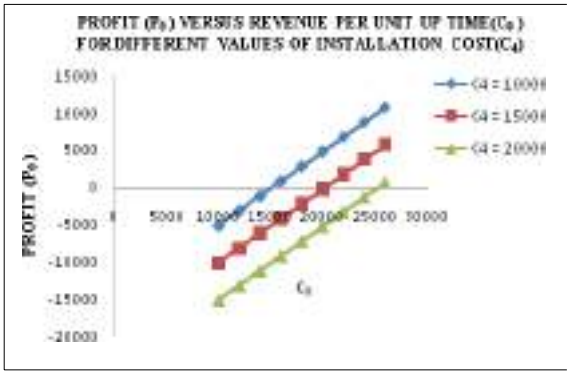


Fig. 2 Profit versus Revenue per unit up time

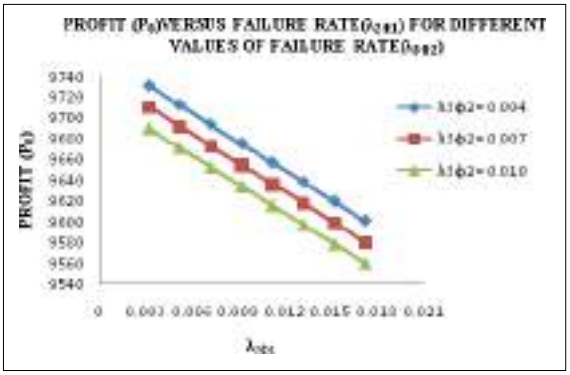


Fig. 3 Profit versus failure rate

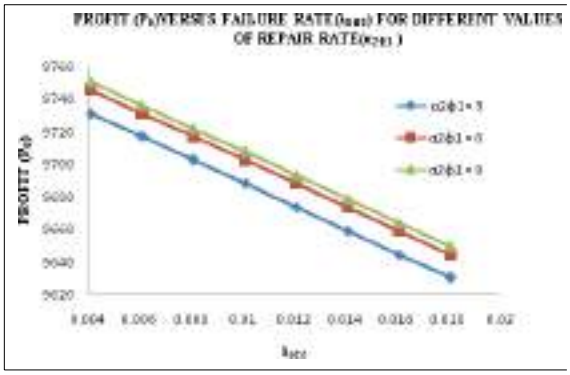


Fig. 4 Profit versus Failure Rate

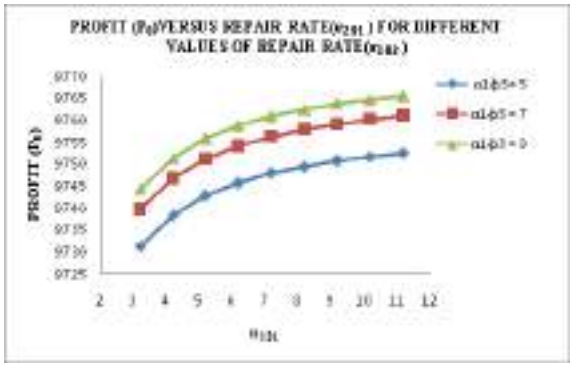


Fig. 5 Profit versus Repair rate

CONCLUSION

For the analysis purpose, various graphs have been plotted using the above particular case by giving numerical values to the parameters involved. Various costs is studied by plotting various graphs. The following conclusions have been drawn from the graphs:

Fig.2 depicts the behavior of profit (P_0) of the system with respect to revenue per unit uptime (C_0) of the system for different values of installation cost (C_4). From the graph, it can be concluded that Profit incurred to the system inclines with increment in the values of revenue per unit uptime (C_0) of the system and declines with higher values of installation cost (C_4). Also

Table 2: Revenue per Unit Uptime V/S Installation Cost

	C_4 = 10,000	C_4 = 15,000	C_4 = 20,000
C_0	> or < or = Rs.15135.6171	> or < or = Rs. 20180.8242	> or < or = Rs. 25226.0282

hence to attain Profit, revenue per unit uptime (C_0) of the system should be greater than the above cut-off points.

The behavior of profit (P_0) of the system with respect to failure rate ($\lambda_{2\varphi1}$) for different values of failure rate ($\lambda_{3\varphi2}$) is shown in Fig. 3 It is concluded that Profit incurred to the system declines with increment in the values of failure rate ($\lambda_{2\varphi1}$) and also declines with higher values of failure rate ($\lambda_{3\varphi2}$).

Fig.4 conveys the behavior of profit (P_0) of the system with respect to failure rate ($\lambda_{1\varphi2}$) for different values of repair rate ($\alpha_{2\varphi1}$). From the graph, it can be concluded that Profit incurred to the system declines with increment in the values of failure rate ($\lambda_{1\varphi2}$) and inclines with higher values of repair rate ($\alpha_{2\varphi1}$).

Fig.5 reveals profit (P_0) of the system with respect to repair rate ($\alpha_{2\varphi1}$) for different values of repair rate ($\alpha_{1\varphi3}$). From the graph, it can be concluded that Profit incurred to the system inclines with increment in the values of repair rate ($\alpha_{2\varphi1}$) and also inclines with higher values of repair rate ($\alpha_{1\varphi3}$).

Thus, we have explained three phases and have drawn some graphs. From the graphs, it can be concluded that profit incurred to the system decreases as failure rate increases and has higher values for higher values of repair rates. Also, it has been concluded that the reliability evaluation of phased mission system (by taking a general system) using Markov Modeling is much easier than the other methods like that fault tree analysis and binary decision diagram etc.

Further, the model discussed can be fitted by the designers/users to the real situations. While fitting this model, one can take estimated values of the parameters so that one can improve the reliability of the system. The limits of failure/repair rates are/can be obtained for the system to give higher reliability, availability and profit that is quite useful for both the system designer and the system user.

REFERENCES

[1] Alam, M., Al-Saggaf, U.M., "Quantitative Reliability Evaluation of Repairable Phased-Mission Systems using Markov Approach," *IEEE Trans. on Reliability,* Vol. 35, 1986, pp. 498-503.
[2] Alam, M., Song, M. and Seliga, T.A., **"**Reliability Analysis of Phased-Mission Systems: A Practical Approach," *Proceeding Annual Reliability & maintainability Symposium,* Vol. 2, 2006, pp. 551–558.
[3] Bouissou, M., Dutuit, Y and Maillard, S, "Reliability Analysis of a Dynamic Phased Mission System: Comparison of two Approaches," *Modern Statistical and Mathematical Methods in Reliability,* Vol. 2, 2005, pp. 87-104.
[4] Burdick, G.R., Fussell, J.B., Rasmuson, D.M. and Wilson, J.R., "Phased-Mission Analysis: A Review of New Developments and an Application," *IEEE Trans. on Reliabiability,* Vol. R-26, No.1, 1977, pp. 43-49.
[5] Dugan, J. B., "Automated Analysis of Phased-Mission Reliability," *IEEE Trans. on Reliability,* Vol. 40(1), 1991, pp. 45–52.
[6] Esary, J.D. and Ziehms, H., "Reliability Analysis of Phased Missions, Reliability and Fault Tree Analysis," *Proceeding of the Conference: Society for Industrial Applied Mathematics,* Philadelphia, Pennsylvania, 1975, pp. 213-236.

[7] Huang, X., Coolen, F., Coolen-Maturi, T., Zhang, Y., "A New Study on Reliability Importance Analysis of Phased Mission Systems," *IEEE Transactions on Reliability*, Vol.99, 2019, pp.1-11.
[8] Ma, Y. and Trivedi, K. S., "An Algorithm for Reliability Analysis of Phased-Mission Systems," *Reliability Engineering & System Safety*, Vol. 66, 1999, pp. 157–170.
[9] Nowakowski, T., "Problems of Reliability Modeling of Multiple-Phased Systems," *Wroclaw University of Technology Publishing House*, 2011, pp. 79-84
[10] Pedar, A. and Sarma, V.V.S, "Phased-Mission Analysis for Evaluating the Effectiveness of Aerospace Computing-Systems," *IEEE Transaction on Reliability*, Vol. R-30(5), 1981, pp. 429-437.
[11] Qiu Hui, Yan Xiangbin, Ma Xiaoyang & Peng Rui, "Reliability of a Phased-Mission System with a Storage Component," *Systems Science & Control Engineering*, Vol.6(1) , 2018, pp. 279-292.
[12] Somani, A.K. and Trivedi, K.S., "Phased-Mission System Analysis using Boolean Algebraic Methods," *in the Proceeding of ACM SIGMETRICS Conference of Measurement and Modeling of Computer Sciences*, Nashville, 1994, pp. 98-107.
[13] Tang,Z. and Dugan,J.B., "BDD-Based Reliability Analysis of Phased-Mission Systems with Multimode Failures," *IEEE Transactions on Reliability*, Vol. 55(2), 2006, pp. 350-360.
[14] Vaurio, J.K. , "Fault Tree Analysis of Phased Mission Systems with Repairable and Non-Repairable Components," *Reliability Engineering and System Safety*, Vol. 74, 2001, pp. 169-180.
[15] Zang, X., Sun, H. and Trivedi K. S., "A BDD-Based Algorithm for Reliability Evaluation of Phased Mission Systems," *IEEE Transactions on Reliability*, Vol. 48(1), 1999, pp. 50–60.

International Journal of Mathematics and Statistics,
Year 2021; Volume 22; Issue Number 1;
ISSN 0974–7117 (Print); ISSN 0973-8347 (Online);

Analysis of A Stocastic Model on Three-Similar Units Three-Phased Series-Parallel-Series Mission System

S. Kumari[1] and **R. Kumar**[2]

[1,2]Department of Mathematics,
M.D. University, Rohtak-124001, INDIA;
[1]Corresponding author Email: [1]sudeshmdu@gmail.com,
[2]Email : drrajeevmdu@gmail.com

ABSTRACT

In this article, we deal with the reliability and availability analysis of a stochastic model in a three-phase mission system with three similar units. The developed system was considered in which the units operate in series, parallel and series configuration respectively. The single repair facility is expected to repair drives according to the FCFS (first come first serve) model. Using the semi-Markov process and regenerative point techniques, different measurements of the system performance are obtained in each step. The system was analyzed graphically by taking a particular case. Different conclusions were drawn on the reliability and cost consideration of the system in each phase, as well as for the whole system (such as combined Phase I, Phase II, Phase III).

Keywords: three-phase mission system, series configuration, parallel configuration, reliability, Semi-Markov process, regenerative point techniques.

Mathematics Subject Classification: 62J12, 62G99

1. INTRODUCTION

In various real-world applications, such as aerospace, communications networks, chemical control, electronics, transportation, and nuclear power, a mission can contain several tasks or phases that must be performed in sequence. Most reliability analyzes perform a mission in phases during which system configuration, success criteria, and component behavior remain similar. But multiple stages apply in many applications. Multi-phase systems perform a mission that can be divided into consecutive time periods (phases). At each stage, the system must perform a specific task over different time periods, subject to different environmental conditions and success criteria. Compared to single-phase systems, system configuration, phase duration, operational requirements for individual components, system performance, component behavior, success criteria and parameters such as failure rates and component repair rates may vary from phase to phase. Such systems are known as phased mission systems and have been studied by many researchers. Among the latest developments on phased mission systems, Esary and Ziehms (1975) discussed the reliability analysis of phased mission systems during the dependent phases of a mission that has several independent components. Alam and Al-Saggaf (1986) developed a technique for assessing the reliability of phased mission systems using the Markov approach during which system criteria and failure rates of all components can vary from phase to phase. Dugan (1991) suggested an automated analysis of the phased mission system that has a single Markov chain with a state space that is suitable for joining

ISSN 0974–7117 (Print); ISSN 0973-8347 (Online)
www.ceser.in/ceserp
www.ceserp.com/cp-jour

the state spaces of the individual phases. Bouissou et al. (2005) presented the reliability analysis of a phased dynamic mission system. Tang and Dugan (2006) proposed an algorithm based on a binary decision diagram for the reliability analysis of phase-based mission systems that have multimodal failures. Nowakowski (2011) studied the basic problems related to the reliability of multiphase systems, including logistics and transport systems. Haung et al. (2019) presented and applied the survival signature to assess the reliability of PMS with multiple types of components. A series of practical systems that operate in this sequential manner such as: electronic power transformers, multi-generator power system, nuclear power plant, flight of an airplane, aerospace and distributed computer systems. For example, an airplane mission has many phases, including tax, takeoff, cruise, descent, and landing phases (Tang and Dugan, 2006).

In the literature, researchers (Andrews and Dunnett, 2000; Mura and Bondavalli, 2001; tang and Dugan, 2006; Chew et al., 2008) have focused on the problem of the phase mission system, using mainly the analysis of fault tree, Boolean algebra and Petri nets. All of these techniques are limited by the size of the problem. When configuring system reliability is complicated and the number of components is large, especially when it is necessary to evaluate system reliability from multiple mission cycles, the use of these techniques will not be easy or straightforward. These techniques are suitable when modeling is non-repairable phased mission systems. These techniques avoid blowing up state space. The Markov model is a powerful tool in reliability engineering. The Markov model analyzes the system by identifying all the different states in which the system is able to produce precise measures of system reliability by assigning transition rates between states. Markov-based approaches capture functional dependencies between components and the required order of failures. It is the Markov Reliability analysis of the staged mission system that provides a numerical result of the staged mission system with graphical interpretation.

Taking this point of view, the paper deals with the reliability and availability analysis of a stochastic model in a three-phased mission system of three similar units.

2. DESCRIPTION OF THE MODEL

The model is based on a separate phased model. The system in which the units operate in series, parallel and series respectively has been considered. Initially, three similar units are operational in all respective phases. If any of the units fail, the repairman repairs them. The single repair facility that repairs units according to the FCFS (first come first serve) has been considered. The system works slowly and goes into a state of degradation. Hence, it is assumed that the failure rate and hence the repair rate in later phases varies, however within the phase it remains constant. If all units fail, the system shuts down and goes to the completely failed state. The reliability of the entire phased mission system is considered the combined reliability of these phases. Phase III is assumed to be Phase I but rates are taken differently.

Other essential assumptions made in formulating the model are:

1. Failure rates and repair rates for a particular phase are constant, but can change in a single phase.
2. The system is as good as new after each repair.
3. The time until a unit fails is distributed exponentially, while the other time distributions are general.
4. The transition times between consecutive phases are instantaneous.
5. Switching is perfect and instant.
6. All random variables are mutually independent.

Table 1 shows notations used in developed model and description of the model.

Table 1: Notations

Notations	Description
$\lambda_1/ \lambda_2/ \lambda_3$	Failure rate of unit in j^{th} phase (j = 1, 2, 3) resp.
$\beta_1/ \beta_2/ \beta_3$	Repair rate of unit in j^{th} phase (j = 1, 2, 3) resp.
$q_{ij\varphi j}(t)/ Q_{ij\varphi j}(t)$	Probability density function (P.d.f.) / Cumulative distribution function (C.d.f.) of the first time passage from a regenerative state i to a regenerative state j or to a failed state j without visiting any other regenerative state in (0, t].
$p_{ij\varphi j}(t)/ p_{ij\varphi j}^{(k)}(t)$	Probability of transitioning from regenerative state i to regenerative state j without visiting any other state / and that of visiting state k once in (0, t] respectively.
$\mu_{i\varphi j}$	Mean sojourn time in the regenerative state i before moving to any other state. If Ti denotes the time spent in state i, then the average time spent in state i is $\mu_i(t) = \int_0^\infty P(T_i > t)\, dt$
$UT_i(t)$	Probability that the system is in the active state at time t since the system entered the regenerative state i at time t = 0.
$DT_{i\varphi j}(t)$	Probability that the system is in a degraded state at time t given that the system entered the regenerative state i at time t = 0.
$BR_{i\varphi j}(t)$	Probability that a repairman is busy repairing the failed unit at time t, since the system started from the regenerative state i at t = 0.
$VR_{i\varphi j}(t)$	Expected number of visits by the repairman at instant t, given that the system started from the regenerative state i at t = 0.
$Mu_{i\varphi j}(t)$	Probability that the system is initially in a regenerative state i without passing through a regenerative state or returning to itself through one or more non-regenerative states.
$Md_{i\varphi j}(t)$	Probability that the system is initially inactive in the regenerative state i without passing through a regenerative state or returning to itself through one or more non-regenerative states.
$W_{i\varphi j}(t)$	Probability that the repairman is engaged with the system initially in the regenerative state i at instant t without going through any regenerative state or returning to himself through one or more non-regenerative states.
$g_1(t)/ g_2(t)/ g_3(t)$	Pdf of time for repair of unit in j^{th} phase (j = 1,2,3) resp.
$G_1(t)/ G_2(t)/ G_3(t)$	Cdf of time for repair of unit in j^{th} phase (j = 1, 2, 3) resp.
$\phi_j(t)$	Time duration of j^{th} phase (j = 1, 2, 3)
C_0	Revenue per unit up time of the system.
C_1	Revenue per unit degradation time of the system.

C_2	Cost per unit of busy period of the repairman.
C_3	Cost per visit of the repairman.
C_4	Installation cost
*	Symbol for Laplace Transform e.g. $f^*(s) = \int_0^\infty e^{-st} f(t)\, dt = \int_0^\infty e^{-st}\, dF(t)$
**	Symbol for Laplace-Stieltjes Transform e.g. $F^{**}(s) = \int_0^\infty e^{-st}\, dF(t) = \int_0^\infty e^{-st}\ f(t)$
©	Symbol for Laplace Convolution, e.g. $a(t) \copyright b(t) = \int_0^t a(u)\, b(t-u)\, du$
Ⓢ	Symbol for Stieltjes Convolution, e.g. $a(t) \textcircled{S} B(t) = \int_0^t A(u)\, B(t-u)\, du$

The matter of table 2 shows the states used in developed model.

Table 2: States of Statistical Model

States	Description
O	Operative Unit
F_r	Unit is failed and is under repair
F_R	Failed unit is repair continuing from previous state
F_w	Unit is failed and waiting for repair

Figure 1. shows various transition states of the system. Initially the system works where all phases are operational. The epochs of entry to states 0, 1 in phase I, states 2, 3, 6 in phase II and states 7, 8 in phase III are regenerative points and are therefore considered regenerative states. States 3, 4 and 6 are degraded. State 1 in phase I, state 5 in phase II, and state 8 in phase III fail.

3. STATE TRANSITION DIAGRAM

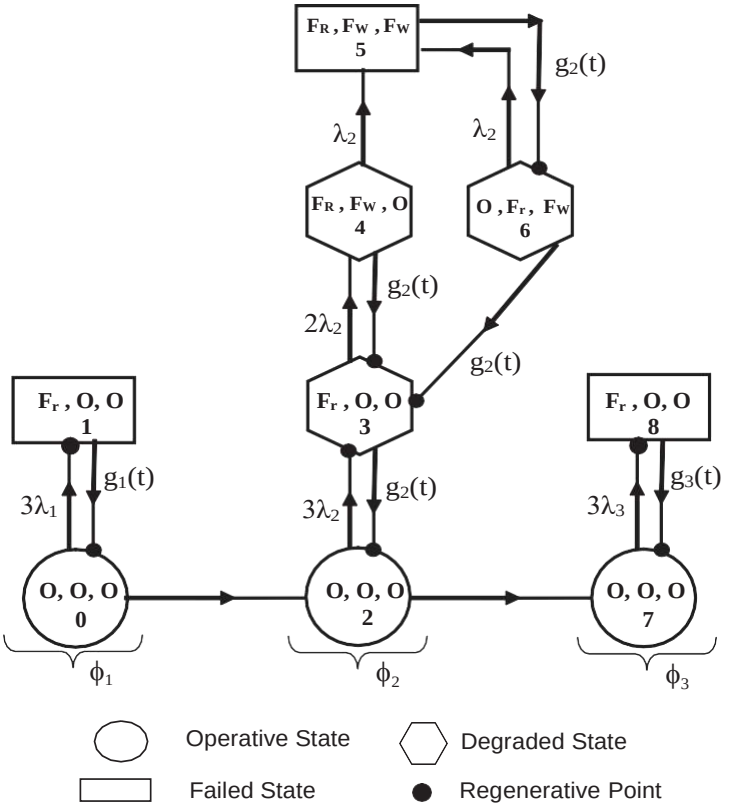


Figure. 1. State Transition Diagram

4. TRANSITION PROBABILITIES AND MEAN SOJOURN TIME

For each phase, various transition probabilities are obtained such as:

Phase I

$$dQ_{01}^{\phi_1}(t) = 3\lambda_1 e^{-3\lambda_1 t}dt \quad ; \qquad dQ_{10\phi_1}(t) = g_1(t)dt$$

Phase II

$$dQ_{23}^{\phi_2}(t) = 3\lambda_2 e^{-3\lambda_2 t}dt \quad ; \qquad dQ_{32\phi_2}(t) = g_2(t)e^{-2\lambda_2 t}dt \; ;$$

$$dQ_{33\phi_2}^{(4)}(t) = [2\lambda_2 e^{-2\lambda_2 t} \copyright e^{-\lambda_2 t}]g_2(t)dt \; ; \qquad dQ_{35\phi_2}^{(4)}(t) = [2\lambda_2 e^{-2\lambda_2 t} \copyright e^{-\lambda_2 t}]\lambda_2 \overline{G_2(t)}dt \; ;$$

$$dQ_{36\phi_2}^{(4,5)}(t) = [2\lambda_2 e^{-2\lambda_2 t} \copyright \lambda_2 e^{-\lambda_2 t} \copyright 1]g_2(t)dt ; \qquad dQ_{63\phi_2}(t) = g_2(t)e^{-\lambda_2 t}dt \; ;$$

$$dQ_{65}^{\phi_2}(t) = \lambda_2 e^{-\lambda_2 t}\overline{G_2(t)}dt \; ; \qquad dQ_{66\phi_2}^{(5)}(t) = [\lambda_2 e^{-\lambda_2 t} \copyright 1]g_2(t)dt$$

Phase III

$$dQ_{78\phi_3}(t) = 3\lambda_3 e^{-3\lambda_3 t}dt \quad ; \qquad dQ_{87\phi_3}(t) = g_3(t)dt$$

Taking Laplace's Stieltjes transforms from the previous derivations, we get the non-zero element $p_{ij\phi_1}$ are given by (Table 3): [illegible]

***Table 3*:** Various Transition Probabilities in steady state are obtained as:

Phase I

$$p_{01\phi_1} = p_{10\phi_1} = 1$$

Phase II

$$p_{23\phi_2} = 1; \quad p_{32\phi_2} = g^*_2(2\lambda_2); \quad p^{(4)}_{33\phi_2} = 2[g^*_2(\lambda_2) - g^*_2(2\lambda_2)];$$

$$p^{(4)}_{35\phi_2} = p^{(4,5)}_{36\phi_2} = 1 - 2g^*_2(\lambda_2) + g^*_2(2\lambda_2); \quad p_{63\phi_2} = g^*_2(\lambda_2); \quad p_{65\phi_2} = p^{(5)}_{66\phi_2} = 1 - g^*_2(\lambda_2)$$

By these transition probabilities, it can be established that

$$p_{23\phi_2} = 1; \quad p_{32\phi_2} + p^{(4)}_{33\phi_2} + p^{(4)}_{35\phi_2} = 1; \quad p_{32\phi_2} + p^{(4)}_{33\phi_2} + p^{(4,5)}_{36\phi_2} = 1;$$

$$p_{63\phi_2} + p_{65\phi_2} = 1; \quad p_{63\phi_2} + p^{(5)}_{66\phi_2} = 1$$

Phase III

$$p_{78\phi_3} = p_{87\phi_3} = 1$$

Table 4. Mean Sojourn Time and Unconditional Mean Time are obtained as:

Phase I

Mean Sojourn Time $\mu_{0\phi_1} = \frac{1}{3\lambda_1}$; $\mu_{1\phi_1} = -g^{*'}_1(0)$

Unconditional Mean Time $m_{01\phi_1} = \mu_{0\phi_1}$; $m_{10\phi_1} = \mu_{1\phi_1}$

Phase II

Mean Sojourn Time $\mu_{2\phi_2} = \frac{1}{3\lambda_2}$; $\mu_{3\phi_2} = \frac{1 - g^*_2(2\lambda_2)}{2\lambda_2}$;

$$\mu_{4\phi_2} = \mu_{6\phi_2} = \frac{1 - g^*_2(\lambda_2)}{\lambda_2}$$

Unconditional Mean Time $m_{23\phi_2} = \mu_{2\phi_2}$; $m_{63\phi_2} + m_{65\phi_2} = \mu_{6\phi_2}$

$$m_{32\phi_2} + m^{(4)}_{33\phi_2} + m^{(4,5)}_{36\phi_2} = m_{63\phi_2} + m^{(5)}_{66\phi_2} = -g^{*'}_2(0) = k_1;$$

$$m_{32\phi_2} + m^{(4)}_{33\phi_2} + m^{(4)}_{35\phi_2} = \frac{3 - 4g^*_2(\lambda_2) + g^*_2(2\lambda_2)}{2\lambda_2} = k_2$$

Phase III

Mean Sojourn Time $\mu_{7\phi_3} = \frac{1}{3\lambda_3}$; $\mu_{8\phi_3} = -g^{*'}_3(0)$

Unconditional Mean Time $m_{78\phi_3} = \mu_{7\phi_3}$; $m_{87\phi_3} = \mu_{8\phi_3}$

5. MEASURES OF SYSTEM PERFORMANCE

Phase I

To calculate the mean system failure time (MTSF), the failure state is considered as an absorbing state. Using probabilistic arguments, we obtain the following recursive relations for:

$$\Phi_{\phi_1}$$

Taking L.S.T of these equations and solving for $\Phi^{**}_{0\phi_1}(s)$, we get $\Phi^{**}_{0\phi_1}(s) = \frac{N_{1\phi_1}(s)}{D_{1\phi_1}(s)}$

where

$N_{1\phi_1}(s) = Q^{**}_{01\phi_1}(s)$ and $D_{1\phi_1}(s) = 1$

Now the mean time to system failure (MTSF) when the system starts from the state (0), is

$$T_{0\phi_1} = \lim_{s\to 0} \frac{1-\Phi^{**}_{0\phi_1}(s)}{s}$$

Using L'Hospital's rule and putting in the value of $\Phi^{**}_{0\phi_1}(s)$, we get

$$T_{0\phi_1} = \frac{N_{1\phi_1}}{D_{1\phi_1}}$$

where

$N_{1\phi_1} = \mu_{0\phi_1}$ and $D_{1\phi_1} = 1$

Similarly

Phase II

The recursive relations are obtained for $\Phi_{i\phi_2}(t)$:

Phase III

The following recursive relations are obtained for $\Phi_{i\phi_3}(t)$:

Thus Other measures of system performance as mean up time, mean degradation time, total fraction of time for which the repairman is busy, expected number of visits by the repairman are obtained in this way. The steady state solutions are obtained as:

Phase I

Mean Time to System Failure: $T_{0\phi_1} = \frac{N_{1\phi_1}}{D_{1\phi_1}}$

Mean Up Time: $UT_{0\phi_1} = \frac{N_{2\phi_1}}{D_{2\phi_1}}$

Mean Degradation Time: $DT_{0\phi_1} = \frac{N_{3\phi_1}}{D_{2\phi_1}}$

Busy Period of the Repairman: $BR_{0\phi_1} = \frac{N_{4\phi_1}}{D_{2\phi_1}}$

Expected Number of Visits by the Repairman: $VR_{0\phi_1} = \frac{N_{5\phi_1}}{D_{2\phi_1}}$

where

$N_{1\phi_1} = \mu_{0\phi_1}$; $N_{2\phi_1} = \mu_{0\phi_1}$; $N_{3\phi_1} = 0$; $N_{4\phi_1} = 1 + \mu_{1\phi_1}$; $N_{5\phi_1} = 1$

$D_{1\phi_1} = 1$; $D_{2\phi_1} = \mu_{0\phi_1} + \mu_{1\phi_1}$

Phase II

Mean Time to System Failure: $T_{2\phi_2} = \frac{N_{1\phi_2}}{D_{1\phi_2}}$

Mean Up Time: $UT_{2\phi_2} = \frac{N_{2\phi_2}}{D_{2\phi_2}}$

Mean Degradation Time: $DT_{2\phi_2} = \frac{N_{3\phi_2}}{D_{2\phi_2}}$

Busy Period of the Repairman: $BR_{2\phi_2} = \frac{N_{4\phi_2}}{D_{2\phi_2}}$

Expected Number of Visits by the Repairman: $VR_{2\phi_2} = \frac{N_{5\phi_2}}{D_{2\phi_2}}$

where

$N_{1\phi_2} = \mu_{2\phi_2}(1 - p^{(4)}_{33\phi_2}) + k_2$; $N_{2\phi_2} = \mu_{2\phi_2} p_{32\phi_2} p_{63\phi_2}$; $N_{3\phi_2} = \mu_{3\phi_2} p_{63\phi_2} + \mu_{4\phi_2} p^{(4,5)}_{36\phi_2}$;

$N_{4\phi_2} = (1 + \mu_{3\phi_2}) p_{63\phi_2} + (1 + \mu_{6\phi_2}) p^{(4,5)}_{36\phi_2}$; $N_{5\phi_2} = p_{32\phi_2} p_{63\phi_2}$

$D_{1\phi_2} = p^{(4)}_{35\phi_2}$; $D_{2\phi_2} = \mu_{2\phi_2} p_{32\phi_2} p_{63\phi_2} + k_2(p_{63\phi_2} + p^{(4,5)}_{36\phi_2})$

Phase III

Mean Time to System Failure: $T_{7\phi_3} = \frac{N_{1\phi_3}}{D_{1\phi_3}}$

Mean Up Time: $UT_{7\phi_3} = \frac{N_{2\phi_3}}{D_{2\phi_3}}$

Mean Degradation Time: $DT_{7\phi_3} = \frac{N_{3\phi_3}}{D_{2\phi_3}}$

Busy Period of the Repairman: $BR_{7\phi_3} = \frac{N_{4\phi_3}}{D_{2\phi_3}}$

Expected Number of Visits by the Repairman: $VR_{7\phi_3} = \frac{N_{5\phi_3}}{D_{2\phi_3}}$

where

$N_{1\phi_3} = \mu_{7\phi_3}$; $N_{2\phi_3} = \mu_{7\phi_3}$; $N_{3\phi_3} = 0$; $N_{4\phi_3} = 1 + \mu_{8\phi_3}$; $N_{5\phi_3} = 1$

$D_{1\phi_3} = 1$; $D_{2\phi_3} = \mu_{7\phi_3} + \mu_{8\phi_3}$

Combined Phases

Mean Time to System Failure: $T_0 = \frac{N_1}{D_1}$

Mean Up Time: $UT_0 = \frac{N_2}{D_2}$

Mean Degradation Time: $DT_0 = \frac{N_3}{D_2}$

Busy Period of the Repairman: $BR_0 = \frac{N_4}{D_2}$

Expected Number of Visits by the Repairman: $VR_0 = \frac{N_5}{D_2}$

where

$$N_1 = \mu_{0\phi_1}\mu_{7\phi_3}[\mu_{2\phi_2}(1 - p^{(4)}_{33\phi_2}) + k_2]\ ; \quad N_2 = \mu_{0\phi_1}\mu_{2\phi_2}\mu_{7\phi_3}p_{32\phi_2}p_{63\phi_2}\ ; \quad N_3 = 0;$$

$$N_4 = [1 + \mu_{1\phi_1}][1 + \mu_{8\phi_3}][(1 + \mu_{3\phi_2})p_{63\phi_2} + (1 + \mu_{6\phi_2})p^{(4,5)}_{36\phi_2}]\ ; N_5 = p_{32\phi_2}p_{63\phi_2}$$

$$D_1 = [\mu_{0\phi_1} + \mu_{7\phi_3}][\mu_{2\phi_2}(1 - p^{(4)}_{33\phi_2}) + k_2] + p^{(4)}_{35\phi_2}\mu_{0\phi_1}\mu_{7\phi_3}$$

$$D_2 = [\mu_{0\phi_1} + \mu_{1\phi_1}][\mu_{7\phi_3} + \mu_{8\phi_3}][\mu_{2\phi_2}p_{32\phi_2}p_{63\phi_2} + k_2(p_{63\phi_2} + p^{(4,5)}_{36\phi_2})]$$

6. PROFIT ANALYSIS OF THE SYSTEM

The expected total profit (P_0) incurred to the system in steady state is given by

$$P_0 = C_0UT_0 + C_1DT_0 - C_2BR_0 - C_3VR_0 - C_4\ ,$$

7. NUMERICAL COMPUTATIONS AND GRAPHICAL ANALYSIS

The following particular case and values of parameters are considered for graphical purpose:

$g_i(t) = \alpha_i e^{-\alpha_i t}$ where $i = 1, 2, 3$

Taking assumed values of parameters: failure rate for phase I (λ_1) = 0.003, failure rate for phase II (λ_2) = 0.004, failure rate for phase III (λ_3) = 0.005, repair rate for phase I (α_1) = 3, repair rate for phase II (α_2) = 4, repair rate for phase III (α_3) = 5, C_0 = 30,000, C_1 = 30,000, C_2 = 1000, C_3 = 800, C_4 = 20000 For the analysis purpose, various graphs have been plotted for mean time to system failure (T_0), mean up time (UT_0) and profit (P_0) of the system with respect to various estimated and

assumed values of the failure rates (λ_1 , λ_2 , λ_3) and repair rates (α_1, α_2 , α_3) and various costs is studied by plotting various graphs.

Table 5: Numerical Measurement of Combined Phases of Statistical Model

Rates						Measures of the system		
Failure Rates			Repair Rates			Measures		
λ_1	λ_2	λ_3	β_1	β_2	β_3	MTSF	Mean Up Time	Profit
0.003	0.004	0.005	3	4	5	41.66663	0.991057	9731.696
0.004	0.005	0.006	3	4	5	33.33328	0.988726	9661.775
0.005	0.006	0.007	3	4	5	27.77772	0.986411	9592.317
0.006	0.007	0.008	3	4	5	23.80945	0.984103	9523.053
0.007	0.008	0.009	3	4	5	20.83325	0.981801	9453.981
0.008	0.009	0.01	3	4	5	18.51843	0.979505	9385.103
0.009	0.01	0.011	3	4	5	16.66656	0.977216	9316.415
0.01	0.011	0.012	3	4	5	15.1514	0.974934	9247.917
						13.88877	0.972658	9179.608

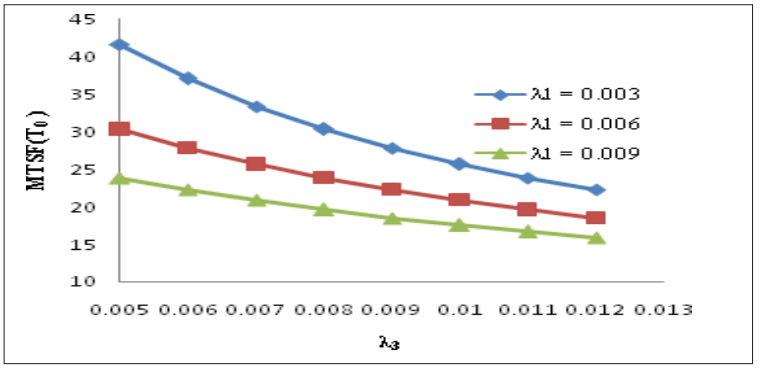


Figure 2. Mean Time to System Failure (T_0) versus Failure Rate (λ_3) for Different Values of Failure Rate(λ_1)

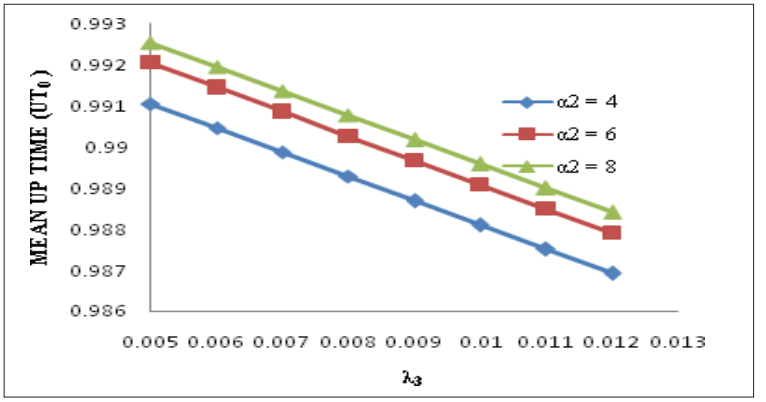


Figure 3. Mean Up Time (UT_0) versus Failure Rate(λ_3) for Different Values of Repair Rate(α_2)

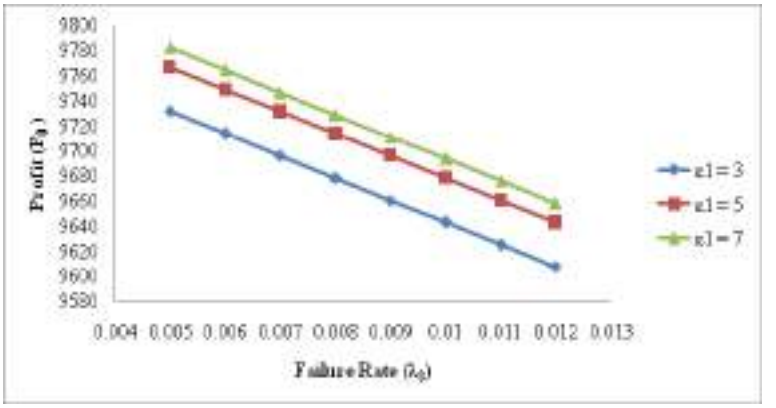


Figure 4. Profit (P_0) versus Failure Rate (λ_3) for Different Values of Repair Rate(α_1)

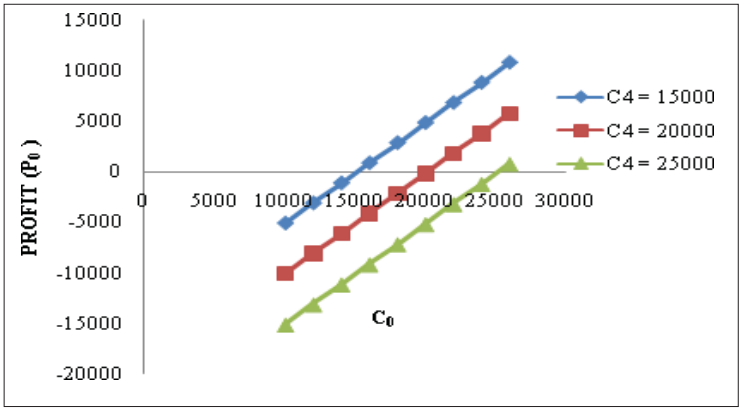


Figure 5. Profit (P_0) versus Revenue Per Unit Up Time(C_0) for Different Values of Installation Cost(C_4)

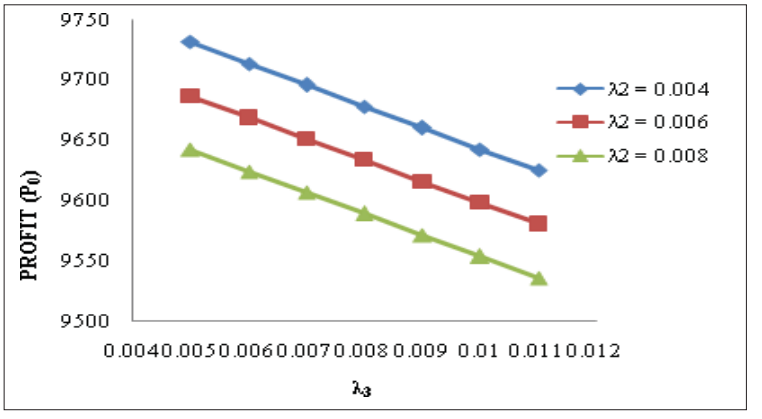


Figure 6. Profit (P_0) versus Failure Rate (λ_3) for Different Values of other Failure Rate (λ_2)

8. CONCLUSION

The following interpretations and conclusions have been drawn from the graphs:

The graph in **Figure 2**. exhibits the behavior of Mean Time to System Failure (T_0) of the system in relation to failure rate (λ_3) for different values of other failure rate (λ_1). The values of other parameters taken are λ_2 = 0.004, α_1 = 3, α_2 = 4, α_3 = 5. It is concluded that mean time to system failure (MTSF) declines with increment in the values of failure rate (λ_3) and also declines with increment in the values of other failure rate (λ_1).

The graph in **Figure 3**. states the behavior of Mean Up Time (UT_0) of the system in relation to failure rate (λ_3) for different values of repair rate (α_2). The values of other parameters taken are λ_1 = 0.003, λ_2 = 0.004, α_1 = 3, α_3 = 5. It is concluded that Mean up time declines with increment in the values of failure rate (λ_3) and inclines with increment in the values of repair rate (α_2).

Figure 4. depicts the patterns of profit (P_0) incurred to the system in relation to failure rate (λ_3) for different values of repair rate (α_1). The estimated/ assumed values of other parameters are taken as λ_1 = 0.003, λ_2 = 0.004, α_2 = 4, α_3 = 5, C_0 = Rs.30000, C_1 = Rs. 30000, C_2 = Rs.1000, C_3 = Rs.800, C_4 = Rs. 20000. It is concluded that Profit incurred to the system declines with increments in the values of failure rate (λ_3) and inclines with increments in the values of repair rate (α_1)

Figure 5. demonstrates the behaviour of profit (P_0) incurred to the system in relation to revenue per unit up time (C_0) for different values of installation cost (C_4). The values of other parameters taken are λ_1 = 0.003, λ_2 = 0.004, λ_3 = 0.005, α_1 = 3, α_2 = 4, α_3 = 5, C_1 = Rs. 30,000, C_2 = Rs.1000, C_3 = Rs. 800.

Following conclusion is drawn from the graph.

- Profit incurred to the system inclines with increment in the values of revenue per unit uptime (C_0) of the system and declines with higher values of installation cost (C_4). Also
- when C_4 = 15,000. Profit incurred to the system inclines for C_0 > Rs.15135.5850, declines for C_0 < Rs.15135.5850, remains unchanged for C_0 = Rs.15135.5850 and hence to attain Profit, revenue per unit uptime (C_0) of the system should be greater than Rs.15135.5850.
- when C_4 = 20,000. Profit incurred to the system inclines for C_0 > Rs. 20180.7824, declines for C_0 < Rs. 20180.7824, remains unchanged for C_0 = Rs. 20180.7824 and hence to attain Profit, revenue per unit uptime (C_0) of the system should be greater than Rs. 20180.7824.
- when C_4 = 25,000. Profit incurred to the system inclines for C_0 > Rs. 25225.9796, declines for C_0 < Rs. 25225.9796, remains unchanged for C_0 = Rs. 25225.9796 and hence to attain Profit, revenue per unit uptime (C_0) of the system should be greater than Rs. 25225.9796.

Figure 6. depicts the patterns of profit (P_0) incurred to the system in relation to failure rate (λ_3) for different values of other failure rate (λ_2). The estimated/ assumed values of other parameters are taken as λ_1 = 0.003, α_1 = 3, α_2 = 4, α_3 = 5, C_0 = Rs.30000, C_1 = Rs. 30000, C_2 = Rs.1000, C_3 = Rs.800, C_4 = Rs. 20000. It is concluded that Profit incurred to the system declines with increments in the values of failure rate (λ_3) and also declines with increments in the values of other failure rate (λ_2).

10. REFERENCES

Alam, M., Al-Saggaf, U.M., 1986, Quantitative Reliability Evaluation of Repairable Phased-Mission Systems using Markov Approach. *IEEE Trans. on Reliability* 35, 498-503.

Andrews, J. D. and Dunnett, S. J., 2000, Event-tree Analysis using Binary Decision Diagrams, *IEEE Transactions on Reliability*, 49, 230-238.

Bouissou, M., Dutuit, Y., Maillard, S., 2005, Reliability Analysis of a Dynamic Phased Mission System: Comparison of two Approaches. *Modern Statistical and Mathematical Methods in Reliability,* 2, 87-104.

Chew, S.P., Dunnett, S.J. and Andrews, J.D., 2008, Phased Mission Modelling of Systems with Maintenance Free Operating Periods using Simulated Petri Nets, *Reliability Engineering and System Safety*, 93, 980-994.

Dugan, J.B.,1991, Automated Analysis of Phased-Mission Reliability, *IEEE Trans. on Reliability*, 40(1), 45–52.

Esary, J.D., Ziehms, H., 1975, Reliability Analysis of Phased Missions, Reliability and Fault Tree Analysis, *Proceeding of the Conference: Society for Industrial Applied Mathematics, Philadelphia, Pennsylvania*, 213-236.

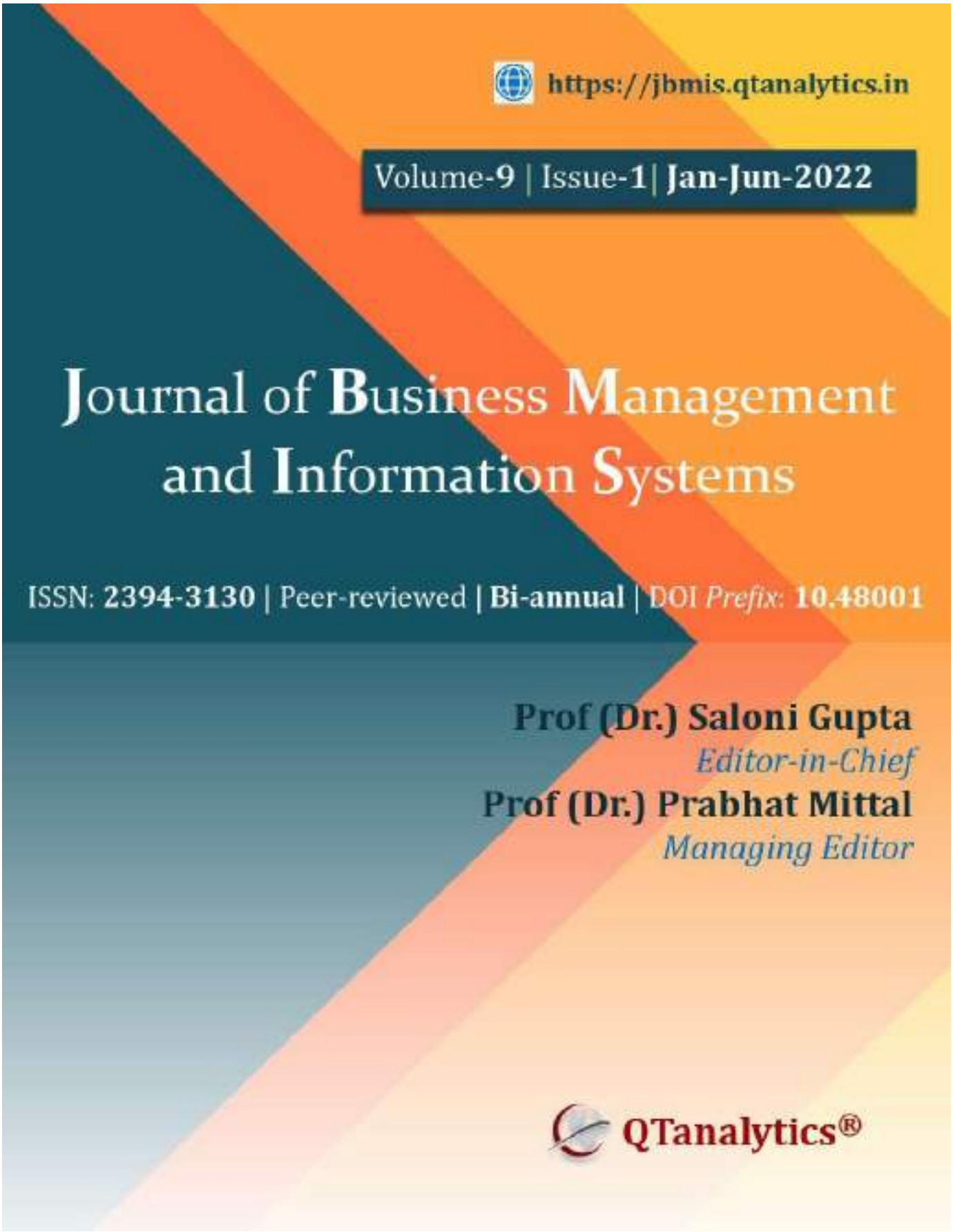
Huang, X., Coolen, F., Coolen-Maturi, T., Zhang, Y., 2019, A New Study on Reliability Importance Analysis of Phased Mission Systems, *IEEE Transactions on Reliability*, 99, 1-11.

Mura, I. and Bondavalli, A.2001, Markov Regenerative Stochastic Petri Nets to Model and Evaluate Phased Mission Systems Dependability, *IEEE Transactions on Reliability*, 50 (12), 1337-1351.

Nowakowski, T., 2011, Problems of Reliability Modelling of Multiple-Phased Systems, *Wroclaw University of Technology Publishing House*, 79-84.

Tang, Z, Dugan, J.B., 2006, BDD-Based Reliability Analysis of Phased-Mission Systems with Multimode Failures, *IEEE Transactions on Reliability,* 55(2), 350-360.

20. Dr. Sunil Kumari "Reliability Evaluation Factors of Millennial Perceptions towards Digital Payments" Year 2022



Research Article

Volume-9 | Issue-1| Jan-Jun-2022|

Check for updates

JOURNAL OF BUSINESS MANAGEMENT AND INFORMATION SYSTEMS

E-ISSN: **2394-3130**

Double Blind Peer Reviewed Journal

URL: https://jbmis.qtanalytics.in

Reliability Evaluation of Factors of Millennial Perception towards Digital Payments

Sunil Kumari[1], Jaya Gupta[2], Renu Jain[3*]

[1]Government College, Mehem, Haryana INDIA

[2]New Delhi Insitute of Management, New Delhi INDIA

[3]Satyawati College, University of Delhi INDIA

*Correspondence: profsrenu@gmail.com

ABSTRACT: Post-demonetization, digital payments in transactions became substantial; nonetheless, these services are still relatively new to Indian customers and are still in their infancy. Investigating the variables that influence customers' intentions to utilise digital payment services in India, particularly among millennials, is necessary to promote the development of computer enabled devices as an alternative payment method. Present study is to do a pilot study on millennial perception towards Mobile Banking/Digital wallets/UPI. The study makes use of Cronbach's Alpha to see if the data is internally consistent. Millennials will make up 35% of the global workforce just this year. The results based on Cronbach's Alpha show that the data is internally consistent after dropping each variable for challenges faced and customer satisfaction.

KEYWORDS: Reliability analysis, pilot survey, digital transactions, banking

INTRODUCTION

In India, mobile banking began in 2002, with transactions conducted via SMS at the time. Almost every banking transaction can now be completed on a computer, laptop, or smartphone. Everything can be done online, from checking account balances to paying credit card bills, utility bills, and transferring funds (Mittal, 2020b). Mobile banking evolved from online banking to provide even greater convenience and accessibility. In 2018, nearly all banks will provide financial transaction mobile phone apps. These apps eliminate the need for a computer or laptop to transfer funds, and as technology advances, bank visits will become obsolete (Gupta et. al., 2022; Mehta et. al., 2022; Mittal, 2020). Banking transactions can be completed as usual once a customer has downloaded the mobile banking app to their smartphone.

The most important demographic and economic forces in our time are millennials and Generation Z. Millennials will make up 35% of the global workforce just this year. Their total revenue will top $4 trillion within ten years. We're talking about a global population of 1.8 billion technologically savvy individuals who will have more disposable income than any previous generation (Mandal et. al., 2022). They are a group of people who spend more than 35 hours per week online, which is 50% higher than the average amount of time spent online by all other groups put together. There will be a tectonic upheaval in the fundamental character of finance when a force this large connects with the world economy, which is historically led by boomers and Gen X. One of today's most significant demographic and economic forces is the millennial generation. They have more purchasing power than ever before, and the banking sector has advanced by using technology and streamlining the procedure for customers (Ashokan & Menon, 2016; Harchekar, 2018). Technology has completely changed the financial sector, and everything is now digital and personalised, which is probably the only way to go in the future (Mittal, 2020a). By making

DOI: https://doi.org/10.48001/jbmis.2022.0901003

banking simple, approachable, and transparent, it has effectively targeted the millennial generation and laid the groundwork for the growth of the nation's economy.

Today, mobile technologies are being used more and more, but India is surprising in how little it uses digital payment systems. For Indian customers, digital payment systems are still in their infancy and are relatively new. By examining the critical variables influencing customers' propensity to utilise digital payment services, this study aims to provide light on the growth of digital payment services in India (OECD, 2019). To gain a competitive edge, digital payment services are crucial for businesses engaged in electronic and mobile commerce. Numerous studies have examined digital payment services from both the technical and user acceptability aspects in various nations. The variables influencing Indian customers' inclination to adopt digital payment systems have only been partially understood by previous studies. Little is being done to close the knowledge gap about the critical elements influencing Indian customers' intention to use digital payment services, which motivates the implementation of digital payment to meet its expectations.

LITERATURE REVIEW

The evolution of payment methods began with barter and moved on to money, checks, and credit before focusing on mobile payments in the age of electronic and mobile commerce (Garg, 2014). According to Smart Card Alliance, depending on the sort of technology used to enable them, mobile payments can be either contactless or remote (Horticulture 2011; Lipton et. al., 2016) . Remote mobile payments are made using a mobile device without interacting with the physical point of sale (POS) system of the merchant. Examples of such transactions include conducting electronic commerce over a mobile internet connection, transferring money using a mobile application, and downloading pay-per-download news articles (Kumar & Pavithra, 2017). It is dependent on technologies like mobile applications, secure mobile browsers, and short messaging service (SMS).

Proximity mobile payments is a phenomenon paid for a products or services at the point-of-sale (POS) using smartphones by the customers. It is considered to happen in interactive mode (physical) between the merchant's terminal and the customer device like mobile phones. It may be used in both face-to-face interactions between customers and retailers and unattended points of sale like vending machines (Ting et. al., 2019).

Arora et. al., (2019) in a study observed a considerable difference in overall mean agreement on employment satisfaction among the various populations. Yadav et. al. (2019) indicated that the customer satisfaction is positively associated with e-wallet solutions and adversely related to e-wallet challenges. Lochab, A. (2018) show a significant difference in average agreement on customer satisfaction in mobile banking among the various edifications. Graduates are also more in agreement on the threat of infrastructure than postgraduates. Graduates could be used to educate the general public on mobile banking. Mobile banking should also be covered in graduate-level courses.

Arora and Yadav (2018) in a research study show a significant variance in the causes of customer satisfaction among different age groups. Generation Y is more concerned with the procedures that must be taken in order for digital wallets to function properly. Key distinctions between age groups include insecure payment systems, difficulties using them, and limited working aid. The current study advises that security measures be introduced to enhance the use of E-wallets. Arora (2018) The data reveals two clusters: the first, which includes 144 persons, is classed as dissatisfied with the use of digital wallets. They fear that paying using a digital wallet is dangerous. It's also difficult for them to operate. The second group of 210 working professionals is classified as satisfied consumers because they think digital wallets are a good idea. Each cluster was divided into four categories: difficult factors, customer satisfaction, and risk factors. Singh & Arora (2014) examines a data collected from primary survey analysis. The result findings show a significant difference between the responses of the married and unmarried about their perception to improvise security risk solutions, performance/service quality risk solutions, technological risk solutions, and financial risk solutions in mobile banking is influenced by their age. When it comes to boosting mobile banking, unmarried respondents prioritise security risk solutions, performance/service quality risk solutions, technological risk solutions, and financial risk solutions above married respondents. Age has a significant impact on agreement on rising security risk solutions, according to the data. Between single and married respondents, the average agreement on upgrading security risk solutions, performance/service quality risk solutions, technological risk solutions, and financial risk solutions in mobile banking vary significantly. Women who are entrepreneurs should be charged a cheaper processing fee and need a provision of financial aids and subsidies products and services to boost their business. Other benefits like lower interest rates, loans would empower them and improvise their economic conditions. It is also suggested to provide on frequent basis distinctive upliftment projects for the housewives from the bank. The needed support from the banks can play a significant role in women's empowerment.

Previous research demonstrate the influence of respondents' behavioural intentions toward adopting mobile banking in various Indian cities (Tamil & Balaji, 2019). Primary information about mobile banking uptake was gathered from clients of commercial and public sector banks using a standardised questionnaire. The outcome demonstrates that consumers' behaviour intentions toward adopting mobile banking in the research region are highly influenced by performance

DOI: https://doi.org/10.48001/jbmis.2022.0901003

expectation, effort expectancy, hedonic incentive, trust, and loyalty. Sinha et. al. (2019) made an effort to investigate the variables influencing the perspective of Indian e-wallet users toward both public and private mobile wallet providers. To gather primary data from 433 respondents in the form of structured questionnaires, the researchers used a survey method and a hypothetical study design. The IBM SPSS statistical analysis programme was used to perform the Independent Sample t test. According to the findings, public sector e-wallet providers are perceived less favourably than competitors from the private sector. Public sector and private sector e-wallet providers in India have significantly different perceptions of issues, customer service, and personal danger.

RESEARCH METHODOLOGY

The present research is descriptive in nature. We have used primary data collected using a structured questionnaire administered on google form. The primary objective to check the consistency of the indicators using reliability analysis. Target population includes Millennials from different parts of Delhi-NCR in the age group of 23-35.

We have used non-probability snow-ball technique to collect responses of the questionnaire. In total we received 140 responses (42% female and 58% male respondents). The statements in the questionnaire were recorded on five-point likert scale.

DATA ANALYSIS

Table 1: Scale Reliability Statistics for Challenges faced by Millennial in using UPI

	Cronbach's α
scale	0.879

In a pilot study, the reliability test is the main tool considered for analysis. If Cronbach's α> .7, data is considered internally consistent. Table 1 shows Cronbach's α=.879, so data is fit for further analysis.

Table 2: Item Reliability Statistics for Challenges faced by Millennial in using UPI

if item dropped	
	Cronbach's α
1. Risk in transaction	0.841
2. Difficulty in transaction	0.865
3. No support staff	0.840
4. Unreliable	0.849
5. Interferences/restriction in choice	0.867

Item Reliability Statistics for Challenges faced by Millennial in using UPI shows that if Unsafe mode of payments is dropped then Cronbach's α=.841, so data is still fit and has internal consistency. If Difficult to Use is dropped then Cronbach's α=.865, so data is still fit and has internal consistency. Similarly, if Inadequate Working Assistance is dropped then Cronbach's α=.840, so data is still fit and has internal consistency. Likewise, if Not Reliable is dropped then Cronbach's α=.849, so data is still fit and has internal consistency. Also if Restricted Choice is dropped then Cronbach's α=.867, so data is still fit and has internal consistency. If Cronbach's α> .7, data is considered internally consistent. So all statements if dropped individually, then also internal consistency is maintained.

Table 3: Scale Reliability Statistics for Customer satisfaction by Millennial in UPI

	Cronbach's α
Scale	0.776

In a pilot study, the reliability test is the main tool considered for analysis. If Cronbach's α> .7, data is considered internally consistent. Table 3 shows Cronbach's α=.879, so data is fit for further analysis.

Table 4: Item Reliability Statistics for Customer satisfaction by Millennial in UPI

if item dropped	
	Cronbach's α
1. Managing funds efficiently	0.761
2. Perceived ease of use	0.773
3. Brand value	0.787
4. Economic condition	0.734
5. Reduced waiting time for digital payments through wallet	0.735
6. Rapidness	0.734
7. Service comfort	0.751
8. Valuable	0.733

Item Reliability Statistics Customer satisfaction by Millennial in using UPI shows that if Unsafe mode of payments is dropped then Cronbach's α=.761, so data is still fit and has internal consistency. If Ease to Use is dropped then Cronbach's α=.773, so data is still fit and has internal consistency. Similarly, if Status Symbol is dropped then Cronbach's α=.787, so data is still fit and has internal consistency. Likewise, if Economical is dropped then Cronbach's α=.734, so data is still fit and has internal consistency. Also if waiting time for a transaction involving use of wallet is dropped then Cronbach's α=.735, so data is still fit and has internal consistency. If Quickness is dropped then Cronbach's α=.734, so data is still fit and has internal consistency. In the same way if Service Efficiency is dropped then Cronbach's α=.751, so data is still fit and has internal consistency. If Valuable is dropped then Cronbach's α=.733, so data is still fit and have internal consistency If Cronbach's α> .7, data is considered internally consistent. So all statements if dropped individually, then also internal consistency is maintained.

Table 5: Scale Reliability Statistics for boosting satisfaction level by Millennial in using UPI

	Cronbach's α
Scale	0.771

In a pilot study, the reliability test is the main tool considered for analysis. If Cronbach's α> .7, data is

DOI: https://doi.org/10.48001/jbmis.2022.0901003

considered internally consistent. Table 5 shows Cronbach's α=.879, so data is fit for further analysis.

Table 6: Item Reliability Statistics for boosting satisfaction level by Millennial in using UPI

if item dropped	Cronbach's α
1. Application of Security tools	0.736
2. Benchmarks for Service vendors	0.712
3. Deployment of Skilled Workers	0.737
4. High Speed of transactions	0.749
5.Compensation in case of frauds and cybercrimes by hackers	0.708

Item Reliability Statistics for boosting satisfaction level by Millennial in using UPI shows that if Implementation of Security is dropped then Cronbach's α=.734, so data is still fit and has internal consistency. If Performance Benchmark for Service Providers is dropped then Cronbach's α=.712, so data is still fit and has internal consistency. Similarly, if Skilled Wallet Staff is dropped then Cronbach's α=.737, so data is still fit and has internal consistency. Likewise, if High Speed of Processing the Transaction is dropped then Cronbach's α=.749, so data is still fit and has internal consistency. Also if Compensation to customers for monetary loss by Hackers is dropped then Cronbach's α=.708, so data is still fit and has internal consistency. If Cronbach's α> .7, data is considered internally consistent. So all statements if dropped individually, then also internal consistency is maintained.

CONCLUSION

Mobile Banking in today's time has gained immense popularity especially among the millennials. This study is a pilot study to check the fitness of data based on Challenges faced by Millennial in using UPI, Customer satisfaction by Millennial in UPI and boosting Satisfaction Level of Millennials in using UPI. The results based on Cronbach's Alpha show that the data is internally consistent after dropping each variable for challenges faced and customer satisfaction.

However, compared to Generation X and Baby Boomers, Millennials are seen to have good knowledge of products on ecommerce but have less financial awareness on banking. Millennials and other generations tend to invest in complicated financial items like stocks and bonds as perceived financial literacy increases. Financial literacy may be increased through straightforward training to advance financial understanding. By offering individualised guidance through goal-setting and monitoring, financial coaching may also be a successful strategy for boosting financial literacy and awareness.

Due to time and money restrictions, this study's pilot survey analysis was restricted to a sample size of 140. The major technique of data collection for the current study was an online survey. Therefore, the constraints of an online survey will also apply to this empirical investigation. Since it is not possible to generalise the results to the entire state or nation, the main study only included digital payment transactions carried out in the Delhi NCR region. To choose respondents, the nonprobability snow-ball sampling method was used. Therefore, the present study is similarly subject to the limits of non-probability sampling. Therefore, the perspective before and after a lockdown may differ from the results of the current study. The current study may also be expanded to other cities, states, and countries to further understand the attitudes of Indian customers concerning digital payments.

REFERENCES

Arora M and Yadav M (2018), A Study On Perception of Different Generation in The Use of E Wallet, The Journal of IMS Group 15 (1), 39-45

Arora, M., &Lochab, A. (2018). A Study on Post Hoc Analysis on Education Level in Mobile Banking. Effulgence Journal, Volume 16 ((Special Issue)), 1-8

Ashokan, S., & Menon, S. S. (2016). Efficiency and Profitability of State Bank of India and its Associate Banks in India. Journal of Business Management and Information Systems, 3(2), 23–32. https://doi.org/10.48001/jbmis.2016.0302003

Garg, S. (2014). Global Financial Crisis and Banking Sector Efficiency: The Indian Perspective. Make in India, 1(1), 90–109. https://doi.org/10.48001/jbmis.2014.0101008

Gupta, A., Mittal, P., Gupta, P. K., & Bansal, S. (2022). Implication of Privacy Laws and Importance of ICTs to Government Vision of the Future (pp. 383–391). https://doi.org/10.1007/978-981-16-3071-2_32

Harchekar, M. J. S. (2018). Digitalization in Banking Sector. International Journal of Trend in Scientific Research and Development, Special Is(Special Issue-ICDEBI2018), 103–109. https://doi.org/10.31142/ijtsrd18681

Horticulture, D. H.-B. U., & 2011, undefined. (2011). Promoting banking products in the context of the digital economy. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca - Horticulture, 68(2), 85–89. https://doi.org/10.15835/buasvmcn-hort:7065

Kumar, P., & Pavithra, J. (2017). RECENT TRENDS IN INDIAN BANKING SECTOR. International Journal of Pure and Applied Mathematics, 116(18), 529–534.

Lipton, A., Shrier, D., & Pentland, A. (2016). Digital banking manifesto: the end of banks?

Mandal, A., Saxena, A., & Mittal, P. (2022). Financial literacy and digital product use for financial inclusion: A GETU model to develop financial literacy. In 2022 8th International Conference on Advanced Computing and Communication Systems

(ICACCS) (pp. 1614–1619). IEEE. https://doi.org/10.1109/icaccs54159.2022.9784962

Mehta, K., Mittal, P., Gupta, P. K., & Tandon, J. K. (2022). Analyzing the Impact of Forensic Accounting in the Detection of Financial Fraud: The Mediating Role of Artificial Intelligence (pp. 585–592). https://doi.org/10.1007/978-981-16-2597-8_50

Mittal, P. (2020a). Big data and analytics: a data management perspective in public administration. International Journal of Big Data Management, 1(2), 152. https://doi.org/10.1504/ijbdm.2020.112415

Mittal, P. (2020b). Impact of Digital Capabilities and Technology Skills on Effectiveness of Government in Public Services. In 2020 International Conference on Data Analytics for Business and Industry: Way Towards a Sustainable Economy (ICDABI) (pp. 1–5). IEEE. https://doi.org/10.1109/ICDABI51230.2020.9325647

OECD. (2019). Strengthening Digial Government.

Prasad Yadav, M., & Arora, M. (2019). Study on impact on customer satisfaction for E-wallet using path analysis model. International Journal of Information Systems & Management Science, 2(1).

Singh, S., Chaudhary, S., & Arora, M. (2014). Business ethics, and human resources accounting. International Journal of Management and Social Sciences Research, 3(5), 8-10.

S Singh, M Arora (2014), Demographic perception towards mobile banking in India, International Journal of Management, IT and Engineering 4 (7), 251

Sinha, M., Majra, H., Hutchins, J., & Saxena, R. (2019). Mobile payments in India: the privacy factor. International Journal of Bank Marketing, 37(1), 192–209. https://doi.org/10.1108/IJBM-05-2017-0099

Ting, H., Thaichon, P., Chuah, F., & Tan, S. R. (2019). Consumer behaviour and disposition decisions: The why and how of smartphone disposition. Journal of Retailing and Consumer Services, 51(July 2018), 212–220. https://doi.org/10.1016/j.jretconser.2019.06.002

vuqlakku

Anusandhan

NDIM's Journal of Business and Management Research

Vol. IV, Issue 1, February, 2022
ISSN No.: 2581-8120

Guru Gobind Singh Indraprastha University

New Delhi Institute of Management

Contents

Forecasting SGD-INR Exchange Return: An application of Autoregressive Integrated Moving Average

Dr. Sunil Kumari
Assistant Professor, Government College. Mehem

Ms. Jaya Gupta
Assistant Professor, New Delhi Institute of Management, New Delhi

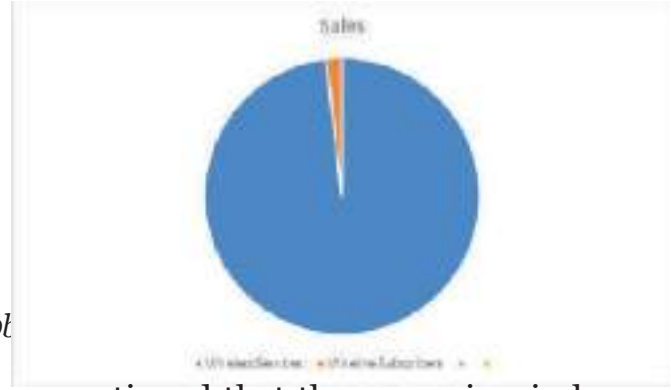
Abstract
Predicting currency has always been open to doubt because in financial as well as in managerial decisions making process it plays a crucial role and it is not easy to forecast foreign rates with higher accuracy than a naive random walk model. The main goal of this paper is to use the Arima model to forecast the yearly exchange rate, here we use real foreign exchange data to check the suitable level of the Arima model for forecasting and it also shows how suitable the Arima model is to estimate foreign exchange. There has been considerable improvement in profitability of MNC which conducts substantial currency transfer in business courses and forecasts exchange rate accurately. The time series Arima model is applied to forecast the exchange return of SND to INR. To better understand how the Arima model applies within the period 1st February 2011 - 1st February 2021. In this report monthly or daily exchange returns are used for variable inputs. This model is based on a few observations on the Arima model to help predict and solve financial forecasting problems for the best and worst possible situations which results in demonstrating the predictive strength and potential but is still a problematic task.

Keywords: ARIMA, Exchange Rate, Exchange rate forecasting, forecasting, time series analysis

Introduction
The exchange rate is a price which measures the worth of domestic currency in terms of other nation's currency and it is always a topic of discussion in financial literature. Exchange rate is also known as forex and foreign exchange rate. It is an important factor in the growth of the economy of most developed countries where high volatility becomes a major obstacle in economic growth of the country. Currency in forecasting rate at least predicts the trend accurately with the underlying process by obtaining more efficient and some statistical model that represents variability which is important for future investments and also demanding application for time series forecasting but it doesn't assure the complete information.

Exchange rate is hard to foresee. Thus, exchange rate development is constantly beginning with the utilization of the adaptable flexible exchange rate to forecast the exchange standards. This is so because changes in rate effects import, external trades, inflation and balance of payments. In this regard, exchange rate is a significant factor in an economy for indicating demand and furthermore for its use in the monetary strategies and their values. Exchange rates are not completely predictable moments with exchange rates profoundly changing disorderly and with noisy structure. This makes difficult and significant topic in socialistic system in business life. Constantly, this has been a principle worry of academicians and other specialists in multinational financing. Endeavors to make more understanding and prediction of exchange rate movements have united numerous methodologies to predict but, all of them have their own limitations which are full of

Chart 1.1
Composition of Market Share Wireless and Wireline Subscribers



Source: (TRAI, 2019b

In Table 1.1 it has been mentioned that there are six wireless service providers which are currently operating in the industry but from the analysis point of view only five have been considered. Reliance Communications has been removed from the analysis due the reason that it had declared itself bankrupt in the recent past and currently not providing services to any subscribers. As per the latest report of TRAI (2019b) its market share had been recorded as 0.001 from the last two years.

Sampling:
As mentioned in the above paragraph, the complete enumeration method is adopted in the study and the sample size is equal to the population which is the total number of service providers in the industry.

List of Wireless Service Providers as on 31st December, 2019

Sl.No.	Service Provider	Area of Operation
1	Bharti Airtel Ltd	All India
2	Reliance Communications/ Reliance Telecom Ltd	All India (except Assam & NE) / Kolkata, MP, WB, HP, Bihar, Odisha, Assam & NE
3	Vodafone Idea Ltd	All India
4	BSNL	All India (except Delhi & Mumbai)
5	MTNL	Delhi & Mumbai
6	Reliance Jio Infocom Ltd	All India

Source: (TRAI, 2019b)

Therefore, in the present study only five out of six service providers have been considered for the analysis and divided into two categories. Category I comprises of three Private Sector Service Providers who've acquired Foreign Direct Investment from any of the international source. Category II comprises of two state owned service providers which are Bharat Sanchar Nigam Limited d/b/a BSNL and Mahanagar Telephone Nigam Limited, d/b/a MTNL. The area of their operations are mentioned in Table 1.1.

Time Period of the Study: The study has been conducted on the subscribers from 2015 to 2019 only. The reason behind selecting such years is to reflect the recent trends. It has been observed that before 2015 the trends in the industry were entirely different and there were many service providers. But after the debut of Reliance Jio in 2016, many of them opted for the exit route or merged with the existing service providers.

Source of Data for Analysis: In the year ending performance reports of TRAI, the data of Rural and total number of subscribers are provided. Values of rural subscribers are extracted directly form there and for urban subscribers the values are retrieved by subtracting number of rural subscribers from the total number of subscribers (See Table 1.2 & 1.3).

Table 1.2
Rural and Urban Wireless Subscribers of Category I
(With Foreign Direct Investment) (in millions)

Year	Bharti Airtel+Telenor		Vodafone Idea		Reliance Jio	
	Rural Subscribers	Urban Subscribers	Rural Subscribers	Urban Subscribers	Rural Subscribers	Urban Subscribers
15-Dec	133.16	160.83	197.28	168.31	-	-
16-Dec	130.57	135.28	214.29	180.92	4.12	68.04
17-Dec	159.89*	142.22	220.93**	188.1	41.08	119.01
18-Dec	168.63	171.63	220.71	198.04	100.47	179.65
19-Dec	145.48	181.82	172.44	160.17	152.14	217.88
Source: TRAI (2015, 2016, 2017, 2018, 2019a)						

Table 1.3
Rural and Urban Wireless Subscribers of Category II
(Without Foreign Direct Investment)

YEAR	BSNL(All India except Delhi and Mumbai)		MTNL(Delhi & Mumbai)	
	Rural Subscribers	Urban Subscribers	Rural Subscribers	Urban Subscribers
15-Dec	27.53	54.97	0	3.61
16-Dec	31.63	65.16	0.05	3.58
17-Dec	35	72.92	0.05	3.53
18-Dec	39.04	75.33	0.05	3.42
19-Dec	37.35	80.77	0.05	3.33

Source: TRAI(2015, 2016, 2017, 2018, 2019a)

There are 3 leading private service providers in the industry as per the latest reports of TRAI but above mentioned three are the leading service providers. Bharti Airtel reported the subscribers of Tata Tele (TRAI, 2019a). Also. Quadrant is serving in the state of Punjab only and Reliance Communications had already reported itself bankrupt before lockdown. Although the news about the merger of BSNL and MTNL was also in the air but nothing can be said confidently until it happens.

For the year 2018, Telenor merged with Bharti Airtel and the TRAI reported the total values, Vodafone and Idea merged, Tata Tele and Reliance Communications were reporting negligible subscribers (TRAI, 2018).

For the year 2017, There were 12 wireless service providers. But Sistema Shyam merged with Reliance communications.

Bharti Airtel merged with Telenor therefore the total number of subscribers includes the values of Bharti and Telenor. Vodafone and Idea merged in 2018 therefore, total of their subscribers has been considered. The reason behind doing this is that the subscriber's base of merging companies, also merged ultimately.

For year 2017, even after merger the Reliance communications didn't manage to gain enough subscribers. Also, the subscribers of Tata were very few in numbers, so couldn't affect the analysis. Aircel was the company which reported 30.81 million rural subscribers in 2017 but it vanished in 2018 therefore, it has been considered void and null from the point of view of analysis. It is expected that the subscribers of Aircel might have opted for another service provider or they are still lacking the services.

On Feb 15, 2017 the Videocon telecom announced shutting down its operations. It was a small telecom company which got licences and permit in 17 circles in nation in 2008 lost all its permit in 2012 in 2G spectrum scam but after bidding again it won the airwaves. It also received approval for GSM and dual technology but the authority denied its permits in 2015 after which the company couldn't make it to survival.

Same is the case with Quadrant but the TRAI ordered the Telco to serve the subscribers till the expiration of its license. For which it denied.

There were nearly about 85 million subscribers of the Aircel, which are not less in number. But the company was fourth in the list of those telcos who bankrupted after the entry debut of Jio in Reliance Jio in September 2016. It was lying under the heavy burden of 15,500 crore debt and was planning to merge with Reliance communication but due to regulatory delays and lack of consensus in loan restructuring, the merger couldn't happen. So, after filling the bankruptcy, it was notified by the TRAI to all the subscribers of AIRCEL to opt for number porting. By 31st August 2019, they have to shift their plan to Jio, Bharti Airtel, MTNL or BSNL. Due to this reason, the subscribers of AIRCEL weren't included in DDI calculation as they were already spread between the companies considered for analysis.

Statistical Technique:
The famous 'Index Numbers' approach has been adopted in the study. The calculation was based on the below given formulae:

Rural Tele-density = (Total Rural Wireless Subscribers/ Rural Population) * 100
Urban Tele-density (TD) = (Total Urban Wireless Subscribers/ Urban Population) * 100
Urban- Rural Digital Divide Index = (Urban Tele-density/ Rural Tele-density) *100.

Data Analysis:

Table:1.4
Digital Divide Index for Category I

YEARS	**Total Rural Wireless Subscribers**	**Total Urban Wireless Subscribers**	**Rural Population**	**Urban Population**	**Rural Tele Density**	**Urban Tele Density**	**Digital Divide Index= (Urban Tele-density/ Rural Tele-density) *100**
15-Dec	330.44	329.14	881	429	37.50738	76.72261	204.5534
16-Dec	348.98	384.24	885	439	39.43277	87.5262	221.9631
17-Dec	421.9	449.33	889	450	47.45782	99.85111	210.3997
18-Dec	489.81	549.32	892	460	54.91143	119.4174	217.4727
19-Dec	470.06	559.87	897	472	52.40357	118.6165	226.352

Source: Author

Table 1.4 depicts ambiguous results of the DDI for the years 2015-2019. The DDI for the year 2015 was 204.5 which instead of declining, grew more every year. In the year 2019 it was 226.352 which is higher than the previous five year's DDI.

Table: 1.5
Digital Divide Index for Category II

Year	**Total Rural Wireless Subscribers**	**Total Urban Wireless Subscribers**	**Rural Population**	**Urban Population**	**Rural Tele Density**	**Urban Tele Density**	**Digital Divide Index= (Urban Tele-density/ Rural Tele-density) *100**
15-Dec	27.53	58.58	881	429	3.124858	13.65501	436.9802
16-Dec	31.68	68.74	885	439	3.579661	15.65831	437.4245
17-Dec	35.05	76.45	889	450	3.942632	16.98889	430.9022
18-Dec	39.09	78.75	892	460	4.382287	17.11957	390.6537
19-Dec	37.4	84.1	897	472	4.169454	17.8178	427.3413

Source: Author

Table 1.5 depicts the DDI for the Category II which declined in year 2018 but again showed increment in year 2019.

Table 1.6
DDI for Category I, Category II and DDI of India with the Annual Growth Rates

Year	**Digital Divide Index for Category I**	**Annual growth rate of DDI for Category I**	**Digital Divide Index for Category II**	**Annual growth rate of DDI for Category II**	**Digital Divide Index for India**	**Annual growth rate of DDI for India**
15-Dec	204.5534		436.9802		316.24	
16-Dec	221.9631	17.4097	437.4245	0.444288	312.3391	-3.9009
17-Dec	210.3997	-11.5634	430.9022	-6.5223	290.4051	-21.934
18-Dec	217.4727	7.073	390.6537	-40.2485	262.8571	-27.548
19-Dec	226.352	8.8793	427.3413	36.6876	269.374	6.5169

Source: Author

Table 1.6 indicates that the Digital Divide Index of India has declined substantially from the year 2015 however a slight increment has been noticed in the year 2019.

Null Hypothesis: There is no significant difference between the average DDI of Category I and the average DDI of the Category II.

Table 1.7
t-Test: Two-Sample Assuming Unequal Variances

	Digital Divide Index for Category I	**Digital Divide Index for Category II**
Mean	216.14818	424.66038
Variance	76.792384	379.3256644
Observations	5	5
Hypothesized Mean Difference	0	
df	6	
t Stat	-21.83121184	
P(T<=t) one-tail	3.02E-07	
t Critical one-tail	1.943180281	
P(T<=t) two-tail	6.03E-07	
t Critical two-tail	2.446911851	

Source: Author

Findings:
The values of DDI of Category I which includes telcos having back up of FDI in the companies, is less than the DDI of Category II of Non FDI telcos. But the results of annual growth rates are quite ambiguous and unable to reflect the right nature of the DDI difference in the two categories. In the initial years it has been observed in both the cases that DDI has been reduced but in the latent years the DDI showed increased values. The t-test for differences of means have been used for interpreting the true nature of the DDI calculated. The p-value is less than 0.01 therefore reject the null hypothesis therefore it can be stated that the average difference between the DDI of two categories is significant. Therefore, after ignoring the temporary effects it can be stated that the telcos which are backed up by the FDI are able identify the need of catering rural market. They are undoubtedly engaged in doing so, which will benefit them in future as the largest part of Indian population resides in rural areas only. But the Stated owned companies are lagging behind in such issue and unable to cater the needs of rural areas. It is also possible that they thrust for expansion has been reduced and the private owners are still fighting for the market share.

Conclusion:
The study addressed the unequal diffusion of Telecom Services in the rural and urban areas of the nation, which is popularly known as Digital Divide. After dividing the leading telecom service providers into two categories, one with FDI and another without FDI, it has been identified that the telcos backed with FDI are contributing more in reducing Digital Divide and the difference between their contribution is significant. It is essential for the industry

players to identify the rural market as an opportunity and extract maximum revenue from it.

REFERENCES:

1. Cruz-Jesus, F., Oliveira, T., & Bacao, F. (2018). The global digital divide: Evidence and drivers. Journal of Global Information Management, 26(2), 1–26. https://doi.org/10.4018/JGIM.2018040101
2. David, M. E., & Amey, M. J. (2020). Undrestanding the digital divide. Organisation for Economic Co-operation and Development. The SAGE Encyclopedia of Higher Education, https://doi.org/10.4135/9781529714395.n417
3. Jung, J. (2020). Institutions and Telecommunications Investment. Information Economics and Policy, 50(100849), 1-10. https://doi.org/10.1016/j.infoecopol.2020.100849
4. Philip, L., Cottrill, C., Farrington, J., Williams, F., & Ashmore, F. (2017). The digital divide: Patterns, policy and scenarios for connecting the 'final few' in rural communities across Great Britain. Journal of Rural Studies, 54, 386–398. https://doi.org/10.1016/j.jrurstud.2016.12.002
5. Rao, S. S. (2005). Bridging digital divide: Efforts in India. Telematics and Informatics, 22(4 SPEC. ISS.), 361–375. https://doi.org/10.1016/j.tele.2005.01.007
6. Sampath Kumar, B. T., & Shiva Kumara, S. U. (2018). The digital divide in India: use and non-use of ICT by rural and urban students. World Journal of Science, Technology and Sustainable Development, 15(2), 156–168. https://doi.org/10.1108/wjstsd-07-2017-0021
7. Sharma, E. (2020). Developing ICT adoption model based on the perceived awareness and perceived usefulness of technology among telecom users. International Journal of Technology Enhanced Learning, 12(1), 99–114. https://doi.org/10.1504/IJTEL.2020.103818
8. Singh, S. (2010). Digital Divide in India. International Journal of Innovation in the Digital Economy, 1(2), 1–24. https://doi.org/10.4018/jide.2010040101
9. Szeles, M. R. (2018). New insights from a multilevel approach to the regional digital divide in the European Union. Telecommunications Policy, 42(6), 452–463. https://doi.org/10.1016/j.telpol.2018.03.007
10. TRAI. (2019a). Telecom Regulatory Authority of India The Indian Telecom Services Performance Indicators December 2019. https://www.trai.gov.in/sites/default/files/PIR_30062020.pdf
11. TRAI. (2019b). Telecom Regulatory Authority of India Yearly Performance Indicators of Indian Telecom Sector 2019. https://www.trai.gov.in/sites/default/files/YIR_25112020_0.pdf
12. TRAI. (2018). Telecom Regulatory Authority of India Yearly Performance Indicators of Indian Telecom Sector 2018. https://www.trai.gov.in/sites/default/files/PIR_25092019.pdf
13. TRAI. (2017). Telecom Regulatory Authority of India Yearly Performance Indicators of Indian Telecom Sector 2017. https://www.trai.gov.in/sites/default/files/YPIRReport04052018.pdf
14. TRAI. (2016). Telecom Regulatory Authority of India Yearly Performance Indicators of Indian Telecom Sector 2016. https://www.trai.gov.in/sites/default/files/Yearly_PI_Reports_2016.pdf
15. TRAI. (2015). Telecom Regulatory Authority of India Yearly Performance Indicators of Indian Telecom Sector October - December 2015. https://www.trai.gov.in/sites/default/files/QPIR_Oct_to_Dec-15.pdf
16. Zhang, X. (2018). Frugal innovation and the digital divide: Developing an extended model of the diffusion of innovations. International Journal of Innovation Studies, 2(2), 53–64. https://doi.org/10.1016/j.ijis.2018.06.001

22. Dr. Sunil Kumari "An Empirical study on Gender perceptions towards UPI" Year 2022

V vuqla/kku

Anusandhan

NDIM's Journal of Business and Management Research

Vol. IV, Issue 2, August 2022
ISSN No.: 2581-8120

Guru Gobind Singh Indraprastha University

doi Crossref

NDIM

Crossref.ID/D
OI-10.56411

New Delhi Institute of
Management

Contents

An Empirical study on Gender perceptions towards UPI

Anusandhan-NDIM's Journal of Business and Management Research
Vol.4, Issue 2
August - 2022
https://qtanalytics.in/journals/index.php/ANUSANDHAN
https://doi.org/10.56411/anusandhan.2022.v4i2.41-46

Dr. Sunil Kumari, Assistant Professor, Government College, Meham, Haryana, India

Abstract: T*his study is an empirical study on gender perceptions towards UPI. Five points likert scale is used to prepare a structured questionnaire. Primary data was based on 643 persons out of which 310 males and 333 females were found eligible in the form of completed questionnaires. Reliability statistics is up to mark and data is suitable for further analysis. T-Test statistics show no significant difference between gender perceptions towards UPI. Limitation of the study is that study is based on only gender perception. Age wise, education wise and other demographic variables can be studied in future studies.*

Key Words: Empirical, Gender, UPI, Problems, Customer, Satisfaction

Introduction:

UPI stands for Unified Payments Interface which merges a lot of bank related services, into a single mobile application of banks. It has become so simple and common that laymen in India are also using it in day to day operations. The National Payments Corporation of India (NPCI) is the company in-charge of the RuPay payment infrastructure, which is comparable to Visa and MasterCard. The Immediate Payments Service (IMPS) is another NPCI project. UPI transactions are protected by a highly secured encryption format that is difficult to decrypt. Every day, the IMPS network of the NPCI processes millions in transactions. With the advent of UPI technology, this is projected to skyrocket. Every transaction is verified using a two-factor authentication approach similar to OTP. For validation, however, UPI PIN will be used instead of OTP. The UPI applications' primary goal is to promote digital transactions and pave the way for a cashless economy. Users can avoid carrying cash or plastic money by using UPI. Their smartphone will handle all the transactions.

Literature Review

The statistics showed by M. Arora and M. P. Yadav (2018) states that the factors that influence customer satisfaction change significantly depending on the age group. The steps that must be completed in order for digital wallets to operate effectively are more of an issue for Generation Y. Insecure payment methods, problems using them, and limited working assistance are significant differences between age groups. The current study suggests adding security precautions to improve the adoption of e-wallets. Yadav, M., and M. Arora (2019) customer satisfaction is positively correlated with e-wallet solutions but negatively correlated with e-wallet problems. According to M. Arora (2018), utilising a digital wallet to make payments is dangerous. Additionally, they find it difficult to function. Gandhi, M., Gupta, N., & Rawat, S. (2019) states there is a significant association in overall mean agreement on job satisfaction between the various populations. Khurana, P., Arora, M., &

Yadav, M. P. (2017) stresses on providing female students lower-interest college loans could help empower women by providing distinctive domestic upliftment projects for housewives, banks can play an important role in women's empowerment. Singh, S., Chaudhary, S., & Arora, M. (2015) the impact of age on consensus on growing security risk solutions is significant. Singh, S., & Arora, M. (2014) state that when it comes to boosting mobile banking, unmarried respondents place a larger importance on different types of risks and related solutions than married respondents. Arora, M., & Lochab, A. (2018) the average agreement on consumer satisfaction in mobile banking varies significantly across educational institutions. S. Singh, S. Chaudhary, and M. Arora (2014) been concerned about the well-being of others in their research. Benefits of Human Development Research Lochab, Arora, Madhu, and Anshu (2019) were studies as well as in A Lochab and M Arora (2018) also. The consequences of different generations may differ. M Arora and M Mittal (2020) believe that project-based education can help with the continuous development of technological advances, and that human resources are an important part of it Arora M (2012).

There is no study on Customer Satisfaction in UPI so An Empirical study on Gender perceptions towards UPI, is an effort to fill the gap.

Table A: Scale used in Study

Authors	Year	Scale	Cronbach Alpha
Singh, S., & Arora, M.	2014	1. Unsafe mode of payments	0.773
		2. Difficult to Use	
		3. Inadequate Working Assistance	
		4. Not Reliable	
		5. Restricted Choice	
		6. Slow Speed of Data Transmission	
		7. Receiving of Fake SMS and Scams	
Singh, S., & Arora, M	2014	1. Efficient Management of Funds	0.89
		2. Easy to Use	
		3. Status Symbol	
		4. Economical	
		5. Reduction in the waiting time for any transaction in the wallet	
		6. Quickness	
		7. Service Efficiency	
		8. Valuable	

Source: compiled from Literature Review

Research Methodology

Study is descriptive in nature. Secondary data for literature review and primary data for empirical analysis is conducted from 643 respondents. Questionnaire was sent to 1000 people. Some responses were incomplete and were removed during the screening process. 643 responses were complete and found suitable for further analysis. Random sampling method is used. T-test is used to test the statistics for 5 percent level of significance and confidence level 95 percent. Overall response rate is 64.3 percent.

Objectives of the study:

Main objective of the study is an Empirical study on Gender perceptions towards UPI. To achieve the main objective following objectives are portrayed:

- To know gender perception towards problems faced in UPI
- To analyze gender wise customer satisfaction in UPI
- To provide suggestions to improve UPI experience in Males and Females

Hypothesis (H_o): Null hypothesis is considered for the study.

(H_o) = There is no significant difference assumed in the perception of Gender for customer satisfaction in UPI.

Table B: Gender wise distribution of respondents:

Gender	Number
Male	310
Female	333
Total	643

Source: Survey

Table B shows there are 310 male respo ndents and 333 f emal e respondents in the study.

Results and Discussions

Table 1: Scale Reliability Statistics of Problems faced by customers in UPI

	N	Mean	sd	Cronbach'sα
Problemsfacedby customersinUPI	643	3.9	0.52	0.773

Source: Survey

As observed in Table 1, Mean of N=643 respondents perception towards problems faced in UPI is 3.90, Standard deviation =.520, Cronbach's α=,773, data is internally consistent as Cronbach's α > .7 is treated as reliable.

Table 2: Scale Reliability Statistics of Customer satisfaction in UPI

	Mean	sd	Cronbach'sα
Customersatisfactionin UPI	3.38	0.867	0.89

Source: Survey

As observed in Table 1, Mean of N=643 respondents perception towards problems faced in UPI is 3.38, Standard deviation =.867, Cronbach's α=,890, data is internally consistent as Cronbach's α > .7 is treated as reliable.

Table 3: Item Reliability Statistics of Problems faced by customers in UPI

	if item dropped Cronbach's á
1. Unsafe mode of payments	0.865
2. Difficult to Use	0.882
3. Inadequate Working Assistance	0.864
4. Not Reliable	0.869
5. Restricted Choice	0.875
6. Slow Speed of Data Transmission	0.876
7. Receiving of Fake SMS and Scams	0.887

Source: Survey

Table 3 shows Cronbach's α, if one item is dropped from scale. If Unsafe mode of payments is dropped, then Cronbach's α,=.865, if Difficult to Use is dropped, then Cronbach's α,=.882, similarly If Unsafe Inadequate Working Assistance, then Cronbach's α=.864, if Not Reliable is dropped, then Cronbach's α,=.869, if . Receiving of Fake SMS and Scams is dropped, then Cronbach's α =.887. This indicates that no single statement can affect overall results. All statements together show reliability.

Table 4: Item Reliability Statistics of Customer satisfaction in UPI

	if item Cronbach's á
1. Efficient Management of Funds	0.759
2. Easy to Use	0.771
3. Status Symbol	0.784
4. Economical	0.73
5. Reduction in the waiting time for any transaction in the wallet	0.731
6. Quickness	0.731
7. Service Efficiency	0.748
8. Valuable	0.73

Source: Survey

Table 4 shows Cronbach's α, if one item is dropped from scale. If Efficient Management of Funds is dropped, then Cronbach's α,=.759, if Easy to Use is dropped, then Cronbach's α,=.771, similarly. If Status Symbol is removed, then Cronbach's α=.784, if economical is dropped, then Cronbach's α,=.730, if . valuables are dropped, then Cronbach's α =.730. This indicates that no single statement can affect overall results. All statements together show reliability.

Table 5: Independent Samples T-Test

Variables	T-Statistic	df	p
Problems in Using UPI	0.377	641	0.706
Customer Satisfaction in using UPI	0.184	641	0.854
Suggestions to Improve experience of UPI	0.377	641	0.706

Source: Survey

Table 5 shows value of independent T test in males and females, about Problems in Using UPI, T-Statistic=.377, degree of freedom (df) =641, and p value=.706, it shows there is no significant difference in perception of males and females towards Problems in Using UPI.

Also T-Statistic=.184, degree of freedom (df) =641, and p value=.854, it shows there is no significant difference in perception of males and females towards Customer Satisfaction in Using UPI.

Similarly T-Statistic=.377, degree of freedom (df) =641, and p value=.706, it shows there is no significant difference in perception of males and females towards Suggestions to Improve experience in Using UPI.

Table 6: Imperical Results

	Group	N	Mean	SD	SE
Problems in using UPI	Male	310	3.9	0.485	0.0276
	Female	333	3.89	0.551	0.0302
Customer Satisfaction in using UPI	Male	310	3.37	0.836	0.0475
	Female	333	3.387	0.823	0.0451
Suggestions to boost experience in UPI	Male	310	3.9	0.485	0.0276
	Female	333	3.89	0.551	0.0302

Source: Survey

Table 6 shows Group Descriptive of two groups, Male (N=310) and Female (N=333), Mean for problems in using UPI is 3.90 is more for males than Mean for problems in using UPI is 3.89 for females perception. It shows Male respondents have more problems in UPI than female respondents.

Mean for Customer Satisfaction in using UPI is 3.387 is more for females than Mean for problems in using UPI is 3.37 for male perception. It shows Female respondents have more Customer Satisfaction in UPI than male respondents. But as per statistical test of significance at 5 Percent level, no significant difference is found, so null hypothesis is accepted.

Conclusion

This study examines how gender affects perceptions of UPI empirically. 310 male and 333 female subjects out of a total of 643 people were discovered to be eligible in the form of a questionnaire that was filled out. The reliability statistics are satisfactory and the data is appropriate for further study. According to T-Test statistics, there is no discernible difference in how men and women view the experience of UPI. Therefore, the null hypothesis stands accepted. This study is based on gender perception only, so it can be considered as a limitation too. But it provides further scope of study for other demographic variables like age, income, marital status, area of residence etc.

References

• Arora M (2012), Human resource accounting for academics, International Journal of Advanced Research in Management and Social Sciences, 1(3), 209-215

• Arora M and Yadav M (2018), A Study On Perception of Different Generation in The Use of E Wallet, The Journal of IMS Group 15 (1), 39-45

• Arora, M. (2018). Use of Digital Wallets-Cluster Analysis for Expectation and Voice of the Customers. Vimarsh-An Endeavor to Share Knowledge, 9(2), 16-24.

• Arora, M., &Lochab, A. (2018). A Study on Post Hoc Analysis on Education Level in Mobile Banking. Effulgence Journal, Volume 16 ((Special Issue)), 1-8

• Arora, M., & Yadav, M. P. (2018). A Study on Perception of Different Generation in the Use of E Wallet. Journal of IMS Group, 15(1), 39-45.

• Arora, M., Gandhi, M., Gupta, N., &Rawat, S. (2019). Influence of Occupation on the Outlook of Digital Wallets. Vivekananda Journal of Research, 8(2), 131-148.

• Arora, Madhu & Lochab, Anshu. (2019). A Research on Consumption Pattern and Attributes of Curd by Lambert Academic Publishing (ISBN: 9783330078949)

• Epskamp, S. (2017).semPlot: Path Diagrams and Visual Analysis of Various SEM Packages' Output. [R package].Retrieved from https://cra n.r-project.org/package=semPlot.

• Khurana, P., Arora, M., & Yadav, M. P. (2017). An empirical research on role of banks in women empowerment. JIMS 8M: The Journal of Indian Management & Strategy, 22(2), 40-44.

• M Arora and M Mittal (2020), Relation of live projects with employability using path analysis model Procedia Computer Science 167, 1675-1683

• M Arora, A Lochab(2018), A Study on Post Hoc Analysis on Education Level in Mobile Banking, Effulgence, (Special Issue), 1-8

• Prasad Yadav, M., & Arora, M. (2019). Study on impact on customer satisfaction for E-wallet using path

analysis model. International Journal of Information Systems & Management Science, 2(1).

• R Core Team (2020).R: A Language and environment for statistical computing. (Version 4.0) [Computer software].Retrievedfrom https:// cran. r- project. org. (R packages retrieved from MRAN snapshot 2020-08-24).

• Revelle, W. (2019).psych: Procedures for Psychological, Psychometric, and Personality Research. [R package].Retrieved from https://cran.r-project.org/package=psych.

• Rosseel, Y., et al. (2018). lavaan: Latent Variable Analysis. [R package].Retrieved from https://cran.r-project.org/package=lavaan.

• S Singh, M Arora (2014), Demographic perception towards mobile banking in India, International Journal of Management, IT and Engineering 4 (7), 251

• S Singh, S Chaudhary, M Arora, (2014) Intellectual property rights in sole proprietorship form of business, International Journal of Advanced Research in Management and Social Sciences 3(6), 16-24

• Singh, S., & Arora, M. (2014). Demographic perception towards mobile banking in India. International Journal of Management, IT and Engineering, 4(7), 251.

• Singh, S., Chaudhary, S., & Arora, M. (2014). Business ethics, and human resources accounting. International Journal of Management and Social Sciences Research, 3(5), 8-10.

• Singh, S., Chaudhary, S., & Arora, M. (2015). Study of significant predictors of customer satisfaction in mobile banking. SAARJ Journal on Banking & Insurance Research, 4(4and5), 33-40.

• The jamovi project (2021). jamovi. (Version 1.6) [Computer Software].Retrievedfrom https://www.jamovi.org.

Understanding the Complex Effects of CO2 on Plant Productivity in the Context of Climate Change

Dr. Veena Sachdeva[1], Dr. Santosh Hooda[2]

[1]Associate Professor, Department of Botany, Government PG College for Women, Rohtak
[2]Associate Professor, Department of Zoology, Government PG College for Women, Rohtak

****

ABSTRACT

Significant changes in plant growth, distribution, and productivity are all caused by climate change. The development and photosynthesis of plants are aided by rising atmospheric CO_2 levels, but this effect is constrained by other environmental conditions. In addition to causing significant harm to plant populations and ecosystems, extreme weather events including droughts, heat waves, floods, storms, cyclones, and wildfires can also do so. Climate change can also affect relationships between species and changes in the timing of plant phenology. It is true that elevated atmospheric carbon dioxide (CO_2) levels can occasionally increase plant output. This is due to the fact that plants need CO_2 for photosynthesis, and higher amounts of CO_2 can speed up photosynthesis, which promotes greater plant growth. The effects of increased CO_2 on plant productivity, however, are complicated and can be regulated by a variety of other elements, such as the availability of nutrients, water, and temperature. The advantages of higher CO_2 may occasionally be outweighed by these additional limiting variables. Additionally, while higher plant productivity might be advantageous for some crops and ecosystems, it might also be detrimental for other types.

INTRODUCTION

Increased photosynthesis in plants results from the carbon fertilisation effect brought on by rising CO_2 levels in the atmosphere, which may increase agricultural yields for some crops. Increased CO_2 levels affect how much water plants use, which reduces water loss. Nitrogen is become harder to get in terrestrial ecosystems, which has an impact. Increased CO_2 has complex effects on plant productivity that are regulated by a variety of other variables, such as the availability of nutrients, water, and temperature. The advantages of higher CO_2 may occasionally be outweighed by these additional limiting variables. While higher plant productivity might be advantageous for some crops and ecosystems, it might also be detrimental for other types. An overgrowth of invasive species, for instance, may result from increasing plant productivity in some locations, which can destabilise ecosystems and drive out local plant species. Increased plant production in agricultural contexts may also result in misuse of fertilisers and other chemicals, which could be harmful to the health of the soil and the quality of the water.

Increased Photosynthesis Due to Climate Change on Plants and Ecosystems

A variety of climatic and ecological factors influence the increased photosynthesis brought on by climate change, making it a complicated subject. On the one hand, greater photosynthesis in plants may result from rising atmospheric carbon dioxide (CO_2) levels, which are brought on by human activities like burning fossil fuels. This is due to the fact that CO_2 is an essential component of photosynthesis and that higher levels of CO_2 can accelerate photosynthesis, which promotes greater plant growth and output. The results of increased photosynthesis brought on by climate change, however, are not necessarily favourable. For instance, droughts, heat stress, and other environmental stresses that can harm or kill plants can result from rising temperatures and altered precipitation patterns brought on by climate change. In some situations, this can lead to the loss of significant harvests and food supplies, as well as decreased plant development and production. Furthermore, the increased photosynthesis brought on by climate change may indirectly affect agricultural practises and ecosystems. For instance, greater CO_2 levels may cause invasive species to overgrow, disrupting ecosystems and displacing local plant species. In agricultural situations, increased photosynthesis may also result in misuse of fertilisers and other chemicals, which can have detrimental effects on the health of the soil and the water supply. While it is possible that increased photosynthesis brought on by climate change will have some positive effects on plant growth and productivity, it is crucial to take into account the changes wider ecological and environmental effects. For the sake of maintaining the health and well-being of plants and the ecosystems they sustain, combating climate change and lowering greenhouse gas emissions remain a top concern. For crops like wheat, rice, and soybeans, which make up a sizable share of the world's food output, this effect is particularly important. However, other factors, such as nutrient availability, may limit the advantages of increased CO_2.Climate change is having a significant impact on plant life, including changes in plant distribution, growth, and productivity. The increasing atmospheric carbon dioxide (CO_2) levels have been found to enhance plant photosynthesis and growth, but this effect is limited by

other environmental factors such as temperature, water availability, and nutrient availability [1]. Rising temperatures and changes in precipitation patterns can lead to droughts, heat waves, and floods, which can affect plant survival and productivity [2]. Extreme weather events such as hurricanes, cyclones, and wildfires can also cause severe damage to plant communities and ecosystems [3]. Climate change can also lead to changes in the timing of plant phenology, such as flowering and leafing out, which can have cascading effects on other species in the ecosystem [4]. Changes in the timing of plant growth can disrupt the timing of pollinator emergence, migration patterns of birds and insects, and even lead to changes in predator-prey relationships [5]. Moreover, climate change can alter the plant-microbe interactions and soil microbial communities, which are critical for soil health and nutrient cycling. Changes in temperature and precipitation patterns can affect the microbial community composition and function, leading to shifts in soil nutrient availability and cycling [6]. The impact of climate change on plants is complex and multifaceted, affecting plant growth, distribution, phenology, and interactions with other species. The effects can be both positive and negative, depending on the plant species, environmental conditions, and the magnitude and rate of climate change. The challenge ahead is to understand and predict these impacts to develop effective strategies for mitigating the negative effects of climate change on plant communities and ecosystems.

Plants use carbon dioxide (CO_2), water, and sunlight to carry out photosynthesis, producing oxygen and carbohydrates for energy and growth. The carbon fertilization effect, caused by increasing levels of CO_2 in the atmosphere, leads to a boost in plant photosynthesis. Global plant photosynthesis increased by 12% from 1982 to 2020, correlating with a 17% rise in atmospheric CO_2 levels. The majority of this increase in photosynthesis is attributed to carbon dioxide fertilization [7].

The growth of certain plants increases in response to elevated CO_2 levels. Above-ground plant growth, on average, has increased by 21%, while below-ground growth has increased by 28% [7]. This increase in photosynthesis and growth has the potential to improve crop yields for some crops such as wheat, rice, and soybeans, with expected increases ranging from 12% to 14% [8].

However, the growth of certain crops, such as corn, sugar cane, sorghum, and millet, are less responsive to elevated CO_2 levels [9]. One possible explanation for this is that these crops already have optimal levels of CO_2 for photosynthesis [10].

In addition to affecting plant growth, elevated CO_2 concentrations also influence plant water use. Plants have openings called stomata that release moisture into the atmosphere and allow CO_2 absorption. As CO_2 levels increase, plants can partially close their stomata and maintain a high rate of photosynthesis, which reduces water loss by 5% to 20% [11]. This may lead to a reduction in water released by plants into the atmosphere, which can have implications for the water cycle.

Overall, while the carbon fertilization effect may benefit certain crops, the complex interactions between climate change and plant growth make it difficult to predict the future impacts of climate change on plant productivity and ecosystems [12].

Climate change-related increases in CO_2 have the potential to reduce water use while also stimulating plant growth because of the carbon fertilisation effect. However, other factors like temperature, nutrient availability, and water availability make it difficult to determine how climate change will affect plant growth.

Impact of Climate Change on Nitrogen Cycle

Nitrogen is an essential nutrient for plant development and growth, and it frequently limits plant yield. These nutrients, which come in the form of nitrate or ammonium and are absorbed by plants from the soil, are necessary for the synthesis of proteins and other significant molecules. The lack of nitrogen in many terrestrial ecosystems, the researchers discovered, can restrict plant growth and production. Nitrogen is one essential nutrient that is becoming increasingly scarce in terrestrial ecosystems. Researchers observed that unfertilized terrestrial ecosystems are growing low in nutrients, notably nitrogen, between 1980 and 2017, after studying hundreds of plant species. Global factors, such as increasing temperatures and CO_2 levels, are blamed for this decline in nutrients. It has been reported that most unfertilized ecosystems are becoming nitrogen-deficient as a result of global changes, including rising temperatures and CO_2 levels (13). Nitrogen is a crucial ingredient for plant growth and is required for the synthesis of proteins and carbohydrates in plants. However, because atmospheric nitrogen gas is triple bonded and thus difficult to disintegrate into a form that can be used by plants, they are unable to utilise it. Natural nitrogen fixation can happen as a result of lightning, fertiliser manufacturing processes, or symbiotic bacterial relationships with plant roots, such as those of legumes, in soil.

The amount of nitrogen in leaves may be diluted when CO_2 levels rise, which can affect plant production (14). Gains in productivity may only last a short time if plants are unable to use the extra CO_2 if nitrogen is limited. The availability of

nitrogen will determine whether trees can continue to absorb the huge amounts of CO_2 emissions brought on by human activity (14). Previous studies projected that the rate of nitrogen fixation would decrease as temperatures rose over 25°C, resulting in lower plant productivity and more warming. The ideal temperature for nitrogen fixation is really about 5°C higher than previously thought, according to new research (15). This means that nitrogen fixation is more likely to increase than previously thought, which might assist sustain plant productivity and avert a runaway situation.
According to Griffin's (2020) research, photosynthesis is less affected by temperature increases than nitrogen fixation in plants. This is so because the temperature response of nitrogen fixation, which uses enzymes produced of nitrogen, is separate from the temperature response of photosynthesis. These enzymes, such as Rubisco, which converts carbon dioxide into carbohydrates during photosynthesis, can function less effectively at higher temperatures. As temperatures rise, Rubisco becomes less effective and loses precision, which causes it to fix oxygen rather than carbon dioxide and reduces the effectiveness of photosynthesis. The plant might squander resources as a result of this. Rubisco's efficiency declines at higher temperatures, although nitrogen fixation can make up for it [14].

The lengthening and warming of growing seasons as a result of global warming may result in drier soils and less runoff for streams and rivers. This is due to the fact that plants' increased water needs caused by prolonged growth will outweigh the advantages of partially closing their stomata [16]. Since evapotranspiration—the process by which plants expel moisture into the atmosphere—helps keep the air cooler, this could lead to more local warming. Dry soils have the potential to reduce photosynthesis by limiting carbon dioxide absorption [17]. Even if plants take in more carbon than they need for photosynthesis during a wet year, this may not be enough to make up for the less carbon dioxide they took in during the previous dry year [17].

Pests, diseases, and invasive species that destroy vegetation may potentially gain from warmer winters and a longer growing season. More generations of pests can proliferate over longer growing seasons as a result of faster insect life cycles, and more pests and pathogens can survive hotter winters [18]. Insects can have catastrophic consequences on local plants as a result of expanding their range due to rising temperatures [19].

Crops are more susceptible to weeds, insects, and disease, which already result in large agricultural losses, as a result of higher temperatures and greater rainfall [19].The yields of significant crops, such corn and soybeans, can decrease by 3 to 7 percent for every degree of additional warming [20].In reaction to rising temperatures, plants are also relocating, with some species going to cooler altitudes or farther north. For instance, every ten years, plants in North America have shifted by 10.5 miles or 36 feet to higher latitudes [19].However, these migratory species may find their new environments less hospitable, and some species may ultimately suffer as a result of these changes [19].

Climate change: Impact on India

According to climate change projections, India would experience more frequent and severe extreme weather events, such as drought, heat waves, and extreme precipitation [21]. Extreme precipitation events can disrupt plant growth, especially in places vulnerable to landslides and flooding, and increase the risk of soil erosion and flooding for plants [22]. A loss of forest cover and the biodiversity it supports due to more frequent high winds that stress tree stands and cause defoliation and even tree uprooting [23].

In India, there will probably be more hot waves and droughts together, which could cancel out any positive effects of the carbon fertilisation impact. In some regions of India, the combination of heat and dryness could result in a 20% reduction in maize yields, which is a common occurrence during hot growing seasons [24]. In areas like the Indo-Gangetic plains, which heavily rely on monsoon rains for agricultural production, the combination of heat and water constraint may also lower crop yields [25]. The effects on the region's food security could be severe. Climate change is projected to bring more frequent and severe extreme weather events, including extreme precipitation, wind disturbance, heat waves, and drought in India [21]. Extreme precipitation events can disturb plant growth, particularly in areas prone to floods and landslides, and make plants more vulnerable to flooding and soils to erosion [22]. More frequent high winds can stress tree stands, leading to defoliation and even uprooting of trees, resulting in loss of forest cover and the biodiversity it supports [23]. India is also likely to experience more combined heat waves and droughts, which could offset any benefits from the carbon fertilization effect. Crop yields often decrease during hot growing seasons, and the combination of heat and dryness could cause maize yields to fall by 20 percent in some parts of India [24]. In addition, the combination of heat and water scarcity may reduce crop yields in places like the Indo-Gangetic plains, which are highly dependent on monsoon rainfall for agricultural production [25]. This could have serious implications for food security in the region.

Global warming and climate change are causing a variety of impacts on plant life. Warming temperatures and changes in precipitation patterns are causing alterations in vegetation growth and phenology. In India, there has been a decline in winter crops such as wheat and potato due to warmer winters and a shorter frost season. This has led to a decline in the productivity of the agricultural sector, which is the primary source of income for a large section of the population [26].Higher temperatures and increased moisture can also make crops more vulnerable to weeds, insects, and diseases,

which can cause significant crop losses. Each degree of added warmth can cause a 3 to 7 percent loss in the yields of important crops, such as corn and soybeans [27].Climate change is also expected to bring more frequent and severe extreme weather events, including extreme precipitation, wind disturbance, heat waves, and drought. Extreme precipitation events can disturb plant growth, particularly in recently burned forests, and make plants more vulnerable to flooding and soils to erosion. The combination of heat and water scarcity may reduce crop yields in places like India, where crop yields are projected to increase because of warmer temperatures [28].While some crop yields may increase, rising CO_2 levels affect the level of important nutrients in crops. With elevated CO_2, protein concentrations in grains of wheat, rice and barley, and in potato tubers decreased by 10 to 15 percent in one study. Crops also lose important minerals including calcium, magnesium, phosphorus, iron, and zinc. This could have serious implications for India, which is home to a large vegetarian population that relies heavily on grains for their daily diet [29].In India, where a large proportion of the population is engaged in agriculture, plants face an uncertain future due to the impacts of climate change. The complex interactions between plant physiology and behavior, resource availability and use, shifting plant communities, and other factors make it difficult to predict the overall impact of climate change on plant life in the country (30).

There are numerous effects of climate change and global warming on plant life. Vegetation growth and phenology are being affected by warming temperatures and altered precipitation patterns. Winter crops like wheat and potatoes have decreased in India as a result of warmer winters and a shorter frost season. The productivity of the agricultural industry, which provides the majority of the population's income, has decreased as a result [26].In addition to making crops more susceptible to weeds, insects, and diseases, higher temperatures and more moisture can also result in considerable crop losses. Important crops like corn and soybeans might lose 3 to 7 percent of their production for every degree of increased heat [27].excessive weather events, such as drought, heat waves, and excessive precipitation, are predicted to become more common and severe as a result of climate change. Extreme precipitation events have the potential to disrupt plant growth, especially in recently burned forests, and increase the risk of flooding and soil erosion for plants. In places like India, where agricultural yields are expected to rise due to rising temperatures, the combination of heat and water constraint may diminish crop output [28].

While some crop yields may increase, the amount of critical nutrients in crops is impacted by rising CO_2 levels. According to one study, the protein content of potato tubers, wheat, rice, and barley grains fell by 10 to 15 percent with increased CO_2. Important minerals including calcium, magnesium, phosphorus, iron, and zinc are also lost by crops. India, which has a sizable vegetarian population and consumes a lot of grains on a daily basis, could be seriously impacted by this [29]. Due to the effects of climate change, plants in India, where a major section of the population works in agriculture, face an uncertain future. It is challenging to foresee the total effects of climate change on plant life in the nation due to the intricate interactions between plant physiology and behaviour, resource availability and usage, shifting plant communities, and other factors (30).

Addressing Effect of Climate Change on Plants

It will be necessary to take a comprehensive and interdisciplinary approach that takes into account the ecological, environmental, and sociological issues involved in order to address the consequences of climate change on plants.

The following are some crucial tactics for managing these effects:

Reducing greenhouse gas emissions: It's essential for maintaining the health and well-being of plants and the ecosystems they support to address climate change and reduce greenhouse gas emissions. A variety of tactics, such as switching to renewable energy sources, increasing energy efficiency, and lowering dependency on fossil fuels, can be used to accomplish this.

Agro forestry and conservation agriculture are two examples of sustainable land use practises that can improve plant yield and safeguard soil quality. These methods, which can enhance soil quality, lessen erosion, and foster biodiversity, include crop rotation, intercropping, and the use of cover crops.

Natural ecosystem preservation and restoration are essential for preserving biodiversity and ecosystem services. Examples of such ecosystems include wetlands, grasslands, and forests. These ecosystems can also act as significant carbon sinks, lowering atmospheric levels of greenhouse gases.

Creating plant types that are more resistant to the effects of climate change, such as drought, heat stress, pests, and diseases, can aid in ensuring food security and maintaining the health of the ecosystem. Conventional breeding methods, genetic engineering, and other biotechnological methods can all be used to accomplish this.

Continuing to invest in research and development will be essential for creating new approaches and technology to deal with the consequences of climate change on plants. These fields include plant biology, ecology, and agriculture. The

ability to safeguard and improve plant productivity in the face of a rapidly changing climate can be ensured thanks to this.

CONCLUSIONS

The world of plants is being significantly impacted by the rising temperatures and rising levels of carbon dioxide (CO_2) in the atmosphere. Here are some ways that plants are being impacted by climate change:

Increased Plant Growth: Since plants need carbon dioxide for photosynthesis, locations with higher atmospheric CO_2 concentrations may experience an increase in plant growth. However, other elements like the availability of nutrients and water may have a limit on this effect.

Changes in Plant Distribution: Plant distribution may change when temperatures rise; some plant species may move to cooler climates, while others may die extinct or become less widespread. Ecosystems and the animals who rely on these plants for food and habitat may be significantly impacted by this. Ecosystems and the animals who rely on these plants for food and habitat may be significantly impacted by this.

Changes in Plant Phenology: The time of plant development and flowering, or "plant phenology," can shift as a result of climate change. The timing of interactions between plants and animals, such as the activity of pollinators and the availability of food for migratory birds, may be significantly impacted by this.

Increased Risk of Wildfires: Wildfire risk has increased as temperatures have risen and droughts have become more frequent. In locations with great biodiversity, this can have a substantial impact on plant communities.

Changes in Plant Productivity: Crop yields and plant productivity are both impacted by climate change. In locations with high populations and restricted access to resources, this may have a considerable impact on food security.

There are numerous and diverse effects of climate change on plants. Warmer temperatures and greater CO_2 levels may be advantageous for some plant species, but these advantages may be outweighed by the detrimental effects on plant distribution, phenology, and production. Protecting the health and well-being of plants and the ecosystems they sustain depends on addressing climate change and cutting greenhouse gas emissions. Tackling the impacts of climate change on plants would require a thorough and interdisciplinary approach because these effects are complex and linked. Reducing greenhouse gas emissions, promoting sustainable land use, safeguarding and restoring natural ecosystems, creating plant varieties that are more tolerant to climate change, and funding research and development are all methods for addressing the effects of climate change on plants. By doing these things, we can combat the effects of a fast-changing climate while also preserving plant productivity, preserving biodiversity, and ensuring food security. For the sake of both the natural world and our own wellbeing, it is imperative that we take action right away to address the effects of climate change on plants and ecosystems.

REFERENCES

[1]. Ainsworth, E. A., & Rogers, A. (2007). The response of photosynthesis and stomatal conductance to rising [CO2]: mechanisms and environmental interactions. Plant, Cell & Environment, 30(3), 258-270.
[2]. IPCC. (2018). Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change.
[3]. Bond-Lamberty, B., & Thomson, A. (2010). Temperature-associated increases in the global soil respiration record. Nature, 464(7288), 579-582.
[4]. Cleland, E. E., Chuine, I., Menzel, A., Mooney, H. A., & Schwartz, M. D. (2007). Shifting plant phenology in response to global change. Trends in Ecology & Evolution, 22(7), 357-365.
[5]. Thackeray, S. J., Henrys, P. A., Hemming, D., Bell, J. R., Botham, M. S., Burthe, S., ... & Wanless, S. (2016). Phenological sensitivity to climate across taxa and trophic levels. Nature, 535(7611), 241-245.
[6]. Bais, H. P., Weir, T. L., Perry, L. G., Gilroy, S., & Vivanco, J. M. (2006). The role of root exudates in rhizosphere interactions with plants and other organisms. Annual Review of Plant Biology, 57(1), 233-266.
[7]. Piao, S., et al. (2019). Evidence for a weakening relationship between interannual temperature variability and northern vegetation activity. Nature Communications, 10(1), 1-8.
[8]. Kimball, B. A., et al. (2002). The impacts of elevated CO2 concentration on the productivity and water use of irrigated alfalfa. Global Change Biology, 8(8), 749-764.
[9]. Ainsworth, E. A., & Long, S. P. (2005). What have we learned from 15 years of free-air CO2 enrichment (FACE)? A meta-analytic review of the responses of photosynthesis, canopy properties and plant production to rising CO2. New Phytologist, 165(2), 351-372.

[10]. Long, S. P., & Ort, D. R. (2010). More than taking the heat: crops and global change. Current Opinion in Plant Biology, 13(3), 241-248.
[11]. Leakey, A. D. B., et al. (2009). Elevated CO2 effects on plant carbon, nitrogen, and water relations: six important lessons from FACE. Journal of Experimental Botany, 60(10), 2859-2876.
[12]. Ziska, L. H. (2016). Climate change, carbon dioxide and agriculture: an editorial comment. Agriculture, Ecosystems & Environment, 215, 1-2.
[13]. Elser, J. J., Bracken, M. E. S., Cleland, E. E., Gruner, D. S., Harpole, W. S., Hillebrand, H., ... & Smith, J. E. (2007). Global analysis of nitrogen and phosphorus limitation of primary producers in freshwater, marine and terrestrial ecosystems. Ecology Letters, 10(12), 1135-1142. doi: 10.1111/j.1461-0248.2007.01113.x
[14]. Griffin, K. L., & Rogers, H. H. (2020). Carbon dioxide enrichment and nitrogen fertilization alter growth and nutrient dynamics of tree seedlings. Plant Ecology, 221(9), 685-698. doi: 10.1007/s11258-020-01071-5
[15]. Sprent, J. I., Ardley, J., James, E. K., &Frommlet, J. C. (2021). Temperature and the nitrogen-fixing symbiosis. Plant and Soil, 461(1-2), 21-29. doi: 10.1007/s11104-020-04826-x
[16]. Allen, C. D., Macalady, A. K., Chenchouni, H., Bachelet, D., McDowell, N., Vennetier, M., … Cobb, N. (2010). A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. Forest Ecology and Management, 259(4), 660-684. https://doi:0.1016/j.foreco.2009.09.001
[17]. Adams, H. D., Zeppel, M. J. B., Anderegg, W. R. L., Hartmann, H., Landhäusser, S. M., Tissue, D. T., … McDowell, N. G. (2017). A multi-species synthesis of physiological mechanisms in drought-induced tree mortality. Nature Ecology & Evolution, 1(9), 1285–1291.
[18]. https://doi.org/10.1038/s41559-017-0248-x
[19]. Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., & Hanson, C. E. (Eds.). (2007). Climate change 2007: impacts, adaptation and vulnerability: contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.
[20]. IPCC. (2014). Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.
[21]. Wheeler, T., von Braun, J., & Beddington, J. (2020). Climate change impacts on global food security. Science, 341(6145), 508-513.
[22]. Kundzewicz, Z. W., Kanae, S., Seneviratne, S. I., Handmer, J., Nicholls, N., Peduzzi, P., … Sherstyukov, B. (2019). Flood risk and climate change: global and regional perspectives. Hydrological Sciences Journal, 64(4), 344-362.
[23]. Pandey, A., Pandey, R., & Tripathi, M. P. (2021). Climate change-induced disaster risks: a review of evidence from India. Journal of Environmental Planning and Management, 1-19.
[24]. Nagendra, H., Lucas, R., Honrado, J. P., Jongman, R. H., Tarantino, C., Adamo, M., … &Mairota, P. (2018). Remote sensing for conservation monitoring: assessing protected areas, habitat extent, habitat condition, species diversity, and threats. Ecological Indicators, 93, 871-880.
[25]. Kumar, P., Bhardwaj, A. K., Gupta, A., & Singh, J. (2021). A Review on Impact of Climate Change on Crop Productivity. In Environmental Sustainability and Climate Change Management (pp. 241-249). Springer.
[26]. Acharya, S., Mahapatra, S., & Bhattacharya, S. (2017). Agricultural droughts in India: A review. Journal of water and climate change, 8(3), 349-362.
[27]. Ministry of Earth Sciences, Government of India. (2019). India's Second Biennial Update Report to United Nations Framework Convention on Climate Change. Retrieved from https://www.moef.gov.in/wp-content/uploads/2021/09/India%e2%80%99s_Second_BUR.pdf
[28]. Wheeler, T., von Braun, J., & Meinke, H. (2020). Climate change impacts on global food security. Science, 369(6509), 856-859.
[29]. Chaturvedi, R. K., Joshi, J., & Jayaraman, M. (2012). Impacts of climate change on Indian agriculture: a review. Climatic Change, 111(2), 445-476.
[30]. Myers, S. S., Zanobetti, A., Kloog, I., Huybers, P., Leakey, A. D., Bloom, A. J., ... & Tingley, M. P. (2014). Increasing CO2 threatens human nutrition. Nature, 510(7503), 139-142.
[31]. Pandey, D. N., & Pandey, V. (2018). Climate change and Indian agriculture: Impacts, adaptation and mitigation. In Climate Change and Agriculture (pp. 1-14). Springer, Cham.

"Exploring the Diverse Applications of Industrial Enzymes: Catalysts for Sustainable Industrial Processes"

Dr. Santosh Hooda[1], Dr. Veena Sachdeva[2]

[1]Associate Professor, Department of Zoology, Government PG College for Women, Rohtak
[2]Associate Professor, Department of Botany, Government PG College for Women, Rohtak

Corresponding Author, Dr. Veena Sachdeva, Email:veenasachdevaa@gmail.com

ABSTRACT

Industrial enzymes are specialised proteins used in a variety of industrial processes owing to their capacity to catalyse particular chemical reactions. These enzymes, which are produced by microbial fermentation or genetically modified organisms, have a number of benefits over conventional chemical catalysts, including more selectivity, milder reaction conditions, and better sustainability. Due to their exceptional catalytic efficiency and specificity, enzymes serve as biocatalysts and are essential in many industrial applications. Enzymes are frequently used in the food and beverage industries, where they help turn basic ingredients like carbohydrates, proteins, and lipids into tasty finished goods. Additionally, the textile sector uses enzymes for procedures like desizing, bio-polishing, and denim fading to enhance fabric quality and minimise environmental impact. Enzymes play a crucial role in laundry detergents in the detergent business, providing efficient stain removal and energy efficiency. Enzymes are used in medication synthesis by the pharmaceutical industry, resulting in more productive production methods and a smaller environmental impact. Enzymes are also essential for producing biofuels, notably the enzymatic hydrolysis of biomass to produce bioethanol. Finally, enzymes are used in waste management to help treat and degrade a variety of contaminants. Enzymes provide a viable and effective replacement for conventional chemical processes in many industrial sectors, encouraging environmentally friendly practices and raising product quality.

Key Words: Industrial Enzymes, Catalysis, Biofuels, Fermentation, Sustainable

INTRODUCTION

Biocatalysts that are commonly employed in many areas of industrial production are industrial enzymes. In comparison to conventional chemical processes, these specialised proteins promote and speed up chemical reactions. Industrial enzymes have drawn a lot of interest because of their adaptability, focus, and environmental friendliness.

Enzymes have been used in industrial operations since ancient times when they were used in things like brewing, cheese-making, and bread-making. The industrial enzyme business has undergone a revolution, though, because of developments in contemporary biotechnology, which have made it possible to produce enzymes on a massive scale and broaden their applications.

The ability of industrial enzymes to operate in benign operating conditions, such as moderate temperatures and pH ranges, minimises energy consumption and has a positive impact on the environment. Furthermore, enzymes have excellent substrate and reaction specificity, which increases efficiency and decreases waste production.

The enzyme industry has undergone rapid development primarily in the past four decades, driven by advancements in modern biotechnology [1]. Enzymes have been utilized since ancient times in the production of various food products, including cheese, sourdough, beer, wine, and vinegar, as well as in the manufacturing of commodities such as leather, indigo, and linen [2][3]. In those early processes, enzymes were derived from spontaneously

growing microorganisms or added preparations like calves' rumen or papaya fruit, without being purified or well-characterized [3].

However, the development of fermentation processes in the later part of the last century revolutionized the production of enzymes by using selected production strains, enabling large-scale manufacturing of purified and well-characterized enzyme preparations [4]. This breakthrough facilitated the integration of enzymes into true industrial products and processes, including the detergent, textile, and starch industries [3]. Additionally, the application of recombinant gene technology further improved manufacturing processes and made the commercialization of previously inaccessible enzymes possible [4].

Furthermore, recent advancements in modern biotechnology, such as protein engineering and directed evolution, have significantly transformed the development of industrial enzymes [3]. These innovations have facilitated the production of tailor-made enzymes with new activities and adapted characteristics for diverse process conditions, leading to further expansion of their industrial applications [4]. As a result, the enzyme industry has become highly diversified and continues to grow in terms of size and complexity [3].

The majority of industrial enzymes in use today have a hydrolytic function and are used to break down a variety of natural compounds. Due to their extensive use in the dairy and detergent sectors, proteases in particular continue to be the most common enzyme class. Amylases and cellulases, the second-largest group of carbohydrases, are used in the starch, textile, detergent, and baking industries [1].

Industrial enzymes now have a $1.5 billion market value worldwide, up from $1 billion in 1995 [5]. However, in certain important technical industries, including the detergent industry, growth has been static [5].

The baking and animal feed industries have experienced the fastest growth in the past decade, while other industries, ranging from organic synthesis to paper and pulp and personal care, have also contributed to the overall expansion of the enzyme market [1].

Recombinant DNA technologies, protein engineering, and developments in fermentation methods have all aided in the development of industrial enzymes. Enzyme manufacturing on a wide scale is made possible by fermentation procedures that make use of particular microbes or genetically modified organisms. Through the use of recombinant DNA technology, desirable genes can be introduced into host species, enabling the creation of enzymes that were previously scarce. Enzymes can be altered and optimised using protein engineering techniques to improve their functionality, stability, and specificity for different industrial applications [6].

Industrial enzymes are becoming more and more valued resources for attaining these aims as the need for sustainable and ecologically friendly processes rises. They provide substantial advantages like decreased energy use, reduced waste production, and increased process effectiveness. The field of industrial enzymes is anticipated to grow further with continued study and technical development, resulting in the creation of novel enzymes and the investigation of innovative uses in a variety of industries.In addition to enhancing process economics, their utilisation promotes environmental sustainability[6].

This review will examine the most recent improvements in the technical uses of enzymes, segment by segment, highlighting the important developments that have facilitated these uses.

Enzymes in Detergent Industry

The detergent industry, which represents the largest utilisation in terms of volume and value [7], continues to be at the forefront of industrial enzyme uses. Proteases are the most common enzymes utilised, although other hydrolases with unique features are often added to offer a variety of advantages, including the elimination of specific stains [8]. Proteases and amylases are examples of conventional detergent enzymes that have undergone improvements as a result of ongoing biotechnological developments. These enzymes from the second and third generations have undergone extensive optimisation to satisfy the changing performance standards for detergents, whose composition is continually being improved [9].

The compatibility of enzymes with detergent components, notably their stability features, is one of the major factors to be taken into account while developing detergent enzymes. Additionally, recent work has concentrated on improving the enzymes' effectiveness at lower temperatures, which is in line with the development of less energy-intensive laundry and dishwashing practises [10]. When it comes to overcoming the difficulties of effective cleaning and stain removal at lower temperatures, enzyme technology is essential.

Novel amylases that have been engineered to display increased activity at lower temperatures and alkaline pH, while preserving stability under detergent conditions, are notable examples of second-generation detergent enzymes. These enzymes are created using a combination of rational protein engineering techniques and microbial

screening [11]. Proteases that can operate at low temperatures have been found in nature, and additional advancements have been made via techniques of lab-directed evolution [12]. Scientists have isolated new proteases from a pool of 26 subtilisin proteases via DNA shuffling, producing enzymes with improved activity and stability at alkaline pH—important properties for detergent proteases [13].

An important development in detergent enzymes in recent years has been the appearance of a new enzyme class, notably mannanases. Procter & Gamble and Novozymes worked together to develop this innovation [14]. The collaboration between Procter & Gamble and Novozymes to create mannanases is a prime example of the detergent enzymes' ongoing innovation and advancement. Manufacturers can improve the effectiveness and efficiency of stain removal by broadening the variety of enzymes used in detergents. This advancement is essential because it tackles unique difficulties in erasing guar gum stains, which can be extremely difficult.

Procter & Gamble and Novozymes' partnership demonstrates the industry's dedication to expanding enzyme technology and developing cutting-edge cleaning and stain removal methods. The detergent business may offer consumers cleaners that are more effective and efficient by consistently researching and launching new enzyme classes, such mannanases.

Guar gum, a typical stabiliser and thickening component in food items, plays a significant role in the efficient removal of numerous food stains.Guar gum, a stabiliser and thickening substance frequently used in food items, is recognised for helping to remove various food stains effectively. The detergent sector has been actively working to improve enzyme activity, stability, and compatibility with detergent formulations since they understand how important it is to deal with these stains. The breakthroughs in industrial enzymes have been fueled by this continual research and development in the detergent sector.

The detergent business improves enzyme activity, stability, and compatibility to offer more potent stain removal and cleaning capabilities. This is especially true now that energy-saving techniques are increasingly emphasized in home and commercial cleaning methods.In order to satisfy changing consumer needs, the detergent industry must make improvements to enzyme activity and compatibility with detergent formulations. These advancements help remove stains more successfully and offer energy savings by lowering the temperature requirements for cleaning procedures.With a continuing focus on enhancing enzyme activity, stability, and compatibility with detergent formulations, the detergent industry remains the primary force behind the research and use of industrial enzymes. These developments pave the way for more effective stain removal and cleaning, which helps domestic and commercial cleaning procedures save energy.

Enzymes in Fuel Production

Based on the primary ingredients and production methods, biofuels are divided into generations. Bio-alcohols like ethanol, butanol, and propanol are produced as a by-product of the fermentation process used to produce first-generation biofuels from sugar and starch-producing plants. Cellulose from non-food crops and leftover biomass is used to make cellulosic biofuels, which are a type of second-generation biofuel. Algal/microalgae species are used to create third-generation biofuels, which have high energy efficiency and provide benefits for the economy, society, and environment for both domestic and industrial use [15][16].

Municipal garbage, agricultural residues, industrial organic waste, and livestock waste are all examples of waste biomass that can make good sources for biofuel production and help to create a low-carbon environment and a circular economy that is sustainable [17][18]. For instance, the creation of biochar from orange peels effectively makes use of waste biomass [18].

Various characteristics, including water content, volatile components, ash content, net calorific value, and chemical composition, influence the choice of suitable waste biomass for biofuel generation [19][20]. In comparison to rice waste and date fruit waste, studies have indicated that Jatropha fruit waste (cake) demonstrates the superior potential for the manufacture of biofuels [20].

In the process of producing biofuel, enzymes provide benefits like process effectiveness, cost-effectiveness, and environmental friendliness. Microbial-driven enzymes are frequently employed, highlighting the significance of a thorough understanding of microorganisms and their particular enzymes for various biofuels [21]. Enzyme-based biofuel cells (EBCs), which focus on using glucose as a biofuel to generate power through the use of different nanomaterials, are a recent discovery [22].With the development and improvement of cost-effective bioprocesses, the generation of biohydrogen, biodiesel, biogas, and bioethanol would be an ideal option to replace the energy of fossil fuels. Along with having a thorough understanding of its process and the microorganisms from which these enzymes are derived, it is crucial to place emphasis on the enzymes involved in the generation of various biofuels. Enzymes that work well and efficiently will help the economy's transition to a biofuels-based one. As engineering techniques and synthetic biology have advanced, many microbe strains have been employed to increase the production of sustainable enzymes for biofuels.

Enzymes in the Production of Textiles

Despite having a large impact on the world economy, the manufacture of textiles frequently has negative environmental effects. Enzymes have become useful tools in the textile industry in recent years, providing effective and sustainable solutions to a variety of problems. One of the areas of industrial enzymology that is expanding the fastest is the use of enzymes in the textile industry. Amylases, catalase, and laccase are the enzymes that are utilised in the textile industry to remove starch, break down excess hydrogen peroxide, bleach fabrics, and break down lignin. Due to their non-toxic and environmentally friendly qualities, enzymes are being used more and more in the chemical processing of textiles as the need for textile manufacturers to prevent pollution in textile production becomes more and more significant. The most recent commercial advancements involve the use of cellulases for denim finishing and lactases for bleaching and decolorizing textile effluents. Because enzymes are highly specific, effective, and operate in benign settings, their employment in technology is appealing. Additionally, using enzymes speeds up processes, saves energy and water, improves product quality, and has the ability to integrate processes. The objective is to educate the textile technologist about enzymes and how to employ them with textiles.

Biocatalysts known as enzymes speed up chemical reactions. Enzymes have various benefits over conventional chemical processes for processing textiles, including less energy and water use, softer processing conditions, and better product quality. The textile industry uses enzymes at several stages [23].

Biocatalysts known as enzymes speed up chemical reactions. Enzymes have various benefits over conventional chemical processes for processing textiles, including less energy and water use, softer processing conditions, and better product quality. Enzymes are utilised in the desizing, scouring, bleaching, dying, and finishing stages of textile manufacture.

Desizing and scouring: While scouring eliminates impurities including waxes, pectins, and oils, desizing involves the removal of sizing agents from fabrics. Alpha-amylases and cellulases are employed for effective desizing and scouring, which enhances the absorbency, dye uptake, and general quality of the cloth. These enzymatic procedures are less harmful to the environment than conventional chemical ones.

Bleaching: Enzymes are essential to the bleaching process because they break down lignin, pectin, and other contaminants in the cloth. Utilising enzymes like xylanase and laccase, enzymatic bleaching lessens the need for harsh chemicals and high heat, reducing the impact on the environment and improving fabric brightness.

Dyeing and Colouring: Enzymes are used in several stages of textile dyeing, such as colour removal, denim fading, and enhancing colour fastness. The fabric surface can be better prepared for dye penetration using enzymatic techniques like bio-bleaching and bio-scouring, which can improve colour intensity and cut down on dye usage.

Finishing: Enzymes offer creative approaches to textile finishing, giving materials the desired practical qualities. For instance, soft, smooth, wrinkle-free finishes can be produced using enzymes like cellulases and lipases instead of harsh chemicals and mechanical treatments. The popularity of enzymatic finishing techniques has grown as a result of their sustainability, enhanced fabric feel, and low energy requirements.

Environmental Benefits: The textile industry uses enzymes to preserve the environment and promote sustainability. Low temperatures and quick processing durations are typical requirements for enzymatic reactions, which work under more tolerant circumstances. As a result, energy is saved, and carbon emissions are decreased. Enzymatic processes also minimise the ecological effect by using less water and releasing fewer dangerous chemicals into the environment.

Higher-quality finished goods are a result of desired fabric qualities acquired by enzymatic activities, such as greater fabric absorbency, increased dye uptake, improved colour fastness, and desirable fabric features. By increasing processing effectiveness and minimising the need for harsh chemicals and repetitive treatments, enzymes can also assist lower production costs.

The textile industry has undergone a revolution because to enzymes, which offer effective and environmentally friendly substitutes for conventional chemical procedures. Enzymes are used in textile processing for a variety of reasons, including decreased environmental impact, higher performance, and better fabric quality. An important step towards a greener and more sustainable future is the adoption of enzyme technology in the textile industry [24].

Enhancing Nutrient Utilisation and Environmental Sustainability with Enzymes in the Feed Industry

Enzymes have become significant feed additions in the cattle business, solving issues with sustainability and nutrient utilisation. In the feed industry's use of enzymes like xylanases, β-glucanases, and phytases is very well

documented, with special emphasis on how they help animals better absorb nutrients and have a smaller negative impact on the environment.

Cereal-based feed with xylanases and beta-glucanases:
For monogastric animals, xylanases and beta-glucanases are added as feed additives to cereal-based diets. These enzymes aid in the breakdown of the complex carbohydrates found in plant-based feeds, improving nutritional availability and improving animal performance [25].

Phytases for Better Utilisation of Phosphorus:
Although phosphorus is an essential mineral for animal diets, it is frequently bound in phytic acid in feeds made from plants. Monogastric animals' low phosphorus utilisation results from a lack of the enzymes needed for effective phytic acid breakdown. Enzymes called phytoses, which break down phytic acid, have drawn a lot of interest as feed additives. Phytases increase animal phosphorus uptake by enhancing the release of phosphorus from phytic acid [26]. This is especially important since there are restrictions on conventional inorganic phosphorus sources, including bone meal, and because phosphorus excretion must be decreased to lessen environmental effect [27].

Research is now being done to improve the effectiveness of phytases in feed formulations. In order to increase phosphorus release, new fungal phytases with noticeably greater specific activity have been discovered [28]. To improve the catalytic activity of fungal phytases, methods including site-directed mutagenesis based on three-dimensional structural analyses have been used [29]. These developments are meant to maximise phytases' abilities to increase phosphorus utilisation in animal diets.

Feed enzymes, such as phytases, have been discovered to have indirect impacts on the intake of other nutrients in addition to their direct impact on phosphorus utilisation [30]. In order to better understand these impacts and create enzyme formulations that enhance nutrient utilisation and advance animal health, more research is now being conducted. Future prospects include the continuous development of enzyme technology, which will promote sustainable livestock production methods and allow for better nutrient utilisation in animal diets.By increasing nutrient utilisation and minimising environmental effect, enzymes are essential in the feed sector. In monogastric animals, the use of enzymes such xylanases, β-glucanases, and phytases improves the utilisation of phosphorus and the breakdown of complex polysaccharides. The optimisation of nutrient utilisation in animal diets has potential for supporting efficient and sustainable livestock production, according to ongoing research and developments in enzyme technology.

Enzymes for the Food Industry: Innovations and Various Uses
The use of enzymes in the food business has grown significantly, with uses ranging from texturizing to flavouring. This article examines the various uses of enzymes in the food-processing industry, highlighting current developments and their potential for further development in the future.

Using transglutaminase to Texture:
Through protein cross-linking, transglutaminase has become recognised as a useful texturizing agent in the food processing industry, enhancing the viscoelastic qualities of goods like sausages, noodles, and yoghurt [31]. Although ongoing attempts are being made to expand the availability of economically viable transglutaminase enzymes through recombinant synthesis, this problem still exists.

Lipolytic Enzymes in Baking: According to studies [32, 33], lipolytic enzymes are being used more and more in baking. Recent research suggests that phosphor-lipases can produce emulsifying lipids in situ by degrading polar wheat lipids in place of or in addition to conventional emulsifiers. Additionally, studies are concentrating on the causes of bread staling and the enzymatic prevention of staling employing xylanases and α-amylases [34]. Bread softness and elasticity are maintained in part by the starch and hemicellulose fractions' ability to retain and bind water.

Novel Applications: Although there is a dearth of literature on a number of promising new applications of enzymes in the food business. By catalysing the cross-linking of polyphenols, laccase enzymes have been employed to clarify juice by enabling their simple removal through filtration. By catalysing the cross-linking of polyphenols, laccase enzymes have been employed to clarify juice by enabling their simple removal through filtration. Additionally, laccases have been used to improve the flavour of beer. New uses in the food sector may be discovered by further investigation of various enzyme classes [35].

Enzymes have completely changed the way that food is produced, with uses ranging from flavouring to texturizing. Recent developments have demonstrated tremendous potential for enhancing product quality and processing effectiveness, including the use of transglutaminase for texturizing and lipolytic enzymes in baking. In addition,

new uses for enzymes, such as laccase enzymes, show how widely used they are in the food sector. Enzyme technology will improve further with continued study and invention, resulting in better food processing.

Oil and Fat Processing

Several innovative enzyme-based techniques have recently been established in the fat and oil industries. Even though the technique of interesterifying triglycerides using immobilised lipases was first reported in the 1980s, it has not yet proven to be sufficiently cost-effective to be used in actual large-scale applications, such the manufacturing of margarine [36]. However, these issues have been resolved by improvements in enzyme synthesis and immobilisation methods.

Utilising granulated silica to immobilise lipases has greatly decreased process costs, which is a significant development [37]. This breakthrough has made it possible to produce commodity fats and oils free of trans fatty acids using enzyme-based techniques, which will result in healthier food items [37].

The "de-gumming" process, which eliminates phospholipids from vegetable oils, is another notable enzyme-based procedure. Highly selective microbial phospholipases are used in this procedure [38]. This enzymatic step can be added to save energy and water, which is good for the environment as well as the industry [38].

These enzyme-based procedures show how enzymes can improve sustainability and productivity in the fat and oil sectors. It is anticipated that ongoing research and development in enzyme technologies will spur additional improvements in these procedures and broaden their applications.

Enzymes for organic synthesis

Chemical synthesis depends on enzymes for organic synthesis, which have many advantages over conventional chemical processes. In contrast to other industries, the chemical industry has been rather sluggish to adopt enzyme catalysis despite its considerable promise. However, the manufacture of numerous compounds using enzyme-based techniques has seen tremendous growth and wide adoption recently, signalling a turning point in the industry [34].

The creation of single-enantiomer intermediates for use in the synthesis of medicines and agrochemicals is a well-known application of enzymes in organic synthesis. The required biological activity and safety of these chemicals depend on the selective production of particular enantiomers, which is only possible through enzymatic reactions. Due to the fact that only a few number of enzymes have broad applicability across several synthetic pathways, this market segment is highly fragmented.

Novel enzymatic processes have been created as a result of recent developments in enzyme-based catalysis. For instance, lipases are useful in the synthesis of enantiopure alcohols and amides. These enzymes have a high degree of selectivity and are effective at resolving chiral mixtures from racemic mixtures. While acylases have been used to create novel semi-synthetic penicillins, nitrilases have been used to produce enantiopure carboxylic acids [39].

It is significant to remember that many businesses are only just beginning to investigate and utilise the potential of enzyme-based catalysis in organic synthesis. This suggests that there is still a great deal of space for new research and breakthroughs in this area. Expanding the range of enzymes and improving their catalytic capabilities for certain chemical transformations are the goals of ongoing research in the fields of enzyme engineering, directed evolution, and protein design.

The use of enzyme-based techniques in organic synthesis has a number of benefits. Enzymes frequently operate with excellent selectivity and under benign reaction conditions, minimising the creation of undesirable byproducts and minimising waste. Enzyme catalysis can also increase overall process efficiency and allow the use of renewable starting materials. With predictions of continuous development and innovation in the upcoming years, these considerations help to explain the increased interest in and investment in enzyme-based organic synthesis.

CONCLUSION

Enzymes are now crucial in many industrial fields, and their uses are constantly growing. Enzymes are being created for processes that were previously thought to be improbable candidates for enzymatic catalysis thanks to breakthroughs in biotechnology. This development broadens the use of enzyme utilisation and creates new possibilities.

The capacity of enzymes to function as extremely effective catalysts under benign reaction circumstances is one of their main advantages. This trait results in enormous resource savings, including water and energy, which are advantageous to the economy and the environment. Such resource preservation is especially important in a world that is struggling with issues like population growth and resource depletion.Enzyme technology has a great deal of potential for solving problems that different sectors will confront in the future. It provides environmentally friendly

substitutes for conventional chemical processes, lessening the impact on the environment and encouraging resource utilisation that is more effective. We can anticipate even bigger discoveries and innovative uses of enzymes in the years to come as study and development in protein design, biocatalysis, and enzyme engineering continue.The development of an industrial environment that is more resource- and sustainably efficient depends in large part on enzyme technology. Industries may help fulfill the demands of a changing world while reducing their ecological impact by utilising the power of enzymes. The potential of enzymes will be further realised by continued innovation and cooperation between academics, business, and biotechnology, which will be advantageous for society, the economy, and the environment.

REFERENCES

[1]. Wong SL. Industrial Enzymes: Trends, Scope, and Relevance. In: Satyanarayana T, Littlechild J, Kawarabayasi Y, eds. Advances in Biochemical Engineering/Biotechnology. Springer; 2016.
[2]. Pandey A, Selvakumar P, Soccol CR, Nigam P. Solid-State Fermentation for the Production of Industrial Enzymes. In: Pandey A, Soccol CR, Larroche C, eds. Current Developments in Solid-State Fermentation. Springer; 2008.
[3]. Nielsen J, Johansen CL. Enzymes. In: Biotechnology: An Introduction. CRC Press; 2019.
[4]. Bornscheuer UT, Höhne M. Biocatalysts and Enzyme Technology. Wiley-VCH; 2012.
[5]. Bommarius AS, Riebel-Bommarius BR. Biocatalysis: Fundamentals and Applications. Wiley-VCH; 2004.
[6]. Godfrey, T., West, S. Industrial Enzymes: Structure, Function, and Applications. Springer, 2007.
[7]. Bornscheuer UT, Höhne M. Biocatalysts and Enzyme Technology. Wiley-VCH; 2012.
[8]. Borchert TV, Decker CH. Industrial Applications of Enzymes. In: Hage T, editor. Industrial Biotechnology: Products and Processes. Wiley-VCH; 2017. p. 241-271.
[9]. Patel R, Dodia M. Protease: Industrial Applications. In: Encyclopedia of Food Chemistry. Elsevier; 2019. p. 185-191.
[10]. Ojima Y, Liu M, Mitsunaga H. Rational Design and Engineering of Detergent Enzymes. Catalysts. 2019;9(4):372.
[11]. Jeya M, Lee JK, Moon HJ, Kim IW, Lee JK. Enzyme Applications in Detergents. In: Dhillon GS, editor. Enzymes in Food Biotechnology: Production, Applications, and Future Prospects. CRC Press; 2019. p. 131-160.
[12]. Wongnate T, Chaiyen P. Directed evolution of enzymes and biosynthetic pathways. Biotechnol Adv. 2019;37(8):107385.
[13]. Ness JE, Welch M, Giver L, Buhr CA, Minteer CJ, Gustafsson C, et al. DNA shuffling of subgenomic sequences of subtilisin. Nature. 1999 Mar 11;399(6732):670-3. doi: 10.1038/21450. PubMed PMID: 10385122.
[14]. Smith, R.M., Gruner, J., Schörgendorfer, K., Nosper, A., and Pietsch, A. (2015). Enzymes in Detergents: An Overview. In: Patel, R.N., editor. Industrial Biotechnology: Sustainable Production and Bioresource Utilization. Wiley-VCH, Weinheim, Germany. p. 137-161.
[15]. Demirbas, A. (2008). Biofuels sources, biofuel policy, biofuel economy and global biofuel projections. Energy Conversion and Management, 49(8), 2106-2116. doi: 10.1016/j.enconman.2008.02.020
[16]. Singh, A., & Pant, D. (2019). A review on third generation biofuel: A new perspective to sustainable development. Renewable and Sustainable Energy Reviews, 102, 103-112. doi: 10.1016/j.rser.2018.11.015
[17]. Raghav, M., & Gupta, R. (2021). Municipal solid waste as a potential source of renewable energy: A comprehensive review. Journal of Cleaner Production, 305, 127144. doi: 10.1016/j.jclepro.2021.127144
[18]. Yusoff, S., & Huat, C. B. (2016). Valorisation of orange peel via slow pyrolysis for biochar production. Waste Management, 48, 537-544. doi: 10.1016/j.wasman.2015.10.050
[19]. Ravindran, B., Krishnakumar, R., & Kumar, T. A. (2018). Waste to energy: A sustainable approach from bioenergy to advanced materials. In Waste to Energy Conversion Technology (pp. 1-31). Springer. doi: 10.1007/978-981-10-5122-1_1
[20]. Ratnavathi, C. V., Raghavan, V. G. S., & Ranganathan, K. (2010). Potential applications of non-edible oilseed crops in India. Renewable and Sustainable Energy Reviews, 14(9), 3226-3245. doi: 10.1016/j.rser.2010.07.035
[21]. Singh, S., Kumari, A., & Sharma, S. (2020). Advances in enzymes and microorganisms for biofuels production: A review. Fuel, 267, 117136. doi: 10.1016/j.fuel.2020.117136
[22]. Thakur, V. V., Abidi, N., & Dixit, Y. (2020). Nanotechnology-enabled enzyme-based biofuel cells: A review. Bioresource Technology, 298, 122443. doi: 10.1016/j.biortech.2019.122443
[23]. Cavaco-Paulo, A., &Gübitz, G. M. (Eds.). (2010). Textile Processing with Enzymes. Woodhead Publishing.
[24]. Dincer, I., & Akin, N. (2021). Enzymes in the textile industry: Sustainable applications and future perspectives. Journal of Cleaner Production, 314, 128
[25]. Bedford, M. R., & Partridge, G. G. (2010). Enzymes in Farm Animal Nutrition. CABI Publishing.

[26]. Cowieson, A. J., & Bedford, M. R. (2009). The effect of phytase and carbohydrase on ileal amino acid digestibility in monogastric diets: complimentary mode of action? World's Poultry Science Journal, 65(4), 609-624. doi:10.1017/S0043933909000446

[27]. Selle, P. H., Ravindran, V., & Ravindran, G. (2009). Microbial phytase in poultry nutrition. Animal Feed Science and Technology, 150(3-4), 259-280. doi:10.1016/j.anifeedsci.2008.09.013

[28]. Lei, X. G., & Stahl, C. H. (2001). Biotechnological development of effective phytases for mineral nutrition in monogastric animals. Journal of Animal Science, 79(1), E76-E83. doi:10.2527/jas2001.79E-SupplementE76x

[29]. Wyss, M., Pasamontes, L., Remy, R., Kohler, J., Kusznir, E., Gadient, M., . . . Furst, P. (1998). Comparison of the thermostability properties of three acid phosphatases from molds: Aspergillus fumigatus phytase, A. niger phytase, and A. niger pH 2.5 acid phosphatase. Applied and Environmental Microbiology, 64(11), 4446-4451. doi:10.1128/AEM.64.11.4446-4451.1998

[30]. Selle, P. H., & Ravindran, V. (2007). Microbial phytase in poultry nutrition. Animal Feed Science and Technology, 135(1-2), 1-41. doi:10.1016/j.anifeedsci.2006.06.010

[31]. Choi, J. H., & Acton, J. C. (2019). Application of microbial transglutaminase in the food industry: An overview. Applied Microbiology and Biotechnology, 103(3), 1119-1130. doi:10.1007/s00253-018-09514-4

[32]. Kieliszek, M., & Misiewicz, A. (2014). Microbial transglutaminase and its application in the food industry. A review. Folia Microbiologica, 59(3), 241-250. doi:10.1007/s12223-013-0293-5 [33]. Gobbetti, M., &Gänzle, M. (2015). Handbook on sourdough biotechnology. Springer.

[34]. Kapoor, M., & Goyal, G. (2016). Lipase applications in food industry. In Enzymes in Food Technology (pp. 223-251). Academic Press.

[35]. Gallagher, E., Gormley, T. R., & Arendt, E. K. (2004). Recent advances in the formulation of gluten-free cereal-based products. Trends in Food Science & Technology, 15(3-4), 143-152.doi:10.1016/j.tifs.2003.09.012

[36]. Xu, X., & Hanna, M. A. (2005). Continuous enzymatic interesterification of soybean oil and fully hydrogenated soybean oil in a packed-bed reactor: Process optimization. Journal of the American Oil Chemists' Society, 82(10), 733-738. doi:10.1007/s11746-005-1137-2

[37]. Nie, H., Li, T., & Nie, S. (2016). Immobilization of lipases on mesoporous silica: A review. Journal of Molecular Catalysis B: Enzymatic, 134, 285-299. doi:10.1016/j.molcatb.2016.09.007

[38]. Kuo, C. M., Chen, P. Y., & Liu, Y. C. (2011). Removal of phospholipids from vegetable oils by using an immobilized phospholipase. Food Chemistry, 126(2), 694-700. doi:10.1016/j.foodchem.2010.11.009

[39]. Faber, K. (2011). Biotransformations in organic chemistry: A textbook (6th ed.). Springer.


IJNRD.ORG
ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH
AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal
International Research Journal
IJNRD
Research Through Innovation

Title: Effectiveness of E-Governance Mix in India

Authors:

1. Dr. Sunil Kumari, Assistant Professor, Govt. College Meham, Rohtak
2. Mrs. Jyoti, Assistant Professor, Pt. NRS Govt. College, Rohtak

Abstract

As it is being witnessed that in present global scenario product economies are turning to information and knowledge economies, so governance of such economies needs also to be electronically consequently concept of E-Governance is emerging of which effectiveness depends upon IT infrastructure, service quality of web portals of E-Governance and its delivery to citizens at affordable cost with accuracy and proper security. Present study aims at finding the level of effectiveness of E-Governance in India. Study reveals that efficacy of E-governance depends upon the service quality of web portals provided by the Govt. to citizens.

Key Words: Web Portals, E-Governance Mix, Service, Quality

1. Introduction

In present era of information and communication technology where economies are undergoing to transform to E-governance as a broader government modernization programs, so how India can isolate itself at this counterpart. At the same time, not all Indian state governments are at the same level on the e-governance curve. While some states have been proactive and faster adopt e-governance concept, others are still in the process of transforming the domain of citizen-centric governance. Some developed countries at global level, however, have already achieved the goals of Governance 1.0, and are now moving on to Government 2.0, described as the next phase, or next step of good governance and India is also trying to pick the same track of E-governance.

E-governance is nothing but an application of electronic media in Govt services. To make the E-governance more effective E-governance mix is framed that signifies the mixture of 4As i.e. Awareness, Accessibility, Adaptability and Affordability in optimal manner. Goodness of E-governance depends upon service quality of web portals provided by the Govt. regarding these 4As. The central and state governments have taken several initiatives to harness the power of ICT to improve G2G, G2C and G2B interactions Government's concern seems in adoption of National e-governance Plan (NeGP), which aims to make all government services accessible to common citizens in their localities through common service delivery outlets and ensure efficiency, transparency and reliability of such services at bearable costs. Now question arises whether Govt web portals are meeting the needs of citizens so that more steps can be taken by Govt to improve the efficacy of E-Governance which initiates the researcher to make the study on this topic.

2. Literature Review

M. Shamsul Haque (2002) revealed in his study that E-governance must show more than this dismal scenario of human conditions in India. After all, the poor citizens need the basic material preconditions of living — including food, health, education and employment — before they become interested in non-material concerns like information and knowledge provided by e-governance. There is no doubt that e-governance has been useful for certain services enjoyed by citizens, especially the affluent high-income families and foreign investors. But it is yet to be seen whether e-governance can eradicate poverty, reduce inequality and satisfy basic human needs in a poor country like India**.**

A. Monga (2008) concluded that with the introduction of e-government applications, the service delivery mechanisms in India have made clear departure from the past - cramped spaces, shabby ambience, long queues, delaying tendencies of officials procedural complexities, direct and indirect demands for bribe, and inefficiency in work. The introduction of Information Technology in the governance process has brought about a revolution in the quality of service delivered to its citizens.

Xenia Papadomichelaki and Gregoris Mentzas (2009) conceptualized an e-government service quality model (e-GovQual) to develop, refine, validate, confirm and test a multiple-item scale for measuring e-government service quality for public administration sites where citizens seek either in-formation or services. Within E-GovQual four factors are used: reliability, efficiency, citizen support and trust. Each of the four factors had a

significant impact on overall service quality. Through understanding the service quality dimensions for governmental sites, an organization will stand a much better chance of gaining and serving much more citizens.
Dr. Sanjay Kumar Dwivedi & Ajay Kumar Bharti (2010) stated in their study that 81% citizens report reduction in corruption, 95% find cost of e-governance affordable and 78% favors fast of delivery of services. Therefore we can say that e-Governance is the key to the "Good Governance" for the developing countries like India to minimize corruption, provides efficient and effective or quality services to their citizens.
Debjani Bhattacharya, Umesh Gulla, M.P. Gupta, (2012) took seven constructs – i.e. citizen centricity, transaction transparency, technical adequacy, usability, complete information, privacy and security and usefulness of information – were identified from the analyses, which can be used to assess the demand side service quality of government portals. **Jaya Iyer & R.K.Srivastav (2012**) measured the website quality, proposing nine dimensions which are identified based on a review of the literature and on the analysis of data of a pilot survey.

Sushil Kumar Singla & Himanshu Aggarwal (2013) focused in the study at discovering e-Governance inventiveness initiated by the Punjab Government. The study found why e-Governance is not appropriately applied in rural areas of the Punjab. It emphasized on determinants of e-Governance to control the corruption. It has also been explained the awareness of citizens about internet required for effective implementation of e-Governance. This study is useful to know the impact of e-Governance projects implemented and find out the scope of e-Governance in the State of Punjab.

Parul Jain & Pradeep Suri (2017) explored that an e-governance project where citizen is taking as a central point witnessed extraordinary value of theoretical S-A-P variables is anticipated to be well thought-out by high public value. The study has made in depth to determine the relationship between S-A-P variables and civic value of e-governance plans.

P. Adjei-Bamfo & T.M. Nyamekye et al (2019) reveals that dynamisms in building a healthy ICT infrastructure, web portals, and human capability to adopt Information communication technology is a proposal to developing countries inter alia an informative stage to share and communicate SPP necessities. E-governance also assists a broader model for market keenness valuation and a cohesive e- procurement structure towards impactful SPP observing and assessment.

Atta Addo & PK Senyo (2021) examined the role of digital identity in socio-development and inclusion and determines a relationship model between both. Study contributes in advancement of E-Governance by establishing the relationship between socio-economic development and inclusion.

Furthermore, many more researches have also been done to determine the quality of the e-Government websites in different countries. To move on the same line in Indian context, present study aims to provide an instrument for measuring the quality dimensions of Government web portals to make the E-governance mix more effective in India.

3. Objectives of the study

- To assess the service quality of Govt Web Portals in India**.**
- To explore the determinants to optimize the E-Governance mix.

4. Research Methodology

Research is exploratory in nature for which both types of data primary as well as secondary, has been collected. Primary data has been collected through circulation of questionnaire to 100 citizens of India rating at 5 point Likert's scale and secondary from Newspapers, magazines, internet etc. proper weights were given to scores gathered as per their significance. Principal Component Analysis has been used to testify the adequacy of various factors affecting E-Governance mix and grouping thereof. Further X^2-test has been applied to know the validity of the results of the study.

5. Hypothesis:

- **H_0:** E-Governance Mix is independent of the stated five factors (F_1 F_2, F_3, F_4 and F_5)/Variables.
- **H_1:** E-Governance Mix is not independent of the stated five factors (F_1 F_2, F_3, F_4 and F_5)/Variables.

6. Parameters of the Study:

Following factors have been taken as parameters of study which will assess the quality of the Government web portals in India.

Table: Parameters of the Study

Website Design (F_1)	**Reliability (F_2)**	**Familiarity (F_3)**	**Personalization (F_4)**	**Security/Privacy (F_5)**
Easy in Use	Promise to respond	Familiar with Website	Offers a Choice	Assurance of Privacy
Visual Appeal	Services' righteous	Conducting Online Transaction	Links to Other Websites	Non sharing of my information
Well organized Outlook	Reasonability of charges	Interactions with Govt. Agencies	Delivering the Services	Protects information
Availability to Citizens			Variety in Service Options	
Doesn't Crash				
Loads its pages Faster				

7. E-governance Framework

Taking the various views of different scholars it has been explored that optimal framework of following 4 As, which can be named as E-Governance Mix, can make the E-governance most effective.

Awareness: This metric of the 4A framework requires all citizens are aware of all web portals of e-governance available made by the Government.
Accessibility: All reports, information, notifications etc provided by the Govt electronically must be accessible to all citizens. Moreover, it needs adequate infrastructure.
Adaptability: The metric ensures the E-governance system ability to adapt to the changing needs of society and fight the regional disparity as well as local issues and contexts. This must be flexible and respond to the needs of its citizens, meet their best interests and adapt to different contexts.
Affordability: Govt. should also ensure that all web portal of e-governance are either free of cost or affordable to the all citizens.

8. Results and Discussions

Question wise analysis was made with the help of Excel and SPSS version 12.0. The questionnaire was based 5 different variables that were considered to be significant while using the ICT based Web Portals of E-Governance and it was measured against a 5-point Likert scale, depending on the level of importance attached to each variable. The facts obtaining from the questionnaire were analyzed by using Factor Analysis. Variables that have factor loading of more than 0.5 were grouped under one factor. Only the factors having Eigen values greater than one were considered and the remaining factors have not been considered as part the analysis. Further statistical tests were performed on the data collected.

Table 8.1: Rotated Component Matrix

S. No	Constituents	F_1	F_2	F_3	F_4	F_5
1.	Offers a Choice					0.811
2.	Easy in Use	0.766				
3	Non sharing of my information			0.733		
4.	Familiar with Website	0.812				
5.	Well organized in outlook			0.711		
6	Assurance of Security				0.556	
7	Conducting Online Transaction	0.749				
8	Doesn't Crash		0.829			
9	Services' righteous		0.538			
10	Reasonability of Charges		0.614			
11	Promises to respond				0.849	
12.	Loads its pages faster	0.543				
Eigen Values		2.414	2.404	1.792	1.455	1.366
Commutative Percentage		20.032	34.968	47.089	58.470	67.534
Note: F_1, F_2, F_3, F_4 and F_5 are the five derived factors.						

Source: Survey

From the Table 8.1, we can infer that the 12 variables have coded against the 5 point Likert scale. Table 1 shows the Rotated Component Matrix (RCM) for the 12 variable giving the proper weight as per their importance to each variable. This has been used by using SPSS version 16.0. The Principal Component Analysis is a commonly used method to group the variables under few unconnected factors. This method is closely related to Factor Analysis. A factor is a co-relation between the concerned variable with a specified factor. Thus, it is very important to analyze the nature of a particular factor, and then group them under one factor. Factor Analysis using Varimax rotations has derived 5 factors, with each having Eigen values greater than I have been shown in the Table 8.1. From the table, it can be seen that $Factor_1$ has the Eigen value of 2.404 and explains 20.032% of the variance. The Eigen values and percentage of variance for other factors are also shown respectively in the table. The total Variance accounted by 5 factors is 65.534%, which is acceptable thus establishers the validity of the study.

9. Testing of Hypothesis

Table 9.1: Cross Tabulation of Factors & E-governance Mix

		Factors				
		F_1	F_2	F_3	F_4	F_5
E-governance Mix	A_1	18	3	5	6	0
	A_2	5	0	7	6	1
	A_3	2	1	5	9	5
	A_4	8	2	10	6	2

Source: Survey Analysis

Table 9.2: Pearson's Chi-square Tests

		Factors/Determinants
E-governance Mix	Chi-square	25.945
	Df.	12
	Sig.	.010*
The chi-square statistics is significant at the 0.05 level		

Source: Survey Analysis

From the table 9.2 and 9.3, it was found that the chi value i.e. 0.01□0.05 at (95% confidence level). Hence, the researcher reject the null hypothesis that the various elements of E-governance Mix is not affected by various stated factors i.e. Website Design (F_1), Reliability($F_{2)}$, Familiarity (F_3), Personalization (F_4) and Security/ Privacy (F_5).

From the analysis, it is clear that effectiveness of E-governance is influenced by mainly awareness and affordability. Other factors have also significant impact on the E-Governance mix. Thus the researcher accepts the alternative hypothesis that E-governance Mix is affected by stated variables i.e. Website Design (F_1), Reliability ($F_{2)}$, Familiarity (F_3), Personalization (F_4) and Security/ Privacy (F_5).

10. Conclusion:

Present study finds that E-governance is an emergent counteractive mechanism to govern the information system or knowledge economy to give the assurance of accountability, truthfulness and limpidity. If E-Governance portals are constructed on the basis of stated 5 pillars, it would make the web site quality better in E-governance. It would assist as well stimulate the citizens to use the web portals. Hence the Govt. should design the websites in such a manner that to provide the better governance**.** So web portals have significant impact on the E-Governance effectiveness, its quality matters a lot in this regard and all stated variables i.e. Website Design, Reliability, Familiarity, Personalization and Security/ Privacy can optimize the E-Governance mix. Furthermore, Govt. should design its E-governance mix consisting of 4 As i.e. Awareness, Accessibility, Adaptability, and Affordability in such a manner so that service quality of web portals provided to citizens can be improved. So study proves the alternate hypothesis true which means there is a strong relationship between service quality of govt. web portals and effectiveness of E-governance mix.

References

- Haque Shamsul M. (2002); International Review of Administrative Sciences[0020–8523(200206)68:2] IIAS. SAGE Publications (London, Thousand Oaks, CA and New Delhi), Vol. 68, 231–250; 024079
- alaris, C., Magoutas, B., Papadomichelaki, X., Mentzas, G (2007); Classification and Synthesisof Quality Approaches in E-government Services. Internet Research: Electronic Networking Applications and Policy 17(4), 378–401
- Monga, A. (2008). E-government in India: Opportunities and challenges, JOAAG, Vol. 3. No. 2
- Mentzas Gregoris & Papadomichelaki Xenia(2009): M.A. Wimmer et al. (Eds.): EGOV 2009, LNCS 5693, pp. 163–175.
- Dwivedin Kumar Sanjay Dr. & Bharti Kumar Ajay (2010), Journal of Theoretical and Applied Information Technology viewed at http://www.jatit.org/
- Bhattacharya Debjani, Gulla Umesh & Gupta M.P. (2012), Journal of Enterprise Information Management, Vol. 25, Issue: 3, pp.246 – 271
- Iyer Jaya & R.K. Srivastav (2012). The IUP Journal of Information Technology. Vol VIII, No 3, Sept 2012, pp 39-52
- Singla Kumar Sushil & Aggarwal Himanshu (2013). International Journal of Computer Applications. Volume 44. Number 14
- Parul Jain Gupta, Pradeep Suri (2017), "Measuring public value of e-governance projects in India: citizens' perspective" Transforming Government: People, Process and Policy, Publisher: Emerald Publishing Limited, ISSN: 1750-6166, Issue: 2, 15 May, 2017
- Basel Institute on Governance (July 2017), "New perspectives in e-government and the Prevention of corruption" Working Paper Series 23, pages 60 at https://baselgovernance.org/sites/default/files/2019-06/WP_23_web.pdf
- P.T. Bamfo & T.M. Nyamekye et al (2019), "The role of e-government in sustainable public procurement in developing countries: A systematic literature review", Resources, Conservation and Recycling, Volume 142, March 2019, Pages 189-203
- Atta Addo & PK Senyo (2021), "Advancing E-governance for development: Digital identification and its link to socioeconomic inclusion", Government Information Quarterly, Volume 38, Issue 2, April 2021, 101568
- India's e-governance framework viewed at http://www.microsoft.com/india/msindia/perspective/e_governance.aspx
- E-Governance at http://en.wikipedia.org/wiki/E-Governance
- Integrated MMPs at http://india.gov.in/e-governance/mission-mode-projects
- e-Governance in India: The Society for Promotion of e-Governance at http://www.egovindia.org/
- About IT & e-Governance | STQC at http://www.stqc.gov.in/content/about-it-e-governancehttps://issuu.com/itls/docs/journal/55
- https://www.researchgate.net/publication/306916391_Effective_Implementation_of_E-Governance_in_Technical_Institutions_in_India_using_ICT_to_Make_them_World_Class
- https://issuu.com/itls/docs/journal

Yoga Education: A Tool of Human Development

Dr. Sunil Kumari, Assistant Professor,
Govt. College Meham, Rohtak
Email Id: jiyasunil17@yahoo.com

ABSTRACT

The main aim of Yoga is to harmonize the body, mind and soul which enhance the human development. Being the yoga an intangible force, its objectivity has always been questioned by a common man. Present study aims at investigating the relationship between yoga and human development that would ensure whether yoga education should be incorporated in educational courses. The Study is experimental in nature which has been made through organizing a yoga training camp for 30 people and assessing its outcome by differential analysis. T-test has been used to study the relationship between yoga and various aspects of human development. Results of training programme showed that yoga has significant impact on various aspects of human development. Thus, study recommends that yoga education should be given to people.

Key Words: Yoga, Human Development, Asanas, Pranayamas, Sheath, Training.

INTRODUCTION

Modern era is of technological innovations and developments which lead to ease of doing all things whether it is economical, educational, and social or of other kind but people moving with this fast pace of technology; undesirably they are losing something that is humanity. Humanity consists of values and sound health that is the composition of physical and mental equilibrium. Now question arises how to raise the humanity in the people and answer of which lies in yoga education Yoga is a fantastic remedy for overcoming such problems that a modern man is facing in his daily life. We all strive for success which is which needs fine tuning of body, mind and soul.Success may be in terms of career, money, social status, political power, being a human and spirituality etc, which differs for person to person. But real success of a personlies in human development. Humanity is another name of truth, honesty, dignity which exhibits in our behavior. Non humanity is caused by lack of harmony (uniformity) between body (behavior) and mind (thinking). When a person is about to act upon something, soul always shouts its righteous or wrongness and wrongness is generally

veiled by a person using brain (mind) to bring the outcome of act in his/her favor. Generally diversity is found among righteous (voice of soul), greed (manipulations made by mind), and behavior (acts by body) which detroits the humanity. However such lack of co-ordination among body, mind and soul also causes the various diseases like, headache, anemia, stress, back pain, digestion etc. Yoga is inner force which enables one to mergeone's body and mind with souland introduces one to oneself and brings near to God as well. Yoga is an ancient but a scientific discipline which was going to be lost in fast pace of world but the Modi, the prime minister of India rehabilitated it by making it compulsory in school education and promoting at large as a sports. Modi also brought it at the platform of US assembly to get it recognized at global level and member states of UN consented it without any anonymity and UN declared the 21 June as International yoga day in the year of 2014. Today entire world is facing the severe problem of terrorism which is the outcome of ill minds. Yoga can also cure such illness of minds and can stop the people to involve in such unfair and unethical practices to some of extent. One more worldwide problem is sustainable development. Yogic view of human development will bring the all United Member States together to work on achievement of goals of sustainable development (ValentinaIeri, 2016). Yoga practices would also assist to consumers raising their awareness of the planet's resources and individuals' duty to value and live in peace with theneighbors (UN Secretary-General, Ban Ki-moon, 2016). The only people with inner peace can make the world peaceful. How world can be transformed without transforming the people and yoga is looking for inner well being of people (Sadguru' JaggiVasudev, 2016). Yoga would also have the bearing on consciousness and implementation of collective 17 global sustainable development goals (Akbarridin, India's permanent representative in UN, 2016).

CONCEPT OF HUMAN DEVELOPMENT

A human being is made of following five sheaths, so human development depends upon the well being of these sheaths.

1) **Conscious sheath(AnnamayaKosha)** which is related to our conscious physical deeps including walking, talking, viewing and other such functions which are performed using the physical body deliberately

2) **Subconscious Physical sheath (Pranamayakosha):** deals with physical activities that are performed in the subconscious state. Digestion, movement of hearts and lungs fall in this category. No any deliberate effort for these actions are made still the body knows how to perform them. These are autonomous.

3) Mental Sheath (Manomaya): deals with mind, emotions and thoughts. The gross thinking and emotions fall in this category.

4) Intellectual Sheath (VigyanmayaKosha): Intellect is the faculty that decides what is good and what is bad. It is ability for rational thought or inference or discrimination. The vigyanmayakosha helps us to identify true from false.

5) Blissful Sheath (AnandmayaKosha): is a pure state of happiness and joy which is beyond any material pleasure (Bipin Joshi, 2006). Each of these sheaths or layers of physical body in yogic philosophy actually represents the different aspects of human personality

Integration of all stated sheaths of human body leads to human development. If all these sheaths or layers don't work in coordinated form, a person can't be taken as humanly developed..

LITERATURE REVIEW

S. S.Saraswati (1975)focused on how human potential can be developed with the help of yoga. Study revealed that awareness is inherent to a human, yoga only unveils it by expanding the consciousness over the instincts. Yoga activates the body, mind and soul in harmonized manner that enhances the sensibility, intellectuality, psyche, spirituality in coordination with the physical activities.

Sunil Kumari (2011) also made a study titled ‒Yoga: A Tool of Stress Management at Work Place‖ and found the yoga an effective tool of stress management at work place.

Shelley Brown (2014) made an effort to know whether karma yoga helps in self development and found the karma yoga as a powerful tool of self development as suggested by Swami Vivekanand. Each act superseded by right spirit always leads to instinctive holiness and raises the divine power in a human being.

S. J. Bharati (2018) studied the Maslow's Needs of Hierarchy with advanced yoga psychology. Swami ji classified the yoga development in four stages – Gross, Subtle, Causal and Absolute. Study stated that all five needs of human being quoted by Maslow come under the first stage of yogic view. Yoga is progressive in nature which transcends a person towards development.

R. Acharya& G.P. Mahapatra (2021) conducted a survey of participants to know the effectiveness of General Yoga Programme (GYP) in terms of their wellness. Analyzing the survey and connecting it to related literature and researches made in the arena, it was found that GYP is anexpedient tool for augmentingseveral wellness dimensions. They suggest that GYP can be protracted to the workplace and human resources can perform a supportive role in the procedure.

Being the yoga at the initial stage of rehabilitation, only few studies have been made thereon and no study has been made specifically on rationale of yoga education in human development which initiates the researcher to choose this topic for the purpose of the study. Thus, present study is exclusive in nature.

OBJECTIVES OF THE STUDY

- To explain the concepts of yoga and human development.
- To measure the impact of yoga on human development.
- To ensure whether yogamakes the human development or not.

RESEARCH METHODOLOGY:

- **Research Design:** Being the study experimental in nature, it went through conducting a yoga training camp, systematic pattern of data collection through observation and comparison of scores collected at five rating scale before and after the training programme**.**
- **Sampling:** 30 people were chosen in deliberated manner to join the yoga training camp/ programme consisting of both male and female equally.
- **Procedures:** Yoga training was given to selected people for a period of 3 months under close supervision and observed the change between pre and after the training programme.
- **Tools/ Measures:** Data collected through observation has been averaged to attribute results to an individualand arithmetic mean has been used to compute the mean values of scores. Standard deviations have also been computed to know the variability status of values (scores) from the mean values, further which have been taken into computations of t-values. At the end t-values at 1% level of confidence, have been used to signify the difference between the mean values of controllable variables and experimental variables.

PARAMETERS OF HUMAN DEVELOPMENT:

Human development is a vast subject which contains many aspects but in present study it has been tried to cover all aspects categorizing them into five heads. These five heads also have sub-aspects. Table 1 indicates the various aspects of human and their corresponding parameters along with specifications on which basis effect of yoga on various dimensions of human development has been measured. Proper weights have also been given to each parameter.

Table 1:Aspects of human development&their corresponding parameterswith specifications

S.N.	Aspect of Personality	Parameters	Specifications of Parameters
1.	Conscious physical sheath	Physical Fitness	Weight, size of waist
2.	Subconscious physical sheath	Shorten the breathing	Respiratory rate, Heart beats rate and Blood pressure
3.	Mental sheath	Intelligence	Intelligence Quotient
4.	Intellectual Sheath	Values and Ethics	Scale Rating (Being Quality)
5.	Spiritual sheath	Belief in God	Scale Rating (Being Quality)

HOW YOGA CAN MAKE THE HUMAN DEVELOPMENT?

Each sheath of a human being is wrapped by previous sheaths in succession. Yoga is a systematic process which has various stages to develop various aspects of person gradually as shown in Table 2**.**

Table 2: Aspects of Human development and their corresponding Yoga tools to nourish them

S. N.	Aspect/or Layer of Personality	Type Of Yoga
1	Physical Conscious	Yoga Asanas
2	Subconscious physical	Pranayama
3	Mental	Concentration
4	Intellectual	Meditation
5	Blissful /Spiritual	Samadhi

Important instruction was given to the trainees to do yoga twice in a day with empty stomach. They were also said to do it before sunrise and after sunset as it gives more benefits at that time.

RESULTS AND DISCUSSION

Table 3 indicates the pre training mean values and post training mean values of each aspect of human development

Table 3: Effect of Yoga on Human Development

S. No.	Aspects of Human Development	Pre-training Mean Values	Post-training Mean Values
1	Physical Conscious Sheath	36.97	24.58
2	Physical sub-conscious Sheath	27.48	17.45
3	Mental Sheath	16.93	18.54
4	Intellectual Sheath	13.02	13.89
5	Blissful/ Spiritual Sheath	8.12	8.72

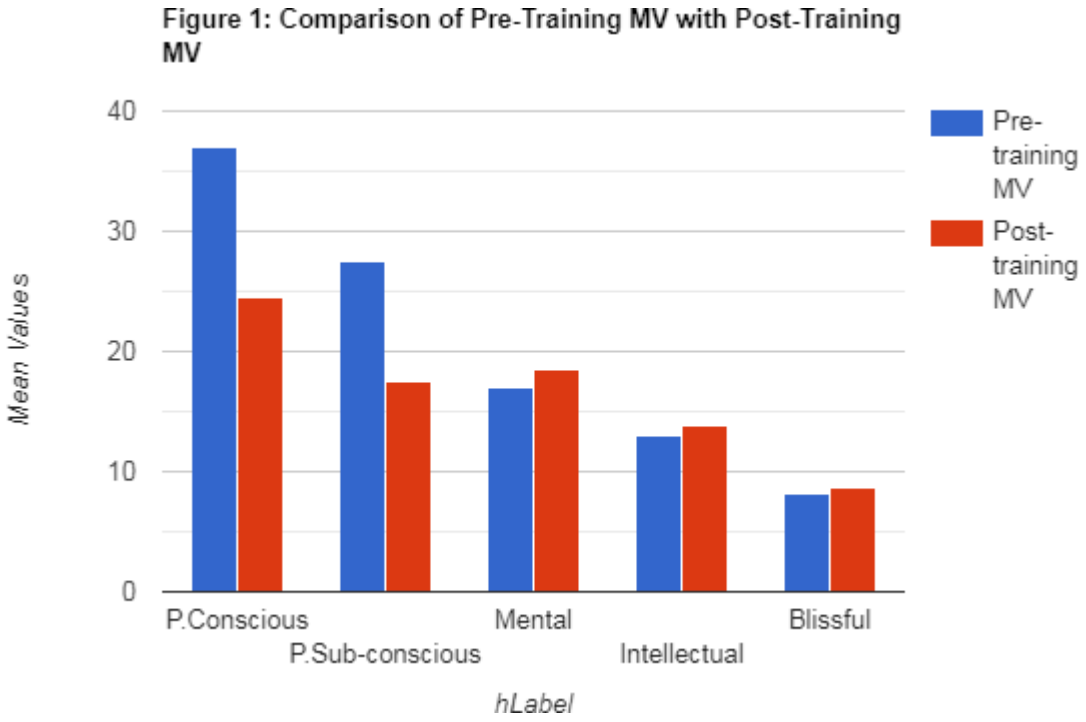


Table 3and figure 1 show that scores of physical conscious have been decreased from 36.97 to 24.58. Being the parameters of both sheaths weight, waist size, such decrease in scores is a positive sign which indicates that yoga asanas stretch the body and makes it more effluent by directing energies in most controlled fashion. They provide the vital force and cause it to flow in specific parts of body. Alike the physical sheath, the subconscious sheath's score has also been decreased from 27.48 to 17.45 that shows the reduction in heart beats rate,

respiratory rate and blood pressure averagely which proves the effectiveness of Pranayamas on shortening the breath. So it is taken as an excellent remedy for back aches, digestion problems and heart problems. Moreover, mental, intellectual and spiritual sheaths' mean values have been increased which indicates a positive sign for human development but amount of increase is not too much because it takes a long time. Being a training programme for a short time period i.e. 3 months, it is not found much high but it is significant.

Table 4: Effect of Yoga on Human Development

S. No.	**Aspects of Human Development**	**Pre-training SD**	**Post-training SD**	**t-value**
1	Physical Conscious	5.61	6.13	15.94
2	Physical sub-conscious	5.12	3.51	12.89
3	Mental	3.15	2.11	6.78
4	Intellectual	2.12	1.94	3.56
5	Blissful/ Spiritual	2.13	1.45	1.98

T-values of both aspects physical conscious and physical sub-conscious are 15.94 and 12.89 respectively which are significant at 1% level of confidence. Mean values of mental sheath have been increased from 16.93 to 18.54 having the significant t-value i.e. 6.78 which indicates that yoga sharpens the mind, power of imagination and creativity with concentration. Further scores of intellect sheath have also been increased from 13.02 to 13.89, but difference is very little which means yoga especially meditation slightly enriches the intellect personality raising the comprehensive thinking and sensitizing emotions. One can think calm, care and affection to others. Maya can't delude the individual anymore and majority of decisions prove to be correct. Finally same indications are in case spiritual sheath which means yoga Samadhi move towards the casual state of mind by introspection where in the subtle layers of the mind unfold themselves and inner dimensions of personality open out. So yoga also brings the ultimate bliss, the joy that is impossible to achieve through worldly enjoyments. In case of intellect sheath and spiritual sheath, the significance of difference in scores in terms of t-values is 3.56 and 1.98 respectively which is also significant at 1% level of confidence. Above table shows that t-values are decreasing for each next sheath of personality which means yoga has more impact on the physical conscious than subconscious personality and so on. Such decreasing trend proves that each sheath of personality is

wrapped by previous sheaths in succession. Yoga is a systematic process which has various stages to develop various aspects of personality gradually, so the later stages of yoga need long time practice to get more effectiveness or perfection. The blissful is the innermost sheath wrapped by other sheaths in succession and it has been least affected because of the short duration of training.

CONCLUSION

Yoga gives a lot of physical and mental energy. A person, who acts upon the soul's voice, can never be wrong at any front. Yoga is nothing but to bring the transparency between soul, mind and acts thereupon. The contrast of the post-training scores of the 'Yoga' with the pre-test scores followed by Gain score analysis (post-training, pre-training, dependent 't' test) was deemed the most powerful and complete analytic framework to evaluate the outcome of this study. The outcomes recommends that regular practice of yoga techniques had a positive impact on the various aspects of human development i.e. physical, mental, emotional and intellectual levels of people under training compared to the untrained people. In conclusion, going by the results of the present study, yoga techniques may prove to be an effective means ofhuman development.It has been found thatyoga is a truth of life that makes the human development. It unfolds the human potentials. So study recommends incorporating the yoga education to people to enhance the human developments of the learners.

LIMITATIONS OF THE STUDY

- Study period of 3 months was short because optimization in yoga needs a long term practice.
- Complete yoga has so many limbs, but only some yoga asanas, pranayama, concentration and a little bit of meditation have been included in yoga practices.
- Being the deliberate sampling, trainees were only young employees that limit its universality.

REFERENCES

- Swami SatyanandaSaraswati .Yoga magazine of Bihar School of Yoga, 1974, originally printed in YOGA, Vol. XIII, No. 3/4, March/April 1975 at http://www.yogamag.net/archives/2007/ajan07/pot.shtml

- Sripriya Krishnan (October 2006); ‒Personality Development through Yoga Practices‖ , Indian Journal of Traditional Knowledge, Vol. 5(4), pg 445-449.
- Bipin Joshi (2006, March 22); ― Yoga and Personality Development‖, Retrieved from: http://ezinearticles.com/?Yoga-and-Personality-Development&id=163126
- VarunMalhotra., O.P. Tandon (2009); ―SuryanadiAnulomaViloma Pranayama Modifies Autonomic Activity of Heart‖. JOY: The Journal of Yoga, Vol. 8, No. 1.
- Mohan Kotwal (2010). A Study of Meditation and Other Self Development Techniques for Effective Management. Retrieved from: http://www.aims-international .org/aicvm/AICVMCD/pdf/Valud-based%20Management/YV345-done.pdf
- Sunil Kumari (2011). Yoga: A Tool of Stress Management at Work Place. Lingaya'sLalita Devi Journal of Professional Studies, LLDIMS Publishing House, ISSN 2230-987X, pp- 141-146
- Shelley Brown , (2014) "The power of karma yoga in human development", International Journal of Development Issues, NY: Klapa tree, Vol. 13 Iss: 3, pp.242 – 249 at DOI: http://dx.doi.org/10.1108/IJDI-05-2014-0034, retrieved from http://www.emeraldinsight.com/doi/abs/10.1108/IJDI-05-2014-0034
- ValentinaIeri (2016). Yoga Unites the UN for Sustainable Development. http://www.globalissues.org/news/2016/06/21/22243
- Swami JnaneshvaraBharati (2018).Maslow's Needs Hierarchy and Advanced Yoga Psychology. SwamiJ.com Home Page at http://www.swamij.com/maslow-yoga.htm
- Acharya, R., Mahapatra, G. P., &Acharya, K. (2021). Yoga and Wellness—Key Insights from the Study on General Yoga Programme. NHRD Network Journal, 14(1), 51–63. https://doi.org/10.1177/2631454120979763
- MeenaVenkatesh, ‒The Effect of Yoga on the Personality Development of Students‖ Retrieved from: http://www.vyasa.org/report/theses3.asp
- Personality Development through Yoga.Retrieved from:http://www.squidoo.com/ personality-development- through-yoga
- Yoga and Personality Development. Retrieved from: http://www.yoga-all.com/Yoga-and-Personality-Development.html

27. Mr. Deepak "Religious Sculptures in Kushan Period Mathura Art "Year 2023

शोध-प्रभा
Shodha Prabha

UGC CARE LISTED
ISSN : 0974-8946

CERTIFICATE OF PUBLICATION

This is to certify that the article entitled

कुषाण कालीन मथुरा कला में धार्मिक मूर्तियॉ

दीपक कुमार, सहायक प्राध्यापक, राजकीय महाविद्यालय, महम शोधार्थी, इतिहास विभाग,बाबा मस्तनाथ विश्वविद्यालय, अस्थल बोहर।

Authored By

Published in

Shodha Prabha; ISSN 0974-8946

Volume (वर्ष)-48, प्रदम अंक (Issue-01), Book No.02 : **2023**

UGC Care Approved, Group I, Peer Reviewed and Referred Journal

UGC
University Grants Commission

Editor
Mandan Mishra

शोध-प्रभा
Shodha Prabha

UGC CARE LISTED
ISSN : 0974-8946

CERTIFICATE OF PUBLICATION

This is to certify that the article entitled

कुषाण कालीन मथुरा कला में धार्मिक मूर्तियॉ

Authored By

डॉ नीलम रानी

शोध –निर्देशक, एसोसिएट प्रोफेसर, इतिहास विभाग,बाबा मस्तनाथ विश्वविद्याल अस्थल बोहर

Published in

Shodha Prabha; ISSN 0974-8946

Volume (**वर्ष**)-48, **प्रदम अंक** (Issue-01), Book No.02 : **2023**

UGC Care Approved, Group I, Peer Reviewed and Referred Journal

Editor
Mandan Mishra

कुषाण कालीन मथुरा कला में धार्मिक मूर्तियॉ

दीपक कुमार, (सहायक प्राध्यापक, राजकीय महाविद्यालय, महम) शोधार्थी, इतिहास विभाग,बाबा मस्तनाथ विश्वविद्यालय, अस्थल बोहर।
डॉ नीलम रानी शोध –निर्देशक, एसोसिएट प्रोफेसर, इतिहास विभाग,बाबा मस्तनाथ विश्वविद्याल अस्थल बोहर।

सारांश

प्रत्येक युग में कला का अपना विशिष्ट महत्व होता है। फिर चाहे वह हड़प्पा कला हो या फिर मौर्य काल की काल या कोई अन्य कला। कुषाण काल में मूर्तिकला में एक विशिष्ट शैली का उदय हुआ, जिसे इतिहास में 'मथुरा कला' के नाम से जाना जाता है। यह पूर्णरूपेण विशुद्ध भारतीय कला थी। इसके जन्म एवं विकास में भरहुत एवं सांची की कलाओं का विशेष योगदान था। इस कला में शासक एवं जनसाधारण की मूर्तियों के अतिरिक्त बौद्ध, जैन एवं हिंदू धर्म से संबंधित मूर्तियों का निर्माण किया गया। महात्मा बुद्ध की प्रथम मानव स्वरूप मूर्ति बनाने का श्रेय भी मथुरा कला को ही जाता है।

मुख्य शब्दः– बौद्ध, जैन, हिंदू, धर्म, मूर्तिकला, मथुरा कला, कुषाण।

भूमिका

मथुरा, महाजनपद काल में शूरसेन जनपद की राजधानी थी। इसकी गणना तात्कालिन सात महापूरियों में होती थी।[1]इसमें विभिन्न दिशाओं से व्यापारिक पथ आकर मिलते थे।[2]इसलिए प्राचीन उत्तरापथ पर जितनी महत्वपूर्ण स्थिति मथुरा की थी, उतनी किसी अन्य नगर की नहीं थी।[3] पुराणों के अनुसार मधु नामक असुर ने इस 'पूरी' की स्थापना की थी, इसलिए उसके नामानुसार यह 'मधुपुरी' कहलाई। कालांतर में उसके पुत्र लवणासुर को भगवान राम के छोटे भाई शत्रुघ्न ने पराजित करके मथुरा नगरी की स्थापना की।

सर्वप्रथम मथुरा में भारतीय, इरानी एवं यूनानी संस्कृतियों का मिलन हुआ। द्वितीय विशेषता में तीन बड़ी धार्मिक विचारधाराओं (ब्राह्मण, जैन एवं बौद्ध) का मिलन यहां हुआ। इस समन्वय प्रधान वातावरण में, ये तीनों धर्म कई सदियों तक आपस में मिलकर फलते–फूलते रहे। प्राचीन भारत में शायद ही कोई ऐसा स्थान हो, जहां पर तीनों धर्म एक साथ पनपे हो। तीनों धर्मों से इसका गहरा संबंध था।[4]

यहां पर बौद्धों के सर्वास्तिवादी, महांसधिक और धर्मगुप्तक संप्रदायों के केंद्र थे। महात्मा बुद्ध ने भी इसकी यात्रा की थी।[5] दिव्यवदान के अनुसार बुद्ध ने भविष्यवाणी की थी कि आगे चलकर मथुरा एक बड़ी नगरी होगी।[6] जैन शिलालेखों के अनुसार मथुरा के देवनिर्मित स्तूप संघों में अनेक गण रहते थे। भगवान कृष्ण के जन्म ने इस नगरी को इतिहास में अमर कर दिया। तीनों धर्मों का केंद्र होने के कारण, यह स्वाभाविक है कि इन तीनों धर्मों ने मथुरा कला को प्रेरित किया हो।

शुंग काल में वैदिक धर्म और भागवत धर्म ने मिलकर हिंदू धर्म का एक नया लोकग्राही रूप सबके सामने प्रस्तुत किया। इस दौरान पुष्यमित्र शुंग ने अश्वमेध यज्ञ करवाया। बेसनगर राजा भागभद्र की सभा में यूनानी राजदूत हेलियोडोरस द्वारा गुरुड़ध्वज स्थापित करवाया गया। शोडास के समय मोरा नामक गांव से प्राप्त लेख में, पांच वृष्णवीरों की मूर्तियां एवं मंदिर स्थापना का उल्लेख हुआ है। इससे भागवत धर्म लोकप्रिय हुआ। जिसका सर्वाधिक प्रभाव बौद्ध धर्म पर पड़ा और जिससे परिणामस्वरूप महायान शाखा का उदय हुआ। महायान धर्म को भागवत धर्म का बौद्ध रूपांतरण कहा जा सकता है। बौद्ध धर्मावलंबी बुद्ध को सदृश मूर्ति के रूप में देखना चाहते थे। अश्वघोष द्वारा रचित 'बुद्ध चरित', इसी सार्वजनिक मांग की पूर्ति माना जाता है। इसलिए महात्मा बुद्ध की मूर्ति, भारतीय धार्मिक विकास की स्वाभाविक देन मानी जाती है।

मथुरा, कुषाणों की पूर्वी राजधानी होने के साथ–साथ तक्षशिला एवं पाटलिपुत्र के महत्वपूर्ण व्यापारिक उत्तरापथ मार्ग पर स्थित थी। इसलिए यहां अनेक व्यवसायी आकर रुकते थे।[7] कुषाण शासक कनिष्क, हुविष्क और वासुदेव का शासनकाल इस कला का स्वर्णयुग माना जाता है।[8] इस कला की बड़ी और भारी मूर्तियों का भी सैकड़ों मील दूर स्थानों पर जाना एवं छोटी मूर्तियां का मध्यएशिया तक भेजा जाना, इसकी लोकप्रियता को प्रमाणित करता है।[9] तात्कालिन अधिकतर मूर्तियां आज भी भारतीय संग्रहालयों में सुरक्षित हैं।[10] जो तक्षशिला, सांची, सारनाथ, कौशांबी, श्रीवास्ती, राजस्थान, बंगाल एवं अहिछात्रा आदि स्थानों से प्राप्त हुई है। इनके निर्माण में प्रयुक्त लाल पत्थर रुपवास तथा सीकरी की खानों से मंगवाया जाता था।[11]

विभिन्न धार्मिक सम्प्रदायों की मूर्तियांः–

मथुरा कला का आकर्षण भौतिक क्षेत्र में भी उतना ही चमत्कारपूर्ण है, जितना की आध्यात्मिकता के क्षेत्र में। मथुरा के शिल्पियों द्वारा निर्मित जैन, बौद्ध तथा ब्राह्मण सम्प्रदाय से सम्बन्धित मूर्तियों का वर्णन इस प्रकार हैः–

जैन मूर्तियांः– मथुरा, जैन धर्म का अति प्राचीन केन्द्र था। बौद्धों और हिंदुओं की तरह जैनियों ने भी यहां अनेक स्तूपों एवं मंदिरों का निर्माण करवाया। कंकाली टीले से जैन स्तूप तथा दो प्रसादों के अवशेष मिले हैं। यहां से कोट्टिय गण की

वज्री शाखा के वाचक आचार्य बृहहस्ती की प्रेरणा से एक श्रावक ने यहां अठारहवें तीर्थकर अरसनाथ की एक देवनिर्मित मूर्ति स्थापित करवाने के प्रमाण भी मिलते हैं।[12]यहां से प्राप्त स्तूप को कुबेरा नामक स्त्री ने सातवें तीर्थकर सुपार्श्वनाथ की स्मृति में बनवाया था। स्तूप के अवशेषों में आचागपट्ट या आर्यकपट्ट– जो पूजा के लिए स्थापित मूलपट्ट, जिस पर स्वास्तिक, धर्मचक्र या तीर्थंकरों की मूर्तियां बनी होती थी, का शिल्प की दृष्टि से विशेष महत्व है।[13]

कुषाण कालीन मथुरा कला में जैन तीर्थकरों की स्वतन्त्र प्रतिमाएं बनने लगी थी। कंकाली टीले के स्तूप से तीर्थकरों की बहुसंख्यक मूर्तियां मिली है। इन मूर्तियों के वक्षस्थल पर श्रीवत्स एवं सिर के पीछे प्रभामण्डल दिखाया गया है। इन मूर्तियों में भुजाएं घुटने के नीचे तक प्रसारित और भौहों के मध्य रोम गुच्छे दर्शाएं गए हैं। इनके विश्लेषण से ज्ञात होता है कि जैन मूर्तियों में दो आदर्श अपनाएं गए हैं, योगी और चक्रवती सम्राट।[14] कंकाली टीले के दक्षिणपूर्वी भाग से डॉ. बर्जेश को सरस्वती देवी की मूर्ति मिली हैं। इसके बाएं हाथ में पुस्तक मिलती है, यह सरस-

वती देवी की प्राचीनतम मूर्ति है। प्राचीन जैन धर्म में सरस्वती एवं लक्ष्मी देवी की मान्यता एवं पूजा प्रचलित थी।[15]

आर्यवतीः– कंकाली टीले से संवत 42 की एक आर्यवती देवी की मूर्ति मिली है, जिसमें छत्र एवं चंवट लिए दो स्त्रियों को उनकी सेवा करते हुए दिखाया गया है। जिससे उसका राजपद सूचित होता है। संभवत इस आर्यवती का चित्रण महावीर की माता त्रिशला के लिए हुआ है।

नैगमेश देव मूर्तिः– कंकाली टीले से नैगमेश देवता की भी एक मूर्ति मिली है। इसी देवता ने गर्भस्थ बालक महावीर को ब्राह्मणी देवनंदा के गर्भ से निकालकर क्षत्रिणी त्रिशला के गर्भ में स्थापित किया था। इसे बच्चों का मंगल देवता माना जाता है।

बौद्ध धर्म से संबंधित मूर्तियांः–

कुषाण काल से पूर्व महात्मा बुद्ध को मानवीय स्वरुप की अपेक्षा प्रतीकों द्वारा दर्शाया जाता था। ये प्रतीक उनके जीवन की प्रमुख घटनाओं से संबंधित थे। सांची तथा भरहुत कलाओं में भी वेदिका स्तम्भों पर बुद्ध का चित्रण प्रतीकों के माध्यम से हुआ है। मथुरा के निकटवर्ती कंकाली टीले एवं भूतेश्वर आदि पुरास्थलों से लगभग एक सौ पचास अलंकरणयुक्त वेदिका सतम्भ प्राप्त हो चुके है जो कभी स्तूपों के अंग रहे होंगे।[16] इन पर अलंकरणात्मक और कथानक चित्रण किया हुआ है। कुछ पर प्रतीकों के साथ जातक कथाओं का भी अंकन किया गया है। किन्तु कुषाणयुग में महायान सम्प्रदाय के उदय के परिणामस्वरूप महात्मा बुद्ध की मानवीय मूर्तियां बननी प्रारंभ हुई।

बुद्ध तथा बोधिसत्व प्रतिमाएँ :–

मथुरा कला की सबसे बड़ी विशेषता है– प्रथम शताब्दी ई. में बनी महात्मा बुद्ध की मानवस्वरूप मूर्ति है, जो कुषाण काल से संबंधित है। महात्मा बुद्ध की मूर्तियां, दो मुद्राओं में मिलती है– आसन एवं स्थानक मुद्रा। कलात्मक दृष्टि से स्थानक मुद्रा की मूर्तियां, यक्ष मूर्तियों के समान एवं आसन मुद्रा की मूर्तियां योगी के समान बनाई गई है।[17] बोधि प्राप्ति से पूर्व गौतम की संज्ञा बोधिसत्व है, और बोधि प्राप्ति के पश्चात वे बुद्ध कहलाए। बोधिसत्व मूर्तियां राजकुमारों की तरह मुकुट और आभूषणों से अलंकृत हैं। परन्तु बुद्ध मूर्तियों में उन्हें साधारण वेशभूषा में पद्मासन लगाए हुए, दायां हाथ अभयमुद्रा में तथा बायां हाथ घुटने पर स्थित दिखाया गया है। उनके सिर पर बालों का जटाजूट बना हुआ है, जो उनके बुद्धत्व का सूचक है। हाथों और तलवों पर धर्मचक्र एवं त्रिरत्न बनाए गए हैं। पीछे सिंह की प्रतिमा दर्शाई गई है।[18] बौद्ध साहित्य में बुद्ध के वस्त्रों की उपमा मगध देश में फैले धान के खेतों से की गई है।[19]

मथुरा से प्राप्त कुछ मूर्तियों में पीपल का पेड़, मूर्ति के पीठ पीछे चित्रित किया गया है। ऐसी मूर्तियों के दर्शन सामने और पीछे दोनों तरफ से किए जा सकते थे। इनकी खुले बोधिखंड पर रखकर पूजा की जाती थी। महात्मा बुद्ध की मूर्तियों में उनके जीवन संबंधी सात दृश्यों (जन्म, बोधिसत्व की प्राप्ति, धर्मचक्र परिवर्तन, महापरिनिर्वाण, इन्द्र को दर्शन देना, स्वर्ग में माता को ज्ञान देना एवं लोकपालों द्वारा बुद्ध को भिक्षापात्र देना) के साथ–साथ देवत्व के 32 लक्षण जैसे उष्णीय, उर्ण, चरणपाद आदि दर्शाए गए है।[20]

इन प्रतिमाएँ में हाथों द्वारा अनेक भाव व्यक्त किए गए है। जैसे:–

- **ध्यान मुद्राः–** इसमें बुद्ध को पदमासन में बैठे हुए और बाएँ हाथ के ऊपर दायाँ हाथ रखे हुए दिखाया गया है।
- **अभय मुद्राः–** इसमें दाएं हाथ को उठाकर उसे कंधे की ओर मोड़कर श्रोताओं या दर्शकों को अभय प्रदान करते हुए दिखाया गया है।
- **भूमि स्पर्श मुद्राः–** इसमें ध्यानावस्थित बुद्ध दाएँ हाथ से भूमि को छूते हुए प्रदर्शित किए गए हैं।
- **धर्मचक्र प्रवर्तक मुद्राः–** इसमे भगवान बुद्ध बाएँ हाथ की उगलियों के ऊपर दाएं हाथ की उंगलियों को इस प्रकार रखे हुए हैं, मानों वे चक्र घुमा रहे हो।[21]

ब्राह्मण धर्म मूर्तियाँः–

मथुरा कला में ब्राह्मण धर्म से सम्बन्धित अनेक मूर्तियों का निर्माण हुआ है। प्रथम शताब्दी ई. से पहले ही मथुरा में ब्राह्मण धर्म सम्बन्धी मन्दिरों का निर्माण प्रारम्भ हो गया था। पौराणिक देवी–देवताओं के मूर्तिविज्ञान के अध्ययन के लिए, इस कला में महत्वपूर्ण सामग्री उपलब्ध है। कुषाणकालीन मथुरा कला में निम्नलिखित देवी–देवताओं की मूर्तियाँ मिलती हैः–

1. ब्रह्मा मूर्तियांः– ब्रह्मा का चित्रण सर्वप्रथम बुद्ध जीवन घटनाओं के अंकन में हुआ है। स्वर्ग में अपनी माता को धर्मज्ञान देकर जब महात्मा बुद्ध स्वर्ग से वापस आ रहे थे, तो उनकी एक ओर ब्रह्मा और दूसरी ओर इंद्र को चलते हुए दिखाया गया हैं। मथुरा संग्रहालय में भी ब्रह्मा की दो मूर्तियां है। इनमें एक चर्तुमुखी मूर्ति में तीन मुख सीधे और में चौथा मुख बीच वाले सिर के पीछे दर्शाया गया है। इनमें भी बुद्ध मूर्तियों के समान प्रभामण्डल तथा अभय मुद्रा दिखाई गई है।[22]

2. संकर्षण–बलराम मूर्तियांः– पतंजलि के महाभाष्य से पता चलता है कि कृष्ण के बड़े भाई बलराम की संकर्षण के रुप में पूजा की जाती थी। बेसनगर अभिलेख में भी संकर्षण और वासुदेव का वर्णन हुआ है। मथुरा से बलराम की दो हाथों वाली मूर्ति मिली है, जो प्रायः नाग मूर्तियों के समान है। इसमें उनका दांया हाथ सिर से ऊपर उठा हुआ है और बाएं हाथ में हल पकड़े हुए है। कुषाणकालीन बलराम मूर्तियों का दायां हाथ अभयमुद्रा में एवं बाएं हाथ में चषक दिखाया गया है।[23] मथुरा अभिलेख के अनुसार शोडास के शासनकाल में वासुदेव का मंदिर बनवाया गया। मथुरा के निकट मोरा गांव में पांच कृष्णवीरों (संकर्षण, वासुदेव, प्रद्युम्न, साम्ब और अनिरुद्ध) का मंदिर बनवाने का उल्लेख है। इन्हें वंशवीर कहा जाता है अर्थात जो मनुष्य होते हुए देवपद को प्राप्त कर चुके थे। मोरा मंदिर उत्खनन में चार मूर्तियां मिली हैं, इनमें तीन कृष्णवीरों की तथा चौथी एक 'तोषा' नामक महिला की है, जिसने इस मंदिर का निर्माण करवाया था।

3. शिव मूर्तियांः– मथुरा कला में शिव की अनेक मूर्तियाँ मिली है। कुषाण शासक विम कैडफिसिस, कनिष्क, हुविष्क, वासुदेव, कनिष्क तृतीय आदि के सिक्कों पर महेश्वर उपाधि का प्रयोग किया गया है। इनपर शिव की एक मुखी या बहुमुखी मूर्तियाँ मिलती है। मथुरा–कला में शिव की दो प्रकार की मूर्तियाँ मिलती हैं– लिंग रूपी तथा मानव रूपी। लिंग रूप में निर्मित शिव मूर्तियां मथुरा एवं लखनऊ म्यूजियम में सुरक्षित है। इस काल में सादे एकमुखी और पंचमुखी लिंगों का निर्माण हुआ है। विम कैडफिसिस के समय शिव की मूर्तियां दो भुजाओं वाली होती थी, जिनके दाएं हाथ मे त्रिशूल और बाएं हाथ में अमृत घट दर्शाया गया है। कनिष्क एवं हुविष्क के समय में दो भुजाओं के स्थान पर चतुर्भुजाओं का अंकन प्रारंभ हुआ। हुविष्क के सिक्कों पर शिव के साथ महादेवी का भी चित्रण हुआ है।[24] वासुदेव के एक सिक्के पर चतुर्भुजी शिव अमृतघट, पाश, त्रिशूल और व्याघ्रचर्म लिए हुए दिखाए गए हैं, उनके वाहन नंदी के गले में घंटी दिखाई गई है। कुषाण कालीन इंसापुर गांव से एक छोटी अर्धनारीश्वर मूर्ति मिली है। इसमें वृष वाहन के सहारे खड़े हुए शिव के दक्षिणार्ध भाग में ऊर्ध्वलिंग है और वामार्ध भाग स्त्री विग्रह से युक्त दर्शाया गया है। बाएं पैर में कंटक पहना हुआ है। कुषाण कालीन एक मूर्ति में शिव एवं पार्वती को दंपतिभाव से एक–दूसरे के गले में बाहें डाले हुए एक साथ खड़े दिखाया गया हैं। शिव का दाहिना हाथ अभयमुद्रा में है और पार्वती का बायां हाथ कटवप लंबित दिखाया गया है। मूर्ति के गले में कंठ, कानों में कुंडल और सिर पर टोपी की तरह केश ढके हुए हैं।

4. विष्णु मूर्तियांः– वासुदेव शरण अग्रवाल ने मथुरा कला में निर्मित विष्णु की चौदह मूर्तियों का विस्तृत परिचय प्रस्तुत किया है। कुषाण कालीन विष्णु मूर्तियों के साथ गजलक्ष्मी, शिव–पार्वती, कुबेर–हरीती, बुद्ध और मैत्रेय की मूर्तियां मिलती है। इन विष्णु मूर्तियों पर छोटा–सा शिलापात्र मिलता है, जिन पर चार देव मूर्तियां अंकित हैंः–

अर्धनारीश्वर– इसमें दायां भाग पुरुष का और बायां भाग स्त्री का है। दायां हाथ अभयमुद्रा में है और बाएं हाथ में गोल दर्पण पकड़ा हुआ है। बाएं भाग में स्तन बनाए हुए हैं।

चतुर्भुजी विष्णु– इस मूर्ति में बाएं हाथों में गदा एवं चक्र और दाएं हाथों में बोधिसत्व मूर्तियों के समान अभयमुद्रा और अमृतघट पकड़े हुए दिखाया गया है। मूर्ति की वेशभूषा ठेठ कुषाण कालीन है अर्थात मुकुट, फटेदार धोती और कुछ आभूषण आदि पहने दिखाया गया है।

गजलक्ष्मी– इस मूर्ति के दो हाथ हैं दायां हाथ अभयमुद्रा में और बायां हाथ सनाल कमल लिए हुए हैं। मूर्ति के सिर के ऊपर दो हाथी आमने सामने बैठे हुए दिखाए गए हैं। मूर्ति के बाएं पैर के पास उसके वाहन हाथी का मस्तक दिखाया गया है।

कुबेर– इस मूर्ति में कुबेर का बायां हाथ अभयमुद्रा में है और दाएं हाथ में एक थाली पकड़े दिखाया गया है, बाईं ओर एक दंड खड़ा हुआ हैं।

ये मूर्तियां तत्कालीन धार्मिक सहिष्णुता को दर्शाती है। कुषाण कालीन पालीखेड़ा गांव से विष्णु भगवान की एक अष्टभुजी मूर्ति मिली है, जिसके दाहिने चार हाथ सुरक्षित हैं, जिनमें क्रमशः पत्थर की शिला, शाक, दंड एवं चौथा हाथ धोती की ओर मुड़ा हुआ है। इन अधिकांश विष्णु मूर्तियों के हाथों में शंख, चक्र, गदा एवं चौथा हाथ अभय मुद्रा में प्रदर्शित किया गया है।

5. सूर्य मूर्तियांः– कुषाण कालीन मथुरा कला में ईरानी परम्परा में बनी हुई सूर्यदेव मूर्तियों में मानव रूप में सूर्य को लम्बा कोट, पैजामा एवं जूते पहने हुए, चार अश्वों के रथ पर सवार दिखाया गया है। इनके हाथों में तलवार एवं कमल का फूल दिखाया गया है।[25]

6. कैलासोद्धरणः– मथुरा संग्रहालय में मूर्ति संख्या 2577 में रावण द्वारा कैलासोद्धरण का दृश्य अंकित है। इसमें कैलाश पर्वत के बीच भगवान शिव और उनके दाहिने कंधे का सहारा लिए हुए पार्वती को बैठे हुए दिखाया गया है। नीचे बड़े

सिर वाली दैत्याकार मूर्ति किटकिटाकर पहाड को उठाने का जोर लगा रही है। शिव भगवान अपने दाहिने पैर से रावण की भुजा को दबा रहे हैं।

7. गणपति एवं कार्तिकेय मूर्तियां:– कुनार स्वामी का विचार है कि प्रथम गणपति मूर्ति यक्ष रूप में बनाई गई जान पड़ती है। इसमें भित्ति वेदिकों में छः फूलमाला लिए हुए उपासकों की पंक्तियां और नीचे गजमस्तकयुक्त आकृतियों वाले पांच गजानन यक्षों का अलंकरण किया गया है। एक अन्य मूर्ति में गणेश जी द्विभुज, शूपकर्ण, एकदंत, लंबोदर और बाएं ओर सूंड उठाकर लड्डू खाते हुए दिखाए गए हैं। कार्तिकेय इस युग के लोकप्रिय देवताओं में से है। इन्हें युद्ध देवता के रूप में प्रदर्शित किया गया है। मथुरा कला में निर्मित मूर्तियों में उनका दाहिना हाथ अभयमुद्रा में तथा बाएँ हाथ में शक्ति पकड़े हुए दिखाया गया है।[26]

8. देवियों की मूर्तियाँ:– देवी मूर्तियों में लक्ष्मी, दुर्गा, सरस्वती और पार्वती आदि विशेष उल्लेखनीय है। मथुरा कला में लक्ष्मी को कमल के आसन पर और कभी लता के मध्य प्रदर्शित किया गया है। दुर्गा की महिषासुरमर्दिनी रूप में अधिक मूर्तियां मिली हैं।[27]

निष्कर्ष :–

निष्कर्ष रूप में हम कह सकते हैं कि कुषाण कालीन मथुरा कला अपनी अलौकिकता, संवेदनशीलता एवं गतिशीलता के लिए प्रसिद्ध थी।[28] इसमें ब्राह्मण, बौद्ध व जैन धर्मों से सम्बन्धित अनेक कलाकृतियों का निर्माण हुआ। भारतीय कला के अलंकरण, उपमान और शिल्प विधान निर्धारित करने का श्रेय मथुरा कला को प्राप्त है। धार्मिक सहिष्णुता का यह युग कला को प्रोत्साहित करने वाला सिद्ध हुआ। ऐसे कम स्थान मिलते हैं जहां एक समय में इतनी अधिक आर्थिक एवं धार्मिक विविधताओं का प्रदर्शन हुआ हो और साथ ही साथ पुरातन परंपरा को भी नई व्यवस्थाओं में आत्मसात किया गया हो।[29]

सन्दर्भ सूची

[1] वाजपेयी, कृष्णदत्त, 1980, मथुरा, पृ.170।
[2] प्रसाद, ईश्वरी, 1980, प्राचीन भारतीय संस्कृति, कला, राजनीति, धर्म एवं दर्शन, पृ. 229।
[3] अग्रवाल, वासुदेव शरण, 1964, मथुरा कला, पृ. 3।
[4] कुमार, जितेंद्र, मास्टरपीसेज ऑफ मथुरा म्यूजियम, पृ. 15।
[5] वाजपेयी, कृष्णदत्त, 1980, मथुरा, पृ 171।
[6] अग्रवाल, वासुदेव शरण, 1964, मथुरा कला, पृ. 8।
[7] उपरोक्त।
[8] श्रीवास्तव, बृजभूषण, 1996, प्राचीन भारतीय प्रतिमा विज्ञान एवं मूर्तिकला, पृ. 317–18।
[9] प्रसाद, ईश्वरी, 1980, प्राचीन भारतीय संस्कृति, कला, राजनीति, धर्म एवं दर्शन, पृ. 230।
[10] श्रीवास्तव, बृजभूषण, 1998, प्राचीन भारतीय प्रतिमा विज्ञान एवं मूर्तिकला, पृ. 326।
[11] अग्रवाल, वासुदेव, 1977, भारतीय कला, पृ. 223।
[12] एपीग्राफिया इंडिका, भाग–2, लेख 20।
[13] स्मिथ, वी. ए., 1901, दि जैन स्तूप एंड अदर एंटीक्विटी ऑफ मथुरा, पृ. 80।
[14] अग्रवाल, वासुदेवशरण, 1977, भारतीय कला, पृ. 240।
[15] अग्रवाल, वासुदेव, मथुरा कला, पृ. 84।
[16] गुप्ता, एस. एन., 1954, फंडामेंट ऑफ इंडियन आर्ट, पृ. 73।
[17] श्रीवास्तव, बृजभूषण, 1998, प्राचीन भारतीय प्रतिमा विज्ञान एवं मूर्तिकला, पृ. 333।
[18] मजूमदार, आर. सी.,1953, द एज ऑफ इंपीरियल यूनिटी, पृ.112।
[19] विनय पिटक, 8.10.9।
[20] श्रीवास्तव, बृजभूषण, 1998, प्राचीन भारतीय प्रतिमा विज्ञान एवं मूर्तिकला, पृ.323–25।
[21] वाजपेयी, कृष्णदत्त, 1920, मथुरा, पृ. 235।
[22] श्रीवास्तव, बृजभूषण, 1998, प्राचीन भारतीय प्रतिमा विज्ञान एवं मूर्तिकला, पृ. 225।
[23] अग्रवाल, वासुदेवशरण, 1977, भारतीय कला, पृ. 245।
[24] अग्रवाल, वासुदेव शरण, मथुरा कला, पृ. 69।
[25] अग्रवाल, वासुदेव शरण, 1951, कैटलॉग ऑफ द ब्राह्मीकल इमेज इन मथुरा आर्ट, जर्नल ऑफ यू. पी. हिस्टोरिकल सोसाइटी, पृ.72।
[26] अग्रवाल, वासुदेवशरण, 1977, भारतीय कला, पृ. 271।
[27] श्रीवास्तव, बृजभूषण, 1998, प्राचीन भारतीय प्रतिमा विज्ञान एवं मथुरा कला, पृ. 27।
[28] शर्मा, आर. सी., बुद्धिस्ट आर्ट ऑफ मथुरा, पृ. 321।
[29] कजूमा, स्टैनिस्लो, जे., कुषाण स्कल्पचर इमेजेस फ्रॉम अर्ली इंडिया, पृ. 8।

28. Mr. Deepak "Varna and Caste System During the Kushan Period "Year 2023

मध्य भारती

MADHYA BHARTI
(UGC CARE Group-1, Multi disciplinary)

CERTIFICATE OF PUBLICATION

This is to certify that the article entitled

कुषाणकालीन वर्ण एवं जाति व्यवस्था

Authored By

डॉ नीलम रानी

शोध –निर्देशक, एसोसिएट प्रोफेसर, इतिहास विभाग, बाबा मस्तनाथ विश्वविद्यालय, अस्थल बोहर।

Published in

Madhya Bharti (मध्य भारती) : ISSN **0974-0066** with IF=6.28

Vol. 83, No. 01, January - June : 2023

UGC Care Approved, Group I, Peer Reviewed, Bilingual, Biannual,

Multi-disciplinary Referred Journal

Chief Editor

कुषाणकालीन वर्ण एवं जाति व्यवस्था

दीपक कुमार, (सहायक प्राध्यापक, राजकीय महाविद्यालय, महम) शोधार्थी, इतिहास विभाग, बाबा मस्तनाथ विश्वविद्याल अस्थल बोहर।
डॉ नीलम रानी शोध –निर्देशक, एसोसिएट प्रोफेसर, इतिहास विभाग, बाबा मस्तनाथ विश्वविद्यालय, अस्थल बोहर।

सारांश

ऋग्वेद के दसवें मण्डल के पुरुष सुक्त में चतुवर्ण उत्पत्ति की व्याख्या की गई है। जिसमें प्रजापति के मुख से ब्राह्मण, भुजा से क्षत्रिय, उद्र से वैश्य और पैरों से शूद्र का जन्म बताया गया है, परंतु उत्तर वैदिक साहित्य में आर्य और अनार्य दो ही वर्णों का वर्णन मिलता है। कालांतर में समूह के लिए वर्ण शब्द का प्रयोग प्रारंभ हुआ। मनुस्मृति के अनुसार सृष्टा ने समस्त विश्व की रक्षा एवं कल्याण के लिए चार वर्णों की सृष्टि की है और उनके लिए अलग–अलग कार्य निर्धारित किए हैं। महाभारत में चारों वर्णों से अन्य वर्णों की उत्पत्ति प्रतिलोम विवाह से बताई गई है। इसमें पुरुष का वर्ण, स्त्री के वर्ण से नीचा होता है। मनुस्मृति के अनुसार वर्ण और जाति में अंतर होता है। मनु ने जाति शब्द का प्रयोग प्रतिलोम विवाह से उत्पन्न संतान के लिए किया है। मनुस्मृति के अनुसार इसी तरह के वर्णसंकर से 57 जातियों तथा उप–जातियों का उदय हुआ है। ईसा पूर्व तृतीय शताब्दी तक वर्ण व्यवस्था पूर्णरूपेण जन्मजात और वंशानुगत हो गई थी, यद्यपि इसका वंशगत स्वरूप सूत्र युग से ही प्रारंभ हो गया था, जो कालांतर में और अधिक नियोजित एवं दृढ़ हुआ।

मुख्य शब्दः–ऋग्वेद, मनुस्मृति, महाभारत, जाति, वर्ण, ब्राह्मण, क्षत्रिय, वैश्य, शूद्र।

कुषाणकालीन वर्ण व्यवस्था

कुषाण काल में वर्ण ही समाज का आधार था। तत्कालीन साहित्य एवं स्मृतियों में वर्ण व्यवस्था का विस्तृत उल्लेख मिलता है। जिसका वर्णन इस प्रकार है:–

ब्राह्मणः– धर्मशास्त्रों के अनुसार ब्राह्मण का मुख्य कार्य अध्ययन, यजन, याजन, अध्यापन, एवं दान प्रतिग्रह बताया गया है। मनुस्मृति के अनुसार जाति की विशिष्टता, उत्पत्ति–स्थान की श्रेष्ठता (ब्रह्मा के मुख), अध्ययन–अध्यापन एवं व्याख्यान आदि के द्वारा नियम (श्रुति–स्मृति–विहित आचरण) के धारण करने से और यज्ञोपवीत संस्कार आदि की श्रेष्टता के कारण वर्णों में ब्राह्मण को ही वर्णों का स्वामी माना जाता था। धर्मच्युत होने पर भी उसे दंडित नहीं किया जाता था। गंभीर अपराध करने पर भी उन्हें अपेक्षाकृत कम दंड दिया जाता था। उसे पूर्णरूपेण अवध्य, अदण्ड, अबहिष्कार्य और अपरिहार्य माना जाता था।[1] इसके साथ–साथ ब्राह्मणों को कुछ विशेषाधिकार भी प्राप्त थे। जैसे दान लेना, ब्राह्मणों को दान देना गर्व की बात समझी जाती थी। राजा और धनिक वर्ग ब्राह्मणों को देवतातुल्य मानकर प्रभूत दान देते थे।[2] उपरोक्त कार्यों से यदि वह अपने परिवार का भरण पोषण नहीं कर पाता, तो गौतम धर्मसूत्र और मनुस्मृति के अनुसार संकट काल में वह क्षत्रियवृत्ति को अपना सकता था। नारद स्मृति के अनुसार यदि क्षत्रियवृत्ति से उसकी आजीविका नहीं चले, तो वह वैश्यवृत्ति (कृषि,गोपालन एवं व्यापार) अपना सकता था। कृषि–कर्म हिंसा प्रधान था, इसलिए शास्त्रकारों ने उसे कृषि–कर्म न करने की सलाह दी है।

ब्राह्मण, आपातकाल में शूद्रवृत्ति अपनाकर भी अपना व अपने परिवार का जीवन यापन कर सकता था, परंतु उसका शूद्र के साथ भोजन करना निषेध था। आपातकाल की समाप्ति के पश्चात प्रायश्चित करके वह पुनः अपनी वृर्ती को अपना सकता था। मृतक अध्यापक और अधिक याजन करने वाला ब्राह्मण समाज में हेय माना जाता था।[3]

ब्राह्मणों के विभिन्न प्रकार

आपतधर्म अपनाने से समाज में ब्राह्मणों की कई श्रेणियां बन गई थी। महाभारत में इनकी छः श्रेणियां बताई गई हैं– ब्राह्मणसम, देवसम, शूद्रसम, चांडालसम, क्षत्रसम और वैश्यसम। अत्रि ने इसकी दस श्रेणियां बताई हैं–

1. देवविप्र (संध्या, जप, होम, देव एवं अतिथि पूजन करने वाला)
2. मुनिविप्र (एकांत और निर्जनवन में रहते हुए तप और श्रद्धा में रत)
3. द्विजविप्र (वेदांत, सांख्य और योग दर्शन का अध्ययनकर्त्ता)
4. क्षत्रविप्र (क्षत्रिय कर्मी)
5. वैश्यविप्र (कृषि, गोपालन एवं वाणिज्य में रत)
6. शूद्रविप्र (लाख, लवण, दूध, घी, मधु, नमक, मांसादि विक्रेता)
7. निषादविप्र (चोरी, तस्करी एवं मदिरा, मांस आदि में रुचि रखने वाला)
8. पशुविप्र (ब्रह्मात्व को न जानकर केवल यज्ञोपवीत धारण करने वाला)

9. म्लेच्छविप्र (कुआं, तालाब, कूप आदि को अपवित्र करने वाला)
10.चाण्डालविप्र (क्रियाहीन मूर्ख और निर्दयी ब्राह्मण)[4]

क्षत्रिय

ब्राह्मणों के बाद क्षत्रियों का समाज में क्रमानुसार द्वितीय स्थान था, किंतु उनका मान एवं महत्व ब्राह्मणों से कम नहीं था। अपने युद्धकौशल और प्रशासन से, वे देश और समाज को रक्षित और पोषित करते थे।[5] उन्हें भी ब्राह्मणों की तरह कुछ विशेषाधिकार प्राप्त थे, जैसे युद्ध में विजित वस्तुएं, न्याय संबंधी कार्यों से प्राप्त धन, रक्षण के बदले मिलने वाला धन आदि पर उनका अधिकार होता था।[6]मनुस्मृति के अनुसार रथ, घोड़ा, हाथी, यज्ञ, धन, धान्य (सब प्रकार के अन्न) पशु (गौ, भैंस आदि) स्त्रियां (दासी आदि) दस तरह के द्रव्य (गुड़,नमक आदि) और कृप्य (सोना–चांदी के अतिरिक्त तांबा, पीतल आदि धातु) आदि पर विजित योद्धा का स्वामित्व होता था।

मनुस्मृति के अनुसार क्षत्रियों के लिए कुछ वर्जित कार्य भी थे। जैसे वेदाध्ययन, यज्ञ कराना एवं दान लेना। अपराधी होने पर क्षत्रियों के लिए भी दंड का विधान था। ब्राह्मण का अपमान करने वाले क्षत्रिय को गौतम स्मृति और मनुस्मृति के अनुसार सौ कार्षापण अर्थदंड देने का प्रावधान था। आपस्तम्ब धर्मसूत्र के अनुसार ब्राह्मण के अतिरिक्त चोरी करने वाले अन्य वर्णों का वध कर देना चाहिए।[7] क्षत्रियों के लिए धर्मशास्त्रकारों ने व्यवस्था दी है कि संकटकाल में, वे अपने से निम्न वर्ण के कर्म अपना सकते थे। आपातकाल में वह वैश्यवृत्ति या शूद्रवृत्ति अपना सकते थे, परंतु ब्राह्मणवृत्ति उनके लिए निषेध थी।[8]

गौतम स्मृति, बौधायन धर्मसूत्र एवं मनुस्मृति में जीविकोपार्जन के निमित्त क्षत्रिय, वैश्यवृत्ति (कृषि गोपालन एवं व्यापार) अपना सकता था, परन्तु कृषि–कर्म हिंसात्मक था, इसलिए उसके लिए वर्जित था।[9] पारिवारिक संकट की स्थिति में वह व्यापार कर्म अपना सकता था, परंतु उसके लिए रांगा, सीसा, लौहा, केश, चमड़ा, हड्डी, रस, तिल, नमक, पत्थर और मनुष्य का क्रय–विक्रय, दूध, मधु, विष आदि का व्यापार करना निषिद्ध था।

वैश्य

पाणिनि ने वैश्य के लिए 'अर्य' शब्द का प्रयोग किया है। समाज में वैश्यों का स्थान क्रमानुसार तृतीय था। कृषि एवं व्यापार का दायित्व उनके ऊपर निर्भर था। उसके द्वारा अर्जित संपत्ति को सामाजिक संपत्ति माना जाता था, जिसमें से तीनों वर्ण अपना–अपना भाग ग्रहण कर सकते थे, ताकि समाज में आर्थिक असंतोष न पनपे। इसी कारण दान एवं त्याग करना वैश्य का प्रधान गुण माना जाता था। आर्थिक लिप्सा तथा धन लोभ वैश्य की मनोवृत्ति न बन जाए, इसलिए उसे वेदाध्ययन तथा यज्ञ करने विधान किया गया था। अध्ययन, यजन और दान करना उसका परम कर्तव्य था।[10] कालांतर में वैश्य ने शिक्षा ग्रहण करने का मार्ग त्याग दिया और वह पूर्णरूपेण व्यापार और वाणिज्य में रत हो गया था। इस तरह अध्यात्मिक और बौद्धिक उन्नयन का मार्ग उनसे छूट गया। कृषि, गौरक्षा और वाणिज्य, वैश्य के स्वाभाविक कर्म माने गए थे।[11] परंतु कुछ वस्तुओं का व्यापार उसके लिए निषिद्ध था, जैसे मद्य, मांस, लोहा और चमड़ा जैसी वस्तुएं। आपदकाल में वैश्य शूद्रवृत्ति अपना सकता था। ब्राह्मणवृत्ति और क्षत्रियवृत्ति उसके लिए निषेध थी। धर्मशास्त्रकारों के अनुसार गौ, ब्राह्मण और वर्ण की रक्षा के लिए वैश्य भी शस्त्रधारण कर सकता था। मनु के अनुसार दुःसाहसी मनुष्यों द्वारा अधर्म, राज्य में अराजकता, युद्धकाल, आत्मरक्षा एवं स्त्रियों की रक्षा आदि के लिए द्विजातियों को शस्त्र ग्रहण करना चाहिए।

शूद्र

समाज में शूद्र का स्थान अत्यंत निम्न था। विराट पुरुष के पैरों से उत्पन्न मानकर समाज में उसकी निम्नतम अवस्था की घोषणा की गई थी। गौतम धर्मसूत्र के अनुसार शूद्र का वर्णधर्म एक ही था कि वह ईर्ष्या–द्वेष रहित होकर अन्य तीनों वर्णों की सेवा करें।[12] सामाजिक दृष्टि से उसे अत्यंत पतित, निकृष्ट और हीन माना जाता था। उसके धार्मिक उद्धार के लिए परिस्थितियों अनुसार मनु जैसे कट्टरपंथी विचारक को भी अपने विचारों को उदार बनाना पड़ा। धर्मशास्त्रकारों ने शूद्रों के प्रति उदार भावनाएं व्यक्त करते हुए कहा गया है कि अगर वे भक्ति में निमग्न रहे, मदिरापान न करें, इंद्रियों को संयत रखें और निर्भय रहें, तो उन्हें भी मोक्ष की प्राप्ति हो सकती है।[13] परिचार्य जैसे प्रमुख कार्य के अतिरिक्त वह कुछ शिल्पों के अंतर्गत शिल्पी के रूप में स्वीकार किया गया है।

शूद्रों के प्रकार

कुषाण काल तक शूद्रों के अनेक वर्ग विकसित हो चुके थे। धर्मशास्त्रों में इन्हें दो वर्गों में विभाजित किया जाता है:– प्रथम वह वर्ग, जो ब्राह्मणों के निर्देशानुसार विशुद्ध आचरण और धार्मिक क्रियाएं करता हुआ सदाचार का जीवन जीता था। इस वर्ग के शूद्रों में ही संस्कार और धार्मिक कार्य होता था, किंतु यह सब मंत्रहीन होता था। ऐसे सन्मार्गी मंत्रहीन पंचमहायज्ञ धर्म का पालन करते हुए प्रशंसा के पात्र माने जाते थे।[14] द्वितीय वह वर्ग था, जो विशुद्ध आचरण और सात्विक चरित्र से दूर असभ्य और असंस्कारयुक्त हीन जीवन व्यतीत करता था। इनको समाज में हेय माना जाता था।

गौतम धर्मसूत्र में भी शूद्रों के दो वर्ग बताए गए हैं। अनिरवसित, जो नगर में रहते थे, जैसे तक्षण, लौहार आदि और निरवसित, जो नगर से बाहर रहते थे जैसे चांडाल आदि।[15] निरवसित के दो उपभाग भी थे, भोज्य शूद्र (जिनके हाथों से बना भोजन ब्राह्मण ग्रहण करते थे), और अभोज्य शूद्र(जिनको ब्राह्मणों के लिए भोजन बनाना निषेध था)। प्रो. पी. वी. काणे ने भी शूद्रों को दो वर्गों में विभाजित किया है:– सच्छूद्र (सद्व्यवसाय करने वाले, मांस का त्याग करने वाले एवं द्विज जातियों के सेवक) और असच्छूद्र (मांस खाने वाले एवं द्विज जातियों की सेवा न करने वाले)।[16]

शूद्र का आपत्तिकालिक कर्म

अगर द्विज–सेवा करने से शूद्र की आजीविका नहीं चल पाती थी, तो अपनी भार्या और संतान की आजीविका, व्यापार, पशुपालन और विभिन्न शिल्प को ग्रहण करके अपनी आजीविका चलाएं। मनु ने विपत्तिग्रस्त शूद्र के लिए विभिन्न उद्योग–धंधे अपनाने का निर्देश किया है। वह कट्टरपंथी और कठोर नियमनियन्ता होते हुए भी कहीं–कहीं शूद्रों के प्रति उदार भावना व्यक्त करता है। उसका कथन है कि द्विजों की सेवा करने में असमर्थ शूद्र (भूख से पीड़ित होकर) स्त्री–पुत्रादि के निवारणार्थ कारुकर्म (सूप आदि बनाने का कार्य) अपना सकता था।

जाति व्यवस्था

ऋग्वेद में आर्य और अनार्य दो ही वर्णों का उल्लेख मिलता है।[17] महाभारत में अन्य सभी वर्णों की उत्पत्ति अनुलोम एवं प्रतिलोम विवाह से बताई गई है। मनुस्मृति और महाभारत के तुलनात्मक अध्ययन से डॉक्टर वीएस सुक्थंकर इस निष्कर्ष पर पहुंची है कि यह प्रकरण महाभारत में मनु वंश के उन्हीं विद्वानों ने जोड़े हैं जिन्होंने मनुस्मृति की रचना की थी। डॉ. श्रीनिवास ने भी जाति को सामाज की वास्तविक इकाई माना है। और समाज को व्यवहारिक जीवन में वर्ण और जाति पर परस्पर निर्भर माना है।[18]

जातियों की उत्पत्ति पर धर्मशास्त्रकार एकमत नहीं है, जैसे अंबष्ठ जाति की उत्पत्ति बौधायन धर्मसूत्र, वशिष्ट धर्मसूत्र एवं मनुस्मृति के अनुसार ब्राह्मण पिता एवं क्षत्रिय माता या क्षत्रिय पिता एवं शूद्र माता से माना गया है, परंतु गौतम धर्मसूत्र में इनकी उत्पत्ति क्षत्रिय पिता और वैश्य माता या क्षत्रिय पिता और शूद्र माता से बताई गई है। इसी प्रकार रथकार की उत्पत्ति बौधायन धर्मसूत्र में वैश्य पिता और शूद्र माता से बताई है, परंतु इसके विपरीत गौतम स्मृति एवं याज्ञवल्क्य स्मृति में ऐसी संतान को 'करण' कहा गया है। जातियां अनुलोम एवं प्रतिलोम विवाह से बनी, यह सिद्धांत तर्कसंगत प्रतीत नहीं होता, क्योंकि उग्र और सूत वैदिक काल में उच्च अधिकारी थे। अंबष्ठ, निषाद आदि अनार्य जातियां थीं। विदेह और मागध का नामकरण उनके रहने के प्रदेशों से जान पड़ता है। उपरोक्त जाति की उत्पत्ति के सिद्धांत धर्मशास्त्रकारों की कल्पना मात्र प्रतीत होते हैं। जाति का आधार जन्म है और वर्ग का आधार गुण और कर्म है। वर्ण चार हैं और जातियां उपजातियां सैकड़ों।[19] इस प्रकार कहा जा सकता है कि जाति के आधार पर वर्ण की व्याख्या करना तर्कसंगत नहीं है।[20]

अवे डुवोय के मतानुसार ब्राह्मणों ने अपनी सर्वोच्चता रखने के लिए जाति व्यवस्था का निर्माण किया। इसे हम उनकी राजनीतिक चतुराई भी कह सकते हैं, परंतु ऐसा सत्य प्रतीत नही होता क्योंकि यदि ऐसा होता तो तत्कालीन शक्तिशाली क्षत्रिय वर्ग और आर्थिक रूप से संपन्न वैश्य वर्ग इसका विरोध अवश्य करता। इतिहासकार सोर्नोट का मानना है कि प्रारंभ में एक परिवार से संबंधित लोग अपने पितृ अर्थात पूर्वजों की पूजा करते थे, उसके आधार पर ही एक परिवार से संबंधित लोग एक जाति के रूप में विकसित हो गए। रिजल्ट महोदय का मानना है कि जाति उत्पत्ति का प्रमुख कारण नस्लीय एवं रंगभेद है। इतिहासकार रोमिला थापर के अनुसार जाति उत्पत्ति का मुख्य आधार भाषा है जैसा वैदिक काल में हमें आर्य और अनार्य जाति के बारे में जानकारी मिलती है। भाषा के आधार पर आर्य को उच्च वर्ण और अनार्य को निम्न माना जाता था।

निष्कर्ष

उपरोक्त विवेचन से स्पष्ट होता है कि वर्ण का आधार मनुष्य के गुण और उसके कर्म ही थे। जाति का विशेष महत्व नहीं था। सभी मनुष्यों की अभिरुचि, बुद्धि, प्रतिभा एवं क्षमता समान नहीं हो सकती, इन्हीं विभिन्न गुणों के कारण समाज में वर्णों का बनना स्वाभाविक प्रक्रिया थी। इसी प्रकार जाति–प्रथा के उदय का कोई एक कारण नहीं हो सकता। इसके उदय एवं विकास के लिए अनेक सामाजिक, राजनैतिक एवं धार्मिक कारण हो सकते हैं। जाति का मुख्य उद्देश्य मानव का इहीलोक और परलोक में कल्याण करना माना जाता था। जाति–प्रथा ने भारतीय समाज की अनेक सामाजिक एवं मनोवैज्ञानिक समस्याओं का हल करने में सहायता की है, परंतु जाति प्रथा की कठोरता ने उसकी इस विशेषता को नष्ट कर दिया, जब तक जाति का आधार मानव कल्याण था, तब तक यह उपयोगी थी, परंतु जब जन्म को जाति का आधार माना जाने लगा, तो वह अपनी गरिमा को कायम नहीं रख सकी।

संदर्भ

[1] मिश्र, जयशंकर, (2006), प्राचीन भारत का सामाजिक इतिहास, पृ.122।
[2]उपरोक्त, पृ.123।
[3] पान्थरी, राघवेंद्र, (2017), प्राचीन भारत में सामाजिक परिवर्तन पृ. 42
[4] उपरोक्त, पृ.44।
[5] मिश्र, जयशंकर, (2006), प्राचीन भारत का सामाजिक इतिहास, पृ.129।
[6] मनुस्मृति 10.79।
[7] मिश्र, जयशंकर, (2006), प्राचीन भारत का सामाजिक इतिहास, पृ.132।
[8] गौतम धर्मसूत्र, 6.26।
[9] मनुस्मृति,10.33।
[10] गौतम धर्मसूत्र,10.1–3।
[11] मिश्र, जयशंकर, (2006), प्राचीन भारत का सामाजिक इतिहास, पृ.134–35।
[12] गौतम धर्मसूत्र 1057।
[13] ब्राह्मण पुराण, 4.2.314।
[14] मनुस्मृति, 10.99–100।
[15] धर्मसूत्र, 12.4।
[16] काणे, पी. वी.,(1900), धर्मशास्त्र का इतिहास, पृ.148।
[17] सेर्नाट एम., (1930), कास्ट इन इंडिया, पृ.128।
[18] श्रीनिवास, एम.एन.,(1962), कास्ट इन मॉडर्न इंडिया ट्रस्ट 71।
[19] दत्त, एन. के.(1931), ओरिजन एंड ग्रोथ ऑफ कास्ट इन इंडिया पृ.1।
[20] प्रभु, पी. एच.(1979), हिंदू सोशल आर्गनाइजेशन, पृ. 304।

मध्य भारती

MADHYA BHARTI
(UGC CARE Group-1, Multi disciplinary)

CERTIFICATE OF PUBLICATION

This is to certify that the article entitled

कुषाणकालीन वर्ण एवं जाति व्यवस्था

Authored By

दीपक कुमार

सहायक प्राध्यापक, राजकीय महाविद्यालय, महम, शोधार्थी, इतिहास विभाग,बाबा मस्तनाथ विश्वविद्यालय, अस्थल बोहर।

Published in

Madhya Bharti (मध्य भारती) : ISSN **0974-0066** with IF=6.28

Vol. 83, No. 01, January - June : 2023

UGC Care Approved, Group I, Peer Reviewed, Bilingual, Biannual,

Multi-disciplinary Referred Journal

UGC
University Grants Commission

Chief Editor
प्रो. अभिषेक शर्मा