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3.3.1 NUMBER OF RESEARCH PAPERS PUBLISHED PER TEACHER IN THE JOURNALS NOTIFIED ON UGC CARE LIST DURING THE LAST FIVE YEARS

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1	ON THE CONSTRUCTION OF BALANCED REPEATED MEASUREMENTS DESIGNS WITH GOOD CIRCULAR PROPERTIES	MUHAMMAD DANIYAL, JIGNESH KUMAR GONDALIYA & RASHID AHMED	STATISTIC S	STATISTICAL THEORY AND RELATED FIELDS	2023	2475-4269	HTTPS://WWW.TANDFONLINE.COM/JOURNAL S/TSTF20	HTTPS://WWW.TANDEFONLINE.COM/DOI/FULL/10.1080/24754269.2023.2184607	HTTPS://WWW.SCOPUS.COM/SOURCEID/21100923463
2	MATHEMATICAL MODELLING AND STANDARDIZATION OF TECHNOLOGY FOR THE PRODUCTION OF BAE L FRUIT POWDER	ANADANI SV, AKBARI SH, NAVNEET KUMAR, RAVANI A, GONDALIYA J	STATISTIC S	CURRENT SCIENCE	2023	0011-3891	HTTPS://WWW.CURRENTSCIENCE.AC.IN/INDOWN.AUTHOR.PHP?ID=51684	HTTPS://WWW.CURRENTSCIENCE.AC.IN/SHOW.AUTHOR.PHP?ID=51684	HTTPS://WWW.SCOPUS.COM/SOURCEID/20699
3	EXPLORING MYTHOLOGICAL INFLUENCE IN AMRUTA PATIL’S ADI	MS. VIDHI RAVRANI	ENGLISH	ELT QUARTERLY AN INTERNATIONAL	DEC-23	ISSN: 0975-0258	HTTP://WWW.HMPENGLISH.COM/PUBLICATIONS.PHP	HTTP://WWW.HMPENGLISH.COM/DOC/ELT_QUARTERLY/2023/DECEMBER.PDF	AN INTERNATIONAL REFERENCE

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4	A STUDY ON PROFITABILITY PERFORMANCE BASED ON INVESTMENT OF INDIAN CEMENT INDUSTRY	DR. RAVINDRA L. MOJIDRA	ACCOUNT ANCY	INTERNATIONAL JOURNAL FOR ADVANCED RESEARCH IN MULTIDISCIPLINARY VOLUME 02: ISSUE-01, DECEMBER 2023	DECEMBER 2023	ISSN: 2583-794X	WWW.IJARMY.COM	WWW.IJARMY.COM.PAST-ISSUES	REFERRED PEER REVIEW ED
5	SUSTAINABLE DEVELOPMENT GOALS AND GANDHIAN THOUGHTS	DR.AVANI BHATT	ECONOMICS	ONLINE JOURNAL OF MULTIDISCIPLINARY SUBJECTS VOL 16 ISSUE-4 MARCH 2023	2023	ISSN:2349:266X	WWW.RESEARCHGURU.NET	HTTPS://WWW.RESEARCHGURU.NET/VOLUME/VOLUME%2016/ISSUE%204/RG12.PDF	ONLINE PEER REVIEW ED
6	NEW EDUCATION POLICY	DR. VANDANA G. TRIVEDI*	ECONOMICS	INTERNATIONAL JOURNAL OF EDUCATION, MODERN MANAGEMENT , APPLIED SCIENCE & SOCIAL SCIENCE (IJEMMASS)IMPACT FACTOR: 6.882, VOLUME 05, NO. 02(III), APRIL - JUNE, 2023, PP. 50-52	APRIL - JUNE, 2023	ISSN : 2581-9925	WWW.INSPIRAJOURNALS.COM	HTTPS://WWW.INSPIRAJOURNALS.COM/UPLOADS/ISSUES/1637467225.PDF	INTERNATIONAL PEER REVIEW ED
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7	SUSTAINABLE DEVELOPMENT GOAL'S AND INDIA	DR. AVANI BHATT	ECONOMICS	INTERNATIONAL PEER REVIEWED REFERRED	AUG-22	ISSN 2349:4557	WWW.AYUDHPUBLICATION.COM	HTTP://WWW.AAYUDHPUBLICATION.COM/DOWNLOAD/65THISSUE AUGUST-	AN INTERNATIONAL REFERRED

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8	INDIA AND THE GENESIS OF NATIONALISM	DR H R GOHIL	ENGLISH	THE ATLANTIC LITERARY REVIEW	2022	0972- 3269	HTTPS://WWW. ATLANTICBOOKS.COM/THE- ATLANTIC- CRITICAL- REVIEW	HTTPS://WWW.ATLAN TICBOOKS.COM/THE- ATLANTIC-CRITICAL- REVIEW	AN INTERNATIONAL REFERRE D PEER REVIEW ED
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12	A STUDY ON	DR. RAVINDRA	ACCOUNT	GAP	2022	2581-	<u>(66-73) A</u>	<u>(66-73) A STUDY ON</u>	GLOBAL

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14	SOME CLASSES OF CIRCULAR BALANCED RMDs AND THEIR CONVERSION INTO CIRCULAR STRONGLY AND NEARLY STRONGLY BALANCED RMDs	Z. BASHIR, R. AHMED, J. GONDALIYA AND K. RASHEED	STATISTICS	COMMUNICATIONS IN STATISTICS - THEORY AND METHODS	2022	0361-0926	HTTPS://WWW.TANDFONLINE.COM/JOURNAL/S/LSTA20	HTTPS://WWW.TANDFONLINE.COM/JOURNAL/S/LSTA20	YES
15	DEVELOPMENT OF BANKING SECTOR IN INDIA	DR. RAVINDRA L. MOJIDRA	ACCOUNTANCY	GAP INTERDISCIPLINARITIES - A GLOBAL JOURNAL OF INTERDISCIPLINARY STUDIES	APRIL-JUNE'22	2581-5628	HTTPS://WWW.GAPINTERDISCIPLINARITIES.ORG/VIEW-ARTICLES.PHP?IID=28	HTTPS://WWW.GAPINTERDISCIPLINARITIES.ORG/RES/ARTICLES/(43-48)%20DEVELOPMENT%20OF%20BANKING%20SECTOR%20IN%20INDIA.PDF	GLOBAL LY PEER REVIEW ED
16	A STUDY OF FINANCIAL PERFORMANCE OF SELECTED PSU STEEL COMPANIES	MEET SHAH, DR. PRASHANT JOSHI	ACCOUNTANCY	INTERNATIONAL EDUCATIONAL APPLIED SCIENTIFIC RESEARCH JOURNAL	2022	2456-5040	IEASRJ – INTERNATIONAL EDUCATIONAL APPLIED SCIENTIFIC RESEARCH JOURNAL	IEASRJ – INTERNATIONAL EDUCATIONAL APPLIED SCIENTIFIC RESEARCH JOURNAL	YES
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17	RAM RAJYA AND EMERGING INDIAN	DR. H R GOHIL	ENGLISH	THE ATLANTICCRIT	21-JUL	0972-6373	HTTPS://WWW.ATLANTICBOOKS.COM/THE-	HTTPS://WWW.ATLANTICBOOKS.COM/THE-	PEER REVIEW

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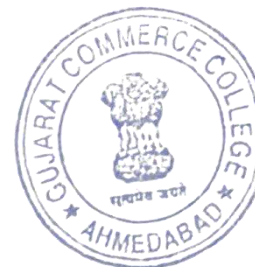
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20	COLLABARATIVE ENVIRONMENT IN WORLD CLASS UNIVERSITY	DR.VANDANA TRIVEDI	ECONOMI CS	INTERNATION AL JOURNAL OF ADAVANCE RESEARCH IN COMMERECE MANAGEMENT AND SOCIAL SCIENCE (IJARCMSS)	OCT-DEC 2021	ISSN:258 17930	CHROME- EXTENSION://E FAIDNBMNNNI BPCAJPCGLCLE FINDMKAJ/HTT PS://WWW.INSPI RAJOURNALS. COM/UPLOADS/ ISSUES/7591624 29.PDF	CHROME- EXTENSION://EFAIDN BMNNNIBPCAJPCGLC LEFINDMKAJ/HTTPS:// WWW.INSPIRAJOURN ALS.COM/UPLOADS/IS SUES/759162429.PDF	PEER REVIEW ED
21	DANGUE IN WEST BENGAL	DR.VANDANA TRIVEDI	ECONOMI CS	INTERNATION AL JOURNAL OF EDUCATION MODERN MANAGEMENT , APPLIED SCIENCE &SOCIAL SCIENCE (IJEMMASSS) VOL-3 NO.2(III) PP 93-104	APR-JUN 2021	ISSN:258 19925	HTTPS://INSPIR AJOURNALS.C OM/HOME/VIE WDETAILS/?ID= 3137	ISSN 0973-3914, OLD UGC JOURNAL NO. 40942, IMPACT FACTOR 5.125, RNI NO. MP BIL 01034/12/1/2005- ZZZPEER - REVIEWED RESEARCH JOURNAL ISSN 0973-3914, OLD UGC JOURNAL NO. 40942, IMPACT FACTOR 5.125, RNI NO. MP BIL 01034/12/1/2005-TC INDEXED & LISTED AT: ULRICH'S INTERNATIONAL PERIODICALS DIRECTORY©, PROQUEST, U.S.A (TITLE ID: 715205), SIX MONTHLY BI- LINGUAL JOURNAL (ENGLISH EDITION AND HINDI EDITION) TC	
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23	DIGITAL PRESERVATION OF LIBRARY RESOURCES: STRATEGIC PLANNING A MANAGEMENTPERSPECTIVE	DR. URMILA RAVAT, DR. RAKESH PARMAR	LIBRARY	LIBRARY PHILOSOPHY AND PRACTICE (E-JOURNAL)	21-JUN	1522-0222	HTTPS://DIGITALCOMMONS.UNL.EDU/LIBPHILPRAC/5905/	HTTPS://DIGITALCOMMONS.UNL.EDU/LIBPHILPRAC/5905/	PEER REVIEWED
24	THE ROLE OF MEDIA IN MAKING MODERN INDIA	DR H R GOHIL	ENGLISH	SAHITYASETU	MAY-JUNE 2021	2249-2372	HTTP://SAHITYASETU.CO.IN/MAIN/INDEX.HTML	HTTP://SAHITYASETU.CO.IN/MAIN/INDEX.HTML	YES
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26	CHANGING PERCEPTION OF RENAISSANCE POLITICS	DR. H R GOHIL	ENGLISH	THE ATLANTIC LITERARY REVIEW	06-JAN 2021	0972-3269	HTTPS://WWW.ATLANTICBOOKS.COM/THE-ATLANTIC-LITERARY-REVIEW	HTTPS://WWW.ATLANTICBOOKS.COM/THE-ATLANTIC-LITERARY-REVIEW	INTERNATIONAL PEER REVIEWED
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27	MO YAN KRUT 'RED SOGHUM' MATHI PRAGAT THATU VASTAVIK CHINESE JIVAN	DR H R GOHIL	ENGLISH	SAHITYASETU	NOV-DEC 2020	2249-2372	HTTP://SAHITYASETU.CO.IN/MAIN/INDEX.HTML	HTTP://SAHITYASETU.CO.IN/MAIN/INDEX.HTML	YES

28	OPTIMAL MINIMAL BALANCED CROSSOVER DESIGNS IN FIRST AND SECOND CARRYOVER EFFECTS	JIGNESHKUMAR GONDALIYA	STATISTICS	COMMUNICATIONS IN STATISTICS - THEORY AND METHODS (INTERNATIONAL)	2020	1532-415X	HTTPS://WWW.TANDEFONLINE.COM/DOI/ABS/10.1080/03610926.2020.1713370	HTTPS://WWW.TANDEFONLINE.COM/DOI/ABS/10.1080/03610926.2020.1713370	YES
29	OPTIONAL ANALYSES OF CROSSOVER TRIALS HAVING TWO TREATMENTS AND A PLACEBO	J. DIVECHA AND J. GONDALIYA	STATISTICS	ELECTRONIC JOURNAL OF APPLIED STATISTICAL ANALYSIS	2020	2070-5948	HTTPS://WWW.SCOPUS.COM/SOURCEID/21100216944	HTTPS://WWW.SCOPUS.COM/SOURCEID/21100216944	YES
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30	A STUDY OF OPTIMUM TIMING OF LAPAROSCOPIC CHOLECYSTECTOMY IN PATIENTS PRESENTING WITH ACUTE CHOLECYSTITIS	HIREN P. VAIDYA, ABHISHEK M. SHAH., ADITYA H. VAIDYA, HEMALI M. SHAH	STATISTICS	JOURNAL OF EVOLUTION OF MEDICAL AND DENTAL SCIENCE(NATIONAL)	DEC. 30, 2019	EISSN-2278-4802, PISSN-2278-4748	HTTPS://PUBMED.NCBI.NLM.NIH.GOV/18361924/	HTTPS://PUBMED.NCBI.NLM.NIH.GOV/18361924/	YES
31	A COMPARATIVE STUDY OF THE PERFORMANCE OF SELECTED INDIAN PHARMACEUTICAL COMPANIES WITH THE REFERENCE OF LIQUIDITY	DR. SHEELA BHADANI	COMMERCE	DEPARTMENT OF HIGHER EDUCATION - GOVERNMENT OF GUJARAT JOURNAL OF COMMERCE & MANAGEMENT -ISSUE 30	APR-MAY 2019	ISSN: 2279-0LSX	DEPARTMENT OF HIGHER EDUCATION - GOVERNMENT OF GUJARAT JOURNAL OF COMMERCE & MANAGEMENT	HTTPS://KCG.GUJARAT.GOV.IN/E-JOURNALS COMMERCE AND MANAGEMENT	PEER REVIEWED
32	THE CONSTRUCTION OF EFFICIENT MINIMAL BALANCED CROSSOVER DESIGNS USING MATLAB	JIGNESHKUMAR GONDALIYA	STATISTICS	INTERNATIONAL JOURNAL OF AGRICULTURAL AND STATISTICAL SCIENCES	2019	0973-1903	HTTPS://WWW.RESEARCHGATE.NET/PUBLICATION/276248744_CONSTRUCTION OF MINIMAL BALANCED CROSS OVER DESIGNS HAVING GOOD EFFICIENCY OF SEPARABILITY	HTTPS://WWW.RESEARCHGATE.NET/PUBLICATION/276248744_CONSTRUCTION OF MINIMAL BALANCED CROSS OVER DESIGNS HAVING GOOD EFFICIENCY OF SEPARABILITY	YES
33	CORPORATE	DR. SONAL S.	COMMERCE	JOURNAL OF	2019	ISSN	43405 KCG	HTTPS://KCG.GUJARAT.GOV.IN/E-JOURNALS COMMERCE AND MANAGEMENT	PEER

	GOVERNANCE DISCLOSURE PRACTICES AND ITS IMPACT ON FINANCIAL PERFORMANCE: A CASE STUDY ON PHARMA SECTOR IN INDIA	SOLANKI	CE	SOCIAL SCIENCES		2279- 025X		<u>T.GOV.IN/E- JOURN</u> HTTPS://KCG.G UJARAT.GOV.IN/E- JOURNALS43405 <u>KCGALS43405 KCG</u>	REVIEW ED
34	A COMPARATIVE TREND ANALYSIS OF LIQUIDITY PERFORMANCE OF SELECTED INDIAN PHARMACEUT ICAL COMPANIES ABSTRACT	DR. SHEELA BHADANI	COMMER CE	DEPARTMENT OF HIGHER EDUCATION - GOVERNMENT OF GUJARAT JOURNAL OF COMMERCE & MANAGEMENT - CONDNUOUS ISSUE - 29	FEB MAR 2019	ISSN: 2279- 025X	DEPARTMENT OF HIGHER EDUCATION - GOVERNMENT OF GUJARAT JOURNAL OF COMMERCE & MANAGEMENT	HTTPS://KCG.GUJARA <u>T.GOV.IN/E- JOURNALS</u> <u>COMMERCE AND</u> <u>MANAGEMENT</u>	PEER REVIEW ED

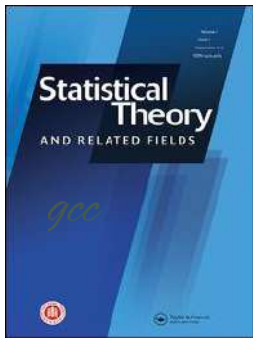


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DOCUMENTS OF THE YEAR

2023



On the construction of balanced repeated measurements designs with good circular properties

Muhammad Daniyal, Jignesh kumar Gondaliya & Rashid Ahmed

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On the construction of balanced repeated measurements designs with good circular properties

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ABSTRACT

Several fields, such as biological, medical, public health, agricultural sciences, etc., require circular balanced repeated measurement designs with fewer unequal number of repeated measurements than the number of treatments. Also, the availability and high cost of experimental subjects in these fields prefer the design in fewer experimental units. However, balancing the carryover effects of the treatments in minimal experimental subjects is one of the problems in this case. In this paper, several new series of minimal circular nearly strongly balanced RMDs in periods of two and three different sizes are constructed. The proposed construction of designs has high efficiency and, therefore, can save the cost of experimentations due to a fewer experimental subjects. Most of the designs are very useful because of the unavailability of strongly balanced RMDs for these combinations of parameters. A list of sets of shifts for the construction of minimal circular nearly SBRMDs has also been mentioned in the Appendix.

ARTICLE HISTORY

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KEYWORDS

Carryover effects; repeated measurement designs; balanced repeated measurement designs; strongly balanced repeated measurement designs; circular nearly strongly balanced repeated measurement designs

1. Introduction

Experimental design deals with the arrangement of experimental units and the assignment of treatments to them in such a way that the comparisons among the treatments are unbiased and as precise as possible. The precision of the experiment depends to a large extent on the size of the experiment and the variations present in the experimental units. In designing experiments, keeping in view the limitation on experimental resources, efforts are made to minimize standard errors of estimated contrasts of interest. Mostly error variation arises because of the variation in experimental units under the same treatments. Therefore, it is suggested to use the same experimental unit for different treatments in an experiment but in different periods. This results in a type of design known as repeated measurements design (RMD) which makes them different from other designs presented in the literature which make use of different experimental units for different treatments. Repeated measurements design (RMD) is the type of experimental design in which experimental subjects are repeatedly measured by giving a sequence of treatments. RMDs are a special kind of carryover design in which each subject is influenced by a treatment applied in a current period called treatment effects and treatment applied in a previous period called carryover effects. Cross-over designs are RMDs in which each unit receives the sequence of each treatment over different periods. RMDs in unequal period sizes are very useful if there is a restriction on the total number of treatments, and some experimental units can receive on the total length of time, while some experimental units can remain in the trial which results in RMDs of different or unequal period sizes. RMDs balanced in treatments and carryover effects are useful in several fields such as medicine, pharmacology, animal sciences and psychology where carryover effects are natural.

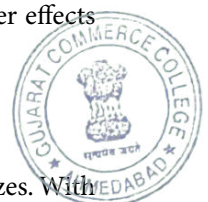
2. Literature review

Cheng and Wu (1980) proposed the construction of BRMDs and CSBRMDs, especially for unequal block sizes. With the help of advanced technology in computer systems, the uses of block designs of unequal sizes k are beneficial, and hence it is very useful in industrial and agricultural experiments. The utilization of different block sizes in biological experiments was mentioned by Pearce (1964). Afsarinejad (1994) constructed minimal CSBRMDs for different period sizes. Iqbal and Jones (1994) proposed the construction of efficient RMDs and CSBs for two different period sizes. Iqbal and Tahir (2009), Iqbal et al. (2010) and Bashir et al. (2018) constructed CSBs for some classes. Rasheed et al. (2018) recently developed some generators to obtain MCSBs in a period of three different sizes for some

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cases of t , where $2 \leq k_3 < k_2 \leq 10$. However, there does not exist MCSBs for certain combinations of treatments and periods when several treatments are less than the number of periods. Here, minimal circular nearly CSBs are useful. A design is said to be CNBs (Circular nearly strongly balanced repeated measurement designs) if every treatment is immediately followed by every other treatment including itself except the treatment (labelled as $t-1$) which is not preceded by itself. In this article, some generators are developed to construct CNBs in periods of (i) two different sizes and (ii) three different sizes. These designs have their own importance in extended scientific and biological experimentations with different block sizes which consist of clinical experimentations of human and also animal behaviour responses for the comparison of several non-curative treatments for their effectiveness. With the advancement of technological computer systems, block designs with unequal sizes p have become very useful in huge industrial and agricultural experiments. In biological experiments, the utilization of different block sizes has been studied significantly. RCTs become prone to the unravelling of sizes of the block when it remains the same throughout the trial, so investigators use different block sizes, i.e. they randomly vary the block size to lower the chances of unbiasedness (Schulz & Grimes, 2002; Schulz, 1995). There exist different scientific research areas such as animal husbandry and genetic experimentation. RCTs, where these designs are applied as within-subject treatment comparisons, are more efficient than between-subject treatment comparisons. These proposed designs are additions to the literature as they are incorporating different period sizes and also possess good efficiency in estimating direct and residual effects.

Important definitions with abbreviations used that will be discussed throughout the article are discussed below briefly.

BRMDs	Balanced repeated measurement designs
CSBs	circular strongly balanced repeated measurement designs
CNBs	Circular nearly strongly balanced repeated measurement designs

2.1. BRMDs

In an RMD each experimental subject or unit receives a series of several treatments in successive periods.

2.2. CSBs

If every treatment is directly preceded by every other treatment (including itself) then it is called CSBs.

2.3. CNBs

In this type of design, every treatment is immediately followed by every other treatment exactly once as well as with itself except the treatment labelled as $v-1$, which is not preceded by itself.

In Section 3, the model and information matrix are described along with the formula for the computation of the efficiency for CNBs. In Section 4, the Method of Cyclic Shifts (MOCS) is described to generate CNBs in different period sizes. A series of generators is proposed in Section 5 to obtain CNBs in two different sizes of periods. Also, a series of generators for the construction of CNBs in three different sizes of periods are proposed in Section 6. Section 7 contains the concluding remarks about the proposed designs. A list of sets of shifts for the construction of CNBs in two and three different sizes of periods with many treatments smaller than thirty is provided in the Appendix.

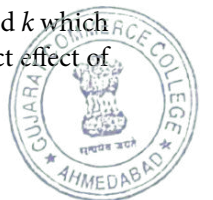
3. Model and efficiency for CNBs

The model used for repeated measurements designs in the literature is the conventional model proposed by Magda (1980)

$$y_{ijk} = \mu + \tau_{d(k,j)} + \gamma_{d(k-1,j)} + \pi_k + \xi_{ij} + \varepsilon_{ijk}, \quad (1)$$

where y_{ijk} is the i th observation from the subject j th with the sequence i in period k for which treatment $d(k, j)$ is given.

μ = Overall mean, $\tau_{d(k,j)}$ = treatment $d(k, j)$ effect, $\gamma_{d(k-1,j)}$ = treatment $d(k-1, j)$ effect in the period k which was applied in the period $k-1$ to the same experimental subject, π_k = k th period effect, ξ_{ij} = j th subject effect of sequence i , and ε_{ijk} is i.i.d normally distributed residual term having mean 0 and fixed variance σ^2 .



The joint information matrix of treatment and carryover effects for the CNB is expressed by

$$A_{(\tau, \gamma)} = \begin{pmatrix} A_{11} & A_{12} \\ A'_{12} & A_{22} \end{pmatrix},$$

where A_{11} , A_{12} and A_{22} in two different period sizes are expressed by

$$A_{11} = R - M - \frac{1}{k_1} N_1 N'_1 - \frac{1}{k_2} N_2 N'_2 + \frac{\underline{r} \underline{r}'}{n_1 k_1 + n_2 k_2} J,$$

$$M = \begin{bmatrix} \left(\frac{s^2(k_2 - 1) + (s - 1)^2}{n_1 + n_2} + \frac{(k_1 - k_2)}{n_1} \right) J_{t-1} & \frac{(t - 1)(s - 1)}{n_1 + n_2} \underline{1}_{t-1} \\ \frac{(t - 1)(s - 1)}{n_1 + n_2} \underline{1}'_{t-1} & \frac{(t - 1)^2}{n_1 + n_2} \end{bmatrix},$$

$$A_{12} = Z - \bar{M} - \frac{1}{k_1} N_1 \bar{N}'_1 - \frac{1}{k_2} N_2 \bar{N}'_2 + \frac{\underline{r} \bar{r}'}{n_1 k_1 + n_2 k_2} J,$$

$$\bar{M} = \begin{bmatrix} \left(\frac{s^2(k_2 - 2) + 2s(s - 1)}{n_1 + n_2} + \frac{(k_1 - k_2)}{n_1} \right) J_{t-1} & \frac{s(t - 1)}{n_1 + n_2} \underline{1}_{t-1} \\ \frac{s(t - 1)}{n_1 + n_2} \underline{1}_{t-1} & 0 \end{bmatrix},$$

$$A_{22} = \bar{R} - M - \frac{1}{k_1} \bar{N}_1 \bar{N}'_1 - \frac{1}{k_2} \bar{N}_2 \bar{N}'_2 + \frac{\bar{r} \bar{r}'}{n_1 k_1 + n_2 k_2} J,$$

and A_{11} , A_{12} and A_{22} in periods of three different sizes are expressed by

$$A_{11} = R - M - \frac{1}{k_1} N_1 N'_1 - \frac{1}{k_2} N_2 N'_2 - \frac{1}{k_3} N_3 N'_3 + \frac{\underline{r} \underline{r}'}{n_1 k_1 + n_2 k_2 + n_3 k_3} J,$$

$$M = \begin{bmatrix} \left(\frac{s^2(k_3 - 1) + (s - 1)^2}{n_1 + n_2 + n_3} + \frac{(s - 1)^2(k_2 - k_3)}{n_1 + n_2} + \frac{(s - 2)^2(k_1 - k_2)}{n_1} \right) J_{t-1} & \frac{n_3(s - 1)}{n_1 + n_2 + n_3} \underline{1}_{t-1} \\ \frac{n_3(s - 1)}{n_1 + n_2 + n_3} \underline{1}'_{t-1} & \frac{n_3^2}{n_1 + n_2 + n_3} \end{bmatrix},$$

$$A_{12} = Z - \bar{M} - \frac{1}{k_1} N_1 \bar{N}'_1 - \frac{1}{k_2} N_2 \bar{N}'_2 - \frac{1}{k_3} N_3 \bar{N}'_3 + \frac{\underline{r} \bar{r}'}{n_1 k_1 + n_2 k_2 + n_3 k_3} J,$$

$$\bar{M} = \begin{bmatrix} \left(\frac{s^2(k_3 - 2) + 2s(s - 1)}{n_1 + n_2 + n_3} + \frac{(s - 1)^2(k_2 - k_3)}{n_1 + n_2} + \frac{(s - 2)^2(k_1 - k_2)}{n_1} \right) J_{t-1} & \frac{sn_3}{n_1 + n_2 + n_3} \underline{1}_{t-1} \\ \frac{sn_3}{n_1 + n_2 + n_3} \underline{1}'_{t-1} & 0 \end{bmatrix},$$

$$A_{22} = \bar{R} - M - \frac{1}{k_1} \bar{N}_1 \bar{N}'_1 - \frac{1}{k_2} \bar{N}_2 \bar{N}'_2 - \frac{1}{k_3} \bar{N}_3 \bar{N}'_3 + \frac{\bar{r} \bar{r}'}{n_1 k_1 + n_2 k_2 + n_3 k_3} J.$$

Here,

n_1	subjects measured repeatedly up to k_1 size
n_3	subjects measured repeatedly up to k_3 size
s	number of sets of shifts
N_1	t incidence matrix vs 1 to n_1
N_2	t incidence matrix vs $n_1 + 1$ to $n_1 + n_2$
N_3	t incidence matrix vs $n_1 + n_2 + 1$ to $n_1 + n_2 + n_3$
\bar{N}_1	residual incidence matrix vs 1 to n_1
\bar{N}_2	residual incidence matrix vs $n_1 + 1$ to $n_1 + n_2$
\bar{N}_3	residual incidence matrix vs $n_1 + n_2 + 1$ to $n_1 + n_2 + n_3$
\underline{r}	vector of replication of treatments
\bar{r}	vector of replication of residual



R diagonal matrix of replication of t
 \bar{R} diagonal matrix of replication of residual
 J matrix of 1s

Then the information matrix of the treatment and carryover effects are $A_\tau = A_{11} - A_{12}A_{22}^-A_{21}$ and $A_\gamma = A_{22} - A_{21}A_{11}^-A_{12}$, respectively.

RMDs should be analysed for their capability of discriminating the effects of treatment from carryover effects. Hanford (2005) has given the criteria to compare the RMDs based on this ability. Divecha and Gondaliya (2014) gave a convenient method for calculating the efficiency of separability (ES) for the BRMDs. This formula considering the provided constraints of our proposed type of RMDs is given by

$$ES = \left[\frac{t\sqrt{t-1} - 1}{t\sqrt{t-1}} \right] \times 100\% \quad (2)$$

4. Construction methodology

Construction of CNBs from all the series of generators requires an understanding of rule II of a MOCS which was proposed by Iqbal and Jones (1994). MOCS (Rule II) is defined here briefly for constructing CNBs in periods of different sizes.

Let $S_1 = [q_{11}, q_{12}, \dots, q_{p_1-1}]$, $S_2 = [q_{21}, q_{22}, \dots, q_{p_2-1}]$ and $S_3 = [q_{31}, q_{32}, \dots, q_{p_3-2}]t$ be the sets of shifts, where $0 \leq q_{ij} \leq v-2$. If every element $0, 1, \dots, v-2$ appears exactly once in S^* , it is CNB in periods of sizes p_1, p_2 and p_3 , where $S^* = [q_{11}, q_{12}, \dots, q_{p_1-1}, q_{21}, q_{22}, \dots, q_{p_2-1}, q_{31}, q_{32}, \dots, q_{p_3-1}, v-1-(q_{11} + q_{12} + \dots + q_{p_1-1}) \bmod (v-1), v-1-(q_{21} + q_{22} + \dots + q_{p_2-1}) \bmod (v-1)]$. In these sets of shifts, the sum of any 2, 3, ..., or $(p-3)$ successive elements should not be $0 \bmod (v-1)$. If so, rearrange them.

Consider here the Rule II of a MOCS briefly for the construction of CNBs with the help of an example as $t = 13$, $S_1 = [3, 4, 5, 9, 8]$ and $S_2 = [6]t$.

Take $t-1$ experimental subjects for one set of shifts $[3, 4, 5, 9, 8]$. Write $0, 1, \dots, t-2$ in the first period of $t-1$ experimental subjects, respectively. For the second period of every subject, add $3 \bmod (t-1)$ to every element of the first period of each subject. Then add $4 \bmod (t-1)$ to every element of the second period which gives the treatment number of the third period in each subject. Similarly add 9, 5 and 8, respectively.

Experimental Subjects												
Periods	1	2	3	4	5	6	7	8	9	10	11	12
1	0	1	2	3	4	5	6	7	8	9	10	11
2	3	4	5	6	7	8	9	10	11	0	1	2
3	7	8	9	10	11	0	1	2	3	4	5	6
4	4	5	6	7	8	9	10	11	0	1	2	3
5	9	10	11	0	1	2	3	4	5	6	7	8
6	5	6	7	8	9	10	11	0	1	2	3	4

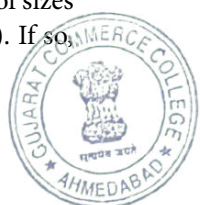
Take $t-1$ more subjects for the second set of shifts $[6]t$. Allocate $0, 1, \dots, t-2$ to every subject in the first period, respectively. To obtain the elements of the second period for every subject, add $6 \bmod (t-1)$ to every element of the first period for all subjects. Then insert $t-1$ (i.e. 12) in each element of the third period.

Subjects												
Periods	13	14	15	16	17	18	19	20	21	22	23	24
1	0	1	2	3	4	5	6	7	8	9	10	11
2	6	7	8	9	10	11	0	1	2	3	4	5
3	12	12	12	12	12	12	12	12	12	12	12	12

The above design is CNB in $t = 13$, $k_1 = 6$, $k_2 = 3$, $n_1 = 12$, $n_2 = 12$ and $ES = 98\%$.

5. Generators to obtain CNBs in two different sizes of periods

Let $S_1 = [e_{11}, e_{12}, \dots, e_{p_1-1}]$ and $S_2 = [e_{21}, e_{22}, \dots, e_{p_2-2}]t$ be two sets of shifts, here $0 \leq e_{ij} \leq t-2$. Define, $S^* = [e_{11}, e_{12}, \dots, e_{p_1-1}, e_{21}, e_{22}, \dots, e_{p_2-2}, t-1-(e_{11} + e_{12} + \dots + e_{p_1-1}) \bmod (t-1)]$. If every element $0, 1, \dots, t-2$ appears exactly once in the new set of shifts S^* , then the design from the set of shifts will be CNB in periods of sizes k_1 and k_2 . The sum of any 2, 3, ..., $(k-3)$ successive elements of any set of shifts should not be $0 \bmod (t-1)$. If so, rearrange the elements.



Example: Sets of shifts $S_1 = [1,7,4,3,9,6]$ and $S_2 = [2,5,8]t$ give following CNB for $t = 11$ in $k_1 = 7$ and $k_2 = 5$ with ES = 97%.

Subjects									
1	2	3	4	5	6	7	8	9	10
0 ₀	1 ₁	2 ₂	3 ₃	4 ₄	5 ₅	6 ₆	7 ₇	8 ₈	9 ₉
1 ₀	2 ₁	3 ₂	4 ₃	5 ₄	6 ₅	7 ₆	8 ₇	9 ₈	0 ₉
8 ₁	9 ₂	0 ₃	1 ₄	2 ₅	3 ₆	4 ₇	5 ₈	6 ₉	7 ₀
2 ₈	3 ₉	4 ₀	5 ₁	6 ₂	7 ₃	8 ₄	9 ₅	0 ₆	1 ₇
5 ₂	6 ₃	7 ₄	8 ₅	9 ₆	0 ₇	1 ₈	2 ₉	3 ₀	4 ₁
4 ₅	5 ₆	6 ₇	7 ₈	8 ₉	9 ₀	0 ₁	1 ₂	2 ₃	3 ₄
0 ₄	1 ₅	2 ₆	3 ₇	4 ₈	5 ₉	6 ₀	7 ₁	8 ₂	9 ₃

Subjects									
1	2	3	4	5	6	7	8	9	10
0 ₁₀	1 ₁₀	2 ₁₀	3 ₁₀	4 ₁₀	5 ₁₀	6 ₁₀	7 ₁₀	8 ₁₀	9 ₁₀
2 ₀	3 ₁	4 ₂	5 ₃	6 ₄	7 ₅	8 ₆	9 ₇	0 ₈	1 ₉
7 ₂	8 ₃	9 ₄	0 ₅	1 ₆	2 ₇	3 ₈	4 ₉	5 ₀	6 ₁
5 ₇	6 ₈	7 ₉	8 ₀	9 ₁	0 ₂	1 ₃	2 ₄	3 ₅	4 ₆
10 ₅	10 ₆	10 ₇	10 ₈	10 ₉	10 ₀	10 ₁	10 ₂	10 ₃	10 ₄

Here, 10₆ means that treatment 10 was applied in the current period, while the subscript '6' is the treatment applied in the previous period.

If $t = 2zi + 2a - 1$, i is an integer, $k_1 = 2z$, $k_2 = 2a$, $a \neq z$ and $a \& z > 1$, then CNBs can be obtained from the sets given below where $j = 0, 1, \dots, i-1$.

$$S_{j+1} = [zj + 1, zj + 2, \dots, zj + z, t - 1 - (zj + 1), t - 1 - (zj + 2), \dots, t - 1 - (zj + z - 1)];$$

$$S_{i+1} = [zi + 1, zi + 2, \dots, zi + a - 1, t - 1 - (zi + 1), t - 1 - (zi + 2), \dots, t - 1 - (zi + a - 2), 0]t$$

Example 5.1: CNBs for $t = 13$, $k_1 = 8$ and $k_2 = 6$ are constructed from the sets of shifts given below with 98% efficiency.

$$S_1 = [1, 2, 3, 4, 11, 10, 9], S_2 = [5, 6, 7, 0]t.$$

If $t = 2zi + 2a$, i is an integer, $k_1 = 2z$, $k_2 = 2a + 1$ and $a \& z > 1$, then CNBs can be obtained from the sets given below where $j = 0, 1, \dots, i-1$.

$$S_{j+1} = [zj + 1, zj + 2, \dots, zj + z, t - 1 - (zj + 1), t - 1 - (zj + 2), \dots, t - 1 - (zj + z - 1)];$$

$$S_{i+1} = [zi + 1, zi + 2, \dots, zi + a - 1, t - 1 - (zi + 1), t - 1 - (zi + 2), \dots, t - 1 - (zi + a - 1), 0]t.$$

Example 5.2: CNBs for $t = 16$, $k_1 = 10$ and $k_2 = 7$ are constructed from the sets given below with 98% efficiency.

$$S_1 = [1, 2, 3, 4, 14, 5, 13, 11, 12], S_2 = [6, 7, 9, 8, 0]t.$$

If $t = 2zi + 4a - 1$, i is an integer, $k_1 = 2z$, $k_2 = 2a$ and $a \neq z$, $a \& z > 1$, then CNBs can be obtained from the sets given below.

$$S_{j+1} = [zj + 1, zj + 2, \dots, zj + z, t - 1 - (zj + 1), t - 1 - (zj + 2), \dots, t - 1 - (zj + z - 1)];$$

$$S_{i+1} = [zi + 1, zi + 2, \dots, zi + a - 1, t - 1 - (zi + a - 1), t - 1 - (zi + a - 2), \dots, t - 1 - (zi + 1)];$$

$$S_{i+2} = [zi + a + 1, zi + a + 2, \dots, zi + 2a - 1, t - 1 - (zi + a + 1), t - 1 - (zi + a + 2), \dots, t - 1 - (zi + 2a - 2), 0]t.$$

Example 5.3: CNBs for $t = 25$, $k_1 = 10$ and $k_2 = 8$ are constructed from the sets given below with 99% efficiency.

$$S_1 = [1, 2, 3, 4, 5, 23, 22, 21, 20], S_2 = [6, 7, 8, 17, 9, 18, 16], S_3 = [10, 11, 12, 14, 13, 0]t.$$



If $t = 2zi + 4a + 1$, i is an integer, $k_1 = 2z$, $k_2 = 2a + 1$ and $a \& z > 1$, then CNBs can be obtained from the sets given below.

$$\begin{aligned} S_{j+1} &= [zj + 1, zj + 2, \dots, zj + z, t - 1 - (zj + 1), t - 1 - (zj + 2), \dots, t - 1 - (zj + z - 1)]; \\ S_{i+1} &= [zi + 1, zi + 2, \dots, zi + a, t - 1 - (zi + 1), t - 1 - (zi + 2), \dots, t - 1 - (zi + a)]; \\ S_{i+2} &= [zi + a + 1, zi + a + 2, \\ &\dots, zi + 2a, t - 1 - (zi + a + 1), t - 1 - (zi + a + 2), \dots, t - 1 - (zi + 2a - 1)]t. \end{aligned}$$

Example 5.4: CNBs for $t = 21$, $k_1 = 8$ and $k_2 = 7$ are constructed from the sets given below with 99% efficiency.

$$S_1 = [1, 2, 3, 4, 19, 18, 17], S_2 = [5, 6, 7, 15, 14, 13], S_3 = [8, 9, 10, 12, 11]t.$$

6. Generators to obtain CNBs in three different sizes of periods

Let $S_1 = [e_{11}, e_{12}, \dots, e_{p_1-1}]$, $S_2 = [e_{21}, e_{22}, \dots, e_{p_2-1}]$ and $S_3 = [e_{31}, e_{32}, \dots, e_{p_3-2}]t$ be the sets of shifts, where $0 \leq e_{ij} \leq t-2$. Define, $S^* = [e_{11}, e_{12}, \dots, e_{p_1-1}, q_{21}, e_{22}, \dots, e_{p_2-1}, e_{31}, e_{32}, \dots, e_{p_3-1}, t-1-(e_{11} + e_{12} + \dots + e_{p_1-1}) \bmod (t-1), t-1-(e_{21} + e_{22} + \dots + e_{p_2-1}) \bmod (t-1)]$. If every element $0, 1, \dots, t-2$ appears exactly once in the new set of shifts S^* , then the design from the set of shifts will be CNB in periods of sizes k_1, k_2 and k_3 . The sum of any $2, 3, \dots, (k-3)$ successive elements of the set of shifts S_{i+1} should not be $0 \bmod (t-1)$. If so rearrange the elements.

Example: Set of shifts $S_1 = [3, 4, 9, 5, 8]$, $S_2 = [1, 2, 11, 10]$ and $S_3 = [6]t$ give the following CNBs for $t = 13$ in $k_1 = 6$, $k_2 = 5$ and $k_3 = 3$ with ES = 98%.

Subjects											
1	2	3	4	5	6	7	8	9	10	11	12
0 ₅	1 ₆	2 ₇	3 ₈	4 ₉	5 ₁₀	6 ₁₁	7 ₀	8 ₁	9 ₂	10 ₃	11 ₄
3 ₀	4 ₁	5 ₂	6 ₃	7 ₄	8 ₅	9 ₆	10 ₇	11 ₈	0 ₉	1 ₁₀	2 ₁₁
7 ₃	8 ₄	9 ₅	10 ₆	11 ₇	0 ₈	1 ₉	2 ₁₀	3 ₁₁	4 ₀	5 ₁	6 ₂
4 ₇	5 ₈	6 ₉	7 ₁₀	8 ₁₁	9 ₀	10 ₁	11 ₂	0 ₃	1 ₄	2 ₅	3 ₆
9 ₄	10 ₅	11 ₆	0 ₇	1 ₈	2 ₉	3 ₁₀	4 ₁₁	5 ₀	6 ₁	7 ₂	8 ₃
5 ₉	6 ₁₀	7 ₁₁	8 ₀	9 ₁	10 ₂	11 ₃	0 ₄	1 ₅	2 ₆	3 ₇	4 ₈

Subjects											
13	14	15	16	17	18	19	20	21	22	23	24
0 ₀	1 ₁	2 ₂	3 ₃	4 ₄	5 ₅	6 ₆	7 ₇	8 ₈	9 ₉	10 ₁₀	11 ₁₁
1 ₀	2 ₁	3 ₂	4 ₃	5 ₄	6 ₅	7 ₆	8 ₇	9 ₈	10 ₉	11 ₁₀	0 ₁₁
3 ₁	4 ₂	5 ₃	6 ₄	7 ₅	8 ₆	9 ₇	10 ₈	11 ₉	0 ₁₀	1 ₁₁	2 ₀
2 ₃	3 ₄	4 ₅	5 ₆	6 ₇	7 ₈	8 ₉	9 ₁₀	10 ₁₁	11 ₀	0 ₁	1 ₂
0 ₂	1 ₃	2 ₄	3 ₅	4 ₆	5 ₇	6 ₈	7 ₉	8 ₁₀	9 ₁₁	10 ₀	11 ₁

Subjects											
25	26	27	28	29	30	31	32	33	34	35	36
0 ₁₂	1 ₁₂	2 ₁₂	3 ₁₂	4 ₁₂	5 ₁₂	6 ₁₂	7 ₁₂	8 ₁₂	9 ₁₂	10 ₁₂	11 ₁₂
6 ₀	7 ₁	8 ₂	9 ₃	10 ₄	11 ₅	0 ₆	1 ₇	2 ₈	3 ₉	4 ₁₀	5 ₁₁
12 ₆	12 ₇	12 ₈	12 ₉	12 ₁₀	12 ₁₁	12 ₀	12 ₁	12 ₂	12 ₃	12 ₄	12 ₅

Here, 11₆ is the treatment 11 applied in the present period, while the subscript '6' is the treatment applied in the previous period.

If $t = 2zi + 2a + 2b$, i is an integer, $k_1 = 2a$, $z \neq a$, $z, a \& b > 1$, $k_2 = 2a + 1$ and $k_3 = 2b$, then CNBs can be obtained from the sets given below where $j = 0, 1, \dots, i-1$.

$$\begin{aligned} S_{j+1} &= [zj + 1, zj + 2, \dots, zj + z, t - 1 - (zj + 1), t - 1 - (zj + 2), \dots, t - 1 - (zj + z - 1)]; \\ S_{i+1} &= [zi + 1, zi + 2, \dots, zi + a, t - 1 - (zi + 1), t - 1 - (zi + 2), \dots, t - 1 - (zi + a)]; \\ S_{i+2} &= [zi + a + 1, zi + a + 2, \dots, zi + a + b - 1, t - 1 - (zi + a + 1), t - 1 - (zi + a + 2), \\ &\dots, t - 1 - (zi + a + b - 1)]t. \end{aligned}$$



Example 6.1: CNBs for $t = 13$, $k_1 = 8$, $k_2 = 7$ and $k_3 = 4$ are constructed from the sets given below with 98% efficiency.

$$S_1 = [1, 2, 3, 4, 16, 15, 14], S_2 = [5, 6, 7, 12, 11, 10] \text{ and } S_3 = [8, 9]t.$$

If $t = 2zi + 2a + 2b - 1$, i is an integer, $k_1 = 2z$, $z \neq a \neq b > 1$, $k_2 = 2a$ and $k_3 = 2b$, then CNBs can be constructed from the sets given below where $j = 0, 1, \dots, i-2$.

$$S_{j+1} = [zj + 1, zj + 2, \dots, zj + z, t - 1 - (zj + 1), t - 1 - (zj + 2), \dots, t - 1 - (zj + z - 1)];$$

$$S_{i+1} = [zi + 1, zi + 2, \dots, zi + a, t - 1 - (zi + 1), t - 1 - (zi + 2), \dots, t - 1 - (zi + a - 1)];$$

$$S_{i+2} = [zi + a + 1, zi + a + 2, \dots, zi + a + b - 1, t - 1 - (zi + a + 1), t - 1 - (zi + a + 2), \dots, t - 1 - (zi + a + b - 2), 0]t \text{ for } b > 2.$$

$$S_{i+2} = [(t - 1)/2, 0]t \text{ for } b = 2.$$

Example 6.2: CNBs for $t = 23$, $k_1 = 10$, $k_2 = 8$ and $k_3 = 6$ are constructed from the sets given below with 99% efficiency.

$$S_1 = [1, 2, 3, 4, 5, 21, 20, 19, 18], S_2 = [6, 7, 8, 9, 16, 15, 14] \text{ and } S_3 = [10, 11, 12, 0]t.$$

If $t = 2zi + 2a + 2b + 1$, $k_1 = 2z$, i is an integer, $k_2 = 2a + 1$, $k_3 = 2b + 1$, $a \neq b > 1$ and $z > 1$, then CNBs can be obtained from the sets given below where $j = 0, 1, \dots, i-1$.

$$S_{j+1} = [zj + 1, zj + 2, \dots, zj + z, t - 1 - (zj + 1), t - 1 - (zj + 2), \dots, t - 1 - (zj + z - 1)];$$

$$S_{i+1} = [zi + 1, zi + 2, \dots, zi + a, t - 1 - (zi + 1), t - 1 - (zi + 2), \dots, t - 1 - (zi + a)];$$

$$S_{i+2} = [zi + a + 1, zi + a + 2, \dots, zi + a + b, t - 1 - (zi + a + 1), t - 1 - (zi + a + 2), \dots, t - 1 - (zi + a + b - 1)]t.$$

Example 6.3: CNBs for $t = 19$, $k_1 = 8$, $k_2 = 7$ and $k_3 = 5$ are constructed from the sets given below with 99% efficiency.

$$S_1 = [1, 2, 3, 4, 17, 16, 15], S_2 = [5, 6, 13, 7, 12, 11], S_3 = [8, 9, 10]t.$$

7. Concluding remarks

CSBs help in estimating direct and carryover effects independently and providing high efficiency of separability. Despite the importance of RMDs, there is no sufficient literature available on the construction of the CSBs and CNBs with high efficiency of separability for unequal period sizes. In situations where CSBs cannot be constructed, they are preferable as they give efficiencies close to CSBs. Through well-known MOCS Rule II, these designs have been constructed for unequal period sizes with high efficiency of separability which covers the lack of designs for unequal period sizes. The experimenters now have more choices when dealing with different period sizes. All the proposed designs possess an efficiency close to 100% and, therefore, they should be a better alternative to CSBs.

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Appendix

Table A1. List of sets of shifts for CNBs in two different sizes of periods and treatments smaller than 30.

t	k ₁	k ₂	Sets of shifts	ES
9	6	4	[1,3,2,7,6] + [4,0]t	96
10	6	5	[1,3,2,8,7] + [4,5,0]t	97
11	8	4	[1,3,2,4,9,8,7] + [5,0]t	97
13	6	4	[1,3,2,11,10] + [4,5,8] + [6,0]t	98
13	8	6	[1,3,2,4,11,10,9] + [5,6,7,0]t	98
13	10	4	[1,3,2,4,5,11,10,9,8] + [6,0]t	98
14	8	7	[1,3,2,4,12,11,10] + [5,6,7,8,0]t	98
15	6	4	[1,3,2,13,12] + [4,5,6,10,9] + [7,0]t	98
15	6	5	[1,2,3,13,12] + [4,5,10,9] + [6,7,8]t	98
15	8	4	[1,3,2,4,13,12,11] + [5,6,9] + [7,0]t	98
16	6	5	[1,3,2,14,13] + [4,5,6,11,10] + [7,8,0]t	98
17	10	4	[1,3,2,4,5,15,14,13] + [6,7,10] + [8,0]t	99
17	10	8	[1,3,2,4,5,15,14,13,12] + [6,7,8,10,9,0]t	99
18	10	9	[1,3,2,4,5,16,15,14,13] + [6,7,8,9,10,11,0]t	99
19	6	4	[1,3,2,17,16] + [4,5,6,14,13] + [7,8,11] + [9,0]t	99
19	8	4	[1,3,2,4,17,16,15] + [5,6,7,8,13,12,11] + [9,0]t	99
21	6	4	[1,3,2,19,18] + [4,5,6,16,15] + [7,8,9,13,12] + [10,0]t	99
21	6	5	[1,2,3,19,18] + [4,5,6,16,15] + [7,8,13,12] + [9,10,11]t	99
21	8	6	[1,3,2,4,19,18,17] + [5,6,7,8,15,14,13] + [9,11,10,0]t	99
21	8	7	[1,2,3,4,19,18,17] + [5,6,7,15,14,13] + [8,9,10,12,11]t	99
22	6	5	[1,3,2,20,19] + [4,5,6,17,16] + [7,8,9,14,13] + [10,11,0]t	99
22	8	7	[1,3,2,4,20,19,18] + [5,6,7,8,16,15,14] + [9,10,11,12,0]t	99
23	8	4	[1,3,2,4,21,20,19] + [5,6,7,8,17,16,15] + [9,10,13] + [11,0]t	99
23	10	4	[1,3,2,4,5,21,20,19,18] + [6,7,8,9,10,16,15,14,13] + [11,0]t	99
25	6	4	[1,3,2,23,22] + [4,5,6,20,19] + [7,8,9,17,16] + [10,11,14] + [12,0]t	99
27	6	4	[1,3,2,25,24] + [4,5,6,22,21] + [7,8,9,19,18] + [10,11,12,16,15] + [13,0]t	99
27	6	5	[1,2,3,25,24] + [4,5,6,22,21] + [7,8,9,19,18] + [10,11,16,15] + [12,13,14]t	99
27	8	4	[1,3,2,4,25,24,23] + [5,6,7,8,21,20,19] + [9,10,11,12,17,16,15] + [13,0]t	99
27	10	4	[1,3,2,4,5,25,24,23,22] + [6,7,8,9,10,20,19,18,17] + [11,12,15] + [13,0]t	99
27	10	8	[1,3,2,4,5,25,24,23,22] + [6,7,8,9,10,20,19,18,17] + [11,12,13,15,14,0]t	99
27	10	9	[1,2,3,4,5,25,24,23,22] + [6,7,8,9,20,19,18,17] + [10,11,12,16,15,14,13]t	99
28	6	5	[1,3,2,26,25] + [4,5,6,23,22] + [7,8,9,20,19] + [10,11,12,17,16] + [13,14,0]t	99
28	10	9	[1,3,2,4,5,26,25,24,23] + [6,7,8,9,10,21,20,19,18] + [11,12,13,14,15,16,0]t	99
29	8	6	[1,3,2,4,27,26,25] + [5,6,7,8,23,22,21] + [9,10,11,12,19,18,17] + [13,15,14,0]t	99
29	8	7	[1,2,3,4,27,26,25] + [5,6,7,8,23,22,21] + [9,10,11,19,18,17] + [12,13,14,16,15]t	99



Table A2. List of sets of shifts for CNBs in three different sizes of periods and treatments smaller than 30.

t	k ₁	k ₂	k ₃	Sets of shifts	ES
14	6	5	4	[1,2,3,12,11] + [4,5,9,8] + [6,7]t	98
17	8	6	4	[1,2,3,4,15,14,13] + [5,6,7,11,10] + [8,0]t	99
19	8	7	5	[1,2,3,4,17,16,15] + [5,6,7,13,12,11] + [8,9,10]t	99
20	6	5	4	[1,2,3,18,17] + [4,5,6,15,14] + [7,8,12,11] + [9,10]t	99
20	8	7	6	[1,2,3,4,18,17,16] + [5,6,7,14,13,12] + [8,9,11,10]t	99
23	10	8	6	[1,2,3,4,5,21,20,19,18] + [6,7,8,9,16,15,14] + [10,11,12,0]t	99
25	8	6	4	[1,2,3,4,23,22,21] + [5,6,7,8,19,18,17] + [9,10,11,15,14] + [12,0]t	99
25	10	9	7	[1,2,3,4,5,23,22,21,20] + [6,7,8,9,18,17,16,15] + [10,11,12,13,14]t	99
26	6	5	4	[1,2,3,24,23] + [4,5,6,21,20,19] + [7,8,9,18,17,16] + [10,11,15,14] + [12,13]t	99
26	10	9	8	[1,2,3,4,5,24,23,22,21] + [6,7,8,9,19,18,17,16] + [10,11,12,15,14,13]t	99
27	8	7	5	[1,2,3,4,25,24,23] + [5,6,7,8,21,20,19] + [9,10,11,17,16,15] + [12,13,14]t	99
28	8	7	6	[1,2,3,4,26,25,24] + [5,6,7,8,22,21,20] + [9,10,11,18,17,16] + [12,13,15,14]t	99



Mathematical modelling and standardization of technology for the production of bael fruit powder

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In this study, pulp from ripe bael fruits was dried in the open sun, solar, greenhouse and hot air (50°C, 60°C, 70°C and 80°C) at three levels of thickness (2, 4 and 6 mm). Maximum antioxidant activity of 107.62 and 108.09 mg/100 g, total phenol content of 41.95 and 43.79 mg/100 g and overall acceptability scores (8.33 and 8.11) were found in bael powder dried using natural (greenhouse) and mechanical (50°C) drying methods respectively, with 2 mm of pulp thickness. The Page model was found to be the best fitted for drying bael pulp.

Keywords: Antioxidant activity, bael pulp, mathematical modelling, thin layer drying, total phenol content.

AEGLE marmelos, belonging to the family Rutaceae, is commonly known as bael in the indigenous system of medicine in India¹. Bael is a deciduous sacred tree having useful medicinal properties, especially cooling and laxative properties². The pulp of the bael fruit is a natural source of essential antioxidants and bioactive compounds. Various parts of the bael plant are used in gastrointestinal-related problems such as diarrhoea, dysentery and diabetes. Bael is well-known to have antibacterial, antifungal, anticancer, pyretic and analgesic activities and relieves constipation. Several phytochemicals have been isolated and recognized from various parts of bael, including alkaloids, phenols, glycoside coumarins, steroids, tannins and carotenoids³.

Drying is the process of removal of moisture which supports the microbial activity. It improves shelf life compared to liquid products and reduces the cost of transportation. Small farmers cannot afford to dry their agricultural products in a commercial dryer as it is expensive with high maintenance costs. So, a farmer-friendly option is to adopt advanced greenhouse and solar drying technologies compared to traditional drying (open-sun drying, OSD). Although researchers have worked on drying bael fruit pulp using a tray dryer, hot-air cabinet dryer and freeze dryer, there are no comparative studies to determine the suitability of different

dryers for drying bael fruit pulp. Assessment of drying kinetics as a function of drying conditions can help in the simulation for predicting suitable drying conditions.

Materials and methodology

Pulp extraction

Bael fruits (*A. marmelos*) of Rajasthani local variety were procured from ICAR-Directorate of Medicinal and Aromatic Plants Research, Boriavi farm, Anand, Gujarat, India. They were sorted to discard the diseased, damaged and broken fruits. The fruits were washed thoroughly under tap water and used for further experiments. The bael pulp with seeds and fibre was added with equal amounts of water, mixed and heated for 1 min at 80°C (refs 4, 5). A brush-type pulp extractor/pulper (Khera Laboratory Instruments, New Delhi) was used to extract bael fruit pulp with a 3 mm size sieve made up of 22 gauge stainless steel.

Drying methods

The pulp was distributed evenly in the trays at three thickness levels (2 (T1), 4 (T2) and 6 (T3) mm). The trays were placed in an open environment for direct exposure of bael fruit pulp to sunlight for OSD (D1). Cabinet-type solar dryer (SD, D2; Sardar Patel Renewable Energy Research Institute (SPRERI), Anand) and a gable roof-type greenhouse dryer (GHD, D3) of span 4.5 m × 3.0 m (College of Food Processing Technology and Bioenergy, Anand Agricultural University (AAU), Anand) were used for drying of bael pulp using the natural drying method.

For mechanical drying, a laboratory hot-air tray dryer (Narang Scientific Works Pvt Ltd, New Delhi) was used. It was fitted with a manually controlled digital thermostat, PT-100 thermocouple, a blower driven by a 0.5 HP motor and electric finned heaters of 3 × 1 kW. The tray dryer was adjusted to selected temperatures (50°C (D4), 60°C (D5), 70°C (D6) and 80°C (D7)). The dried bael pulp was ground using a laboratory mixer-grinder to make the powder.

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Standardization

Standardization of drying parameters was done in two ways – natural drying method and mechanical drying method. It was based on the total phenol content, total antioxidant content and sensory attributes (score) of the bael fruit powder. The critical difference (CD) and coefficient of variation (CV) values were determined using factorial CRD software developed by the Department of Statistics, BA College of Agriculture, AAU. Total phenol was determined by Folin–Ciocalteu method⁶. Total antioxidant content was determined using the FRAP method⁷. The sensory evaluation of bael fruit powder was done using a nine-point hedonic scale⁸.

Modelling of thin-layer drying curves

The development of a model is necessary to study the drying characteristics of bael pulp. The experimental drying data of bael pulp using different drying methods or temperatures and thickness of the pulp were fitted into three thin-layer drying models (Page, two-term and Newton models).

(I) Page model⁹

$$MR = \exp(-kt^n). \quad (1)$$

(II) Two-term model¹⁰

$$MR = a \exp(-kt) + b \exp(-gt). \quad (2)$$

(III) Newton model¹¹

$$MR = \exp(-kt). \quad (3)$$

Here MR is the moisture ratio, t the time (min) and k , n , a , b , g are the empirical constants and coefficients in the drying models.

The root mean square error (RMSE) and χ^2 values were calculated as follows

$$\chi^2 = \frac{\sum_{i=1}^N (MR_{Exp,i} - MR_{Pre,i})^2}{(N - Z)}, \quad (4)$$

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (MR_{Pre,i} - MR_{Exp,i})^2}, \quad (5)$$

where $MR_{Exp,i}$ is the i th experimentally observed moisture ratio, $MR_{Pre,i}$ the predicted moisture ratio, N the number of observations and Z is the number of constants of each respective model.

A model is considered to be the best if the average R^2 value is high, and average χ^2 and RMSE values are low.

Results and discussion

Drying characteristics

The extracted pulp with 576.58% (dry basis; db) moisture content was dried using various natural as well as mechanical drying methods or temperatures for three levels of thickness of pulp. Figure 1 shows the time required to achieve the final moisture content (10–13% db) for all the drying methods. Initially, the drying rate was higher, and it decreased gradually with time for all the drying methods (Table 1).

The drying time required to achieve final moisture content of bael fruit pulp in greenhouse drying was less than OSD and solar drying, because the products placed in trays received solar radiation through plastic film material, and moisture was removed by natural and forced convection. A similar result was observed for the drying of chilli and banana in another study¹². The drying rate was much higher in greenhouse drying compared to OSD for date fruit¹³.

In tray drying, the drying time was reduced with an increase in temperature for all levels of thickness of bael fruit pulp. This was due to increased vapour pressure in the samples with increased temperature from 50°C to 80°C. As a result, moisture was removed comparatively faster. Similar outcomes were observed for drying bael fruit pulp⁵ and stone apple slices¹⁴.

Standardization of drying parameters

Table 2 shows the effect of various drying methods and levels of thickness on total phenol content, total antioxidant content and sensory attributes in terms of colour, flavour and overall acceptability.

For standardization of drying parameters for natural drying, all five parameters, namely total phenol content, total antioxidant content and sensory attributes in terms of colour, flavour and overall acceptability, were considered. It was found that the D3T1 combination (greenhouse drying method with 2 mm thickness of bael fruit pulp) gave better results than the other combinations because this sample gave the highest total antioxidant and total phenol content. Also, the highest colour and overall acceptability (OA) values were also obtained. Hence, the combination D3T1 was considered the standardized drying parameter for natural drying.

For mechanical drying, parameters such as total phenol content, total antioxidant content and sensory attributes in terms of colour, flavour and overall acceptability were considered. The D4T1 combination (50°C drying temperature with 2 mm thickness of pulp) was found to be the best among all combinations because the sample gave the highest total antioxidant and total phenol contents. Also, it had the highest colour, flavour and overall acceptability value. Hence, the combination D4T1 was considered as the drying parameter for mechanical drying method.



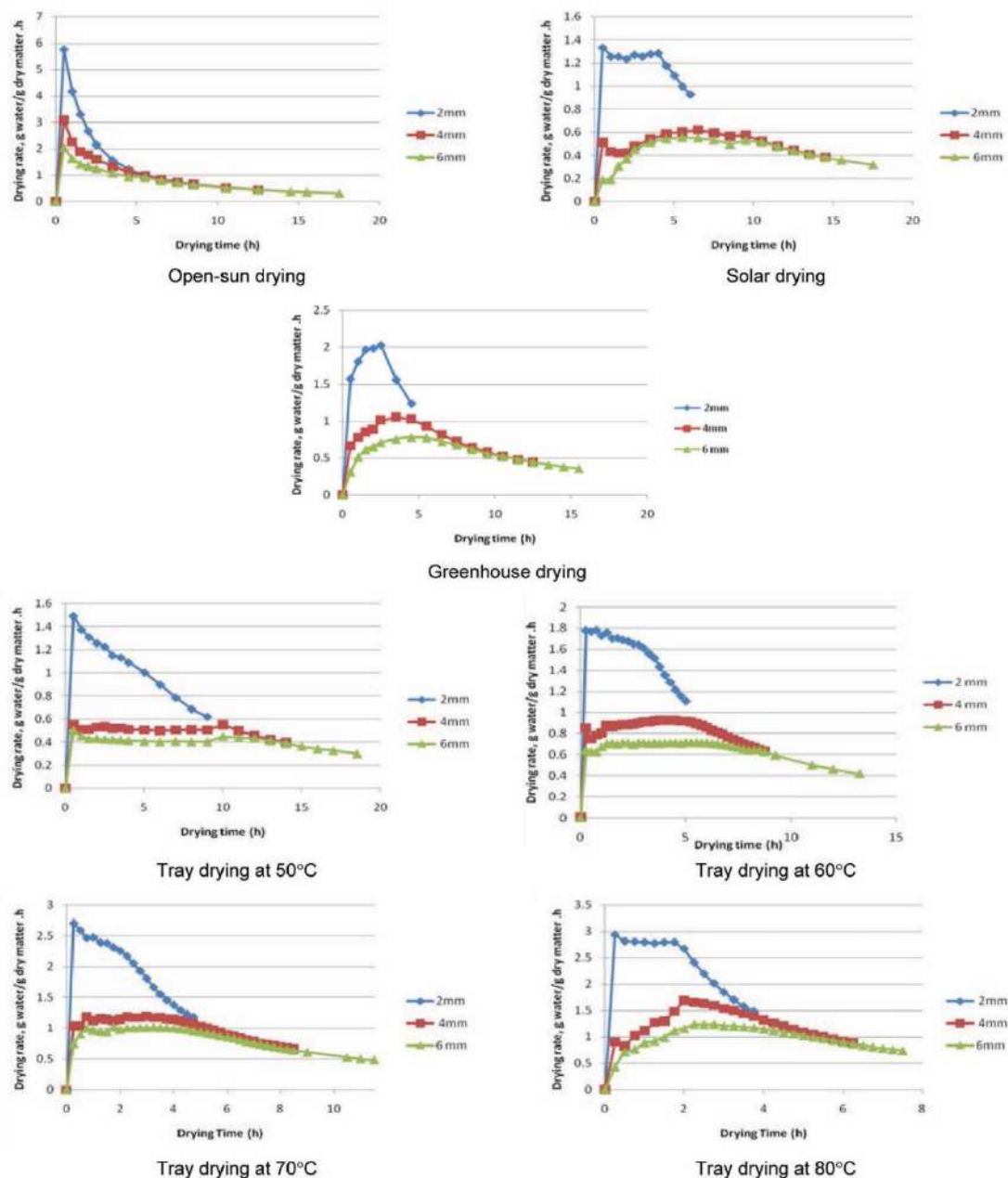


Figure 1. Drying rate versus drying time curves of bael fruit pulp for various drying methods.

Table 1. Time required for drying of bael fruit pulp using various drying methods and for different level of thicknesses of the pulp

Drying method	Temperature (°C)	Drying time (h)		
		Thickness		
		2 mm	4 mm	6 mm
Open-sun drying	—	6.5	12.5	17.5
Solar drying	—	6	14.5	17.5
Greenhouse drying	—	4.5	12.5	15.5
Tray drying	50	9	14	18.5
	60	5.75	8.75	13.25
	70	4.75	8.5	11.5
	80	3.75	6.25	7.5



Table 2. Effect of drying methods and thickness on TPC, TAA and sensory attributes

Parameters	Drying methods	Name of drying methods (D)	Pulp thickness (T) (mm)			CD			CV%
			2	4	6	D	T	DT	
TPC	Natural drying	D1-OSD	26.65	25.53	18.45	0.769	0.769	NS	0.75
		D2-SD	23.04	22.94	20.66				
		D3-GHD	41.95	28.99	28.62				
	Mechanical drying	D4-50°C	43.79	36.15	23.22	2.249	1.948	3.896	7.03
		D5-60°C	35.80	30.24	18.92				
		D6-70°C	38.91	31.05	28.79				
		D7-80°C	41.00	39.16	27.35				
TAA	Natural drying	D1-OSD	106.19	104.76	103.34	0.769	0.769	NS	0.75
		D2-SD	101.91	101.91	100.00				
		D3-GHD	107.62	105.24	103.34				
	Mechanical drying	D4-50°C	108.09	106.19	103.81	0.803	0.695	1.390	0.79
		D5-60°C	106.19	102.38	100.95				
		D6-70°C	104.76	103.81	103.34				
		D7-80°C	108.09	106.66	105.24				
Colour (sensory)	Natural drying	D1-OSD	7.17	6.25	6.58	NS	0.751	NS	16.01
		D2-SD	7.92	7.08	6.50				
		D3-GHD	7.92	7.00	6.42				
	Mechanical drying	D4-50°C	7.83	7.92	6.58	NS	0.485	NS	11.74
		D5-60°C	8.00	6.92	6.33				
		D6-70°C	7.92	7.00	6.92				
		D7-80°C	7.50	6.67	6.33				
Flavour (sensory)	Natural drying	D1-OSD	6.83	6.83	6.75	NS	NS	NS	9.72
		D2-SD	7.58	6.92	6.67				
		D3-GHD	7.75	7.17	7.08				
	Mechanical drying	D4-50°C	7.50	7.17	6.58	NS	0.502	NS	12.49
		D5-60°C	7.58	6.67	6.54				
		D6-70°C	7.75	6.92	6.96				
		D7-80°C	7.00	6.50	6.33				
OAA (sensory)	Natural drying	D1-OSD	7.00	6.50	6.42	NS	0.543	NS	11.50
		D2-SD	7.58	7.00	7.00				
		D3-GHD	7.75	7.08	6.83				
	Mechanical drying	D4-50°C	7.58	7.42	6.42	NS	0.472	NS	11.77
		D5-60°C	7.75	6.75	6.29				
		D6-70°C	7.67	6.83	6.79				
		D7-80°C	7.17	6.50	6.17				

TPC, Total phenol content; TAA, Total antioxidant activity; OAA, Overall acceptability; OSD, Open-sun drying; SD, Solar drying; GHD, Greenhouse drying; CD, Critical difference; CV, Co-efficient of variance.

Fitting of drying models

Based on moisture loss data, the drying rate and moisture ratio were calculated. The coefficient of determination (R^2) was determined using SPSS-15. The three drying models (Page model, two-term model and Newton model) were compared according to their coefficient of determination, RMSE and chi-square values to determine the best-fit model for drying bael fruit pulp for different levels of thickness of pulp (Table 3).

The values of R^2 , χ^2 and RMSE of all the models ranged from 0.924 to 1, 4.4E-05 to 0.011 and 6.61E-03 to 0.102, with an average value of 0.951 to 0.995, 5.21E-04 to 2.7E-03 and 8.39E-03 to 2.06E-02 respectively.

The moisture ratio data of bael fruit pulp dried using different drying methods or temperatures and for different levels of thickness of pulp were fitted into three drying models (Table 3). It was observed that the Page model had the highest average R^2 and lowest average RMSE and χ^2

values compared to the other two models. Table 4 shows the values of constants of the best-fitted drying model (Page model). The Page model was the best-fitting for drying bael fruit pulp with various drying methods or temperatures and levels of pulp thickness, with average values of R^2 , RMSE and χ^2 being 0.995, 5.21E-04 and 8.39E-03 respectively. This model was found to be the best for drying whole and sliced turmeric rhizomes in a solar conduction dryer¹⁵ and freeze-dried aloe vera fillets¹⁶.

Suitability of the model

The accuracy of the established model for thin-layer drying of bael fruit pulp was evaluated by comparing the predicted moisture ratio of the Page model and the experimental moisture ratio. Figure 2 shows the performance of the model for all the drying methods/temperatures and levels of thickness of bael fruit pulp. The predicted moisture ratio data of



Table 3. Statistical parameters for different drying models using various drying methods and different levels of thickness of bael fruit pulp

Drying methods_ thicknesses	Two-term model			Page model			Newton model		
	R^2	Chi-square	RMSE	R^2	Chi-square	RMSE	R^2	Chi-square	RMSE
OSD_2 mm	0.999	8.44E-04	0.023	0.999	8.92E-05	0.008	0.999	8.27E-05	0.009
OSD_4 mm	0.997	4.00E-04	0.017	0.996	4.33E-04	0.019	0.996	4.01E-04	0.019
OSD_6 mm	0.997	3.94E-04	0.017	0.996	4.34E-04	0.019	0.996	4.82E-04	0.021
SD_2 mm	0.945	9.51E-03	0.081	0.99	1.34E-03	0.034	0.932	8.72E-03	0.090
SD_4 mm	0.98	3.71E-03	0.054	0.996	6.06E-04	0.023	0.929	1.10E-02	0.102
SD_6 mm	0.982	3.34E-03	0.052	0.996	7.26E-04	0.026	0.935	9.96E-03	0.097
GHD_2 mm	0.977	5.80E-03	0.054	0.987	2.20E-03	0.041	0.945	7.78E-03	0.083
GHD_4 mm	0.966	6.36E-03	0.070	0.999	1.58E-04	0.012	0.951	7.30E-03	0.083
GHD_6 mm	0.973	4.74E-03	0.061	0.999	9.22E-05	0.009	0.957	6.41E-03	0.078
TD50_2 mm	0.981	2.83E-03	0.045	0.995	5.75E-04	0.022	0.977	2.65E-03	0.050
TD50_4 mm	0.985	2.32E-03	0.043	0.983	2.45E-03	0.047	0.924	1.01E-02	0.098
TD50_6 mm	0.982	2.89E-03	0.049	0.985	2.17E-03	0.045	0.928	9.92E-03	0.097
TD60_2 mm	0.987	1.79E-03	0.039	0.996	5.15E-04	0.022	0.951	5.68E-03	0.074
TD60_4 mm	0.953	5.91E-03	0.073	0.996	5.25E-04	0.022	0.932	7.83E-03	0.087
TD60_6 mm	0.957	5.02E-03	0.067	0.993	7.44E-04	0.027	0.938	6.66E-03	0.081
TD70_2 mm	0.988	1.51E-03	0.035	0.996	4.63E-04	0.020	0.969	3.36E-03	0.056
TD70_4 mm	0.986	1.68E-03	0.039	0.997	3.10E-04	0.017	0.951	5.35E-03	0.072
TD70_6 mm	0.987	1.46E-03	0.036	0.998	2.12E-04	0.014	0.956	4.74E-03	0.068
TD80_2 mm	0.972	4.48E-03	0.058	0.993	9.07E-04	0.028	0.935	8.40E-03	0.089
TD80_4 mm	0.974	3.79E-03	0.057	0.999	1.98E-04	0.014	0.924	9.66E-03	0.096
TD80_6 mm	0.986	1.91E-03	0.041	1	4.67E-05	0.007	0.937	7.58E-03	0.085
Average	0.979	1.81E-03	0.014	0.995	5.21E-04	0.008	0.951	2.70E-03	0.021

TD50, Tray drying at 50°C; TD60, Tray drying at 60°C; TD70, Tray drying at 70°C; TD80, Tray drying at 80°C.

Table 4. Constants of the best-fitted drying model of bael fruit pulp

Drying method	Temperature (°C)	Thickness (mm)	Constants of Page model $MR = \exp(-kt^n)$		Coefficient of determination (R^2)	Chi-square (χ^2)	RMSE
			k	n			
Sun drying	–	2	0.023	1.019	0.999	8.92E-05	8.45E-03
		4	0.009	0.991	0.996	4.33E-04	1.93E-02
		6	0.004	1.059	0.996	4.34E-04	1.96E-02
Solar drying	–	2	0.000	1.685	0.990	1.34E-03	3.37E-02
		4	2.564E-5	1.818	0.996	6.06E-04	2.32E-02
		6	3.201E-5	1.748	0.996	7.26E-04	2.56E-02
Greenhouse drying	–	2	0.001	1.616	0.987	2.20E-03	4.06E-02
		4	0.000	1.741	0.999	1.58E-04	1.18E-02
		6	0.000	1.635	0.999	9.22E-05	9.08E-03
Tray drying	50	2	0.001	1.320	0.995	5.75E-04	2.22E-02
		4	6.360E-5	1.630	0.983	2.45E-03	4.68E-02
		6	3.826E-5	1.658	0.985	2.17E-03	4.45E-02
	60	2	0.001	1.572	0.996	5.15E-04	2.17E-02
		4	0.000	1.682	0.996	5.25E-04	2.23E-02
		6	0.000	1.599	0.993	7.44E-04	2.66E-02
	70	2	0.002	1.435	0.996	4.63E-04	2.04E-02
		4	0.000	1.579	0.997	3.10E-04	1.71E-02
		6	0.000	1.533	0.998	2.12E-04	1.42E-02
	80	2	0.000	1.799	0.993	9.07E-04	2.82E-02
		4	0.000	1.889	0.999	1.98E-04	1.35E-02
		6	0.000	1.701	1.000	4.67E-05	6.61E-03

bael pulp drying followed a straight line with an angle of 45°, which indicates the suitability of the Page model for describing the drying of bael fruit pulp. A similar approach for selecting a model for thin-layer drying has also been reported for carrot pomace¹⁷ and bael fruit pulp^{5,18}.

Conclusion

In this study, the bael fruit pulp was dried using various drying methods and for different levels of pulp thickness. The drying rate decreased gradually with time for various



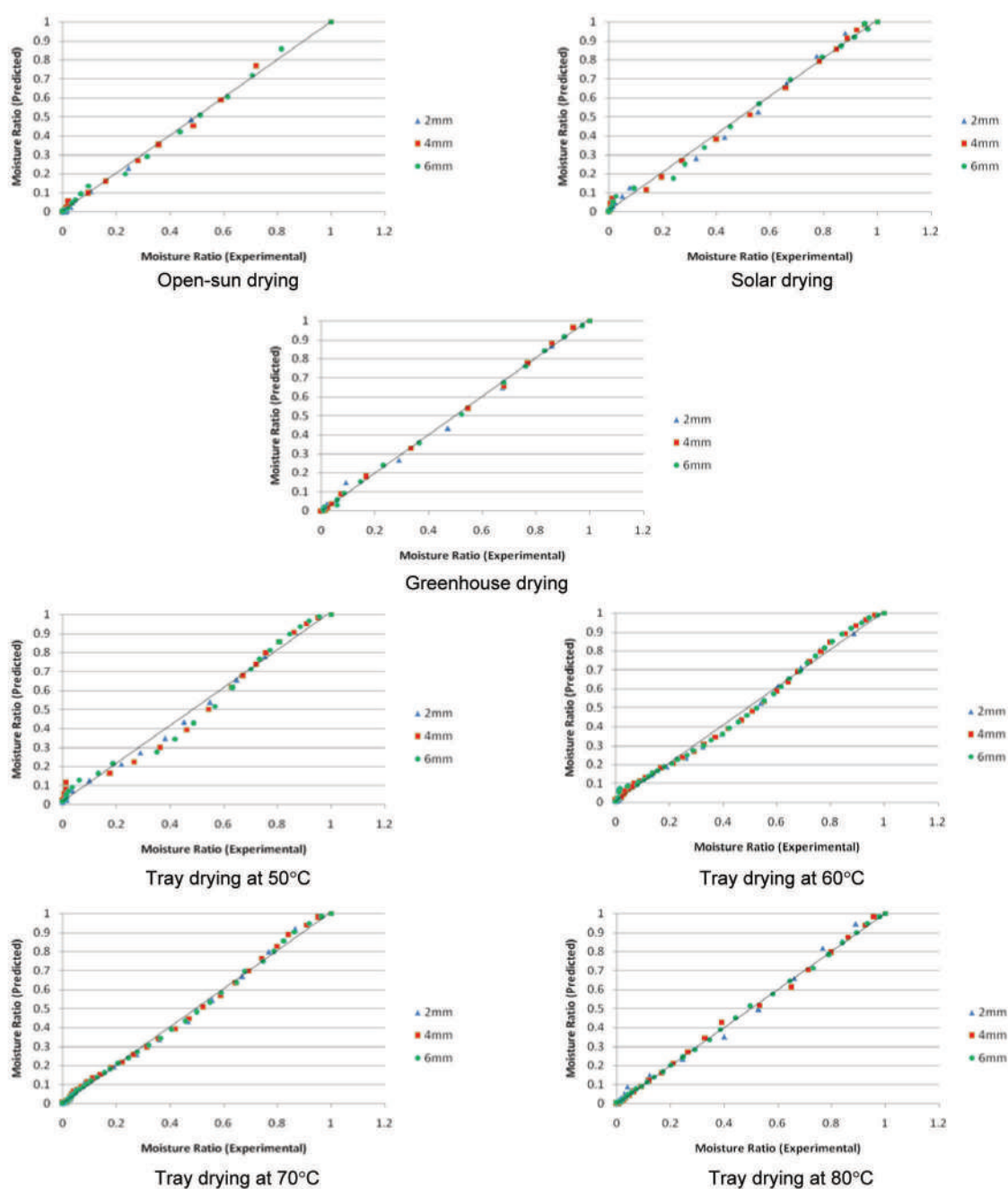


Figure 2. Experimental versus predicted moisture ratio (Page model: $MR = \exp(-kt^n)$).

drying methods and thickness of pulp. The maximum total phenol content of 41.95 mg/100 g was found in bael powder dried using the natural drying method, i.e. greenhouse drying with 2 mm pulp thickness. While in mechanical drying at 50°C and 2 mm pulp thickness, it was 43.79 mg/100 g. Maximum antioxidant activity of 107.62 mg/100 g was found in bael powder dried using a natural drying method with 2 mm thickness of bael pulp. While at 50°C and 80°C with 2 mm thickness of bael pulp, the maximum antioxidant activity of 108.09 mg/100 g was observed for mechanical drying. Maximum overall acceptability score was

found in bael powder with 2 mm thick pulp in both the drying methods, i.e. natural and mechanical. The Page model was found to be the best fitted for drying bael fruit pulp using different drying methods or temperatures and levels of pulp thickness, with average values of R^2 , RMSE and χ^2 being 0.995, 5.21E-04 and 8.39E-03 respectively.

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Exploring Mythological Influence in Amruta Patil's Adi Parva: Churning of the Ocean

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Abstract

The impact of mythology in Indian graphic novels is a fascinating exploration of storytelling, successfully merging mythology with modern visual narratives. Ancient myths are creatively reinterpreted and presented in these vibrant graphic novels, which appeal to contemporary readers by providing new insights and meanings. Indian mythology offers a vast array of characters, epics, and symbols that graphic novelists adeptly use into their works. These graphic novels revitalise mythical stories by using complex visual components and unique storytelling strategies. Indian graphic novels invite readers to explore the enduring relevance and evolving interpretations of mythology in the dynamic realm of visual storytelling. This research paper explores the complex progress of mythology and visual narrative in contemporary Indian literature, specifically examining Amruta Patil's Adi Parva: Churning of the Ocean (2012). The research begins by analysing theories of visual language, investigating the ways in which symbols and visual elements enhance the narrative in graphic novel. The study covers the examination of how graphic novels are received, assessing their influence on popular culture and their evolving interpretation of Indian mythology. This study offers a comprehensive understanding of how Indian graphic novels function as vehicles for cultural reinterpretation and contribute to the continuous development of mythological narratives in contemporary literature.

Key Words: Visual Narratives, contemporary society, Indian graphic novels, Mythology

Mythology has great importance in Indian culture, exerting influence on a wide range of ideas, themes, and narratives. Indian literature has been profoundly impacted by it and has been transmitted across centuries via oral traditions. Myths are intricate narratives that provide profound insights into the nature of the world and human existence, serving as symbolic representations of primal impulses and comprehension of the cosmos. The resurgence of interest in ancient myths among creative writers has been ignited by the recognition of mythology as a source of universal emotions. Indian authors have incorporated mythological elements into



numerous genres of literature, drawing inspiration from Vedic scriptures, Epics, and Puranas. The advent of globalisation in today's day provides an opportunity to reinterpret and re-examine myths, thereby offering new perspectives. Mythofiction, also known as mythic fiction or mythological fiction, is a contemporary trend that involves the reinterpretation, recreation, retelling, remembrance, reintroduction, and reinvention of tales from a contemporary standpoint. Authors such as Anand Neelakantan, Amish Tripathi, Ashok K Banker, Devdutt Pattanaik, Nilanjan P Choudhuri, Chitra Banerjee Divakaruni, Kavita Kane, and Amruta Patil use mythology as a means to discover fresh avenues for artistic representation and build a novel narrative in Indian literature produced in the English language.

Writers innovate semiotics by developing new approaches and styles, aiming to portray the irrationality of existence, its fundamental drives, and ceaseless battles via the use of myths. Ancient myths provide the foundation of history, philosophy, and psychology in contemporary popular culture. Through their involvement in creative processes, they evaluate, examine, and evaluate modern society. Currently, there is a growing trend of experimentation and innovation in several genres of Indian fiction, including graphic novels, science fiction, chick literature, and diaspora writing. Their approaches to examine Indian literature provide a formidable obstacle to our traditional technique, particularly due to the emergence and widespread adoption of novel forms in the contemporary era.

Contemporary graphic novels, which blend text and art to create a compelling tale, have grown to be an important part of Indian mythology. These novels bridge eras and cultures, enabling readers to understand and interact with India's rich mythology. The visual aspect of graphic novels is essential in depicting deities, divine entities, mythological creatures, and the complex symbolism found in Indian mythology. Furthermore, the visual features provide an aesthetic charm that may fascinate a wide range of readers, even those who do not often interact with conventional texts.



Graphic novels provide a distinct platform for reimagining and retelling tales, showcasing the cultural backdrop of contemporary society. Artists and writers have the ability to include their own perspectives into these tales, while still acknowledging the essential themes and principles of Indian mythology. Adaptation is crucial for preserving the significance and applicability of myths in contemporary contexts. Indian myths are characterised by their elaborate story frameworks and the presence of several characters. Graphic novels effectively convey these narratives via unified visual storytelling, hence improving accessibility and understanding for readers. Graphic novels facilitate the dissemination of Indian mythological concepts to a worldwide audience by surpassing language boundaries, so promoting a more extensive comprehension of Indian culture and mythology.

Graphic novels often consist of multimodal tales. They communicate their narratives by using both verbal and visual mediums to establish significances. Will Eisner, a renowned figure in the comic industry, used the term "sequential art" to encompass both comics and graphic novels. He defines it as, "a means of creative expression, a distinct discipline, an art and literary form that deals with the arrangement of pictures or images and words to narrate a story or dramatize an idea" (11). Indian Graphic Novels, originating in the latter half of the 20th century, depicted mythology, everyday life, and imaginative elements, providing profound insights into the culture and customs of India. Anant Pai released the first Indian comic book, *Amar Chitra Katha*, in 1967. The development of Indian graphic novels has progressed swiftly during the 21st century, marked by the emergence of the first Indian Graphic Novel, *River of Stories*, authored and drawn by Orijit Sen in 1994. The genre has undergone a transformation from its origins as comic book series to books, effectively exploring and discussing social, cultural, and political matters. In the present time, a number of authors are making significant contributions to Indian Graphic Novels. Some notable examples include Sarnath Banerjee's works such as *Corridor* (2004), *The Barn Owl's Wondrous Capers* (2007), and *The Harappa Flies*



(2011). Additionally, Naseer Ahmed's Kashmir Pending (2007), Saraswati Napal's Sita, Daughter of the Earth (2011), Draupadi: The Fire-Born Princess (2013) and Chhotu: A Tale of Partition and Love (2019) are also worth mentioning. The recent surge in popularity of Graphic Novels may be attributed to the contemporary preference for novels that include visual elements. The presence of image illustrations in a book also has a big impact on capturing the attention of readers.

Graphic novels typically have a structural framework consisting of a panel, voiceover, speech bubbles, emanta, expressions, gutter, narration, colour, graphic weight, foreground, midground, background, and transitions. The panel provides a perspective for the reader, similar to adjusting the focus of a camera. Voiceover establishes a direct communication channel with the reader, allowing for a discourse about the story. Speech bubbles visually represent a character's thoughts or utterances, while emanta uses symbols like hearts, question marks, and tears to convey emotions. Expressions convey facial or bodily gestures to convey emotional states. The gutter, the space between two panels, prompts the reader to infer events throughout the temporal gaps. Narration uses textual elements and visual imagery to convey the storyline, leaving little room for the reader's interpretation. Colour enhances dramatic elements within narratives, while graphic weight defines how a picture differs or contracts. Foreground, midground, and background provide a comprehensive understanding of the topic, while transitions, such as the gutter, serve as the space between panels in comic or graphic novels. Overall, graphic books effectively convey their intended message and engage the reader.

When analysing a graphic novel, it is crucial to focus our attention on the specific characteristics pertaining to the text, such as,

- the perspective it takes.
- The balance between the written information and its visual features
- Elements of colours and brush strokes.
- Plot: The sequence of events in a story or narrative.



- Grammatical organisation of sentence: The structure and organisation of words and phrases in a sentence.

Amruta Patil is an author of Graphic Novels who gained acclaim for her visual arts and use of new methods in her artwork. Her works not only include modern subjects, but also showcase the display of graphic arts that dynamically convey the depth of her characters and the tale. Amruta Patil, born in Pune in April 1979, gained recognition as the pioneering female Graphic Novelist from India. Her Graphic Novels are enhanced by her independent and traditional visual style, which encompasses watercolour, charcoal, acrylic painting, and collage, resulting in a more aesthetically pleasing outcome. She has used bold portrayals to depict figures from Indian mythology in order to reveal contemporary social concerns, political dilemmas, and environmental abuse that are pertinent to present-day audiences.

Graphic novels, which combine text and images where the images serve to support and offer context for the tales, continue to be both captivating and easily comprehensible. Amruta Patil has used graphic novels as a means to reveal reoccurring motifs such as mythology, sustainable lifestyles, sexuality, identity, the environment, and oral traditions. Through this method, some crucial topics of society are disseminated to the general public and are also relevant to contemporary society. Furthermore, delving into mythology not only simplifies the process of reading, but also provides a profound understanding of the narrative, allowing readers to acquire information about India's ancient history, traditions, and culture.

Adi Parva: Churning of the Ocean (2012) is the second Graphic Novel authored by Patil. Many individuals are drawn to reading epics when they are presented with visual depictions, which is why a significant number of people are familiar with epics via various forms of visual media rather than primarily through books. Amruta Patil's Adi Parva: Churning of the Ocean showcases captivating images, the artist's ingenuity, and imagination as it presents the many characters and history of the Mahabharata. Patil included the intellectual elements of Mahabharata



that resonate with contemporary audiences. The Mahabharata narrative is framed by a meta-narrative in which a woman, who is subsequently revealed to be the goddess Ganga, narrates the story to the audience. The story presents events from the Mahabharata in a non-teleological or chronological fashion. The Adi Parva employs a narrative style that alternates between two levels, progressing thematically rather than only depending on the chronological sequence of events. The narrative's levels are visually distinguished by the deliberate use of lines and colours. The chosen selection emphasises the diverse tones and spatio-temporal characteristics of both the narrative and the actual setting where the storytelling takes place. The first chapters of Adi Parva fulfil the function of creating separate narrative places and levels. One of these areas is a dynamic and referential palimpsest, distinguished by vibrant hues, that forms the narrative universe. In comparison, the other region seems external and devoid of vibrancy, giving the impression of being blurred and mundane, with a prevailing hue of charcoal grey. (Fig 4.1)



Fig 4.1 Free-point (12)

The first chapter, titled "Sutrathar," begins with the culmination of the Kurukshetra conflict, signifying the epitome of the Mahabharata narrative. However, the story then shifts to the investigation of the beginnings of the universe. The first panel features an illustration of a vulture, which is then followed in the next four panels.

The next image shifts to a broader perspective, revealing the existence of white people distinguished by ultramarine contours, symbolising departed persons and those in a state of grief. The background is adorned with an assortment of crimson hues. Page five has a remarkable similarity to the morphology of blood cells inside a blood artery. Prior to reaching the last page of the chapter, there is a full-page panel that shows a metamorphosis taking place. In this transition, the white individuals and scarlet background take on the look of blood platelets. Positioned at the top left corner of the visual composition is a representation of a dead person, showing the head and upper body, with visible blood flowing from the area around the skull. Patil skilfully used visual elements to properly communicate the significance of blood throughout her narrative. (Fig 4.2)



Fig 4.2 Begging (24)

The latter portions of the chapter reveal the noticeable existence of anchoring textual bubbles. The bubbles are created by an anonymous narrator and are penned by hand without any noticeable emphasis. The chapter relies on Patil's analysis of Paul Gauguin's Vision after the Sermon, which sparked her investigation into different shades of red and their contrast with ultramarine blues.

Patil's *Adi Parva*, explore the complex influence of mythology in contemporary society, taking inspiration from Roland Barthes' influential text, "Mythologies." Barthes' analysis of the manner in which myths operate as cultural symbols and

transmitters of social principles is especially pertinent to Patil's artistic pursuits. Patil adeptly reinterprets old Indian stories in "Adi Parva," expertly weaving them together with new surroundings to contemplate the collective consciousness of present-day society. Patil uses Barthes' idea of myths as cultural structures to analyse and scrutinise prevalent beliefs, hence questioning and challenging society conventions within the narrative space.

Patil's graphic novels use mythical ideas to shed light on contemporary concerns and societal systems via a combination of visual and narrative elements. By using visual symbolism and storytelling techniques, she examines the several layers of cultural importance that are intricately woven within myths. In doing so, she illuminates the enduring impact of these ancient legends on our perception and comprehension of the world. By doing this, Patil actively interacts with Barthes' concept that. 'Myths are omnipresent in everyday life, shaping perspectives and strengthening societal beliefs.' Patil's contribution in this endeavour helps to a wider discussion on the fluid and ever-changing connection between mythology and the continuously developing fabric of contemporary society.

Patil's novels, include a complex process of transforming myths via several layers. The historical transfer from oral traditions to written texts included a change in story form, emphasis, and the level of involvement of the audience. The oral tradition facilitated flexibility and spontaneity, enabling the tale to be adjusted according to the audience and circumstances. Written documents led to the standardisation of myths, which were often shaped by the perspectives and objectives of the writers and readers.

Within the modern visual media, specifically in graphic novels, the concept of adaptation assumes a fresh perspective. Patil's visual storytelling is a unique style of adaptation that effectively translates mythology into a language that seamlessly blends picture and narrative. The visual story enables an active and dynamic interaction with the mythical content, as readers explore the interrelationship



between written word and graphic representation. Patil's use of graphics enhances the interpretive aspect of the tales, providing readers with a novel and immersive perspective.

Furthermore, here readers are not passive consumers of text, but rather actively interact with a visual environment that supports and enriches his enduring narrative. The visual medium has the capacity to elicit a more intense and emotive reaction, influencing the way the altered myths are seen in a unique manner. As the saying "A picture is worth a thousand words" implies that an image may convey a complex message or idea more effectively than a large amount of text; In the field of literature, graphic novels play a crucial role in evolving the reading of mythical works in current society.

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A study on Profitability Performance based on Investment of Indian Cement Industry

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Abstract:

Maximum Profit is the final aim of any organization. The gain arising from the investment of capital in the business, the excess of incomes over expenditure is monetary gain or profit in any transactions or occupation. Profitability means the ability of any business unit to earn profit continuously. Profitability is a situation in which an entity is generating a profit. Profit performance is a measure of a company's ability to generate profits from its operations. All stakeholders connected with the business entity are interested to know about the profitability of the entity. In this paper, an attempt is made to study profitability performance based on Investment in the business of selected Cement companies in India. The top 10 cement manufacturing companies in India were selected for study and decided to examine the profitability performance based on investment for the period of 10 years from 2010-11 to 2019-20. The Return on Capital Employed, Return on Equity Shareholders' Fund, and Earnings per Share ratio are calculated to measure profitability performance based on investment. Statistical tools like Mean, S.D., and ANOVA were used to analyze data and test hypotheses. The cement Industry is prime and one of the crucial industries in India as in other countries. In India first Cement Company was established in the year 1914 at Porbandar, Gujarat with a capacity of 10,000 tonnes. Currently, India is the 2nd largest producer in worldwide production of cement after China. A huge investment is required to establish the cement manufacturing plant. Hence organizations are interested to earn more and more returns as profit.

Keywords: Profit, Profitability, cement manufacture, profitability ratio, investment

I. INTRODUCTION:



Currently, India is moving quickly towards a Developed country from a developing country. At present India stands at the 3rd place in economy and trying to reach a 5 trillion \$ economy. The growth and development of any country depend on its economic development and growth. In the country, three sectors are very important for economic development. These three sectors are the agricultural sector (Primary Sector), Industrial sector (Secondary Sector), and Service sector. Every sector plays a vital role and is significant for the economic development of each nation. In the present era, the industrial sector has shaped the economic destiny of various developing countries, especially in the case of India. Made in India is now working very smoothly and playing an important role in the manufacturing sector. One of the important sectors of the Indian industry is Cement Industry. The cement industry provides the basic foundation of infrastructural development and provides social overheads in the country.

At present, the government is emphasizing infrastructure development which can be achieved only through the presence of a strong cement industry. Cement is the basic raw material for the construction of roads, bridges, buildings, etc.

India is a huge country and has a vast geographical size and a massive population; various construction activities undertaken by the central Govt., State Govt., Public Sector Undertakings and other organizations, including the private sector generate huge demand for cement. Moreover, housing is the first and foremost requirement of every household, and therefore, the first private cement industry was laid down in the year 1914, when it first started working in Gujarat.

As India has a huge quantity and quality of limestone deposits throughout the country, the cement industry promises huge growth potential. India has a total of 210 large cement plants out of which 77 are in the states of Andhra Pradesh, Rajasthan, and Tamil Nadu. India is in the 2nd position in the production of cement with 320 MTPA in worldwide production after China followed by the USA, Turkey, and other countries. It is expected to reach at reach 401 MTPA in 2020-21. India's cement production is expected to rise between 5-7 percent in FY20, backed by demands in roads, urban infrastructure, and commercial real estate. The compound Annual Growth Rate (CAGR) in the production of cement in India is 5.59%. The Indian cement industry, a cornerstone of the nation's infrastructure development, has witnessed a dynamic and often volatile journey in terms of profit performance. In recent years, a confluence of factors has reshaped the landscape, presenting both challenges and opportunities for cement manufacturers.

Thrust on infrastructure development and Housing for all with 2 crore houses in Urban areas and 4 Rural areas is likely to revive the demand for the cement sector. These sectors are considered to drive the cement industries in India to a great extent, which held nearly 67 percent



of the total cement consumption in India. Out of the different end-user industries of cement, the housing segment accounted for the highest demand in FY 2018. Within this, 38% of demand was generated by the rural housing sector, followed by the urban housing sector was 32%. Such high demand for cement from the housing sector may be attributed to the fast execution of affordable government housing schemes like Pradhan Mantri Awas Yojna and Housing for All by 2022. Apart from housing, commercial, and industrial investments, the infrastructure segment accounted for a considerable demand for cement in India. The CAGR for the consumption of cement is 5.20%.

There has been a high growth seen in cement manufacturing in the last decade. Huge long-term, as well as short-term funds are required for the cement manufacturing unit. Hence, it requires checking the profit performance of cement companies. The body of the paper may consist of the following points.

1. Introduction
2. Profitability
3. Literature Review
4. Research Methodology
5. Data Analysis
6. Conclusion
7. References
8. Annexure

II. PROFITABILITY:

In economics, profit is the difference between revenue that an economic entity has received from its outputs and the total costs of its inputs, also known as surplus value. It is equal to total revenue minus total cost, including both explicit and implicit costs.

Profitability is a measure of an organization's profit relative to its expenses. More efficient organizations will realize more profit as a percentage of their expenses than a less efficient organization, which must spend more to generate the same profit. Profit performance is a measure of a company's ability to generate profits from its operations.

Profitability can tell key stakeholders whether a company can sustain its position in the market and continue to grow. It is the extent to which a company earns a profit. There are two parts to a company's profitability: revenue and expenses. As such, a company is profitable if its revenue exceeds its expenses.

This metric is often expressed as a financial ratio to help management, analysts, and investors better understand how the company can earn the money necessary to cover its expenses



and other company-related costs. These ratios include profit margins and return on equity (ROE). Another key ratio is the earnings before interest, taxes, depreciation, and amortization (EBITDA). This ratio lets stakeholders know whether a company is financially healthy and how it can generate revenue.

III. LITERATURE REVIEW:

Krishna Swarup Gupta (1988) in his analysis on “Financial Statements of Indian Cement Industry: A case study of Associated Cement Companies”, brought the results that the rate of return on total capital employed was measured at 4.2% against the ideal rate of 18% to 24% which is very poor. The total investment had been highly unprofitable. However, the activity and liquidity position showed significant levels. The stock turnover ratio was uniformly good. Debtors varied from 5% to 8% on total current assets. Credit and collection policies were effectively enforced. The percentage of the equity to net fixed assets was below 45%, indicating that shareholders’ funds were inadequate to finance fixed assets.

Chandrasekaran N. (1993) had attempted to examine “Determinants of Profitability in Cement Industry”. The study aimed at drawing inference on the impact of policy measures that led to changes in price and distribution policies relevant to the cement industry. Determinants of profitability were analysed using the technique of ordinary least squares. To find out whether the profitability function has shifted after estimating the function and the test was also done to ascertain the inference. The main findings of this study were that the profitability of the company was based on the assets structure and proper utilization of the production capacity. Some of the main changes in the cement industry environment during the 1980s identified in this study were: from complete control to decontrol, a number of new entrants and substantial additions of capacity, changing technology from inefficient wet process to efficient dry process and from conditions of scarcity of cement to near gloat in the market.

Padmaja Manoharan (2002) through the analytical study “An Analytical study in Profitability of Cement Industry in India” has revealed the variation in profitability of Indian cement companies depending on age, size, and region. The study identified that the quality of earnings depends on management and leverage management. Further, the analysis concludes that the profitability and quality of earnings are influenced by the liquidity factor.

P. K. Das (2006) examined “The Dividend practices in selected Cement Industry” from 1985-86 to 2004-2005. He found that the company followed a conservative dividend policy during the study period. There was a significant increase in profitability due to earnings per share and the capital employed current ratio was in decreasing trend.



G. Vijayakumar (2009) had completed his Ph. D. on “Financial Performance of Cement Industry in India” in the year 2009. He covered technological changes, new investment, merger and acquisition, government initiatives, Ready mix concrete business. 15 cement companies were selected for study by him. The study covers a period of 10 years i.e. from 1998–99 to 2007-08. The data was analysed by working of Solvency Ratio, Profitability Ratio, and Management efficiency, and other various statistical tools were also used in the study. He found that the average current ratio of the selected companies is 1.45 which is below the ideal ratio of 2:1, while the average quick ratio of the selected companies is 1.22, which is above the ideal industrial benchmark of 1:1. The average current assets to fixed assets ratio is 37% for the samples selected. It is almost matching with the ideal ratio. The average debt-equity ratio is 1.93 times for the samples selected which is almost near to the ideal ratio. The average Gross Profit Ratio for the samples studied is 16.78% and the average net profit ratio of the sample selected is 2.26% while the Average Operating Profit Ratio of all selected samples is 19.57 % and average ROI for the sample selected is 9.07%. The average return in terms of net profit on common equity for the selected sample is 2.11 times and the average dividend pay-out ratio of the selected sample is 0.19:1 while the average annual growth rate of EPS is 61%.

Dr. S. J. Bhayani (2010) had published an article on “Determinant of Profitability in Indian Cement Industry: An Economic Analysis” in the South Asian Journal of Management in the year 2010. In this article, he attempted to identify which variables are judging the profitability of the Indian Cement Industry. The study covers all listed cement firms working in India from 2001 to 2008. To determine profitability backward regression analysis was used on the variables of the study. The result of the study shows that liquidity, age of firm, operating profit ratio, interest rate, and the inflation rate have played a vital role in the determination of the profitability of the Indian Cement Industry.

Zubair Arshad and Muhammad Yasir Gondal (2013) made a study on “Impact of working capital management on profitability- A case of the Pakistan cement industry”. They selected 21 cement companies for a study period of 6 years from 2004-2005 to 2009-2010. The study applied regression analysis and various ratios. The study suggested that the profitability of the undertaking might be increased by shortening inventory periods. The positive relationship between the account receivable period and profitability could be reduced. Therefore their power insufficient competition can lead to a decrease in profitability. Empirical findings of the study indicate that the current ratio and net current ratio on total ratio have significantly positive effects on firm profitability. This means that while accounts receivables and inventory periods lengthen,



profitability increases, or vice versa. The other variables that have significant effects on firm profitability are quick ratio affecting it negatively. This means that any increase in stock leads profits to down. The other variables included in the regression model working capital turnover ratio and inventory turnover ratio has no statistically significant effects on firm profitability.

Ankit D. Patel (2015) had done his Ph. D. on “Financial Analysis of Cement Industry of India: A Statistical Approach” in 2015. He has selected 18 cement companies in his study. The selected companies were Prism Cement Ltd., The India Cement Ltd., Sanghi Industry Ltd., UltraTech Cement Ltd., Binani Cement Ltd., Grasim Industry Ltd., Birla Corporation Ltd., J. K. Cement Ltd., J. K. Lakshmi Cement Ltd., Chettinad Cement Ltd., N. C. L. Industries Ltd., Shree Cement Ltd., Mangalam Cement Ltd., Madras Cement Ltd., Barak Valley Cement Ltd., Sagar Cement Ltd., Everest Industries Ltd., and Deccan Cement Ltd. He covered the period of 10 years from 2002-03 to 2011-12. In his study, he discussed facts of the cement industry in India, strong points of the cement industry and stimulations need for it, comparison with global regional consumption production, and per-capita consumption by different countries. For analysis, he used ratio analysis, trend analysis, and ANOVA test. He found that the Gross Profit ratio of the cement industry in India during the first half of the decade was improved from 11.04 to 27.88, while during the second half of the decade it declined from 29.32 to 13.37. The Net Profit Margin ratio of the cement industry of India during the first half of the decade was improved from -6.57 to 16.46, while during the second half of the decade it was declining from 15.76 to 3.12. The Return on Capital Employed Ratio of the cement industry of India during the first half of the decade was improved from -0.425 to 24.65 and then the trend of Return on Capital Employed Ratio started declining. During the second half of the decade, it was declining from 23.37 to 6.91. The Return on Shareholders' Fund Ratio of the cement industry of India during the first half of the decade was improved from -5.57 to 27.86 respectively and then the trend of Return on Shareholders' Fund Ratio started declining. During the second half of the decade, it was declining from 25.97 to 3.14. He also analyzed that so far as the current ratio is a concern, the trend of this ratio was downward. This ratio indicates a linear downward trend. In the case of the debt-equity ratio had a linear declining trend with a regression coefficient of -15.085 which means during the decade the cement industry of India's performance was satisfactory because the cement industry highly depended on its own equity funds and can repay its long term liability easily.

Pankaj Yadav (2017) published an article “An Analysis of Indian Cement Industries based on Profitability Performance”. He attempts to assess the profitability position of cement companies. He selected 10 listed cement companies for 5 years period i.e. from 2012-13 to 2016-17. ACC



Cement Ltd., Ambuja Cement Ltd., Birla Corporation Ltd., Dalmia Cement Ltd., Heidelberg Cement Ltd., India Cement Ltd., Manglam Cement Ltd., Prism Cement Ltd., Shree Cement Ltd., UltraTech Cement Ltd. were selected by him. He measured the Operating Profit Ratio, PBIT Margin, Net Profit Ratio, Return on Capital Employed Ratio, Return on Equity Shareholders' Fund, Return on Long-term Fund, Earnings per Share, and Dividend per share. Motaal Rank Test was used by him to test hypotheses. He concludes that the companies selected for the study show that the industry is somewhat doing well as far as profitability ratios are concerned. UltraTech Cement Ltd., Ambuja Cement Ltd., Shree Cement Ltd., and ACC Cement Ltd. are a top performer in the industry while Prism Cement and Heidelberg Cement perform badly.

IV. RESEARCH METHODOLOGY:

I.I Objectives:

To examine the profitability performance based on Investment during the period of study of the selected cement companies under study.

I.II Hypotheses:

Null hypotheses constructed for the study are as under:

Ho₁ There is no significant difference in the Return on Capital Employed ratio of selected cement companies.

Ho₂ There is no significant difference in the Return on Equity Shareholder's Fund ratio of selected cement companies.

Ho₃ There is no significant difference in the Earning per Share (EPS) ratio of selected cement companies.

Alternative hypotheses constructed for the study are as under:

H₁₁ There is significant difference in the Return on Capital Employed ratio of selected cement companies.

H₁₂ There is significant difference in the Return on Equity Shareholder's Fund ratio of selected cement companies.

H₁₃ There is significant difference in the Earning per Share (EPS) ratio of selected cement companies.

I.III Universe:

The universe of the study consists of all the limited companies working in India and listed on the stock exchange of India in the cement industry.

I.IV Sample:



The top 10 Indian cement companies were selected based on Revenue and Market share as of 31st March 2020.

I.V Period of Study:

The period of the study is 10 years i.e. 2010-11 to 2019-20.

I.VI Data Collection:

The study is totally based on subsidiary data. The required data for the present study has been collected from the published annual reports and financial statements of selected cement companies in India.

I.VII Tools and Techniques for Data Analysis:

Out of different ratios, three key ratios to measure profitability performance based on Investment were calculated. The Return on Capital Employed ratio, Return on Equity shareholders' Fund ratio and Earning per Share (EPS) ratio was calculated.

For statistical analysis, tools viz. EXCEL and SPSS 22.0 trial versions were used. For the comparison of different ratios among selected 10 companies in the cement sector, techniques of statistical analysis like parametric test (ANOVA) or non-parametric test (Kruskal -Wallis test) can be applied. To decide, which test is applicable for a specific ratio, first of all, the normality assumption is verified using Shapiro-Wilk Test. If the normality assumption is violated, then a non-parametric test (Kruskal -Wallis test) is applied. If the normality assumption is not violated, then a parametric test (ANOVA) is applied. ANOVA has one more assumption of homogeneity of variance. If the homogeneity of variance assumption is not violated then Fisher's ANOVA is used and if the homogeneity of variance assumption is violated then Welch ANOVA is used. The assumption of Normality and assumption of homogeneity of variance are shown in Annexure – I and Annexure – II respectively.

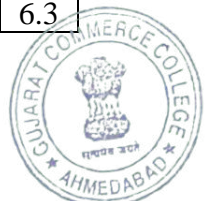
V. Data Analysis:

V.I Return on Capital Employed Ratio:

The Return on Capital Employed ratio for the period of study for 10 cement companies is as under:

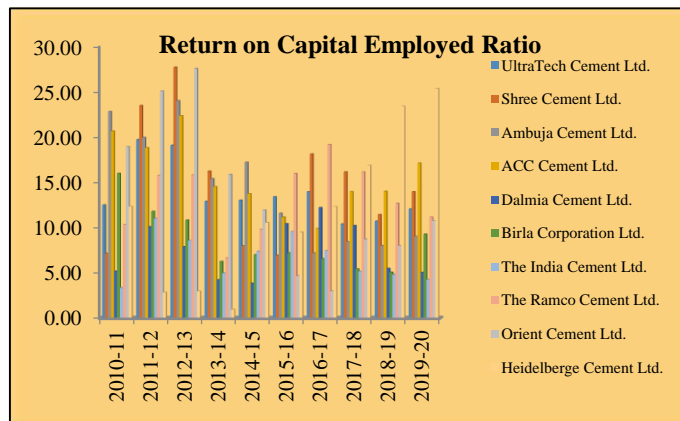
Table: 1 Return on Capital Employed Ratio

Name	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Avg	SD
UCL	12.4	19.6	19.0	12.8	12.9	13.3	13.9	10.3	10.7	12.0	13.7	3.1
ACL	7.15	23.4	27.6	16.2	7.96	6.94	18.0	16.1	11.4	13.9	14.8	6.9
ACCCL	22.7	19.9	23.9	15.3	17.1	11.5	7.17	8.42	8.00	9.01	14.3	6.3



SCL	20.6	18.7	22.3	14.4	13.7	11.1	9.89	13.9	13.9	17.0	15.5	4.0
DCL	5.17	10.0	7.86	4.23	3.84	10.4	12.1	10.1	5.48	5.04	7.45	3.0
BCL	15.9	11.7	10.8	6.25	6.99	7.19	6.55	5.42	5.05	9.25	8.52	3.4
ICL	3.35	10.9	8.56	4.96	7.36	9.53	7.45	5.16	4.81	4.25	6.64	2.5
RCL	10.3	15.7	15.7	6.63	9.78	15.9	19.1	16.1	12.6	11.1	13.3	3.8
OCL	18.9	25.0	27.5	15.8	11.9	4.66	2.99	8.68	7.99	10.7	13.4	8.2
HCL	12.3	2.84	2.97	0.95	10.5	9.48	12.2	16.8	23.3	25.3	11.6	8.3
Overall	11.96											6.0

Graph: 1 Return on Capital Employed Ratio



Interpretation:

From Table- 1 and Graph-1, it is clear that the overall mean of the Return on Capital Employed Ratio for selected companies for the selected period of study was 11.96% and S.D. was 6.04. The range of the Return on Capital Employed ratio was 0.95 to 27.67. The highest ratio during the period was 27.67 for Shree Cement Ltd. in the year 2012-13 while the lowest ratio was 0.95 for Heidelberge Cement Ltd. in the year 2013-14. Out of 10 selected companies, there were 6 companies show Return on Capital Employed ratio higher than the overall average ratio. Those six companies are UltraTech Cement Ltd., Ambuja Cement Ltd., ACC Cements Ltd., Shree Cement Ltd., The Ramco Cement Ltd., and Orient Cement Ltd. with 13.75, 14.34, 15.59, 14.89, 13.32 and 13.43 respectively. The highest average Return on Capital Employed ratio during the period of study was 15.59 for ACC Cement Ltd.

- UltraTech Cement Ltd. shows a ratio between 10.37 and 19.69.
- Shree Cement Ltd. shows a ratio between 6.94 and 27.67. It's a very high-level variation in ratio.
- Ambuja Cement Ltd. shows a ratio between 7.17 and 23.97.
- ACC Cement Ltd. shows a ratio between 9.89 and 22.31.
- Dalmia Cement Ltd. shows a ratio between 3.84 and 12.17.



- Birla Corporation Ltd. shows a ratio between 5.05 and 15.95.
- The India Cement Ltd. varies between 3.35 and 10.99.
- The Ramco Cement Ltd. shows a ratio between 6.63 and 19.12.
- Orient Cement Ltd. shows a ratio between 2.99 and 27.54. It shows very high volatility in Return on Capital Employed ratio.
- Heidelberge Cement Ltd. shows a ratio between 0.95 and 25.32. It shows very high fluctuation in Return on Capital Employed ratio.

Test of Hypothesis:

Ho₁ There is no significant difference in the Return on Capital Employed ratio of selected cement companies.

H1₁ There is significant difference in the Return on Capital Employed ratio of selected cement companies.

Mean Rank for Return on Capital Employed Ratio as per KW Test

Name of the	N	Mean	Company
ACC Cement	10	71.70	1
UltraTech	10	64.50	2
Shree Cement	10	63.10	3
Ambuja Cement	10	61.00	4
The Ramco	10	60.50	5
Orient Cement	10	53.80	6
Heidelberge	10	48.10	7
Birla Corporation	10	33.00	8
Dalmia Cement	10	27.10	9
The India	10	22.20	10

Test Statistics

	Return on Capital Employed Ratio
<i>Chi-Square (KW-ANOVA)</i>	31.910
<i>Df</i>	9
<i>Asymptotic Sig.</i>	0.000

It can be observed from the above table that the p-value of the **Kruskal-Wallis Test** is less than 0.01 which indicates that the null hypothesis is rejected at 1% level of significance. It shows that there is a significant difference in Return on Capital Employed ratio between selected companies.



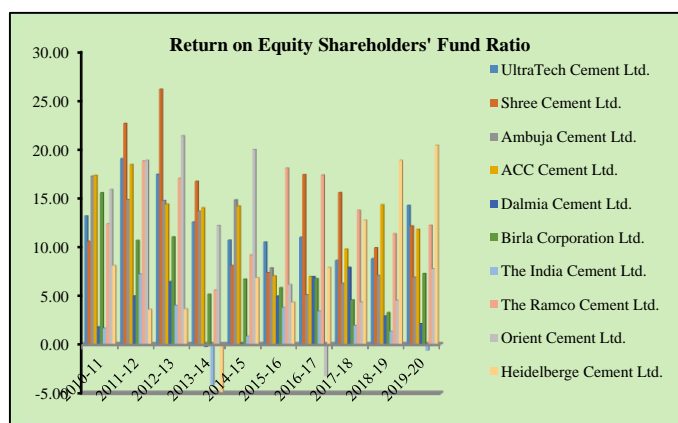
V.II Return on Equity Shareholders' Fund Ratio:

The Return on Equity Shareholders' Fund ratio for the period of study for 10 cement companies is as under:

Table: 2 Return on Equity Shareholders' Fund Ratio

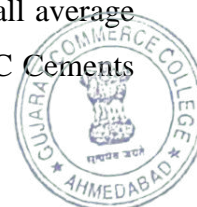
Name	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Avg	SD
UCL	13.1	19.0	17.4	12.5	10.6	10.4	10.9	8.61	8.79	14.2	12.5	3.4
ACL	10.5	22.6	26.1	16.7	8.08	7.36	17.4	15.5	9.91	12.1	14.6	6.2
ACCCL	17.2	14.8	14.7	13.6	14.8	7.84	5.09	6.26	7.08	6.88	10.8	4.5
SCL	17.3	18.4	14.3	14.0	14.1	7.01	6.95	9.77	14.3	11.7	12.8	3.9
DCL	1.79	4.96	6.42	-	0.10	4.95	6.94	7.89	2.90	2.12	3.78	2.8
BCL	15.5	10.6	11.0	5.14	6.69	5.81	6.74	4.56	3.26	7.26	7.67	3.7
ICL	1.67	7.20	4.00	-	0.82	3.78	3.39	1.93	1.33	-	1.92	3.0
RCL	12.3	18.7	17.0	5.55	9.16	18.0	17.3	13.7	11.3	12.2	13.5	4.2
OCL	15.8	18.8	21.3	12.1	19.9	6.12	-	4.33	4.51	7.74	10.7	8.1
HCL	8.08	3.58	3.64	-	6.83	4.32	7.88	12.7	18.8	20.3	8.14	7.5
Overall	9.67											6.3

Graph: 2 Return on Equity Shareholders' Fund Ratio



Interpretation:

From Table-2 and Graph-2, it is clear that the overall mean of the Return on Equity Shareholders' Fund Ratio for selected companies for the selected period of study was 9.67% and S.D. was 6.33. The range of ratio was -4.89 to 26.12. The highest ratio during the period was 26.12 for Shree Cement Ltd. in the year 2012-13 while the lowest ratio was -4.89 for Heidelberg Cement Ltd. in the year 2013-14. Out of 10 selected companies, there were 6 companies show Return on Equity Share Holders' Fund ratio higher than the overall average ratio. Those six companies are UltraTech Cement Ltd., Ambuja Cement Ltd., ACC Cements



Ltd., Shree Cement Ltd., The Ramco Cement Ltd., and Orient Cement Ltd. with 12.59, 10.84, 12.81, 14.65, 13.56 and 10.77 respectively. The highest average Return on Equity Share Holders' Fund ratio during the period of study was 14.65 for Shree Cement Ltd.

- UltraTech Cement Ltd. shows a ratio between 8.61 and 19.02.
- Shree Cement Ltd. shows a ratio between 7.36 and 26.12. It's a very high-level variation in ratio.
- Ambuja Cement Ltd. shows a ratio between 5.09 and 17.24.
- ACC Cement Ltd. shows a ratio between 6.95 and 18.43.
- Dalmia Cement Ltd. shows a ratio between - 0.27 and 7.89.
- Birla Corporation Ltd. shows a ratio between 3.26 and 15.54.
- The India Cement Ltd. varies between - 4.22 and 7.20.
- The Ramco Cement Ltd. shows a ratio between 5.55 and 18.78.
- Orient Cement Ltd. shows a ratio between - 3.25 and 21.36. It shows very high volatility in Return on Equity Share Holders' Fund ratio.
- Heidelberge Cement Ltd. shows a ratio between - 4.89 and 20.39. It shows very high fluctuation in Return on Equity Share Holders' Fund ratio.

Test of Hypothesis:

Ho₂ There is no significant difference in the Return on Equity Share Holders' Fund ratio of selected cement companies.

H₁₂ There is significant difference in the Return on Equity Share Holders' Fund ratio of selected cement companies.

Robust Tests of Equality of Means (Welch)

Statistic ^a	df ₁	df ₂	Sig.
12.282	9	36.523	0.000

a. Asymptotically F distributed

It can be observed from the above table that the p-value of the **Welch ANOVA** is less than 0.01 which indicates that the null hypothesis is rejected at 1% level of significance. It shows that there is a significant difference in Return on Equity Share Holders' Fund ratio between selected companies.

V.III Earnings per Share (EPS) Ratio:

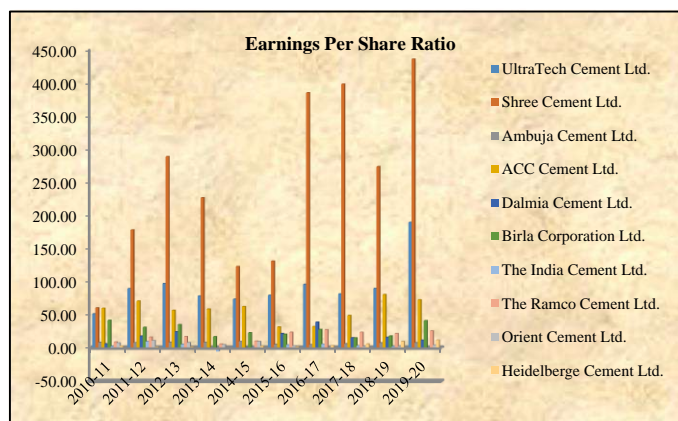
The Earnings per Share (EPS) ratio for the period of study for 10 cement companies is as under:



Table: 3 Earnings per Share (EPS) Ratio

Name	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	Avg.	SD
UCL	51.	89.2	96.8	78.2	73.4	79.2	95.7	81.2	89.4	189.	92.3	36.4
ACL	60.	177.	288.	225.	122.	130.	384.	397.	273.	435.	249.	128.
ACCC	8.2	7.81	8.41	8.37	9.66	5.20	4.89	6.29	7.49	7.70	7.41	1.51
SCL	59.	70.5	56.5	58.3	62.2	31.5	32.0	48.7	80.2	72.3	57.2	16.1
DCL	6.1	17.6	24.2	-	0.38	21.4	38.7	15.1	15.9	11.6	15.0	11.8
BCL	41.	31.0	35.0	16.8	22.7	20.4	27.7	14.9	17.8	41.0	26.9	9.90
ICL	2.2	9.54	5.32	-	0.96	4.49	5.63	3.27	2.24	-	2.72	4.05
RCL	8.8	16.1	16.9	5.79	10.1	23.4	27.2	23.5	21.4	25.5	17.9	7.55
OCL	7.4	10.9	7.89	4.93	9.51	3.04	-	2.16	2.32	4.23	5.08	3.83
HCL	2.7	1.29	1.36	-	2.63	1.71	3.36	5.88	9.74	11.8	3.88	4.14
Overall	47.81											83.5

Graph: 3 Earnings per Share (EPS) Ratio



Interpretation:

From Table- 4.1.3 and Graph 4.1.3, it is clear that the overall mean of the Earnings per Share (EPS) Ratio for selected companies for the selected period of study was 47.81 and S.D. was 83.58. The range of the Earnings per Share ratio was -5.29 to 435.18. The highest ratio during the period was 435.18 for Shree Cement Ltd. in the year 2019-20 while the lowest ratio was -5.29 for The India Cement Ltd. in the year 2013-14. Out of 10 selected companies, there was only 3 companies show Earnings per Share ratio higher than the overall average ratio. Those three companies are UltraTech Cement Ltd., ACC Cements Ltd., and Shree Cement Ltd. with



92.36, 57.23, and 249.49 respectively. The highest average Earnings per Share ratio during the period of study was 249.48 for Shree Cement Ltd.

- UltraTech Cement Ltd. shows a ratio between 51.24 and 189.02.
- Shree Cement Ltd. shows a ratio between 60.19 and 435.18. It's a very high level of positive variation in ratio.
- Ambuja Cement Ltd. shows consistency in the ratio between 4.89 and 9.66.
- ACC Cement Ltd. shows a ratio between 31.51 and 80.23.
- Dalmia Cement Ltd. shows a ratio between - 1.04 and 38.76. It shows high positive volatility in the ratio.
- Birla Corporation Ltd. shows a ratio between 14.95 and 41.54. It shows the volatility in the ratio.
- The India Cement Ltd. varies between - 5.29 and 9.54.
- The Ramco Cement Ltd. shows a ratio between 5.79 and 27.27.
- Orient Cement Ltd. shows a ratio between - 1.57 and 10.92.
- Heidelberge Cement Ltd. shows a ratio between - 1.80 and 11.83.

Test of Hypothesis:

Ho₃ There is no significant difference in the Earnings per Share ratio of selected cement companies.

H1₃ There is significant difference in the Earnings per Share ratio of selected cement companies.

Mean Rank for Earnings per Share Ratio as per KW Test

Name of the	N	Mean	Company
Shree Cement	10	93.90	1
UltraTech	10	85.70	2
ACC Cement	10	76.10	3
Birla Corporation	10	61.30	4
The Ramco	10	51.90	5
Dalmia Cement	10	42.90	6
Ambuja Cement	10	32.80	7
Orient Cement	10	23.90	8
Heidelberge	10	19.70	9
The India Cement	10	16.80	10

Test Statistics

	Earnings Per Share Ratio
<i>Chi-Square (KW-ANOVA)</i>	83.875
<i>Df</i>	9
<i>Asymptotic Sig.</i>	0.000



It can be observed from the above table that the p-value of the **Kruskal-Wallis Test** is less than 0.01 which indicates that the null hypothesis is rejected at 1% level of significance. It shows that there is a significant difference in Earnings per Share between selected companies.

VI. Conclusion:

It is concluded that Ambuja Cement Ltd., UltraTech Cement Ltd., Shree Cement Ltd., The Ramco Cement Ltd., and ACC Cement Ltd. performing well in profit generation. Heidelberg Cement Ltd. and The India Cement Ltd. show very poor performance as regards profitability. The companies selected are doing well as far as profitability ratios are concerned. Notably, Shree Cement Ltd., UltraTech Cement Ltd., The Ramco Cement Ltd., and Ambuja Cement Ltd. are the top performer.

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Annexure – I

Assumption of normality (Shapiro-Wilk)

Ratio	Company Name	Statistic	df	Sig.	Normality Assumption
Return on Capital Employed Ratio	UCL	.822	10	.027	Not follows Normal Distribution. So, a non-parametric test applied.
	ACL	.895	10	.192	
	ACCCL	.948	10	.649	
	SCL	.931	10	.456	
	DCL	.885	10	.147	
	BCL	.877	10	.122	
	ICL	.939	10	.540	
	RCL	.943	10	.591	
	OCL	.937	10	.524	
	HCL	.931	10	.456	
Return on Equity Share Holders Fund Ratio	UCL	.917	10	.333	Follows Normal Distribution. So, a parametric test applied.
	ACL	.851	10	.059	
	ACCCL	.921	10	.363	
	SCL	.931	10	.462	
	DCL	.943	10	.585	
	BCL	.902	10	.228	
	ICL	.963	10	.819	
	RCL	.936	10	.513	
	OCL	.940	10	.557	
	HCL	.942	10	.573	
Earnings per Share Ratio	UCL	.710	10	.001	Not follows Normal Distribution. So, a non-parametric test applied.
	ACL	.921	10	.362	
	ACCCL	.931	10	.462	
	SCL	.950	10	.664	
	DCL	.958	10	.759	
	BCL	.914	10	.309	
	ICL	.973	10	.914	
	RCL	.921	10	.368	
	OCL	.972	10	.909	
	HCL	.897	10	.205	

Annexure – II

Assumption of homogeneity of variance

Ratio	Levene Statistic	df1	df2	Sig.	Homogeneity
Return on Capital	3.715	9	90	.001	Heterogeneous
Return on Equity Shareholders	3.240	9	90	.002	Heterogeneous
Earnings per Share	20.075	9	90	.000	Heterogeneous





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ગાંધી વિશેષાંક

પૂજ્ય વસંતદાદાની સ્મૃતિમાં સરકારી વિનયન અને વાણિજ્ય કોલેજ, જાદર, જિ-સાબરકાંઠા અને ગુજરાત સાહિત્ય અકાદમી, ગાંધીનગરના સંયુક્ત ઉપક્રમે આયોજિત પરિસંવાદ ગાંધીકથા તા. ૩૦ - જાન્યુઆરી ૨૦૨૩



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સંપોષિત વિકાસ અને ગાંધીજીના આર્થિક વિચારો

ડૉ. અવનની મુકુલભટ્ટ

મહદંત્રીશ પ્રાધ્યાપક (અર્થશાસ્ત્ર) સરકારી વિનયન અને વાણિજ્ય કોલેજ, જાદર

રેસ્યુમે:

આધુનિકકણ આંદોલન અને દહેશત થી પરિત વિશ્વ આજે યાંત્રીકરણ ની હોડમા વિશ્વ યુગ્ય ની સ્થિતિમા આવી ગયુ છે ત્યારે ગાંધી ચિંત્યા માર્ગે સમાજવાદ કે મૂડીવાદ થી ઉપર માનવતાવાદ ને અગ્રેસર રાખી સત્ય અને અહિંસાના માર્ગે વિકાસ કરવો રહ્યો કદતરી રીતે વિકાસ અને પર્યાવરણ ની જાળવણી આપણ માટે આજ પ્રથમ કમે છે કારણકે સમજ સંજીવ સંદિ આજ જીવલેલ વર્માગ ની અસરનો ભોગ બની રહી છે અને આપણ અસ્તિત્વ જોખમમા મુકાય છે પરંતુ આટાકલ ગાંધીજીના આર્થિક વિચારોને વર્તમાન અગત્યના વિષય એવેકે સમયોષિત દુકાઈ વિકાસ ની વિલાવના ના સંદર્ભમાં ચકાસે છે આપણે જાણીએ છીએ કે ગાંધીજી એ મૂડીવાદ કે સમાજવાદ થી ઉપર માનવતાવાદી અભિગમ સાથે પોતાના આર્થિક વિચારો પ્રસ્તુત કર્યા છે ગાંધીજીના વિચારો પ્રકૃતિ અને પ્રકૃતિ સાથે સકળાવેલ બાબતો ને પ્રામાન્ય આપે છે પાશ્ચાત્ય ભૌતિક સંવિધાઓનો પ્રતિના ભોગે નહીં પણ સર્વ જન સંખ્યા અને સર્વ જન હિતાય ના અભિગમ થી ઉપયોગ થવો જોઈએ મર્યાદિત જરૂરિયાત થી પર્યાવરણ રક્ષણ સાથેની વિકાસ ગાંધીજી ઇચ્છતા હતા વાલીપણાનો સિધ્ધાંત સ્વેચ્છી યાંત્રીકરણ એવેના વિચારો વિરોધિત વ્યવસ્થા, ગ્રામીણ વિકાસ વગેરે વિચારો અંતેતો માનવ અસ્તિત્વ માટેના જ અભિગમ હતા

પ્રસ્તાવના:

અહીં આ વિચારો વર્તમાન સાતત્યતા અને નવી પેઢીને દિશા નિર્દેશન માટે મહત્વના છે. ગાંધીજી ના આર્થિક વિચારો એ કોઈ વાદ નહીં પણ એક જીવન પ્રણાલી છે જે વ્યાવહારિક સદાચી અને સમાનતા ના અભિગમ સાથે વિકાસની વાત કરે છે ગાંધીજી ના મતે, “ગાંધીવાદ જેવી કોઈ વસ્તુ છેજ નહી. મારે મારી પાછળ કોઈ સંપ્રદાય મૂકી જવો નથી. મે કોઈ નવું તત્વ કે સિધ્ધાંત શોધી કાઢ્યો છે તેવો દાવો નથી. મે તો માત્ર જે શાશ્વત સત્યો છે તેને આપણાં નિત્યના જીવનના પ્રશ્નો ને લાગુ પાડવાનો મારી ઢબે પ્રયાસ કર્યો છે.”

વપત્ર જતુ શહેરીકરણ, યાંત્રીકરણ ગરીબી બેકારી, ભૂખમરો, વિનાશક શસ્ત્રો અને યુધ્ધ જેવા માંડીલ ને કારણે ઉભા થયેલા પર્યાવરણીય જોખમો સામે માનવીએ પોતાના અસ્તિત્વને જાળવી રાખવા માટે થઇને પણ દુકાઈ વિકાસની વિલાવના ને સમજવી અને સ્વીકારવી જ રહી આ માટે ગાંધીજીના આર્થિક વિચારોમાં સાદગી, સ્વાવલંબન, ગ્રામીણીય, ગૃહ ઉદ્યોગ, નાના પાયા પરના ઉદ્યોગો, વિરોધીકરણ, વાલીપણા ની સિદ્ધાંત, નીતિભિત્તિ, શ્રમ-પ્રધાન ઉત્પાદન પદ્ધતિ,

સામાજિક આર્થિક સમાનતા, શ્રમ વિકાસ, અંત્યોદય, સ્વચ્છતા અને પર્યાવરણની જાળવણી ને મહત્વ આપ્યું છે.

ગાંધીજીના વિષે પ્યારેલાલ ‘ભાવિ સમાજ રચના ની દિશામાં’ પુસ્તક માં ગાંધીવાદી અર્થવ્યવસ્થાના લક્ષણોમા જણાવ્યા પ્રજ્ઞા નાનાપાયા પરની વૈયક્તિક અને વિવિધ પ્રકારની સહકારી પ્રયાસોના ટેકાવાળી ખેતી, ગૃહ ઉદ્યોગોનો વિકાસ, પશુપ્રધાન અર્થવ્યવસ્થા, પ્રાણી સૃષ્ટિ, વનસ્પતિ સૃષ્ટિ અને માનવ સૃષ્ટિ વચ્ચે નો સબંધ ઉપકારક હોવાથી તેમની વચ્ચે યોગ્ય સમતુલા હોવી જોઈએ.

જી.ટી. એચ. કોલના મતે, “ગાંધીજીની ખાદી ઉદ્યોગ માટેની પ્રવૃત્તિ હિન્દને ભૂતકાળ માં ઘસડી જવાની ધૂન હતી પણ હિંદના ગામાડાઓમાં વસતા લોકોનોએ ગરીબીમાથી મુક્ત કરવાનો અને તેમનું ઉત્તરમોરણ ઊંચું લઈ જવાનો વ્યવહાર માંગે હતો.”

આલ્ફ્રડ હકઝલીનામતે “ટેક્નોલોજિકલ પ્રગતિએ આપણને માત્ર અયોગ્યતિને માર્ગે જવાનું ખૂબ કાર્યશ્રમ પૂરું પાડ્યું છે. માત્ર અહિંસા માનવજાતને સાચી પ્રગતિ તરફ દોરી જાય તેમ છે. સ્વાયાત અને સ્વાવલંબી ગામાડા વાળી વ્યવસ્થા જ આદર્શ છે.”





દ્વારા આર્થિક વિચારના દરેક ક્ષેત્રનો ઉપયોગ કરી છે.

માનવીય મૂલ્યોને નૈતિકતા, સૌસહકાર, બેરોજગારી નિવારણ (ખાદી વ્યવસાયની હિમાયત) સ્વાવલંબન, સાદગી, સમાનતા અને અભીયોગ સાથેનો વિકાસ.

ગાંધીજીના વિચારોને સમર્પિત વિકાસ

- ગાંધીજીએ આરોગ્યને પોતાની "સૌથી મોટી સંપત્તિ," તરીકે ગણ્યું હતું. તેમણે ઉલ્લેખ કર્યો હતો કે, ભૂખમરી નાબૂદ કરવામાટે વીકારો આરોગ્યપ્રદ આહાર લેવો જોઈએ. આ ધોષણ આપણી વર્તમાન અનુભૂતિ પહેલાની છે કે, જેમ જેમ આપણે ભૂખને નાબૂદ કરીએ છીએ, તેમ તેમ આપણે પોષણની ખાતરી કરવાની જરૂર છે, ખાસ કરીને બાળકો માટે.

- તે જ સમયે, મહાત્મા માનતા હતા કે શિક્ષણ એ પરિવર્તનનું નોંધપાત્ર ચાલકબળ છે, તેમના માટે, શિક્ષણ એ "જીવન-સાધનની ઘટના" છે. "નિરક્ષરતાને દૂર કરવી, તે જરૂરી નથી કે સંપૂર્ણ શિક્ષણ હોય." તેના માટે શિક્ષણનું માપ એ વ્યક્તિની આંતરિક ભાવઈ અથવા સંભાવનાઓની જોડેર થયેલી માત્રા હતી.

- આજકાલ, સામાન્ય રીતે અને ખાસ કરીને એસકીજીમાં આપણા વિકાસ પ્રવચનમાં જાતિય સમાનતા એ એક સુસ્થાપિત ધારણા છે. ગાંધીજીના દ્રષ્ટિકોણમાં પણ જાતિય સમાનતાની ચિંતા જીવા મળતી હતી. લગભગ એક સદી પહેલાં તેમણે કહ્યું હતું, "આપણે એવું ન કહેવું જોઈએ કે સ્ત્રીઓ પુરુષો કરતાં ઊંતરતી કક્ષાની હોય છે, તે બદનસી હશે અને તે પાપ છે." હકીકતમાં, તેમણે સ્ત્રીઓ માટેના શિક્ષણ અને તેમની સમાજિક સ્થિતિ વિશે ખૂબ વિસ્તૃત વાત કરી. તેમણે ઉલ્લેખ કર્યો હતો કે, "જે દિવસે આપણે એમ કહી શકીશું કે આપણી મહિલાઓ રાત્રે રસ્તા પર સુરક્ષિત છે - એ જ દિવસે આપણે જાતિય સમાનતા પ્રાપ્ત કરી છે." તે જ બનાવે છે કે ગાંધીજી તેમના સમય કરતાં કેટલા આગળ હતા.

- સામાજિક આર્થિક વિકાસને આવક, રોજગારી, ટેકનોલોજી અને નવીનતાથી વગર મળે છે. "પૂર્ણ રોજગાર" અને "લખનના

જી સુસંગત છે. જ્યાં તેમણે કહ્યું હતું કે, "આપણે લોકોને એક સારા કાર્યના આધારે યોગ્ય ભોજન આપવાની જરૂર છે, જરૂરી નથી કે તે સખાવત પર આધારિત હોય".

- ચરબો અને લઘુઉદ્યોગો પ્રત્યે ગાંધીજીનો સ્પષ્ટ મોડ પણ યોગ્ય રીતે સમજવાની જરૂર છે. તેમના માટે ટેકનોલોજી અને નવીનતાનો ઉપયોગ લોકોની સેવામાં કરવો પડશે અને રોજગારીની વ્યાપક શક્યતાઓ ઊભી કરવી પડશે. લોકોને તેમની નીકરીઓમાંથી છૂટા કરવા અને શોષ લોકો માટે નફા પેદા કરવાના સાધન તરીકે તેનો ઉપયોગ ન થવો જોઈએ.

- તેમણે ગ્રામીણ રોજગાર અને નાના પાયના ઉદ્યોગોને ગરીબી નાબૂદીના સાધન તરીકે જોયા. ગ્રામીણ વિસ્તારોને શહેરી વિસ્તારોની સમકક્ષ વાળ્યા અને વધુ અગત્યનું "વિકાસને સ્થાનિક બનાવવું" ટેકનોલોજી અને નવીનતાની સંબંધિતતા પ્રત્યે સંવેદનશીલ રહેવું, તેમણે કહ્યું હતું કે, "પ્રકૃતિ અને તમામ સમાજની પ્રદાન કરવાની કે માત્ર કરવાની અમર્યાદિત ક્ષમતાનું ટેકનોલોજીકલ ઇનોવેશન માટેફતે સંપૂર્ણ પણે પરીણાજ કરવાનું બાકી છે."

- ગાંધીજી કાયદાના શાસન અને લોકતાંત્રિક રાજનીતિમાં દૃઢ વિશ્વાસ ધરાવતા હતા. તે દરમિયાન, સામે લડ્યા હતા, તેના દ્વારા તે તેના પોતાના સંદર્ભમાં માનવાધિકાર સ્થાપિત કરવા મંત્રિતા હતા. તેમના માટે, કાયદાનું શાસન અહિંસા, શાંતિપૂર્ણ સહઅસ્તિત્વ અને સહિમશૂતા દ્વારા પ્રગટ થયું હતું. તેમણે કહ્યું "જો તમે બૈરબર માનતા હો કે તમારા વિચારો બીજાઓ કરતાં વધુ સારા છે, તો તમારે બીજાના વિચારો સહન કરવા જોઈએ" આ વિચાર પણ, એસકીજીમાં પ્રતિબિંબિત થાય છે. વિકાસના નવા ચિત્રણો સમર્થન આપે છે કે કાયદાઓ અને જવાબદારીનું શાસન, માત્ર



દેશની અંદર જ નહીં પરંતુ દેશો વચ્ચે સ્થાપિત કરવું પડશે.

તારણ :

ગાંધીજીએ કહ્યું હતું કે, “જ્યારે તમે તેમના માટે કંઈક કરો છો ત્યારે તમારે સૌથી નબળા અને ગરીબ લોકોનો ધ્યાનમાં રાખવા જોઈએ.” તેઓ અહીં માલિકી, સશક્તિકરણ અને એકતા વિશે વાત કરે છે. એકતા અને ભગીદારીનો ગાંધીવાદી વિચાર બીજા વિશ્વયુદ્ધ દરમિયાન ફાસીવાદ સામેની સંયુક્ત લડતના સંદર્ભમાં વસાહતી શક્તિ સાથેના તેમના સંબંધો દ્વારા શ્રેષ્ઠ રીતે વ્યક્ત કરવામાં આવે છે. વર્ષ 2030ની કાર્યસૂચિ હેઠળ, ગરીબી, ભેદભાવ અને અન્યાયના દુશ્મન સામે, વિકાસ અને શાસનભાગમાં કોઈ પણ પ્રકારના તકાવતને ધ્યાનમાં લીધા વિના, વિશ્વવસૈવ કુટુંબકમની ભાવના સાથે એક બને તેવું ઇચ્છનીય છે. મહાત્માગાંધીના મતે, દુનિયાને “સિદ્ધાંતો વિનાના રાજકારણ” અને “નૈતિકતા વિનાના વાણિજ્ય” થી દૂર કરવી પડશે અને શુભલાભના અર્થશાસ્ત્રને અપનાવવું પડશે. માનવતાને મહત્વ આપવું પડશે. એકંદરે ટકાઉ વિકાસના ખ્યાલમાં ગાંધીજીના વિચારો નો સમાવેશ થયેલો જોવા મળે છે. અસ્તુ

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NEW EDUCATION POLICY

Dr. Vandana G. Trivedi*

ABSTRACT

The outcome of teaching must be skill development of a student and achieve the holistic development of the student. In our present education system the number of educated people is increased, but on the other hand there are many burning problems which are still remain in the Economy. Number of students who are committed to suicide is increased. At this time, it is become more important to think about to bring reform in Education policy. Gandhiji (Ramakrishna, 2015) said that, "Literacy in itself is no education ". That means teaching means not to perceive a degree or making a career and earning money. But it is more than it. Keeping in the mind these all aspect New Education policy is formed. It will be implemented in the structure gradually.

Keywords: NEP, Skill Development, Teaching, Career, Economy.

Introduction

National Education policy (NEP) has launched in India on 29th July, 2020 with the goal of bringing transformation in school level and Higher Education. The old Education policy was introduced in 1986. After a long period of 34 years this is the first Education policy of 21st century. The policy will work in the direction of establishment of importance of Education in the new global Economy. Drucker (1993) and Porter (1990) emphasis the importance of Education on the basis of increase of productivity and expansion of the Economy by increase competitiveness national level NEP is based upon four main aspects like, Equality, Access, Quality and Accountability.

New Aspects in NEP

- 10TH and 12th board exam. Will introduce with reconstruction of the structure for the holistic development of the student.
- School examination will take for grade 3, 5 and 8 which will take appropriate Authority.
- A new National Assessment set up is introduced giving importance to as,(Performance assessment, review, and analysis of knowledge for holistic development) which is called "PARAKH"
- Scientific approach, Mathematical ability will get prioritize and coding will introduce from grade 6 onwards.
- The 10+2 structure will be replaced by 5+3+3+4
- In this new structure total 12 years will be of schooling and 3 years of pre-school/ Anganwadi.
- To promote entrepreneurship, vocational course will introduce from grade 6 in which internship is also included.

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- Mother tongue/ Regional language will be the medium of instruction till 5th grade. No language will be forced for students.
- Sanskrit will introduce as an optional language in schools and higher education.
- Literature of India and other classical language will be introduced as an option.
- Higher education will be more flexible, admission in multiple courses will be possible at a same period.
- Education and research will be multidisciplinary. Academic Bank of Credit (ABC) will help the students to choose subject as per their interest. They can earn credit and at the time of the completion of the degree the credit will be counted.
- The curricular in all subjects will reduce, practical and field work will be promoted.

Advantages

- The NEP is targeted to make possible the comeback of approximately Two crore students. This will make possible to achieve the objective of our constitution, "EDUCATION FOR ALL".
- Student's formative learning will increase because in NEP the 5+3+3+4 structure is applied. This 5+3+3+4 structure corresponds to ages from 3 to 8, 8 to 11, 11 to 14 and 14 to 18 years. In this entire process of education, there will be 12 years of schooling and 3 years of pre-school/ Anganwadi.
- Education in Mother tongue/ regional language will let down the early childhood stress of learning foreign language among the children. Researches shows that Mother tongue/ regional language are more efficient medium to learn new things.
- NCERT designed a frame work for early child care, a national level curricular and pedagogical framework for the students up to age 8. Which will promote the holistic development of students?
- Mission fundamental literacy and numeracy will be helpful o set up a strong foundation of fundamental literacy in the country.
- National book promotion policy will bring major benefits to the students.
- School level exams for grade 3, 5 and 8 will organize by appropriate authority. It is the good opportunity to check the student's ability of certain grade. If the student found weak, extra efforts can be made to upgrade them. 10th and 12th board exam. Will organize with modification this change will make easy the board exam. Stress of the students.
- "PARAKH" (Performance assessment, review, and analysis of knowledge for holistic development) policy will encourage the overall development of the students.
- The provision of Balbhavan (special day time boarding school) which will established in every state/ district of the country will encourage the participation of the students in sports, arts and other related activities.
- The provision of Academic Bank of Credit (ABC) will help the students to choose subject as per their interest. They can earn credit and at the time of the completion of the degree the credit will be counted. Multidisciplinary Education and research will bring a high level of intellectual rise in the country. Now there is no boundary of subject.
- Promotion of on line Education will make the student powerful in the use of technology. They can have knowledge of particular subject or topic from any corner of the world. On line education training will prepare the students to face any upcoming pandemic situation.

Challenges

National Education Policy has implemented many new policy which will definitely open up new direction for future India, but There are some challenges in the implementation of it. Like,

- To find out capable teachers who can teach in mother tongue will be difficult in initial stage of the implementation of "NEP".
- Teacher- student ratio is already problematic in the country, If the proper appointment of teacher will not be done, it will create other issues in Education.



- Majority of standard and valuable books regarding any discipline / subjects are available in English language, because since India's Independence English took place as an Important language. At the time of implementation of "NEP" it is the big challenge to make available material in mother tongue or regional language. To promote Education in mother tongue it is very necessary to translate all the material in regional language.
- In India private sector is actively work in the field of Education, there is a huge gap between the level of public school students and private school students. The government must take strong and effective steps to fulfill the gap.
- It may lead to lack of sufficient knowledge of any language in students.

Conclusion

Education is considering a powerful weapon to bring positive changes and to promote development in the country. "NEP" is applied in the country to bring overall development of the students and to build up skilled manpower through it. There are many significant steps are taken in "NEP". With the advantages of "NEP", there are also many challenges. We can hope that the crisis which will occur at the time of change in education system, will get set in few years. When any change take place, some part of the system get badly affected but with the step by step implementation it is become normal in the society. We can hope it for the "NEP" also.

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On the construction of balanced repeated measurements designs with good circular properties

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On the construction of balanced repeated measurements designs with good circular properties

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ABSTRACT

Several fields, such as biological, medical, public health, agricultural sciences, etc., require circular balanced repeated measurement designs with fewer unequal number of repeated measurements than the number of treatments. Also, the availability and high cost of experimental subjects in these fields prefer the design in fewer experimental units. However, balancing the carryover effects of the treatments in minimal experimental subjects is one of the problems in this case. In this paper, several new series of minimal circular nearly strongly balanced RMDs in periods of two and three different sizes are constructed. The proposed construction of designs has high efficiency and, therefore, can save the cost of experimentations due to a fewer experimental subjects. Most of the designs are very useful because of the unavailability of strongly balanced RMDs for these combinations of parameters. A list of sets of shifts for the construction of minimal circular nearly SBRMDs has also been mentioned in the Appendix.

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Carryover effects; repeated measurement designs; balanced repeated measurement designs; strongly balanced repeated measurement designs; circular nearly strongly balanced repeated measurement designs

1. Introduction

Experimental design deals with the arrangement of experimental units and the assignment of treatments to them in such a way that the comparisons among the treatments are unbiased and as precise as possible. The precision of the experiment depends to a large extent on the size of the experiment and the variations present in the experimental units. In designing experiments, keeping in view the limitation on experimental resources, efforts are made to minimize standard errors of estimated contrasts of interest. Mostly error variation arises because of the variation in experimental units under the same treatments. Therefore, it is suggested to use the same experimental unit for different treatments in an experiment but in different periods. This results in a type of design known as repeated measurements design (RMD) which makes them different from other designs presented in the literature which make use of different experimental units for different treatments. Repeated measurements design (RMD) is the type of experimental design in which experimental subjects are repeatedly measured by giving a sequence of treatments. RMDs are a special kind of carryover design in which each subject is influenced by a treatment applied in a current period called treatment effects and treatment applied in a previous period called carryover effects. Cross-over designs are RMDs in which each unit receives the sequence of each treatment over different periods. RMDs in unequal period sizes are very useful if there is a restriction on the total number of treatments, and some experimental units can receive on the total length of time, while some experimental units can remain in the trial which results in RMDs of different or unequal period sizes. RMDs balanced in treatments and carryover effects are useful in several fields such as medicine, pharmacology, animal sciences and psychology where carryover effects are natural.

2. Literature review

Cheng and Wu (1980) proposed the construction of BRMDs and CSBRMDs, especially for unequal block sizes. With the help of advanced technology in computer systems, the uses of block designs of unequal sizes k are beneficial, and hence it is very useful in industrial and agricultural experiments. The utilization of different block sizes in biological experiments was mentioned by Pearce (1964). Afsarinejad (1994) constructed minimal CSBRMDs for different period sizes. Iqbal and Jones (1994) proposed the construction of efficient RMDs and CSBs for two different period sizes. Iqbal and Tahir (2009), Iqbal et al. (2010) and Bashir et al. (2018) constructed CSBs for some classes. Rasheed et al. (2018) recently developed some generators to obtain MCSBs in a period of three different sizes for some

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cases of t , where $2 \leq k_3 < k_2 \leq 10$. However, there does not exist MCSBs for certain combinations of treatments and periods when several treatments are less than the number of periods. Here, minimal circular nearly CSBs are useful. A design is said to be CNBs (Circular nearly strongly balanced repeated measurement designs) if every treatment is immediately followed by every other treatment including itself except the treatment (labelled as $t-1$) which is not preceded by itself. In this article, some generators are developed to construct CNBs in periods of (i) two different sizes and (ii) three different sizes. These designs have their own importance in extended scientific and biological experimentations with different block sizes which consist of clinical experimentations of human and also animal behaviour responses for the comparison of several non-curative treatments for their effectiveness. With the advancement of technological computer systems, block designs with unequal sizes p have become very useful in huge industrial and agricultural experiments. In biological experiments, the utilization of different block sizes has been studied significantly. RCTs become prone to the unravelling of sizes of the block when it remains the same throughout the trial, so investigators use different block sizes, i.e. they randomly vary the block size to lower the chances of unbiasedness (Schulz & Grimes, 2002; Schulz, 1995). There exist different scientific research areas such as animal husbandry and genetic experimentation. RCTs, where these designs are applied as within-subject treatment comparisons, are more efficient than between-subject treatment comparisons. These proposed designs are additions to the literature as they are incorporating different period sizes and also possess good efficiency in estimating direct and residual effects.

Important definitions with abbreviations used that will be discussed throughout the article are discussed below briefly.

BRMDs	Balanced repeated measurement designs
CSBs	circular strongly balanced repeated measurement designs
CNBs	Circular nearly strongly balanced repeated measurement designs

2.1. BRMDs

In an RMD each experimental subject or unit receives a series of several treatments in successive periods.

2.2. CSBs

If every treatment is directly preceded by every other treatment (including itself) then it is called CSBs.

2.3. CNBs

In this type of design, every treatment is immediately followed by every other treatment exactly once as well as with itself except the treatment labelled as $v-1$, which is not preceded by itself.

In Section 3, the model and information matrix are described along with the formula for the computation of the efficiency for CNBs. In Section 4, the Method of Cyclic Shifts (MOCS) is described to generate CNBs in different period sizes. A series of generators is proposed in Section 5 to obtain CNBs in two different sizes of periods. Also, a series of generators for the construction of CNBs in three different sizes of periods are proposed in Section 6. Section 7 contains the concluding remarks about the proposed designs. A list of sets of shifts for the construction of CNBs in two and three different sizes of periods with many treatments smaller than thirty is provided in the Appendix.

3. Model and efficiency for CNBs

The model used for repeated measurements designs in the literature is the conventional model proposed by Magda

$$y_{ijk} = \mu + \tau_{d(k,j)} + \gamma_{d(k-1,j)} + \pi_k + \xi_{ij} + \varepsilon_{ijk}, \quad (1)$$

where y_{ijk} is the i th observation from the subject j th with the sequence i in period k for which treatment $d(k, j)$ is given.

μ = Overall mean, $\tau_{d(k,j)}$ = treatment $d(k, j)$ effect, $\gamma_{d(k-1,j)}$ = treatment $d(k-1, j)$ effect in the period k which was applied in the period $k-1$ to the same experimental subject, π_k = k th period effect, ξ_{ij} = j th subject effect of sequence i , and ε_{ijk} is i.i.d normally distributed residual term having mean 0 and fixed variance σ^2 .



The joint information matrix of treatment and carryover effects for the CNB is expressed by

$$A_{(\tau, \gamma)} = \begin{pmatrix} A_{11} & A_{12} \\ A'_{12} & A_{22} \end{pmatrix},$$

where A_{11} , A_{12} and A_{22} in two different period sizes are expressed by

$$A_{11} = R - M - \frac{1}{k_1} N_1 N'_1 - \frac{1}{k_2} N_2 N'_2 + \frac{\underline{r} \underline{r}'}{n_1 k_1 + n_2 k_2} J,$$

$$M = \begin{bmatrix} \left(\frac{s^2(k_2 - 1) + (s - 1)^2}{n_1 + n_2} + \frac{(k_1 - k_2)}{n_1} \right) J_{t-1} & \frac{(t - 1)(s - 1)}{n_1 + n_2} \underline{1}_{t-1} \\ \frac{(t - 1)(s - 1)}{n_1 + n_2} \underline{1}'_{t-1} & \frac{(t - 1)^2}{n_1 + n_2} \end{bmatrix},$$

$$A_{12} = Z - \bar{M} - \frac{1}{k_1} N_1 \bar{N}'_1 - \frac{1}{k_2} N_2 \bar{N}'_2 + \frac{\underline{r} \bar{r}'}{n_1 k_1 + n_2 k_2} J,$$

$$\bar{M} = \begin{bmatrix} \left(\frac{s^2(k_2 - 2) + 2s(s - 1)}{n_1 + n_2} + \frac{(k_1 - k_2)}{n_1} \right) J_{t-1} & \frac{s(t - 1)}{n_1 + n_2} \underline{1}_{t-1} \\ \frac{s(t - 1)}{n_1 + n_2} \underline{1}_{t-1} & 0 \end{bmatrix},$$

$$A_{22} = \bar{R} - M - \frac{1}{k_1} \bar{N}_1 \bar{N}'_1 - \frac{1}{k_2} \bar{N}_2 \bar{N}'_2 + \frac{\bar{r} \bar{r}'}{n_1 k_1 + n_2 k_2} J,$$

and A_{11} , A_{12} and A_{22} in periods of three different sizes are expressed by

$$A_{11} = R - M - \frac{1}{k_1} N_1 N'_1 - \frac{1}{k_2} N_2 N'_2 - \frac{1}{k_3} N_3 N'_3 + \frac{\underline{r} \underline{r}'}{n_1 k_1 + n_2 k_2 + n_3 k_3} J,$$

$$M = \begin{bmatrix} \left(\frac{s^2(k_3 - 1) + (s - 1)^2}{n_1 + n_2 + n_3} + \frac{(s - 1)^2(k_2 - k_3)}{n_1 + n_2} + \frac{(s - 2)^2(k_1 - k_2)}{n_1} \right) J_{t-1} & \frac{n_3(s - 1)}{n_1 + n_2 + n_3} \underline{1}_{t-1} \\ \frac{n_3(s - 1)}{n_1 + n_2 + n_3} \underline{1}'_{t-1} & \frac{n_3^2}{n_1 + n_2 + n_3} \end{bmatrix},$$

$$A_{12} = Z - \bar{M} - \frac{1}{k_1} N_1 \bar{N}'_1 - \frac{1}{k_2} N_2 \bar{N}'_2 - \frac{1}{k_3} N_3 \bar{N}'_3 + \frac{\underline{r} \bar{r}'}{n_1 k_1 + n_2 k_2 + n_3 k_3} J,$$

$$\bar{M} = \begin{bmatrix} \left(\frac{s^2(k_3 - 2) + 2s(s - 1)}{n_1 + n_2 + n_3} + \frac{(s - 1)^2(k_2 - k_3)}{n_1 + n_2} + \frac{(s - 2)^2(k_1 - k_2)}{n_1} \right) J_{t-1} & \frac{sn_3}{n_1 + n_2 + n_3} \underline{1}_{t-1} \\ \frac{sn_3}{n_1 + n_2 + n_3} \underline{1}'_{t-1} & 0 \end{bmatrix},$$

$$A_{22} = \bar{R} - M - \frac{1}{k_1} \bar{N}_1 \bar{N}'_1 - \frac{1}{k_2} \bar{N}_2 \bar{N}'_2 - \frac{1}{k_3} \bar{N}_3 \bar{N}'_3 + \frac{\bar{r} \bar{r}'}{n_1 k_1 + n_2 k_2 + n_3 k_3} J.$$

Here,

n_1	subjects measured repeatedly up to k_1 size
n_3	subjects measured repeatedly up to k_3 size
s	number of sets of shifts
N_1	t incidence matrix vs 1 to n_1
N_2	t incidence matrix vs $n_1 + 1$ to $n_1 + n_2$
N_3	t incidence matrix vs $n_1 + n_2 + 1$ to $n_1 + n_2 + n_3$
\bar{N}_1	residual incidence matrix vs 1 to n_1
\bar{N}_2	residual incidence matrix vs $n_1 + 1$ to $n_1 + n_2$
\bar{N}_3	residual incidence matrix vs $n_1 + n_2 + 1$ to $n_1 + n_2 + n_3$
\underline{r}	vector of replication of treatments
\bar{r}	vector of replication of residual



R diagonal matrix of replication of t
 \bar{R} diagonal matrix of replication of residual
 J matrix of 1s

Then the information matrix of the treatment and carryover effects are $A_\tau = A_{11} - A_{12}A_{22}^-A_{21}$ and $A_\gamma = A_{22} - A_{21}A_{11}^-A_{12}$, respectively.

RMDs should be analysed for their capability of discriminating the effects of treatment from carryover effects. Hanford (2005) has given the criteria to compare the RMDs based on this ability. Divecha and Gondaliya (2014) gave a convenient method for calculating the efficiency of separability (ES) for the BRMDs. This formula considering the provided constraints of our proposed type of RMDs is given by

$$ES = \left[\frac{t\sqrt{t-1} - 1}{t\sqrt{t-1}} \right] \times 100\% \quad (2)$$

4. Construction methodology

Construction of CNBs from all the series of generators requires an understanding of rule II of a MOCS which was proposed by Iqbal and Jones (1994). MOCS (Rule II) is defined here briefly for constructing CNBs in periods of different sizes.

Let $S_1 = [q_{11}, q_{12}, \dots, q_{p_1-1}]$, $S_2 = [q_{21}, q_{22}, \dots, q_{p_2-1}]$ and $S_3 = [q_{31}, q_{32}, \dots, q_{p_3-2}]t$ be the sets of shifts, where $0 \leq q_{ij} \leq v-2$. If every element $0, 1, \dots, v-2$ appears exactly once in S^* , it is CNB in periods of sizes p_1, p_2 and p_3 , where $S^* = [q_{11}, q_{12}, \dots, q_{p_1-1}, q_{21}, q_{22}, \dots, q_{p_2-1}, q_{31}, q_{32}, \dots, q_{p_3-1}, v-1-(q_{11} + q_{12} + \dots + q_{p_1-1}) \bmod (v-1), v-1-(q_{21} + q_{22} + \dots + q_{p_2-1}) \bmod (v-1)]$. In these sets of shifts, the sum of any 2, 3, ..., or $(p-3)$ successive elements should not be $0 \bmod (v-1)$. If so, rearrange them.

Consider here the Rule II of a MOCS briefly for the construction of CNBs with the help of an example as $t = 13$, $S_1 = [3, 4, 5, 9, 8]$ and $S_2 = [6]t$.

Take $t-1$ experimental subjects for one set of shifts $[3, 4, 5, 9, 8]$. Write $0, 1, \dots, t-2$ in the first period of $t-1$ experimental subjects, respectively. For the second period of every subject, add $3 \bmod (t-1)$ to every element of the first period of each subject. Then add $4 \bmod (t-1)$ to every element of the second period which gives the treatment number of the third period in each subject. Similarly add 9, 5 and 8, respectively.

Experimental Subjects												
Periods	1	2	3	4	5	6	7	8	9	10	11	12
1	0	1	2	3	4	5	6	7	8	9	10	11
2	3	4	5	6	7	8	9	10	11	0	1	2
3	7	8	9	10	11	0	1	2	3	4	5	6
4	4	5	6	7	8	9	10	11	0	1	2	3
5	9	10	11	0	1	2	3	4	5	6	7	8
6	5	6	7	8	9	10	11	0	1	2	3	4

Take $t-1$ more subjects for the second set of shifts $[6]t$. Allocate $0, 1, \dots, t-2$ to every subject in the first period, respectively. To obtain the elements of the second period for every subject, add $6 \bmod (t-1)$ to every element of the first period for all subjects. Then insert $t-1$ (i.e. 12) in each element of the third period.

Subjects												
Periods	13	14	15	16	17	18	19	20	21	22	23	24
1	0	1	2	3	4	5	6	7	8	9	10	11
2	6	7	8	9	10	11	0	1	2	3	4	5
3	12	12	12	12	12	12	12	12	12	12	12	12

The above design is CNB in $t = 13$, $k_1 = 6$, $k_2 = 3$, $n_1 = 12$, $n_2 = 12$ and $ES = 98\%$.

5. Generators to obtain CNBs in two different sizes of periods

Let $S_1 = [e_{11}, e_{12}, \dots, e_{p_1-1}]$ and $S_2 = [e_{21}, e_{22}, \dots, e_{p_2-2}]t$ be two sets of shifts, here $0 \leq e_{ij} \leq t-2$. Define, $S^* = [e_{11}, e_{12}, \dots, e_{p_1-1}, e_{21}, e_{22}, \dots, e_{p_2-2}, t-1-(e_{11} + e_{12} + \dots + e_{p_1-1}) \bmod (t-1)]$. If every element $0, 1, \dots, t-2$ appears exactly once in the new set of shifts S^* , then the design from the set of shifts will be CNB in periods of sizes k_1 and k_2 . The sum of any 2, 3, ..., $(k-3)$ successive elements of any set of shifts should not be $0 \bmod (t-1)$. If so, rearrange the elements.



Example: Sets of shifts $S_1 = [1,7,4,3,9,6]$ and $S_2 = [2,5,8]t$ give following CNB for $t = 11$ in $k_1 = 7$ and $k_2 = 5$ with $ES = 97\%$.

Subjects									
1	2	3	4	5	6	7	8	9	10
0 ₀	1 ₁	2 ₂	3 ₃	4 ₄	5 ₅	6 ₆	7 ₇	8 ₈	9 ₉
1 ₀	2 ₁	3 ₂	4 ₃	5 ₄	6 ₅	7 ₆	8 ₇	9 ₈	0 ₉
8 ₁	9 ₂	0 ₃	1 ₄	2 ₅	3 ₆	4 ₇	5 ₈	6 ₉	7 ₀
2 ₈	3 ₉	4 ₀	5 ₁	6 ₂	7 ₃	8 ₄	9 ₅	0 ₆	1 ₇
5 ₂	6 ₃	7 ₄	8 ₅	9 ₆	0 ₇	1 ₈	2 ₉	3 ₀	4 ₁
4 ₅	5 ₆	6 ₇	7 ₈	8 ₉	9 ₀	0 ₁	1 ₂	2 ₃	3 ₄
0 ₄	1 ₅	2 ₆	3 ₇	4 ₈	5 ₉	6 ₀	7 ₁	8 ₂	9 ₃

Subjects									
1	2	3	4	5	6	7	8	9	10
0 ₁₀	1 ₁₀	2 ₁₀	3 ₁₀	4 ₁₀	5 ₁₀	6 ₁₀	7 ₁₀	8 ₁₀	9 ₁₀
2 ₀	3 ₁	4 ₂	5 ₃	6 ₄	7 ₅	8 ₆	9 ₇	0 ₈	1 ₉
7 ₂	8 ₃	9 ₄	0 ₅	1 ₆	2 ₇	3 ₈	4 ₉	5 ₀	6 ₁
5 ₇	6 ₈	7 ₉	8 ₀	9 ₁	0 ₂	1 ₃	2 ₄	3 ₅	4 ₆
10 ₅	10 ₆	10 ₇	10 ₈	10 ₉	10 ₀	10 ₁	10 ₂	10 ₃	10 ₄

Here, 10₆ means that treatment 10 was applied in the current period, while the subscript '6' is the treatment applied in the previous period.

If $t = 2zi + 2a - 1$, i is an integer, $k_1 = 2z$, $k_2 = 2a$, $a \neq z$ and $a \& z > 1$, then CNBs can be obtained from the sets given below where $j = 0, 1, \dots, i-1$.

$$S_{j+1} = [zj + 1, zj + 2, \dots, zj + z, t - 1 - (zj + 1), t - 1 - (zj + 2), \dots, t - 1 - (zj + z - 1)];$$

$$S_{i+1} = [zi + 1, zi + 2, \dots, zi + a - 1, t - 1 - (zi + 1), t - 1 - (zi + 2), \dots, t - 1 - (zi + a - 2), 0]t$$

Example 5.1: CNBs for $t = 13$, $k_1 = 8$ and $k_2 = 6$ are constructed from the sets of shifts given below with 98% efficiency.

$$S_1 = [1, 2, 3, 4, 11, 10, 9], S_2 = [5, 6, 7, 0]t.$$

If $t = 2zi + 2a$, i is an integer, $k_1 = 2z$, $k_2 = 2a + 1$ and $a \& z > 1$, then CNBs can be obtained from the sets given below where $j = 0, 1, \dots, i-1$.

$$S_{j+1} = [zj + 1, zj + 2, \dots, zj + z, t - 1 - (zj + 1), t - 1 - (zj + 2), \dots, t - 1 - (zj + z - 1)];$$

$$S_{i+1} = [zi + 1, zi + 2, \dots, zi + a - 1, t - 1 - (zi + 1), t - 1 - (zi + 2), \dots, t - 1 - (zi + a - 1), 0]t.$$

Example 5.2: CNBs for $t = 16$, $k_1 = 10$ and $k_2 = 7$ are constructed from the sets given below with 98% efficiency.

$$S_1 = [1, 2, 3, 4, 14, 5, 13, 11, 12], S_2 = [6, 7, 9, 8, 0]t.$$

If $t = 2zi + 4a - 1$, i is an integer, $k_1 = 2z$, $k_2 = 2a$ and $a \neq z$, $a \& z > 1$, then CNBs can be obtained from the sets given below.

$$S_{j+1} = [zj + 1, zj + 2, \dots, zj + z, t - 1 - (zj + 1), t - 1 - (zj + 2), \dots, t - 1 - (zj + z - 1)];$$

$$S_{i+1} = [zi + 1, zi + 2, \dots, zi + a - 1, t - 1 - (zi + a - 1), t - 1 - (zi + a - 2), \dots, t - 1 - (zi + 1)];$$

$$S_{i+2} = [zi + a + 1, zi + a + 2, \dots, zi + 2a - 1, t - 1 - (zi + a + 1), t - 1 - (zi + a + 2), \dots, t - 1 - (zi + 2a - 2), 0]t.$$

Example 5.3: CNBs for $t = 25$, $k_1 = 10$ and $k_2 = 8$ are constructed from the sets given below with 99% efficiency.

$$S_1 = [1, 2, 3, 4, 5, 23, 22, 21, 20], S_2 = [6, 7, 8, 17, 9, 18, 16], S_3 = [10, 11, 12, 14, 13, 0]t.$$



If $t = 2zi + 4a + 1$, i is an integer, $k_1 = 2z$, $k_2 = 2a + 1$ and $a \& z > 1$, then CNBs can be obtained from the sets given below.

$$\begin{aligned} S_{j+1} &= [zj + 1, zj + 2, \dots, zj + z, t - 1 - (zj + 1), t - 1 - (zj + 2), \dots, t - 1 - (zj + z - 1)]; \\ S_{i+1} &= [zi + 1, zi + 2, \dots, zi + a, t - 1 - (zi + 1), t - 1 - (zi + 2), \dots, t - 1 - (zi + a)]; \\ S_{i+2} &= [zi + a + 1, zi + a + 2, \\ &\dots, zi + 2a, t - 1 - (zi + a + 1), t - 1 - (zi + a + 2), \dots, t - 1 - (zi + 2a - 1)]t. \end{aligned}$$

Example 5.4: CNBs for $t = 21$, $k_1 = 8$ and $k_2 = 7$ are constructed from the sets given below with 99% efficiency.

$$S_1 = [1, 2, 3, 4, 19, 18, 17], S_2 = [5, 6, 7, 15, 14, 13], S_3 = [8, 9, 10, 12, 11]t.$$

6. Generators to obtain CNBs in three different sizes of periods

Let $S_1 = [e_{11}, e_{12}, \dots, e_{p_1-1}]$, $S_2 = [e_{21}, e_{22}, \dots, e_{p_2-1}]$ and $S_3 = [e_{31}, e_{32}, \dots, e_{p_3-2}]t$ be the sets of shifts, where $0 \leq e_{ij} \leq t-2$. Define, $S^* = [e_{11}, e_{12}, \dots, e_{p_1-1}, q_{21}, e_{22}, \dots, e_{p_2-1}, e_{31}, e_{32}, \dots, e_{p_3-1}, t-1-(e_{11} + e_{12} + \dots + e_{p_1-1}) \bmod (t-1), t-1-(e_{21} + e_{22} + \dots + e_{p_2-1}) \bmod (t-1)]$. If every element $0, 1, \dots, t-2$ appears exactly once in the new set of shifts S^* , then the design from the set of shifts will be CNB in periods of sizes k_1, k_2 and k_3 . The sum of any $2, 3, \dots, (k-3)$ successive elements of the set of shifts S_{i+1} should not be $0 \bmod (t-1)$. If so rearrange the elements.

Example: Set of shifts $S_1 = [3, 4, 9, 5, 8]$, $S_2 = [1, 2, 11, 10]$ and $S_3 = [6]t$ give the following CNBs for $t = 13$ in $k_1 = 6$, $k_2 = 5$ and $k_3 = 3$ with ES = 98%.

Subjects											
1	2	3	4	5	6	7	8	9	10	11	12
0 ₅	1 ₆	2 ₇	3 ₈	4 ₉	5 ₁₀	6 ₁₁	7 ₀	8 ₁	9 ₂	10 ₃	11 ₄
3 ₀	4 ₁	5 ₂	6 ₃	7 ₄	8 ₅	9 ₆	10 ₇	11 ₈	0 ₉	1 ₁₀	2 ₁₁
7 ₃	8 ₄	9 ₅	10 ₆	11 ₇	0 ₈	1 ₉	2 ₁₀	3 ₁₁	4 ₀	5 ₁	6 ₂
4 ₇	5 ₈	6 ₉	7 ₁₀	8 ₁₁	9 ₀	10 ₁	11 ₂	0 ₃	1 ₄	2 ₅	3 ₆
9 ₄	10 ₅	11 ₆	0 ₇	1 ₈	2 ₉	3 ₁₀	4 ₁₁	5 ₀	6 ₁	7 ₂	8 ₃
5 ₉	6 ₁₀	7 ₁₁	8 ₀	9 ₁	10 ₂	11 ₃	0 ₄	1 ₅	2 ₆	3 ₇	4 ₈

Subjects											
13	14	15	16	17	18	19	20	21	22	23	24
0 ₀	1 ₁	2 ₂	3 ₃	4 ₄	5 ₅	6 ₆	7 ₇	8 ₈	9 ₉	10 ₁₀	11 ₁₁
1 ₀	2 ₁	3 ₂	4 ₃	5 ₄	6 ₅	7 ₆	8 ₇	9 ₈	10 ₉	11 ₁₀	0 ₁₁
3 ₁	4 ₂	5 ₃	6 ₄	7 ₅	8 ₆	9 ₇	10 ₈	11 ₉	0 ₁₀	1 ₁₁	2 ₀
2 ₃	3 ₄	4 ₅	5 ₆	6 ₇	7 ₈	8 ₉	9 ₁₀	10 ₁₁	11 ₀	0 ₁	1 ₂
0 ₂	1 ₃	2 ₄	3 ₅	4 ₆	5 ₇	6 ₈	7 ₉	8 ₁₀	9 ₁₁	10 ₀	11 ₁

Subjects											
25	26	27	28	29	30	31	32	33	34	35	36
0 ₁₂	1 ₁₂	2 ₁₂	3 ₁₂	4 ₁₂	5 ₁₂	6 ₁₂	7 ₁₂	8 ₁₂	9 ₁₂	10 ₁₂	11 ₁₂
6 ₀	7 ₁	8 ₂	9 ₃	10 ₄	11 ₅	0 ₆	1 ₇	2 ₈	3 ₉	4 ₁₀	5 ₁₁
12 ₆	12 ₇	12 ₈	12 ₉	12 ₁₀	12 ₁₁	12 ₀	12 ₁	12 ₂	12 ₃	12 ₄	12 ₅

Here, 11₆ is the treatment 11 applied in the present period, while the subscript '6' is the treatment applied in the previous period.

If $t = 2zi + 2a + 2b$, i is an integer, $k_1 = 2a$, $z \neq a$, $z, a \& b > 1$, $k_2 = 2a + 1$ and $k_3 = 2b$, then CNBs can be obtained from the sets given below where $j = 0, 1, \dots, i-1$.

$$\begin{aligned} S_{j+1} &= [zj + 1, zj + 2, \dots, zj + z, t - 1 - (zj + 1), t - 1 - (zj + 2), \dots, t - 1 - (zj + z - 1)]; \\ S_{i+1} &= [zi + 1, zi + 2, \dots, zi + a, t - 1 - (zi + 1), t - 1 - (zi + 2), \dots, t - 1 - (zi + a)]; \\ S_{i+2} &= [zi + a + 1, zi + a + 2, \dots, zi + a + b - 1, t - 1 - (zi + a + 1), t - 1 - (zi + a + 2), \\ &\dots, t - 1 - (zi + a + b - 1)]t. \end{aligned}$$



Example 6.1: CNBs for $t = 13$, $k_1 = 8$, $k_2 = 7$ and $k_3 = 4$ are constructed from the sets given below with 98% efficiency.

$$S_1 = [1, 2, 3, 4, 16, 15, 14], S_2 = [5, 6, 7, 12, 11, 10] \text{ and } S_3 = [8, 9]t.$$

If $t = 2zi + 2a + 2b - 1$, i is an integer, $k_1 = 2z$, $z \neq a \neq b > 1$, $k_2 = 2a$ and $k_3 = 2b$, then CNBs can be constructed from the sets given below where $j = 0, 1, \dots, i-2$.

$$S_{j+1} = [zj + 1, zj + 2, \dots, zj + z, t - 1 - (zj + 1), t - 1 - (zj + 2), \dots, t - 1 - (zj + z - 1)];$$

$$S_{i+1} = [zi + 1, zi + 2, \dots, zi + a, t - 1 - (zi + 1), t - 1 - (zi + 2), \dots, t - 1 - (zi + a - 1)];$$

$$S_{i+2} = [zi + a + 1, zi + a + 2, \dots, zi + a + b - 1, t - 1 - (zi + a + 1), t - 1 - (zi + a + 2), \dots, t - 1 - (zi + a + b - 2), 0]t \text{ for } b > 2.$$

$$S_{i+2} = [(t - 1)/2, 0]t \text{ for } b = 2.$$

Example 6.2: CNBs for $t = 23$, $k_1 = 10$, $k_2 = 8$ and $k_3 = 6$ are constructed from the sets given below with 99% efficiency.

$$S_1 = [1, 2, 3, 4, 5, 21, 20, 19, 18], S_2 = [6, 7, 8, 9, 16, 15, 14] \text{ and } S_3 = [10, 11, 12, 0]t.$$

If $t = 2zi + 2a + 2b + 1$, $k_1 = 2z$, i is an integer, $k_2 = 2a + 1$, $k_3 = 2b + 1$, $a \neq b > 1$ and $z > 1$, then CNBs can be obtained from the sets given below where $j = 0, 1, \dots, i-1$.

$$S_{j+1} = [zj + 1, zj + 2, \dots, zj + z, t - 1 - (zj + 1), t - 1 - (zj + 2), \dots, t - 1 - (zj + z - 1)];$$

$$S_{i+1} = [zi + 1, zi + 2, \dots, zi + a, t - 1 - (zi + 1), t - 1 - (zi + 2), \dots, t - 1 - (zi + a)];$$

$$S_{i+2} = [zi + a + 1, zi + a + 2, \dots, zi + a + b, t - 1 - (zi + a + 1), t - 1 - (zi + a + 2), \dots, t - 1 - (zi + a + b - 1)]t.$$

Example 6.3: CNBs for $t = 19$, $k_1 = 8$, $k_2 = 7$ and $k_3 = 5$ are constructed from the sets given below with 99% efficiency.

$$S_1 = [1, 2, 3, 4, 17, 16, 15], S_2 = [5, 6, 13, 7, 12, 11], S_3 = [8, 9, 10]t.$$

7. Concluding remarks

CSBs help in estimating direct and carryover effects independently and providing high efficiency of separability. Despite the importance of RMDs, there is no sufficient literature available on the construction of the CSBs and CNBs with high efficiency of separability for unequal period sizes. In situations where CSBs cannot be constructed, they are preferable as they give efficiencies close to CSBs. Through well-known MOCS Rule II, these designs have been constructed for unequal period sizes with high efficiency of separability which covers the lack of designs for unequal period sizes. The experimenters now have more choices when dealing with different period sizes. All the proposed designs possess an efficiency close to 100% and, therefore, they should be a better alternative to CSBs.

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Appendix

Table A1. List of sets of shifts for CNBs in two different sizes of periods and treatments smaller than 30.

t	k ₁	k ₂	Sets of shifts	ES
9	6	4	[1,3,2,7,6] + [4,0]t	96
10	6	5	[1,3,2,8,7] + [4,5,0]t	97
11	8	4	[1,3,2,4,9,8,7] + [5,0]t	97
13	6	4	[1,3,2,11,10] + [4,5,8] + [6,0]t	98
13	8	6	[1,3,2,4,11,10,9] + [5,6,7,0]t	98
13	10	4	[1,3,2,4,5,11,10,9,8] + [6,0]t	98
14	8	7	[1,3,2,4,12,11,10] + [5,6,7,8,0]t	98
15	6	4	[1,3,2,13,12] + [4,5,6,10,9] + [7,0]t	98
15	6	5	[1,2,3,13,12] + [4,5,10,9] + [6,7,8]t	98
15	8	4	[1,3,2,4,13,12,11] + [5,6,9] + [7,0]t	98
16	6	5	[1,3,2,14,13] + [4,5,6,11,10] + [7,8,0]t	98
17	10	4	[1,3,2,4,5,15,14,13] + [6,7,10] + [8,0]t	99
17	10	8	[1,3,2,4,5,15,14,13,12] + [6,7,8,10,9,0]t	99
18	10	9	[1,3,2,4,5,16,15,14,13] + [6,7,8,9,10,11,0]t	99
19	6	4	[1,3,2,17,16] + [4,5,6,14,13] + [7,8,11] + [9,0]t	99
19	8	4	[1,3,2,4,17,16,15] + [5,6,7,8,13,12,11] + [9,0]t	99
21	6	4	[1,3,2,19,18] + [4,5,6,16,15] + [7,8,9,13,12] + [10,0]t	99
21	6	5	[1,2,3,19,18] + [4,5,6,16,15] + [7,8,13,12] + [9,10,11]t	99
21	8	6	[1,3,2,4,19,18,17] + [5,6,7,8,15,14,13] + [9,11,10,0]t	99
21	8	7	[1,2,3,4,19,18,17] + [5,6,7,15,14,13] + [8,9,10,12,11]t	99
22	6	5	[1,3,2,20,19] + [4,5,6,17,16] + [7,8,9,14,13] + [10,11,0]t	99
22	8	7	[1,3,2,4,20,19,18] + [5,6,7,8,16,15,14] + [9,10,11,12,0]t	99
23	8	4	[1,3,2,4,21,20,19] + [5,6,7,8,17,16,15] + [9,10,13] + [11,0]t	99
23	10	4	[1,3,2,4,5,21,20,19,18] + [6,7,8,9,10,16,15,14,13] + [11,0]t	99
25	6	4	[1,3,2,23,22] + [4,5,6,20,19] + [7,8,9,17,16] + [10,11,14] + [12,0]t	99
27	6	4	[1,3,2,25,24] + [4,5,6,22,21] + [7,8,9,19,18] + [10,11,12,16,15] + [13,0]t	99
27	6	5	[1,2,3,25,24] + [4,5,6,22,21] + [7,8,9,19,18] + [10,11,16,15] + [12,13,14]t	99
27	8	4	[1,3,2,4,25,24,23] + [5,6,7,8,21,20,19] + [9,10,11,12,17,16,15] + [13,0]t	99
27	10	4	[1,3,2,4,5,25,24,23,22] + [6,7,8,9,10,20,19,18,17] + [11,12,15] + [13,0]t	99
27	10	8	[1,3,2,4,5,25,24,23,22] + [6,7,8,9,10,20,19,18,17] + [11,12,13,15,14,0]t	99
27	10	9	[1,2,3,4,5,25,24,23,22] + [6,7,8,9,20,19,18,17] + [10,11,12,16,15,14,13]t	99
28	6	5	[1,3,2,26,25] + [4,5,6,23,22] + [7,8,9,20,19] + [10,11,12,17,16] + [13,14,0]t	99
28	10	9	[1,3,2,4,5,26,25,24,23] + [6,7,8,9,10,21,20,19,18] + [11,12,13,14,15,16,0]t	99
29	8	6	[1,3,2,4,27,26,25] + [5,6,7,8,23,22,21] + [9,10,11,12,19,18,17] + [13,15,14,0]t	99
29	8	7	[1,2,3,4,27,26,25] + [5,6,7,8,23,22,21] + [9,10,11,19,18,17] + [12,13,14,16,15]t	99



Table A2. List of sets of shifts for CNBs in three different sizes of periods and treatments smaller than 30.

t	k ₁	k ₂	k ₃	Sets of shifts	ES
14	6	5	4	[1,2,3,12,11] + [4,5,9,8] + [6,7]t	98
17	8	6	4	[1,2,3,4,15,14,13] + [5,6,7,11,10] + [8,0]t	99
19	8	7	5	[1,2,3,4,17,16,15] + [5,6,7,13,12,11] + [8,9,10]t	99
20	6	5	4	[1,2,3,18,17] + [4,5,6,15,14] + [7,8,12,11] + [9,10]t	99
20	8	7	6	[1,2,3,4,18,17,16] + [5,6,7,14,13,12] + [8,9,11,10]t	99
23	10	8	6	[1,2,3,4,5,21,20,19,18] + [6,7,8,9,16,15,14] + [10,11,12,0]t	99
25	8	6	4	[1,2,3,4,23,22,21] + [5,6,7,8,19,18,17] + [9,10,11,15,14] + [12,0]t	99
25	10	9	7	[1,2,3,4,5,23,22,21,20] + [6,7,8,9,18,17,16,15] + [10,11,12,13,14]t	99
26	6	5	4	[1,2,3,24,23] + [4,5,6,21,20,19] + [7,8,9,18,17,16] + [10,11,15,14] + [12,13]t	99
26	10	9	8	[1,2,3,4,5,24,23,22,21] + [6,7,8,9,19,18,17,16] + [10,11,12,15,14,13]t	99
27	8	7	5	[1,2,3,4,25,24,23] + [5,6,7,8,21,20,19] + [9,10,11,17,16,15] + [12,13,14]t	99
28	8	7	6	[1,2,3,4,26,25,24] + [5,6,7,8,22,21,20] + [9,10,11,18,17,16] + [12,13,15,14]t	99



Mathematical modelling and standardization of technology for the production of bael fruit powder

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In this study, pulp from ripe bael fruits was dried in the open sun, solar, greenhouse and hot air (50°C, 60°C, 70°C and 80°C) at three levels of thickness (2, 4 and 6 mm). Maximum antioxidant activity of 107.62 and 108.09 mg/100 g, total phenol content of 41.95 and 43.79 mg/100 g and overall acceptability scores (8.33 and 8.11) were found in bael powder dried using natural (greenhouse) and mechanical (50°C) drying methods respectively, with 2 mm of pulp thickness. The Page model was found to be the best fitted for drying bael pulp.

Keywords: Antioxidant activity, bael pulp, mathematical modelling, thin layer drying, total phenol content.

AEGLE marmelos, belonging to the family Rutaceae, is commonly known as bael in the indigenous system of medicine in India¹. Bael is a deciduous sacred tree having useful medicinal properties, especially cooling and laxative properties². The pulp of the bael fruit is a natural source of essential antioxidants and bioactive compounds. Various parts of the bael plant are used in gastrointestinal-related problems such as diarrhoea, dysentery and diabetes. Bael is well-known to have antibacterial, antifungal, anticancer, pyretic and analgesic activities and relieves constipation. Several phytochemicals have been isolated and recognized from various parts of bael, including alkaloids, phenols, glycoside coumarins, steroids, tannins and carotenoids³.

Drying is the process of removal of moisture which supports the microbial activity. It improves shelf life compared to liquid products and reduces the cost of transportation. Small farmers cannot afford to dry their agricultural products in a commercial dryer as it is expensive with high maintenance costs. So, a farmer-friendly option is to adopt advanced greenhouse and solar drying technologies compared to traditional drying (open-sun drying, OSD). Although researchers have worked on drying bael fruit pulp using a tray dryer, hot-air cabinet dryer and freeze dryer, there are no comparative studies to determine the suitability of different

dryers for drying bael fruit pulp. Assessment of drying kinetics as a function of drying conditions can help in the simulation for predicting suitable drying conditions.

Materials and methodology

Pulp extraction

Bael fruits (*A. marmelos*) of Rajasthani local variety were procured from ICAR-Directorate of Medicinal and Aromatic Plants Research, Boriavi farm, Anand, Gujarat, India. They were sorted to discard the diseased, damaged and broken fruits. The fruits were washed thoroughly under tap water and used for further experiments. The bael pulp with seeds and fibre was added with equal amounts of water, mixed and heated for 1 min at 80°C (refs 4, 5). A brush-type pulp extractor/pulper (Khera Laboratory Instruments, New Delhi) was used to extract bael fruit pulp with a 3 mm size sieve made up of 22 gauge stainless steel.

Drying methods

The pulp was distributed evenly in the trays at three thickness levels (2 (T1), 4 (T2) and 6 (T3) mm). The trays were placed in an open environment for direct exposure of bael fruit pulp to sunlight for OSD (D1). Cabinet-type solar dryer (SD, D2; Sardar Patel Renewable Energy Research Institute (SPRERI), Anand) and a gable roof-type greenhouse dryer (GHD, D3) of span 4.5 m × 3.0 m (College of Food Processing Technology and Bioenergy, Anand Agricultural University (AAU), Anand) were used for drying of bael pulp using the natural drying method.

For mechanical drying, a laboratory hot-air tray dryer (Narang Scientific Works Pvt Ltd, New Delhi) was used. It was fitted with a manually controlled digital thermostat, PT-100 thermocouple, a blower driven by a 0.5 HP motor and electric finned heaters of 3 × 1 kW. The tray dryer was adjusted to selected temperatures (50°C (D4), 60°C (D5), 70°C (D6) and 80°C (D7)). The dried bael pulp was ground using a laboratory mixer-grinder to make the powder.



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Standardization

Standardization of drying parameters was done in two ways – natural drying method and mechanical drying method. It was based on the total phenol content, total antioxidant content and sensory attributes (score) of the bael fruit powder. The critical difference (CD) and coefficient of variation (CV) values were determined using factorial CRD software developed by the Department of Statistics, BA College of Agriculture, AAU. Total phenol was determined by Folin–Ciocalteu method⁶. Total antioxidant content was determined using the FRAP method⁷. The sensory evaluation of bael fruit powder was done using a nine-point hedonic scale⁸.

Modelling of thin-layer drying curves

The development of a model is necessary to study the drying characteristics of bael pulp. The experimental drying data of bael pulp using different drying methods or temperatures and thickness of the pulp were fitted into three thin-layer drying models (Page, two-term and Newton models).

(I) Page model⁹

$$MR = \exp(-kt^n). \quad (1)$$

(II) Two-term model¹⁰

$$MR = a \exp(-kt) + b \exp(-gt). \quad (2)$$

(III) Newton model¹¹

$$MR = \exp(-kt). \quad (3)$$

Here MR is the moisture ratio, t the time (min) and k , n , a , b , g are the empirical constants and coefficients in the drying models.

The root mean square error (RMSE) and χ^2 values were calculated as follows

$$\chi^2 = \frac{\sum_{i=1}^N (MR_{Exp,i} - MR_{Pre,i})^2}{(N - Z)}, \quad (4)$$

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (MR_{Pre,i} - MR_{Exp,i})^2}, \quad (5)$$

where $MR_{Exp,i}$ is the i th experimentally observed moisture ratio, $MR_{Pre,i}$ the predicted moisture ratio, N the number of observations and Z is the number of constants of each respective model.

A model is considered to be the best if the average R^2 value is high, and average χ^2 and RMSE values are low.

Results and discussion

Drying characteristics

The extracted pulp with 576.58% (dry basis; db) moisture content was dried using various natural as well as mechanical drying methods or temperatures for three levels of thickness of pulp. Figure 1 shows the time required to achieve the final moisture content (10–13% db) for all the drying methods. Initially, the drying rate was higher, and it decreased gradually with time for all the drying methods (Table 1).

The drying time required to achieve final moisture content of bael fruit pulp in greenhouse drying was less than OSD and solar drying, because the products placed in trays received solar radiation through plastic film material, and moisture was removed by natural and forced convection. A similar result was observed for the drying of chilli and banana in another study¹². The drying rate was much higher in greenhouse drying compared to OSD for date fruit¹³.

In tray drying, the drying time was reduced with an increase in temperature for all levels of thickness of bael fruit pulp. This was due to increased vapour pressure in the samples with increased temperature from 50°C to 80°C. As a result, moisture was removed comparatively faster. Similar outcomes were observed for drying bael fruit pulp⁵ and stone apple slices¹⁴.

Standardization of drying parameters

Table 2 shows the effect of various drying methods and levels of thickness on total phenol content, total antioxidant content and sensory attributes in terms of colour, flavour and overall acceptability.

For standardization of drying parameters for natural drying, all five parameters, namely total phenol content, total antioxidant content and sensory attributes in terms of colour, flavour and overall acceptability, were considered. It was found that the D3T1 combination (greenhouse drying method with 2 mm thickness of bael fruit pulp) gave better results than the other combinations because this sample gave the highest total antioxidant and total phenol content. Also, the highest colour and overall acceptability (OA) values were also obtained. Hence, the combination D3T1 was considered the standardized drying parameter for natural drying.

For mechanical drying, parameters such as total phenol content, total antioxidant content and sensory attributes in terms of colour, flavour and overall acceptability were considered. The D4T1 combination (50°C drying temperature with 2 mm thickness of pulp) was found to be the best among all combinations because the sample gave the highest total antioxidant and total phenol contents. Also, it had the highest colour, flavour and overall acceptability value. Hence, the combination D4T1 was considered as the drying parameter for mechanical drying method.



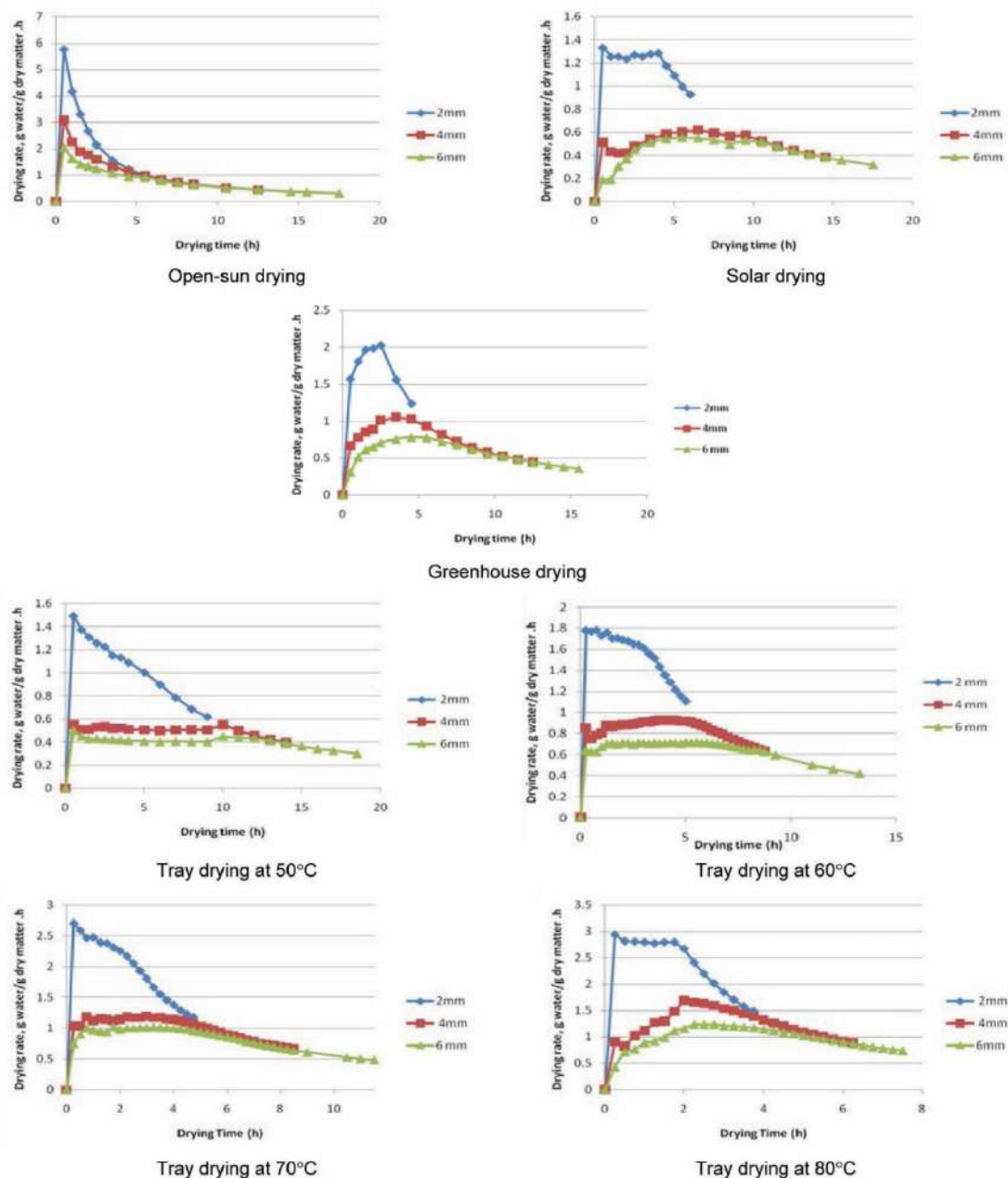


Figure 1. Drying rate versus drying time curves of bael fruit pulp for various drying methods.

Table 1. Time required for drying of bael fruit pulp using various drying methods and for different level of thicknesses of the pulp

Drying method	Temperature (°C)	Drying time (h)		
		Thickness		
		2 mm	4 mm	6 mm
Open-sun drying	—	6.5	12.5	17.5
Solar drying	—	6	14.5	17.5
Greenhouse drying	—	4.5	12.5	15.5
Tray drying	50	9	14	18.5
	60	5.75	8.75	13.25
	70	4.75	8.5	11.5
	80	3.75	6.25	7.5



Table 2. Effect of drying methods and thickness on TPC, TAA and sensory attributes

Parameters	Drying methods	Name of drying methods (D)	Pulp thickness (T) (mm)			CD			CV%
			2	4	6	D	T	DT	
TPC	Natural drying	D1-OSD	26.65	25.53	18.45	0.769	0.769	NS	0.75
		D2-SD	23.04	22.94	20.66				
		D3-GHD	41.95	28.99	28.62				
	Mechanical drying	D4-50°C	43.79	36.15	23.22	2.249	1.948	3.896	7.03
		D5-60°C	35.80	30.24	18.92				
		D6-70°C	38.91	31.05	28.79				
		D7-80°C	41.00	39.16	27.35				
TAA	Natural drying	D1-OSD	106.19	104.76	103.34	0.769	0.769	NS	0.75
		D2-SD	101.91	101.91	100.00				
		D3-GHD	107.62	105.24	103.34				
	Mechanical drying	D4-50°C	108.09	106.19	103.81	0.803	0.695	1.390	0.79
		D5-60°C	106.19	102.38	100.95				
		D6-70°C	104.76	103.81	103.34				
		D7-80°C	108.09	106.66	105.24				
Colour (sensory)	Natural drying	D1-OSD	7.17	6.25	6.58	NS	0.751	NS	16.01
		D2-SD	7.92	7.08	6.50				
		D3-GHD	7.92	7.00	6.42				
	Mechanical drying	D4-50°C	7.83	7.92	6.58	NS	0.485	NS	11.74
		D5-60°C	8.00	6.92	6.33				
		D6-70°C	7.92	7.00	6.92				
		D7-80°C	7.50	6.67	6.33				
Flavour (sensory)	Natural drying	D1-OSD	6.83	6.83	6.75	NS	NS	NS	9.72
		D2-SD	7.58	6.92	6.67				
		D3-GHD	7.75	7.17	7.08				
	Mechanical drying	D4-50°C	7.50	7.17	6.58	NS	0.502	NS	12.49
		D5-60°C	7.58	6.67	6.54				
		D6-70°C	7.75	6.92	6.96				
		D7-80°C	7.00	6.50	6.33				
OAA (sensory)	Natural drying	D1-OSD	7.00	6.50	6.42	NS	0.543	NS	11.50
		D2-SD	7.58	7.00	7.00				
		D3-GHD	7.75	7.08	6.83				
	Mechanical drying	D4-50°C	7.58	7.42	6.42	NS	0.472	NS	11.77
		D5-60°C	7.75	6.75	6.29				
		D6-70°C	7.67	6.83	6.79				
		D7-80°C	7.17	6.50	6.17				

TPC, Total phenol content; TAA, Total antioxidant activity; OAA, Overall acceptability; OSD, Open-sun drying; SD, Solar drying; GHD, Greenhouse drying; CD, Critical difference; CV, Co-efficient of variance.

Fitting of drying models

Based on moisture loss data, the drying rate and moisture ratio were calculated. The coefficient of determination (R^2) was determined using SPSS-15. The three drying models (Page model, two-term model and Newton model) were compared according to their coefficient of determination, RMSE and chi-square values to determine the best-fit model for drying bael fruit pulp for different levels of thickness of pulp (Table 3).

The values of R^2 , χ^2 and RMSE of all the models ranged from 0.924 to 1, 4.4E-05 to 0.011 and 6.61E-03 to 0.102, with an average value of 0.951 to 0.995, 5.21E-04 to 2.7E-03 and 8.39E-03 to 2.06E-02 respectively.

The moisture ratio data of bael fruit pulp dried using different drying methods or temperatures and for different levels of thickness of pulp were fitted into three drying models (Table 3). It was observed that the Page model had the highest average R^2 and lowest average RMSE and χ^2

values compared to the other two models. Table 4 shows the values of constants of the best-fitted drying model (Page model). The Page model was the best-fitting for drying bael fruit pulp with various drying methods or temperatures and levels of pulp thickness, with average values of R^2 , RMSE and χ^2 being 0.995, 5.21E-04 and 8.39E-03 respectively. This model was found to be the best for drying whole and sliced turmeric rhizomes in a solar conduction dryer¹⁵ and freeze-dried aloe vera fillets¹⁶.

Suitability of the model

The accuracy of the established model for thin-layer drying of bael fruit pulp was evaluated by comparing the predicted moisture ratio of the Page model and the experimental moisture ratio. Figure 2 shows the performance of the model for all the drying methods/temperatures and levels of thickness of bael fruit pulp. The predicted moisture ratio data of



Table 3. Statistical parameters for different drying models using various drying methods and different levels of thickness of bael fruit pulp

Drying methods_ thicknesses	Two-term model			Page model			Newton model		
	R^2	Chi-square	RMSE	R^2	Chi-square	RMSE	R^2	Chi-square	RMSE
OSD_2 mm	0.999	8.44E-04	0.023	0.999	8.92E-05	0.008	0.999	8.27E-05	0.009
OSD_4 mm	0.997	4.00E-04	0.017	0.996	4.33E-04	0.019	0.996	4.01E-04	0.019
OSD_6 mm	0.997	3.94E-04	0.017	0.996	4.34E-04	0.019	0.996	4.82E-04	0.021
SD_2 mm	0.945	9.51E-03	0.081	0.99	1.34E-03	0.034	0.932	8.72E-03	0.090
SD_4 mm	0.98	3.71E-03	0.054	0.996	6.06E-04	0.023	0.929	1.10E-02	0.102
SD_6 mm	0.982	3.34E-03	0.052	0.996	7.26E-04	0.026	0.935	9.96E-03	0.097
GHD_2 mm	0.977	5.80E-03	0.054	0.987	2.20E-03	0.041	0.945	7.78E-03	0.083
GHD_4 mm	0.966	6.36E-03	0.070	0.999	1.58E-04	0.012	0.951	7.30E-03	0.083
GHD_6 mm	0.973	4.74E-03	0.061	0.999	9.22E-05	0.009	0.957	6.41E-03	0.078
TD50_2 mm	0.981	2.83E-03	0.045	0.995	5.75E-04	0.022	0.977	2.65E-03	0.050
TD50_4 mm	0.985	2.32E-03	0.043	0.983	2.45E-03	0.047	0.924	1.01E-02	0.098
TD50_6 mm	0.982	2.89E-03	0.049	0.985	2.17E-03	0.045	0.928	9.92E-03	0.097
TD60_2 mm	0.987	1.79E-03	0.039	0.996	5.15E-04	0.022	0.951	5.68E-03	0.074
TD60_4 mm	0.953	5.91E-03	0.073	0.996	5.25E-04	0.022	0.932	7.83E-03	0.087
TD60_6 mm	0.957	5.02E-03	0.067	0.993	7.44E-04	0.027	0.938	6.66E-03	0.081
TD70_2 mm	0.988	1.51E-03	0.035	0.996	4.63E-04	0.020	0.969	3.36E-03	0.056
TD70_4 mm	0.986	1.68E-03	0.039	0.997	3.10E-04	0.017	0.951	5.35E-03	0.072
TD70_6 mm	0.987	1.46E-03	0.036	0.998	2.12E-04	0.014	0.956	4.74E-03	0.068
TD80_2 mm	0.972	4.48E-03	0.058	0.993	9.07E-04	0.028	0.935	8.40E-03	0.089
TD80_4 mm	0.974	3.79E-03	0.057	0.999	1.98E-04	0.014	0.924	9.66E-03	0.096
TD80_6 mm	0.986	1.91E-03	0.041	1	4.67E-05	0.007	0.937	7.58E-03	0.085
Average	0.979	1.81E-03	0.014	0.995	5.21E-04	0.008	0.951	2.70E-03	0.021

TD50, Tray drying at 50°C; TD60, Tray drying at 60°C; TD70, Tray drying at 70°C; TD80, Tray drying at 80°C.

Table 4. Constants of the best-fitted drying model of bael fruit pulp

Drying method	Temperature (°C)	Thickness (mm)	Constants of Page model $MR = \exp(-kt^n)$		Coefficient of determination (R^2)	Chi-square (χ^2)	RMSE
			k	n			
Sun drying	–	2	0.023	1.019	0.999	8.92E-05	8.45E-03
		4	0.009	0.991	0.996	4.33E-04	1.93E-02
		6	0.004	1.059	0.996	4.34E-04	1.96E-02
Solar drying	–	2	0.000	1.685	0.990	1.34E-03	3.37E-02
		4	2.564E-5	1.818	0.996	6.06E-04	2.32E-02
		6	3.201E-5	1.748	0.996	7.26E-04	2.56E-02
Greenhouse drying	–	2	0.001	1.616	0.987	2.20E-03	4.06E-02
		4	0.000	1.741	0.999	1.58E-04	1.18E-02
		6	0.000	1.635	0.999	9.22E-05	9.08E-03
Tray drying	50	2	0.001	1.320	0.995	5.75E-04	2.22E-02
		4	6.360E-5	1.630	0.983	2.45E-03	4.68E-02
		6	3.826E-5	1.658	0.985	2.17E-03	4.45E-02
	60	2	0.001	1.572	0.996	5.15E-04	2.17E-02
		4	0.000	1.682	0.996	5.25E-04	2.23E-02
		6	0.000	1.599	0.993	7.44E-04	2.66E-02
	70	2	0.002	1.435	0.996	4.63E-04	2.04E-02
		4	0.000	1.579	0.997	3.10E-04	1.71E-02
		6	0.000	1.533	0.998	2.12E-04	1.42E-02
	80	2	0.000	1.799	0.993	9.07E-04	2.82E-02
		4	0.000	1.889	0.999	1.98E-04	1.35E-02
		6	0.000	1.701	1.000	4.67E-05	6.61E-03

bael pulp drying followed a straight line with an angle of 45°, which indicates the suitability of the Page model for describing the drying of bael fruit pulp. A similar approach for selecting a model for thin-layer drying has also been reported for carrot pomace¹⁷ and bael fruit pulp^{5,18}.

Conclusion

In this study, the bael fruit pulp was dried using various drying methods and for different levels of pulp thickness. The drying rate decreased gradually with time for various



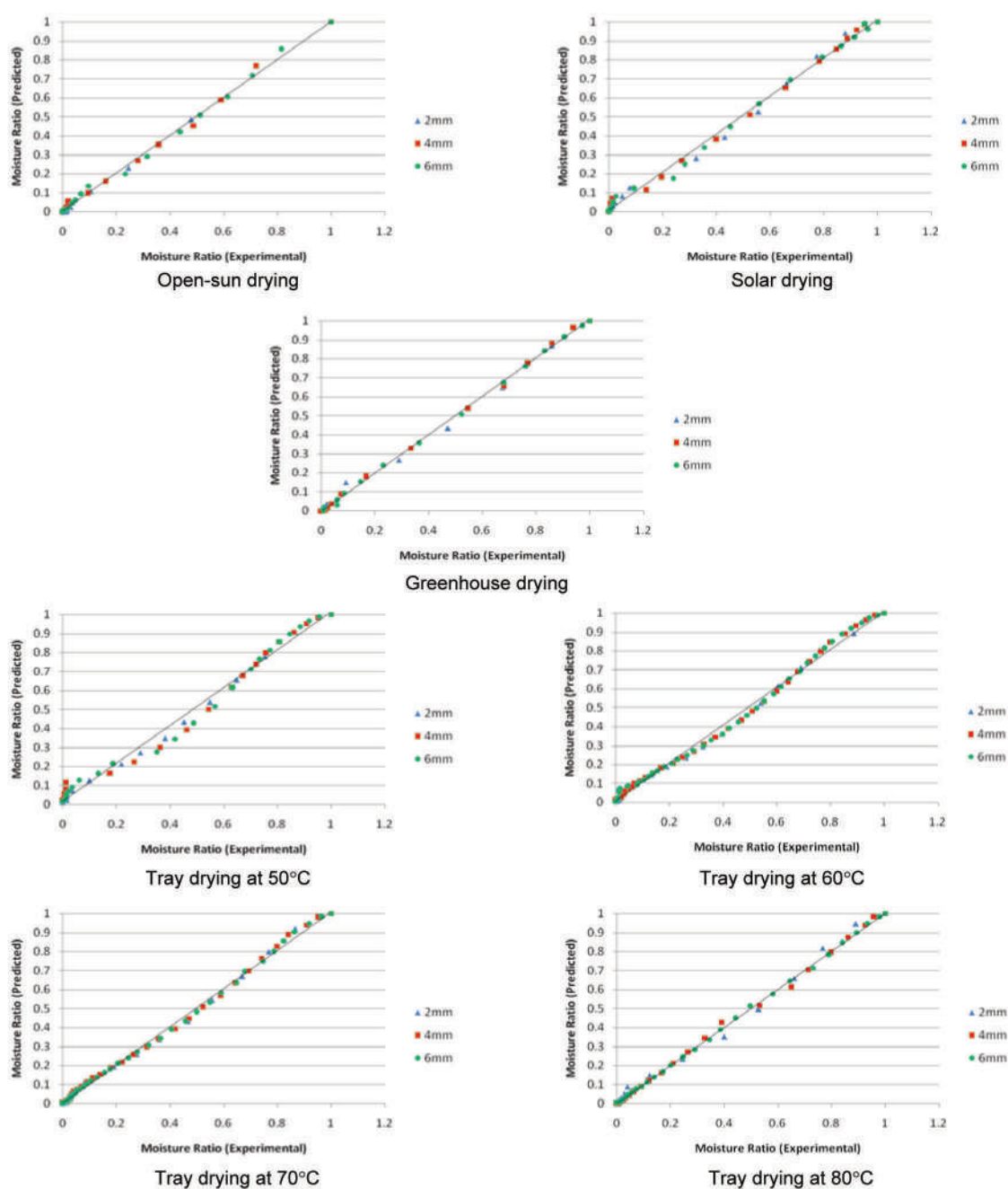


Figure 2. Experimental versus predicted moisture ratio (Page model: $MR = \exp(-kt^n)$).

drying methods and thickness of pulp. The maximum total phenol content of 41.95 mg/100 g was found in bael powder dried using the natural drying method, i.e. greenhouse drying with 2 mm pulp thickness. While in mechanical drying at 50°C and 2 mm pulp thickness, it was 43.79 mg/100 g. Maximum antioxidant activity of 107.62 mg/100 g was found in bael powder dried using a natural drying method with 2 mm thickness of bael pulp. While at 50°C and 80°C with 2 mm thickness of bael pulp, the maximum antioxidant activity of 108.09 mg/100 g was observed for mechanical drying. Maximum overall acceptability score was

found in bael powder with 2 mm thick pulp in both the drying methods, i.e. natural and mechanical. The Page model was found to be the best fitted for drying bael fruit pulp using different drying methods or temperatures and levels of pulp thickness, with average values of R^2 , RMSE and χ^2 being 0.995, 5.21E-04 and 8.39E-03 respectively.

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Exploring Mythological Influence in Amruta Patil's Adi Parva: Churning of the Ocean

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Abstract

The impact of mythology in Indian graphic novels is a fascinating exploration of storytelling, successfully merging mythology with modern visual narratives. Ancient myths are creatively reinterpreted and presented in these vibrant graphic novels, which appeal to contemporary readers by providing new insights and meanings. Indian mythology offers a vast array of characters, epics, and symbols that graphic novelists adeptly use into their works. These graphic novels revitalise mythical stories by using complex visual components and unique storytelling strategies. Indian graphic novels invite readers to explore the enduring relevance and evolving interpretations of mythology in the dynamic realm of visual storytelling. This research paper explores the complex progress of mythology and visual narrative in contemporary Indian literature, specifically examining Amruta Patil's Adi Parva: Churning of the Ocean (2012). The research begins by analysing theories of visual language, investigating the ways in which symbols and visual elements enhance the narrative in graphic novel. The study covers the examination of how graphic novels are received, assessing their influence on popular culture and their evolving interpretation of Indian mythology. This study offers a comprehensive understanding of how Indian graphic novels function as vehicles for cultural reinterpretation and contribute to the continuous development of mythological narratives in contemporary literature.

Key Words: Visual Narratives, contemporary society, Indian graphic novels, Mythology

Mythology has great importance in Indian culture, exerting influence on a wide range of ideas, themes, and narratives. Indian literature has been profoundly impacted by it and has been transmitted across centuries via oral traditions. Myths are intricate narratives that provide profound insights into the nature of the world and human existence, serving as symbolic representations of primal impulses and comprehension of the cosmos. The resurgence of interest in ancient myths among creative writers has been ignited by the recognition of mythology as a source of universal emotions. Indian authors have incorporated mythological elements into



numerous genres of literature, drawing inspiration from Vedic scriptures, Epics, and Puranas. The advent of globalisation in today's day provides an opportunity to reinterpret and re-examine myths, thereby offering new perspectives. Mythofiction, also known as mythic fiction or mythological fiction, is a contemporary trend that involves the reinterpretation, recreation, retelling, remembrance, reintroduction, and reinvention of tales from a contemporary standpoint. Authors such as Anand Neelakantan, Amish Tripathi, Ashok K Banker, Devdutt Pattanaik, Nilanjan P Choudhuri, Chitra Banerjee Divakaruni, Kavita Kane, and Amruta Patil use mythology as a means to discover fresh avenues for artistic representation and build a novel narrative in Indian literature produced in the English language.

Writers innovate semiotics by developing new approaches and styles, aiming to portray the irrationality of existence, its fundamental drives, and ceaseless battles via the use of myths. Ancient myths provide the foundation of history, philosophy, and psychology in contemporary popular culture. Through their involvement in creative processes, they evaluate, examine, and evaluate modern society. Currently, there is a growing trend of experimentation and innovation in several genres of Indian fiction, including graphic novels, science fiction, chick literature, and diaspora writing. Their approaches to examine Indian literature provide a formidable obstacle to our traditional technique, particularly due to the emergence and widespread adoption of novel forms in the contemporary era.

Contemporary graphic novels, which blend text and art to create a compelling tale, have grown to be an important part of Indian mythology. These novels bridge eras and cultures, enabling readers to understand and interact with India's rich mythology. The visual aspect of graphic novels is essential in depicting deities, divine entities, mythological creatures, and the complex symbolism found in Indian mythology. Furthermore, the visual features provide an aesthetic charm that may fascinate a wide range of readers, even those who do not often interact with conventional texts.



Graphic novels provide a distinct platform for reimagining and retelling tales, showcasing the cultural backdrop of contemporary society. Artists and writers have the ability to include their own perspectives into these tales, while still acknowledging the essential themes and principles of Indian mythology. Adaptation is crucial for preserving the significance and applicability of myths in contemporary contexts. Indian myths are characterised by their elaborate story frameworks and the presence of several characters. Graphic novels effectively convey these narratives via unified visual storytelling, hence improving accessibility and understanding for readers. Graphic novels facilitate the dissemination of Indian mythological concepts to a worldwide audience by surpassing language boundaries, so promoting a more extensive comprehension of Indian culture and mythology.

Graphic novels often consist of multimodal tales. They communicate their narratives by using both verbal and visual mediums to establish significances. Will Eisner, a renowned figure in the comic industry, used the term "sequential art" to encompass both comics and graphic novels. He defines it as, "a means of creative expression, a distinct discipline, an art and literary form that deals with the arrangement of pictures or images and words to narrate a story or dramatize an idea" (11). Indian Graphic Novels, originating in the latter half of the 20th century, depicted mythology, everyday life, and imaginative elements, providing profound insights into the culture and customs of India. Anant Pai released the first Indian comic book, Amar Chitra Katha, in 1967. The development of Indian graphic novels has progressed swiftly during the 21st century, marked by the emergence of the first Indian Graphic Novel, River of Stories, authored and drawn by Orijit Sen in 1994. The genre has undergone a transformation from its origins as comic book series to books, effectively exploring and discussing social, cultural, and political matters. In the present time, a number of authors are making significant contributions to Indian Graphic Novels. Some notable examples include Sarnath Banerjee's works such as Corridor (2004), The Barn Owl's Wondrous Capers (2007), and The Harappa Flies



(2011). Additionally, Naseer Ahmed's *Kashmir Pending* (2007), Saraswati Napal's *Sita, Daughter of the Earth* (2011), *Draupadi: The Fire-Born Princess* (2013) and *Chhotu: A Tale of Partition and Love* (2019) are also worth mentioning. The recent surge in popularity of Graphic Novels may be attributed to the contemporary preference for novels that include visual elements. The presence of image illustrations in a book also has a big impact on capturing the attention of readers.

Graphic novels typically have a structural framework consisting of a panel, voiceover, speech bubbles, emanta, expressions, gutter, narration, colour, graphic weight, foreground, midground, background, and transitions. The panel provides a perspective for the reader, similar to adjusting the focus of a camera. Voiceover establishes a direct communication channel with the reader, allowing for a discourse about the story. Speech bubbles visually represent a character's thoughts or utterances, while emanta uses symbols like hearts, question marks, and tears to convey emotions. Expressions convey facial or bodily gestures to convey emotional states. The gutter, the space between two panels, prompts the reader to infer events throughout the temporal gaps. Narration uses textual elements and visual imagery to convey the storyline, leaving little room for the reader's interpretation. Colour enhances dramatic elements within narratives, while graphic weight defines how a picture differs or contracts. Foreground, midground, and background provide a comprehensive understanding of the topic, while transitions, such as the gutter, serve as the space between panels in comic or graphic novels. Overall, graphic books effectively convey their intended message and engage the reader.

When analysing a graphic novel, it is crucial to focus our attention on the specific characteristics pertaining to the text, such as,

- the perspective it takes.
- The balance between the written information and its visual features
- Elements of colours and brush strokes.
- Plot: The sequence of events in a story or narrative.



- Grammatical organisation of sentence: The structure and organisation of words and phrases in a sentence.

Amruta Patil is an author of Graphic Novels who gained acclaim for her visual arts and use of new methods in her artwork. Her works not only include modern subjects, but also showcase the display of graphic arts that dynamically convey the depth of her characters and the tale. Amruta Patil, born in Pune in April 1979, gained recognition as the pioneering female Graphic Novelist from India. Her Graphic Novels are enhanced by her independent and traditional visual style, which encompasses watercolour, charcoal, acrylic painting, and collage, resulting in a more aesthetically pleasing outcome. She has used bold portrayals to depict figures from Indian mythology in order to reveal contemporary social concerns, political dilemmas, and environmental abuse that are pertinent to present-day audiences.

Graphic novels, which combine text and images where the images serve to support and offer context for the tales, continue to be both captivating and easily comprehensible. Amruta Patil has used graphic novels as a means to reveal reoccurring motifs such as mythology, sustainable lifestyles, sexuality, identity, the environment, and oral traditions. Through this method, some crucial topics of society are disseminated to the general public and are also relevant to contemporary society. Furthermore, delving into mythology not only simplifies the process of reading, but also provides a profound understanding of the narrative, allowing readers to acquire information about India's ancient history, traditions, and culture.

Adi Parva: Churning of the Ocean (2012) is the second Graphic Novel authored by Patil. Many individuals are drawn to reading epics when they are presented with visual depictions, which is why a significant number of people are familiar with epics via various forms of visual media rather than primarily through books. Amruta Patil's Adi Parva: Churning of the Ocean showcases captivating images, the artist's ingenuity, and imagination as it presents the many characters and history of the Mahabharata. Patil included the intellectual elements of Mahabharata



that resonate with contemporary audiences. The Mahabharata narrative is framed by a meta-narrative in which a woman, who is subsequently revealed to be the goddess Ganga, narrates the story to the audience. The story presents events from the Mahabharata in a non-teleological or chronological fashion. The Adi Parva employs a narrative style that alternates between two levels, progressing thematically rather than only depending on the chronological sequence of events. The narrative's levels are visually distinguished by the deliberate use of lines and colours. The chosen selection emphasises the diverse tones and spatio-temporal characteristics of both the narrative and the actual setting where the storytelling takes place. The first chapters of Adi Parva fulfil the function of creating separate narrative places and levels. One of these areas is a dynamic and referential palimpsest, distinguished by vibrant hues, that forms the narrative universe. In comparison, the other region seems external and devoid of vibrancy, giving the impression of being blurred and mundane, with a prevailing hue of charcoal grey. (Fig 4.1)



Fig 4.1 Free-point (12)

The first chapter, titled "Sutrathar," begins with the culmination of the Kurukshetra conflict, signifying the epitome of the Mahabharata narrative. However, the story then shifts to the investigation of the beginnings of the universe. The first panel features an illustration of a vulture, which is then followed in the next four panels.

The next image shifts to a broader perspective, revealing the existence of white people distinguished by ultramarine contours, symbolising departed persons and those in a state of grief. The background is adorned with an assortment of crimson hues. Page five has a remarkable similarity to the morphology of blood cells inside a blood artery. Prior to reaching the last page of the chapter, there is a full-page panel that shows a metamorphosis taking place. In this transition, the white individuals and scarlet background take on the look of blood platelets. Positioned at the top left corner of the visual composition is a representation of a dead person, showing the head and upper body, with visible blood flowing from the area around the skull. Patil skilfully used visual elements to properly communicate the significance of blood throughout her narrative. (Fig 4.2)



Fig 4.2 Begging (24)

The latter portions of the chapter reveal the noticeable existence of anchoring textual bubbles. The bubbles are created by an anonymous narrator and are penned by hand without any noticeable emphasis. The chapter relies on Patil's analysis of Paul Gauguin's Vision after the Sermon, which sparked her investigation into different shades of red and their contrast with ultramarine blues.

Patil's *Adi Parva*, explore the complex influence of mythology in contemporary society, taking inspiration from Roland Barthes' influential text, "Mythologies." Barthes' analysis of the manner in which myths operate as cultural symbols and

transmitters of social principles is especially pertinent to Patil's artistic pursuits. Patil adeptly reinterprets old Indian stories in "Adi Parva," expertly weaving them together with new surroundings to contemplate the collective consciousness of present-day society. Patil uses Barthes' idea of myths as cultural structures to analyse and scrutinise prevalent beliefs, hence questioning and challenging society conventions within the narrative space.

Patil's graphic novels use mythical ideas to shed light on contemporary concerns and societal systems via a combination of visual and narrative elements. By using visual symbolism and storytelling techniques, she examines the several layers of cultural importance that are intricately woven within myths. In doing so, she illuminates the enduring impact of these ancient legends on our perception and comprehension of the world. By doing this, Patil actively interacts with Barthes' concept that. 'Myths are omnipresent in everyday life, shaping perspectives and strengthening societal beliefs.' Patil's contribution in this endeavour helps to a wider discussion on the fluid and ever-changing connection between mythology and the continuously developing fabric of contemporary society.

Patil's novels, include a complex process of transforming myths via several layers. The historical transfer from oral traditions to written texts included a change in story form, emphasis, and the level of involvement of the audience. The oral tradition facilitated flexibility and spontaneity, enabling the tale to be adjusted according to the audience and circumstances. Written documents led to the standardisation of myths, which were often shaped by the perspectives and objectives of the writers and readers.

Within the modern visual media, specifically in graphic novels, the concept of adaptation assumes a fresh perspective. Patil's visual storytelling is a unique style of adaptation that effectively translates mythology into a language that seamlessly blends picture and narrative. The visual story enables an active and dynamic interaction with the mythical content, as readers explore the interrelationship



between written word and graphic representation. Patil's use of graphics enhances the interpretive aspect of the tales, providing readers with a novel and immersive perspective.

Furthermore, here readers are not passive consumers of text, but rather actively interact with a visual environment that supports and enriches his enduring narrative. The visual medium has the capacity to elicit a more intense and emotive reaction, influencing the way the altered myths are seen in a unique manner. As the saying "A picture is worth a thousand words" implies that an image may convey a complex message or idea more effectively than a large amount of text; In the field of literature, graphic novels play a crucial role in evolving the reading of mythical works in current society.

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A study on Profitability Performance based on Investment of Indian Cement Industry

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Abstract:

Maximum Profit is the final aim of any organization. The gain arising from the investment of capital in the business, the excess of incomes over expenditure is monetary gain or profit in any transactions or occupation. Profitability means the ability of any business unit to earn profit continuously. Profitability is a situation in which an entity is generating a profit. Profit performance is a measure of a company's ability to generate profits from its operations. All stakeholders connected with the business entity are interested to know about the profitability of the entity. In this paper, an attempt is made to study profitability performance based on Investment in the business of selected Cement companies in India. The top 10 cement manufacturing companies in India were selected for study and decided to examine the profitability performance based on investment for the period of 10 years from 2010-11 to 2019-20. The Return on Capital Employed, Return on Equity Shareholders' Fund, and Earnings per Share ratio are calculated to measure profitability performance based on investment. Statistical tools like Mean, S.D., and ANOVA were used to analyze data and test hypotheses. The cement Industry is prime and one of the crucial industries in India as in other countries. In India first Cement Company was established in the year 1914 at Porbandar, Gujarat with a capacity of 10,000 tonnes. Currently, India is the 2nd largest producer in worldwide production of cement after China. A huge investment is required to establish the cement manufacturing plant. Hence organizations are interested to earn more and more returns as profit.

Keywords: Profit, Profitability, cement manufacture, profitability ratio, investment

I. INTRODUCTION:



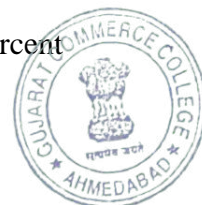
Currently, India is moving quickly towards a Developed country from a developing country. At present India stands at the 3rd place in economy and trying to reach a 5 trillion \$ economy. The growth and development of any country depend on its economic development and growth. In the country, three sectors are very important for economic development. These three sectors are the agricultural sector (Primary Sector), Industrial sector (Secondary Sector), and Service sector. Every sector plays a vital role and is significant for the economic development of each nation. In the present era, the industrial sector has shaped the economic destiny of various developing countries, especially in the case of India. Made in India is now working very smoothly and playing an important role in the manufacturing sector. One of the important sectors of the Indian industry is Cement Industry. The cement industry provides the basic foundation of infrastructural development and provides social overheads in the country.

At present, the government is emphasizing infrastructure development which can be achieved only through the presence of a strong cement industry. Cement is the basic raw material for the construction of roads, bridges, buildings, etc.

India is a huge country and has a vast geographical size and a massive population; various construction activities undertaken by the central Govt., State Govt., Public Sector Undertakings and other organizations, including the private sector generate huge demand for cement. Moreover, housing is the first and foremost requirement of every household, and therefore, the first private cement industry was laid down in the year 1914, when it first started working in Gujarat.

As India has a huge quantity and quality of limestone deposits throughout the country, the cement industry promises huge growth potential. India has a total of 210 large cement plants out of which 77 are in the states of Andhra Pradesh, Rajasthan, and Tamil Nadu. India is in the 2nd position in the production of cement with 320 MTPA in worldwide production after China followed by the USA, Turkey, and other countries. It is expected to reach at reach 401 MTPA in 2020-21. India's cement production is expected to rise between 5-7 percent in FY20, backed by demands in roads, urban infrastructure, and commercial real estate. The compound Annual Growth Rate (CAGR) in the production of cement in India is 5.59%. The Indian cement industry, a cornerstone of the nation's infrastructure development, has witnessed a dynamic and often volatile journey in terms of profit performance. In recent years, a confluence of factors has reshaped the landscape, presenting both challenges and opportunities for cement manufacturers.

Thrust on infrastructure development and Housing for all with 2 crore houses in Urban areas and 4 Rural areas is likely to revive the demand for the cement sector. These sectors are considered to drive the cement industries in India to a great extent, which held nearly 67 percent



of the total cement consumption in India. Out of the different end-user industries of cement, the housing segment accounted for the highest demand in FY 2018. Within this, 38% of demand was generated by the rural housing sector, followed by the urban housing sector was 32%. Such high demand for cement from the housing sector may be attributed to the fast execution of affordable government housing schemes like Pradhan Mantri Awas Yojna and Housing for All by 2022. Apart from housing, commercial, and industrial investments, the infrastructure segment accounted for a considerable demand for cement in India. The CAGR for the consumption of cement is 5.20%.

There has been a high growth seen in cement manufacturing in the last decade. Huge long-term, as well as short-term funds are required for the cement manufacturing unit. Hence, it requires checking the profit performance of cement companies. The body of the paper may consist of the following points.

1. Introduction
2. Profitability
3. Literature Review
4. Research Methodology
5. Data Analysis
6. Conclusion
7. References
8. Annexure

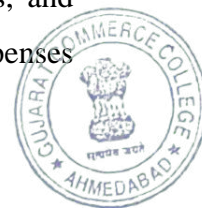
II. PROFITABILITY:

In economics, profit is the difference between revenue that an economic entity has received from its outputs and the total costs of its inputs, also known as surplus value. It is equal to total revenue minus total cost, including both explicit and implicit costs.

Profitability is a measure of an organization's profit relative to its expenses. More efficient organizations will realize more profit as a percentage of their expenses than a less efficient organization, which must spend more to generate the same profit. Profit performance is a measure of a company's ability to generate profits from its operations.

Profitability can tell key stakeholders whether a company can sustain its position in the market and continue to grow. It is the extent to which a company earns a profit. There are two parts to a company's profitability: revenue and expenses. As such, a company is profitable if its revenue exceeds its expenses.

This metric is often expressed as a financial ratio to help management, analysts, and investors better understand how the company can earn the money necessary to cover its expenses



and other company-related costs. These ratios include profit margins and return on equity (ROE). Another key ratio is the earnings before interest, taxes, depreciation, and amortization (EBITDA). This ratio lets stakeholders know whether a company is financially healthy and how it can generate revenue.

III. LITERATURE REVIEW:

Krishna Swarup Gupta (1988) in his analysis on “Financial Statements of Indian Cement Industry: A case study of Associated Cement Companies”, brought the results that the rate of return on total capital employed was measured at 4.2% against the ideal rate of 18% to 24% which is very poor. The total investment had been highly unprofitable. However, the activity and liquidity position showed significant levels. The stock turnover ratio was uniformly good. Debtors varied from 5% to 8% on total current assets. Credit and collection policies were effectively enforced. The percentage of the equity to net fixed assets was below 45%, indicating that shareholders’ funds were inadequate to finance fixed assets.

Chandrasekaran N. (1993) had attempted to examine “Determinants of Profitability in Cement Industry”. The study aimed at drawing inference on the impact of policy measures that led to changes in price and distribution policies relevant to the cement industry. Determinants of profitability were analysed using the technique of ordinary least squares. To find out whether the profitability function has shifted after estimating the function and the test was also done to ascertain the inference. The main findings of this study were that the profitability of the company was based on the assets structure and proper utilization of the production capacity. Some of the main changes in the cement industry environment during the 1980s identified in this study were: from complete control to decontrol, a number of new entrants and substantial additions of capacity, changing technology from inefficient wet process to efficient dry process and from conditions of scarcity of cement to near gloat in the market.

Padmaja Manoharan (2002) through the analytical study “An Analytical study in Profitability of Cement Industry in India” has revealed the variation in profitability of Indian cement companies depending on age, size, and region. The study identified that the quality of earnings depends on management and leverage management. Further, the analysis concludes that the profitability and quality of earnings are influenced by the liquidity factor.

P. K. Das (2006) examined “The Dividend practices in selected Cement Industry” from 1985-86 to 2004-2005. He found that the company followed a conservative dividend policy during the study period. There was a significant increase in profitability due to earnings per share and the capital employed current ratio was in decreasing trend.



G. Vijayakumar (2009) had completed his Ph. D. on “Financial Performance of Cement Industry in India” in the year 2009. He covered technological changes, new investment, merger and acquisition, government initiatives, Ready mix concrete business. 15 cement companies were selected for study by him. The study covers a period of 10 years i.e. from 1998–99 to 2007-08. The data was analysed by working of Solvency Ratio, Profitability Ratio, and Management efficiency, and other various statistical tools were also used in the study. He found that the average current ratio of the selected companies is 1.45 which is below the ideal ratio of 2:1, while the average quick ratio of the selected companies is 1.22, which is above the ideal industrial benchmark of 1:1. The average current assets to fixed assets ratio is 37% for the samples selected. It is almost matching with the ideal ratio. The average debt-equity ratio is 1.93 times for the samples selected which is almost near to the ideal ratio. The average Gross Profit Ratio for the samples studied is 16.78% and the average net profit ratio of the sample selected is 2.26% while the Average Operating Profit Ratio of all selected samples is 19.57 % and average ROI for the sample selected is 9.07%. The average return in terms of net profit on common equity for the selected sample is 2.11 times and the average dividend pay-out ratio of the selected sample is 0.19:1 while the average annual growth rate of EPS is 61%.

Dr. S. J. Bhayani (2010) had published an article on “Determinant of Profitability in Indian Cement Industry: An Economic Analysis” in the South Asian Journal of Management in the year 2010. In this article, he attempted to identify which variables are judging the profitability of the Indian Cement Industry. The study covers all listed cement firms working in India from 2001 to 2008. To determine profitability backward regression analysis was used on the variables of the study. The result of the study shows that liquidity, age of firm, operating profit ratio, interest rate, and the inflation rate have played a vital role in the determination of the profitability of the Indian Cement Industry.

Zubair Arshad and Muhammad Yasir Gondal (2013) made a study on “Impact of working capital management on profitability- A case of the Pakistan cement industry”. They selected 21 cement companies for a study period of 6 years from 2004-2005 to 2009-2010. The study applied regression analysis and various ratios. The study suggested that the profitability of the undertaking might be increased by shortening inventory periods. The positive relationship between the account receivable period and profitability could be reduced. Therefore their power insufficient competition can lead to a decrease in profitability. Empirical findings of the study indicate that the current ratio and net current ratio on total ratio have significantly positive effects on firm profitability. This means that while accounts receivables and inventory periods lengthen,



profitability increases, or vice versa. The other variables that have significant effects on firm profitability are quick ratio affecting it negatively. This means that any increase in stock leads profits to down. The other variables included in the regression model working capital turnover ratio and inventory turnover ratio has no statistically significant effects on firm profitability.

Ankit D. Patel (2015) had done his Ph. D. on “Financial Analysis of Cement Industry of India: A Statistical Approach” in 2015. He has selected 18 cement companies in his study. The selected companies were Prism Cement Ltd., The India Cement Ltd., Sanghi Industry Ltd., UltraTech Cement Ltd., Binani Cement Ltd., Grasim Industry Ltd., Birla Corporation Ltd., J. K. Cement Ltd., J. K. Lakshmi Cement Ltd., Chettinad Cement Ltd., N. C. L. Industries Ltd., Shree Cement Ltd., Mangalam Cement Ltd., Madras Cement Ltd., Barak Valley Cement Ltd., Sagar Cement Ltd., Everest Industries Ltd., and Deccan Cement Ltd. He covered the period of 10 years from 2002-03 to 2011-12. In his study, he discussed facts of the cement industry in India, strong points of the cement industry and stimulations need for it, comparison with global regional consumption production, and per-capita consumption by different countries. For analysis, he used ratio analysis, trend analysis, and ANOVA test. He found that the Gross Profit ratio of the cement industry in India during the first half of the decade was improved from 11.04 to 27.88, while during the second half of the decade it declined from 29.32 to 13.37. The Net Profit Margin ratio of the cement industry of India during the first half of the decade was improved from -6.57 to 16.46, while during the second half of the decade it was declining from 15.76 to 3.12. The Return on Capital Employed Ratio of the cement industry of India during the first half of the decade was improved from -0.425 to 24.65 and then the trend of Return on Capital Employed Ratio started declining. During the second half of the decade, it was declining from 23.37 to 6.91. The Return on Shareholders' Fund Ratio of the cement industry of India during the first half of the decade was improved from -5.57 to 27.86 respectively and then the trend of Return on Shareholders' Fund Ratio started declining. During the second half of the decade, it was declining from 25.97 to 3.14. He also analyzed that so far as the current ratio is a concern, the trend of this ratio was downward. This ratio indicates a linear downward trend. In the case of the debt-equity ratio had a linear declining trend with a regression coefficient of -15.085 which means during the decade the cement industry of India's performance was satisfactory because the cement industry highly depended on its own equity funds and can repay its long term liability easily.

Pankaj Yadav (2017) published an article “An Analysis of Indian Cement Industries based on Profitability Performance”. He attempts to assess the profitability position of cement companies. He selected 10 listed cement companies for 5 years period i.e. from 2012-13 to 2016-17. ACC



Cement Ltd., Ambuja Cement Ltd., Birla Corporation Ltd., Dalmia Cement Ltd., Heidelberg Cement Ltd., India Cement Ltd., Manglam Cement Ltd., Prism Cement Ltd., Shree Cement Ltd., UltraTech Cement Ltd. were selected by him. He measured the Operating Profit Ratio, PBIT Margin, Net Profit Ratio, Return on Capital Employed Ratio, Return on Equity Shareholders' Fund, Return on Long-term Fund, Earnings per Share, and Dividend per share. Mootal Rank Test was used by him to test hypotheses. He concludes that the companies selected for the study show that the industry is somewhat doing well as far as profitability ratios are concerned. UltraTech Cement Ltd., Ambuja Cement Ltd., Shree Cement Ltd., and ACC Cement Ltd. are a top performer in the industry while Prism Cement and Heidelberg Cement perform badly.

IV. RESEARCH METHODOLOGY:

I.I Objectives:

To examine the profitability performance based on Investment during the period of study of the selected cement companies under study.

I.II Hypotheses:

Null hypotheses constructed for the study are as under:

Ho₁ There is no significant difference in the Return on Capital Employed ratio of selected cement companies.

Ho₂ There is no significant difference in the Return on Equity Shareholder's Fund ratio of selected cement companies.

Ho₃ There is no significant difference in the Earning per Share (EPS) ratio of selected cement companies.

Alternative hypotheses constructed for the study are as under:

H₁₁ There is significant difference in the Return on Capital Employed ratio of selected cement companies.

H₁₂ There is significant difference in the Return on Equity Shareholder's Fund ratio of selected cement companies.

H₁₃ There is significant difference in the Earning per Share (EPS) ratio of selected cement companies.

I.III Universe:

The universe of the study consists of all the limited companies working in India and listed on the stock exchange of India in the cement industry.

I.IV Sample:



The top 10 Indian cement companies were selected based on Revenue and Market share as of 31st March 2020.

I.V Period of Study:

The period of the study is 10 years i.e. 2010-11 to 2019-20.

I.VI Data Collection:

The study is totally based on subsidiary data. The required data for the present study has been collected from the published annual reports and financial statements of selected cement companies in India.

I.VII Tools and Techniques for Data Analysis:

Out of different ratios, three key ratios to measure profitability performance based on Investment were calculated. The Return on Capital Employed ratio, Return on Equity shareholders' Fund ratio and Earning per Share (EPS) ratio was calculated.

For statistical analysis, tools viz. EXCEL and SPSS 22.0 trial versions were used. For the comparison of different ratios among selected 10 companies in the cement sector, techniques of statistical analysis like parametric test (ANOVA) or non-parametric test (Kruskal -Wallis test) can be applied. To decide, which test is applicable for a specific ratio, first of all, the normality assumption is verified using Shapiro-Wilk Test. If the normality assumption is violated, then a non-parametric test (Kruskal -Wallis test) is applied. If the normality assumption is not violated, then a parametric test (ANOVA) is applied. ANOVA has one more assumption of homogeneity of variance. If the homogeneity of variance assumption is not violated then Fisher's ANOVA is used and if the homogeneity of variance assumption is violated then Welch ANOVA is used. The assumption of Normality and assumption of homogeneity of variance are shown in Annexure – I and Annexure – II respectively.

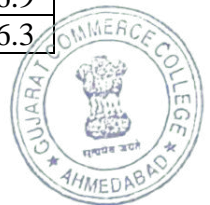
V. Data Analysis:

V.I Return on Capital Employed Ratio:

The Return on Capital Employed ratio for the period of study for 10 cement companies is as under:

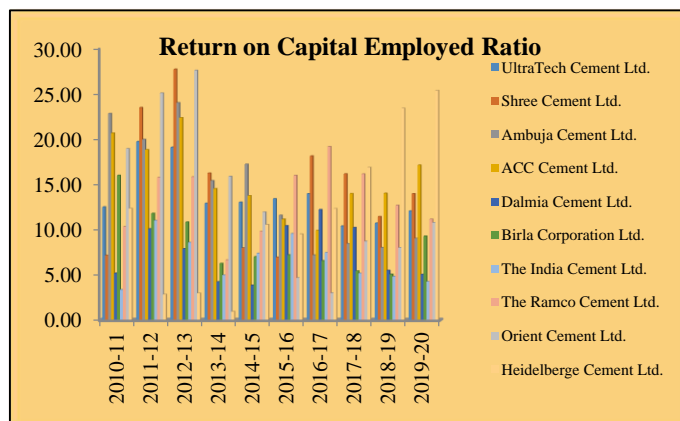
Table: 1 Return on Capital Employed Ratio

Name	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Avg	SD
UCL	12.4	19.6	19.0	12.8	12.9	13.3	13.9	10.3	10.7	12.0	13.7	3.1
ACL	7.15	23.4	27.6	16.2	7.96	6.94	18.0	16.1	11.4	13.9	14.8	6.9
ACCCL	22.7	19.9	23.9	15.3	17.1	11.5	7.17	8.42	8.00	9.01	14.3	6.3



SCL	20.6	18.7	22.3	14.4	13.7	11.1	9.89	13.9	13.9	17.0	15.5	4.0
DCL	5.17	10.0	7.86	4.23	3.84	10.4	12.1	10.1	5.48	5.04	7.45	3.0
BCL	15.9	11.7	10.8	6.25	6.99	7.19	6.55	5.42	5.05	9.25	8.52	3.4
ICL	3.35	10.9	8.56	4.96	7.36	9.53	7.45	5.16	4.81	4.25	6.64	2.5
RCL	10.3	15.7	15.7	6.63	9.78	15.9	19.1	16.1	12.6	11.1	13.3	3.8
OCL	18.9	25.0	27.5	15.8	11.9	4.66	2.99	8.68	7.99	10.7	13.4	8.2
HCL	12.3	2.84	2.97	0.95	10.5	9.48	12.2	16.8	23.3	25.3	11.6	8.3
Overall	11.96											6.0

Graph: 1 Return on Capital Employed Ratio



Interpretation:

From Table- 1 and Graph-1, it is clear that the overall mean of the Return on Capital Employed Ratio for selected companies for the selected period of study was 11.96% and S.D. was 6.04. The range of the Return on Capital Employed ratio was 0.95 to 27.67. The highest ratio during the period was 27.67 for Shree Cement Ltd. in the year 2012-13 while the lowest ratio was 0.95 for Heidelberge Cement Ltd. in the year 2013-14. Out of 10 selected companies, there were 6 companies show Return on Capital Employed ratio higher than the overall average ratio. Those six companies are UltraTech Cement Ltd., Ambuja Cement Ltd., ACC Cements Ltd., Shree Cement Ltd., The Ramco Cement Ltd., and Orient Cement Ltd. with 13.75, 14.34, 15.59, 14.89, 13.32 and 13.43 respectively. The highest average Return on Capital Employed ratio during the period of study was 15.59 for ACC Cement Ltd.

- UltraTech Cement Ltd. shows a ratio between 10.37 and 19.69.
- Shree Cement Ltd. shows a ratio between 6.94 and 27.67. It's a very high-level variation in ratio.
- Ambuja Cement Ltd. shows a ratio between 7.17 and 23.97.
- ACC Cement Ltd. shows a ratio between 9.89 and 22.31.
- Dalmia Cement Ltd. shows a ratio between 3.84 and 12.17.



- Birla Corporation Ltd. shows a ratio between 5.05 and 15.95.
- The India Cement Ltd. varies between 3.35 and 10.99.
- The Ramco Cement Ltd. shows a ratio between 6.63 and 19.12.
- Orient Cement Ltd. shows a ratio between 2.99 and 27.54. It shows very high volatility in Return on Capital Employed ratio.
- Heidelberge Cement Ltd. shows a ratio between 0.95 and 25.32. It shows very high fluctuation in Return on Capital Employed ratio.

Test of Hypothesis:

Ho₁ There is no significant difference in the Return on Capital Employed ratio of selected cement companies.

H1₁ There is significant difference in the Return on Capital Employed ratio of selected cement companies.

Mean Rank for Return on Capital Employed Ratio as per KW Test

Name of the	N	Mean	Company
ACC Cement	10	71.70	1
UltraTech	10	64.50	2
Shree Cement	10	63.10	3
Ambuja Cement	10	61.00	4
The Ramco	10	60.50	5
Orient Cement	10	53.80	6
Heidelberge	10	48.10	7
Birla Corporation	10	33.00	8
Dalmia Cement	10	27.10	9
The India	10	22.20	10

Test Statistics

	Return on Capital Employed Ratio
<i>Chi-Square (KW-ANOVA)</i>	31.910
<i>Df</i>	9
<i>Asymptotic Sig.</i>	0.000

It can be observed from the above table that the p-value of the **Kruskal-Wallis Test** is less than 0.01 which indicates that the null hypothesis is rejected at 1% level of significance. It shows that there is a significant difference in Return on Capital Employed ratio between selected companies.



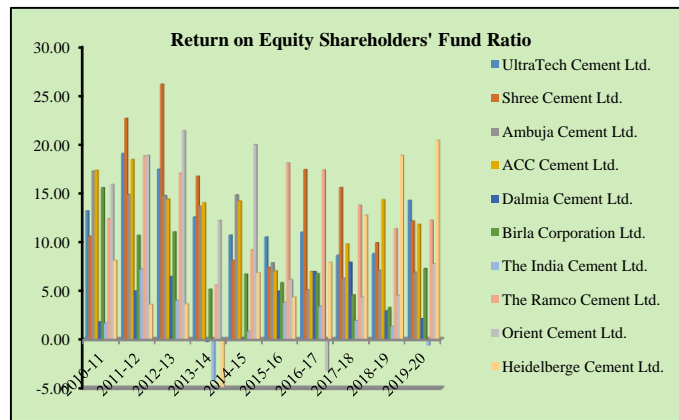
V.II Return on Equity Shareholders' Fund Ratio:

The Return on Equity Shareholders' Fund ratio for the period of study for 10 cement companies is as under:

Table: 2 Return on Equity Shareholders' Fund Ratio

Name	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Avg	SD
UCL	13.1	19.0	17.4	12.5	10.6	10.4	10.9	8.61	8.79	14.2	12.5	3.4
ACL	10.5	22.6	26.1	16.7	8.08	7.36	17.4	15.5	9.91	12.1	14.6	6.2
ACCCL	17.2	14.8	14.7	13.6	14.8	7.84	5.09	6.26	7.08	6.88	10.8	4.5
SCL	17.3	18.4	14.3	14.0	14.1	7.01	6.95	9.77	14.3	11.7	12.8	3.9
DCL	1.79	4.96	6.42	-	0.10	4.95	6.94	7.89	2.90	2.12	3.78	2.8
BCL	15.5	10.6	11.0	5.14	6.69	5.81	6.74	4.56	3.26	7.26	7.67	3.7
ICL	1.67	7.20	4.00	-	0.82	3.78	3.39	1.93	1.33	-	1.92	3.0
RCL	12.3	18.7	17.0	5.55	9.16	18.0	17.3	13.7	11.3	12.2	13.5	4.2
OCL	15.8	18.8	21.3	12.1	19.9	6.12	-	4.33	4.51	7.74	10.7	8.1
HCL	8.08	3.58	3.64	-	6.83	4.32	7.88	12.7	18.8	20.3	8.14	7.5
Overall	9.67											6.3

Graph: 2 Return on Equity Shareholders' Fund Ratio



Interpretation:

From Table-2 and Graph-2, it is clear that the overall mean of the Return on Equity Shareholders' Fund Ratio for selected companies for the selected period of study was 9.67% and S.D. was 6.33. The range of ratio was -4.89 to 26.12. The highest ratio during the period was 26.12 for Shree Cement Ltd. in the year 2012-13 while the lowest ratio was -4.89 for Heidelberg Cement Ltd. in the year 2013-14. Out of 10 selected companies, there were 6 companies show Return on Equity Share Holders' Fund ratio higher than the overall average ratio. Those six companies are UltraTech Cement Ltd., Ambuja Cement Ltd., ACC Cements

Ltd., Shree Cement Ltd., The Ramco Cement Ltd., and Orient Cement Ltd. with 12.59, 10.84, 12.81, 14.65, 13.56 and 10.77 respectively. The highest average Return on Equity Share Holders' Fund ratio during the period of study was 14.65 for Shree Cement Ltd.

- UltraTech Cement Ltd. shows a ratio between 8.61 and 19.02.
- Shree Cement Ltd. shows a ratio between 7.36 and 26.12. It's a very high-level variation in ratio.
- Ambuja Cement Ltd. shows a ratio between 5.09 and 17.24.
- ACC Cement Ltd. shows a ratio between 6.95 and 18.43.
- Dalmia Cement Ltd. shows a ratio between - 0.27 and 7.89.
- Birla Corporation Ltd. shows a ratio between 3.26 and 15.54.
- The India Cement Ltd. varies between - 4.22 and 7.20.
- The Ramco Cement Ltd. shows a ratio between 5.55 and 18.78.
- Orient Cement Ltd. shows a ratio between - 3.25 and 21.36. It shows very high volatility in Return on Equity Share Holders' Fund ratio.
- Heidelberge Cement Ltd. shows a ratio between - 4.89 and 20.39. It shows very high fluctuation in Return on Equity Share Holders' Fund ratio.

Test of Hypothesis:

H₀₂ There is no significant difference in the Return on Equity Share Holders' Fund ratio of selected cement companies.

H₁₂ There is significant difference in the Return on Equity Share Holders' Fund ratio of selected cement companies.

Robust Tests of Equality of Means (Welch)

Statistic ^a	df ₁	df ₂	Sig.
12.282	9	36.523	0.000

a. Asymptotically F distributed

It can be observed from the above table that the p-value of the **Welch ANOVA** is less than 0.01 which indicates that the null hypothesis is rejected at 1% level of significance. It shows that there is a significant difference in Return on Equity Share Holders' Fund ratio between selected companies.

V.III Earnings per Share (EPS) Ratio:

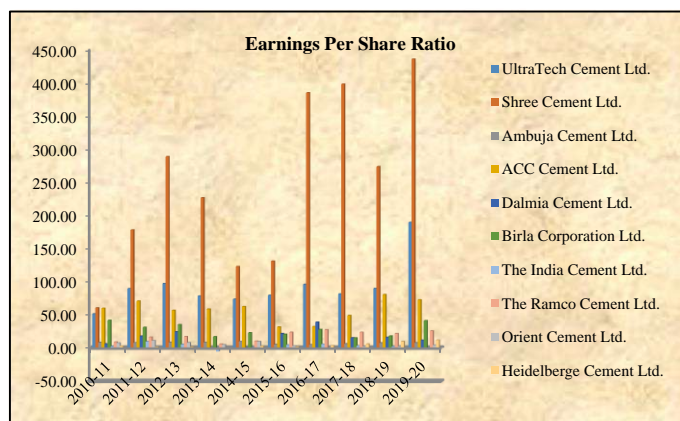
The Earnings per Share (EPS) ratio for the period of study for 10 cement companies is as under:



Table: 3 Earnings per Share (EPS) Ratio

Name	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	Avg.	SD
UCL	51.	89.2	96.8	78.2	73.4	79.2	95.7	81.2	89.4	189.	92.3	36.4
ACL	60.	177.	288.	225.	122.	130.	384.	397.	273.	435.	249.	128.
ACCC	8.2	7.81	8.41	8.37	9.66	5.20	4.89	6.29	7.49	7.70	7.41	1.51
SCL	59.	70.5	56.5	58.3	62.2	31.5	32.0	48.7	80.2	72.3	57.2	16.1
DCL	6.1	17.6	24.2	-	0.38	21.4	38.7	15.1	15.9	11.6	15.0	11.8
BCL	41.	31.0	35.0	16.8	22.7	20.4	27.7	14.9	17.8	41.0	26.9	9.90
ICL	2.2	9.54	5.32	-	0.96	4.49	5.63	3.27	2.24	-	2.72	4.05
RCL	8.8	16.1	16.9	5.79	10.1	23.4	27.2	23.5	21.4	25.5	17.9	7.55
OCL	7.4	10.9	7.89	4.93	9.51	3.04	-	2.16	2.32	4.23	5.08	3.83
HCL	2.7	1.29	1.36	-	2.63	1.71	3.36	5.88	9.74	11.8	3.88	4.14
Overall	47.81											83.5

Graph: 3 Earnings per Share (EPS) Ratio



Interpretation:

From Table- 4.1.3 and Graph 4.1.3, it is clear that the overall mean of the Earnings per Share (EPS) Ratio for selected companies for the selected period of study was 47.81 and S.D. was 83.58. The range of the Earnings per Share ratio was -5.29 to 435.18. The highest ratio during the period was 435.18 for Shree Cement Ltd. in the year 2019-20 while the lowest ratio was -5.29 for The India Cement Ltd. in the year 2013-14. Out of 10 selected companies, there was only 3 companies show Earnings per Share ratio higher than the overall average ratio. Those three companies are UltraTech Cement Ltd., ACC Cements Ltd., and Shree Cement Ltd. with



92.36, 57.23, and 249.49 respectively. The highest average Earnings per Share ratio during the period of study was 249.48 for Shree Cement Ltd.

- UltraTech Cement Ltd. shows a ratio between 51.24 and 189.02.
- Shree Cement Ltd. shows a ratio between 60.19 and 435.18. It's a very high level of positive variation in ratio.
- Ambuja Cement Ltd. shows consistency in the ratio between 4.89 and 9.66.
- ACC Cement Ltd. shows a ratio between 31.51 and 80.23.
- Dalmia Cement Ltd. shows a ratio between - 1.04 and 38.76. It shows high positive volatility in the ratio.
- Birla Corporation Ltd. shows a ratio between 14.95 and 41.54. It shows the volatility in the ratio.
- The India Cement Ltd. varies between - 5.29 and 9.54.
- The Ramco Cement Ltd. shows a ratio between 5.79 and 27.27.
- Orient Cement Ltd. shows a ratio between - 1.57 and 10.92.
- Heidelberge Cement Ltd. shows a ratio between - 1.80 and 11.83.

Test of Hypothesis:

Ho₃ There is no significant difference in the Earnings per Share ratio of selected cement companies.

H1₃ There is significant difference in the Earnings per Share ratio of selected cement companies.

Mean Rank for Earnings per Share Ratio as per KW Test

Name of the	N	Mean	Company
Shree Cement	10	93.90	1
UltraTech	10	85.70	2
ACC Cement	10	76.10	3
Birla Corporation	10	61.30	4
The Ramco	10	51.90	5
Dalmia Cement	10	42.90	6
Ambuja Cement	10	32.80	7
Orient Cement	10	23.90	8
Heidelberge	10	19.70	9
The India Cement	10	16.80	10

Test Statistics

	Earnings Per Share Ratio
<i>Chi-Square (KW-ANOVA)</i>	83.875
<i>Df</i>	9
<i>Asymptotic Sig.</i>	0.000



It can be observed from the above table that the p-value of the **Kruskal-Wallis Test** is less than 0.01 which indicates that the null hypothesis is rejected at 1% level of significance. It shows that there is a significant difference in Earnings per Share between selected companies.

VI. Conclusion:

It is concluded that Ambuja Cement Ltd., UltraTech Cement Ltd., Shree Cement Ltd., The Ramco Cement Ltd., and ACC Cement Ltd. performing well in profit generation. Heidelberg Cement Ltd. and The India Cement Ltd. show very poor performance as regards profitability. The companies selected are doing well as far as profitability ratios are concerned. Notably, Shree Cement Ltd., UltraTech Cement Ltd., The Ramco Cement Ltd., and Ambuja Cement Ltd. are the top performer.

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Annexure – I

Assumption of normality (Shapiro-Wilk)

Ratio	Company Name	Statistic	df	Sig.	Normality Assumption
Return on Capital Employed Ratio	UCL	.822	10	.027	Not follows Normal Distribution. So, a non-parametric test applied.
	ACL	.895	10	.192	
	ACCCL	.948	10	.649	
	SCL	.931	10	.456	
	DCL	.885	10	.147	
	BCL	.877	10	.122	
	ICL	.939	10	.540	
	RCL	.943	10	.591	
	OCL	.937	10	.524	
	HCL	.931	10	.456	
Return on Equity Share Holders Fund Ratio	UCL	.917	10	.333	Follows Normal Distribution. So, a parametric test applied.
	ACL	.851	10	.059	
	ACCCL	.921	10	.363	
	SCL	.931	10	.462	
	DCL	.943	10	.585	
	BCL	.902	10	.228	
	ICL	.963	10	.819	
	RCL	.936	10	.513	
	OCL	.940	10	.557	
	HCL	.942	10	.573	
Earnings per Share Ratio	UCL	.710	10	.001	Not follows Normal Distribution. So, a non-parametric test applied.
	ACL	.921	10	.362	
	ACCCL	.931	10	.462	
	SCL	.950	10	.664	
	DCL	.958	10	.759	
	BCL	.914	10	.309	
	ICL	.973	10	.914	
	RCL	.921	10	.368	
	OCL	.972	10	.909	
	HCL	.897	10	.205	

Annexure – II

Assumption of homogeneity of variance

Ratio	Levene Statistic	df1	df2	Sig.	Homogeneity
Return on Capital	3.715	9	90	.001	Heterogeneous
Return on Equity Shareholders	3.240	9	90	.002	Heterogeneous
Earnings per Share	20.075	9	90	.000	Heterogeneous





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ગાંધી વિશેષાંક

પૂજ્ય વસંતદાદાની સ્મૃતિમાં સરકારી વિનયન અને વાણિજ્ય કોલેજ, જાદર, જિ-સાબરકાંઠા અને ગુજરાત સાહિત્ય અકાદમી, ગાંધીનગરના સંયુક્ત ઉપક્રમે આયોજિત પરિસંવાદ ગાંધીકથા તા. ૩૦ - જાન્યુઆરી ૨૦૨૩



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સંપોષિત વિકાસ અને ગાંધીજીના આર્થિક વિચારો

ડૉ. અવની મુકુલભટ્ટ

મહદંતીશ પ્રાધ્યાપક (અર્થશાસ્ત્ર) સરકારી વિનયન અને વાણિજ્ય કોલેજ, જાદરા

રૂબરૂ:

આધુનિકકણ આંદોલન અને દહેશત થી પ્રેરિત વિદ્ય આજે યાંત્રીકરણ ની હોડમા વિશ્વ યુગ્ય ની સિતિમા આવી ગયુ છે ત્યારે ગાંધી સિંચા માર્ગે સમાજવાદ કે મૂડીવાદ થી ઉપર માનવતાવાદ ને અગ્રેસર રાખી સત્ય અને અહિંસાના માર્ગે વિકાસ કરવો રહ્યો કદતરી રીતે વિકાસ અને પર્યાવરણ ની જાળવણી આપણ માટે આજે પ્રથમ કમે છે કારણકે સમજ સંજીવ સંદિ આજે જીવીલ વર્માગ ની અસરનો ભોગ બની રહી છે અને આપણ અસ્તિત્વ જોખમમાં મુકાય છે પરંતુ આટલક ગાંધીજીના આર્થિક વિચારોને વર્તમાન અગત્યના વિષય એટલેકે સમયોષિત દુકાઈ વિકાસ ની વિલાવના ના સંદર્ભમાં ચકાસે છે આપણે જાણીએ છીએ કે ગાંધીજી એ મૂડીવાદ કે સમાજવાદ થી ઉપર માનવતાવાદી અભિગમ સાથે પોતાના આર્થિક વિચારો પ્રસ્તુત કર્યા છે ગાંધીજીના વિચારો પ્રકૃતિ અને પ્રકૃતિ સાથે સકળાવેલ બાબતો ને પ્રમાન્ય આપે છે પાશ્ચાત્ય ભૌતિક સંવિધાઓનો પ્રતિના ભોગે નહીં પણ સર્વ જન સંખ્યા અને સર્વ જન હિતાય ના અભિગમ થી ઉપયોગ થવો જોઈએ મર્યાદિત જરૂરિયાત થી પર્યાવરણ રક્ષણ સાથેનો વિકાસ ગાંધીજી ઇચ્છતા હતા વાલીપણાનો સિધ્ધાંત સ્વેચ્છી યાંત્રીકરણ અનેના વિચારો, વિકેન્દ્રિત વ્યવસ્થા, ગ્રામીણ વિકાસ વગેરે વિચારો અંતેતો માનવ અસ્તિત્વ માટેના જ અભિગમ હતા

પ્રસ્તાવના:

અહીં આ વિચારો વર્તમાન સાતત્યતા અને નવી પેઢીને દિશા નિર્દેશન માટે મહત્વના છે. ગાંધીજી ના આર્થિક વિચારો એ કોઈ વાદ નહીં પણ એક જીવન પ્રણાલી છે જે વ્યાવહારિક સાદગી અને સમાનતા ના અભિગમ સાથે વિકાસની વાત કરે છે ગાંધીજી ના મતે, ગાંધીવાદ જેવી કોઈ વસ્તુ છેજ નહીં. મારે મારી પાછળ કોઈ સંપ્રદાય મૂડી જવો નથી. મે કોઈ નવું તત્વ કે સિધ્ધાંત શોધી કાઢ્યો છે તેવો દાવો નથી. મે તો માત્ર જે શાશ્વત સત્યો છે તેને આપણાં નિત્યના જીવનના પ્રશ્નો ને લાગુ પાડવાનો મારી ઢબે પ્રયાસ કર્યો છે."

વપત્ર જતુ શહેરીકરણ, યાંત્રીકરણ ગરીબી બેકારી, ભૂખમરો, વિનાશક શસ્ત્રો અને યુધ્ધ જેવા માંહીલ ને કારણે ઉભા થયેલા પર્યાવરણીય જોખમો સામે માનવીએ પોતાના અસ્તિત્વને જાળવો રાખવા માટે થઇને પણ ટકાઈ વિકાસની વિલાવના ને સમજવી અને સ્વીકારવી જ રહી આ માટે ગાંધીજીના આર્થિક વિચારોમાં સાદગી, સ્વાવલંબન, ગ્રામીયોગ, ગૃહ ઉદ્યોગ, નાના પાયા પરના ઉદ્યોગો, વિકેન્દ્રીકરણ, વાલીપણા ની સિદ્ધાંત, નીતિમતા, શ્રમ-પ્રધાન ઉત્પાદન પુષ્કાંત,

સામાજિક આર્થિક સમાનતા, ગ્રામ વિકાસ, અંત્યોદય, સ્વચ્છતા અને પર્યાવરણની જાળવણી ને મહત્વ આપ્યું છે. ગાંધીજીના વિષે પ્યારેલાલ 'માવિ સમાજ રચના ની દિશામાં' પુસ્તક માં ગાંધીવાદી અર્થવ્યવસ્થાના લક્ષણોમાં જણાવ્યા મુજબ નાનાપાયા પરની વૈયક્તિક અને વિવિધ પ્રકારની સહકારી પ્રયાસોના ટેકાવાળી ખેતી, ગૃહ ઉદ્યોગોનો વિકાસ, પશુપ્રધાન અર્થવ્યવસ્થા, પ્રાણી સૃષ્ટિ, વનસ્પતિ સૃષ્ટિ અને માનવ સૃષ્ટિ વચ્ચે નો સબંધ ઉપકારક હોવાથી તેમની વચ્ચે યોગ્ય સમતુલા હોવી જોઈએ.

જી.ટી. એચ. કોલના મતે, ગાંધીજીની ખાદી ઉદ્યોગ માટેની પ્રવૃત્તિ હિન્દને ભૂતકાળ માં ઘસડી જવાની ધૂન હતી પણ હિંદના ગામાડાઓમાં વસતા લોકોનોએ ગરીબીમાથી મુક્ત કરવાનો અને તેમનું ઉત્તરમોરણ ઊંચું લઈ જવાનો વ્યવહાર માંગે હતો."

આર્ટ્ઝ હકમલીનામતે "ટેક્નોલોજિકલ પ્રગતિએ આપણને માત્ર અયોગ્યતિને માર્ગે જવાનું ખૂબ કાર્યશ્રમ પૂરું પાડ્યું છે. માત્ર અહિંસા માનવજાતને સાચી પ્રગતિ તરફ દોરી જાય તેમ છે. સ્વાયત અને સ્વાવલંબી ગામાડા વાળી વ્યવસ્થા જ આદર્શ છે."



રામણીયા વિષય એક જાન વિષય જે બાલકની પાઠની જોડવામાં આવેલા રામીને કદરવી સમયની નો ઉપયોગ કરે અને વિદ્યાર્થી પ્રક્રિયા આગળ વધારે, અન્યના ભોગે મેળવેલ વિદ્યાસને ગણી પૂર્ણ પાપ માને છે, આપણે સૌ જાણીએ છે તેમ 2 ઓક્ટોબર ને વિશ્વ અહીંસા દિવસ તરીકે ઉજવવામાં આવે છે જે દર્શાવે છે કે વિષય પણ ગાંધીજીના વિચારોની વર્તમાન જરૂરિયાતને સમજે છે અને તેથીજ સપ્ટેમ્બર 2015 માં ન્યૂયોર્ક સમિટ માં સંયુક્ત રાષ્ટ્ર સંગઠનની મહાસભામાં 193 જેટલા સભ્ય દેશોએ સાથે મળીને સમ્પ્રોષિત વિદ્યાસના વધારાનો પર ભાર મૂક્યો છે જેમાં 17 જેટલા મુખ્ય વધારા છે જે 2030 સુધીમાં મહદ અંશે પૂર્ણ કરવાનું આયોજન છે જે ટ્રાન્સફોર્મીંગ 2030 સંસ્થાનેબલ ગ્રોથ ધિર્ધક હેઠળ કાર્યરત છે જેમાંનીયે મુજબ ના ઉદ્દેશો નક્કી કર્યા છે

ગરીબીનાબૂદી

શૂન્ય ભૂખમરણનો આંક

સારુ અને સુખરૂપ આરોગ્ય

ગણવત્તા યુક્ત શિક્ષણ

જાતિય સમાનતા

શુધ્ધ પાણી અને સ્વચ્છતા

વ્યાજબી અને શુધ્ધ ઉર્જા

યોગ્ય કાર્યો દ્વારા આર્થિક વૃદ્ધિ

ઉદ્યોગ, ઇનોવેશન, આંતરમાળખાકિય

સુવિધા

અસમાનતામાં ઘટાડો

ટકાઉ શહેરો અને સમુદાયો

યોગ્ય વપરાશ અને ઉત્પાદન પ્રક્રિયા

કલાયમેટ એક્શન

ટકાઉ જળ સંસાધનો અને જળવૃદ્ધિ

ટકાઉ જમીન અને જંગલો

શાંતિ ન્યાય અને મજબૂત સંસ્થાનો

તથા આ ઉદ્દેશો માટે સક્રિય જન ભાગીદારી

આર્થિક ના મતે "કદરત પરતજ એટલું ઉત્પાદન જરૂર જરૂરી માણત પાતાની જરૂરતા મતાથી માત્ર પ્રત્યેક વ્યક્તિ પાતાની વ્યક્તિક જરૂરિયાત પૂર્ણ થાય ન અને વાસીન વ્યક્તિ માટે જરૂરી તો બી પૂર્ણ પર કામ ભવન કે બૂનું તરીકે નહીં કચ્છી પ્રકારના વ્યાખ્યાન સંપ્રોષિત વિદ્યાસ સાથે સંકળાયેલો છે" કુણો

નિવાસી ન ગરીબ પ્રદ્યોજા વિશ્વકોષ માટે ગ્રામ ત્વારક્ષા કિયાની પર આધાર વાયકું, ચેતન્ય ભદ્રાગામી નાની મોટીના દિવડાનું પુસ્તકમાં વાજ્ય ખતો, કૃષિ ઓફીસર, ગ્રામોત્થાન, જેઠાવી આર્થિક અને આરોગ્ય,શિક્ષણ જેવી સામાજિક બાબતોના સમાવેશ કર્યો છે જે ટકાઉ વિકાસના વધારા અને ગાંધી વિચાર સરજીને દર્શાવે છે.

વોડિશ જેન (2016) "ગ્રામીણ વોડાની બદલાતી ઉપયોગ વૃત્તિ અને તેની સમ્પ્રોષિત વિકાસ ઉપર અસર" માં જણાવ્યા મુજબ ગ્રામીણ બજારો વિકસિત થાય તે માટે સમાજ,સરકાર અને સ્નેહિત સંસ્થાઓ દ્વારા સ્વાર્થ હિત વિવેક પૂર્ણ પ્રયાસો હાથ ધરાવવા જોઈએ.

ગાંધીજીના આર્થિક વિચારો અને સમ્પ્રોષિત વિકાસના વધારાનો વાલીપણાનો સિધ્ધાંત

ગાંધીજીનો વાલીપણાનો સિધ્ધાંત જાણવે છે કે આપણે આપણી જરૂરિયાત જરૂર જ વાપરવું અને વધારાના માલિક નહિ પણ દુસ્તરી બની અને તેનો સમાજના અન્ય વ્યક્તિ માટે કે વધુ ઉત્પાદન, રોજગારી અર્થે ઉપયોગ કરવો જે થી સૌનો વિકાસ થાય અને દેશમાં રોજગારી અને ઉત્પાદન વધે સમ્પ્રોષિત વિકાસના લોકભાગીદારી, રોજગારી સજન વ્યક્તિ માટેનું વ્યવસ્થાપન અને સમાનતાના વધારાનો પ્રયાસ સાથે મળતા આવે છે

યાત્રીકરણ:

ગાંધીજી યંત્રોના વિશીષી નહતા પરંતુ યંત્રોના ઉપયોગથી શ્રમ બેકાર બને તો આપણે યાત્રીકરણ દશના વિકાસ નહીં પણ નિર્માણ કરશે તેવું ગાંધીજી માનતા ન હતા.તેના વપરાશ મર્યાદિત રીતે કરવી જોઈએ અને માનવને કામચરત હોવા જોઈએ મનુષ્યને જુલામ બનાવવા જોઈએ નહીં

વિકેન્દ્રિત વ્યવસ્થા

વિકેન્દ્રિત વ્યવસ્થા એક કારીજીકારી છે કે પ્રામાણિક રીતે તો જે સત્વર સ્વયંચાલ ભાગીદારી કરીને સ્થાપના અને વ્યાપકતાને બનાવવી રીતે તો વિકેન્દ્રિત બની વ્યવસ્થા જરૂરી છે વિકેન્દ્રિત વ્યવસ્થા ગાંધીજી ઉદ્યોગ ફરીકે રીતી ની કિમીયત



દ્વારા આર્થિક વિચરતા દર કદરવી કેમ કરી છે.

માનવીય મૂલ્યો નૈતિકતા, સૌસહાનિકરણ બેરોજગારી નિવારણ (ખાદી વ્યવસાયની હિમાયત) સ્વાવલંબન, સાદગી, સમાનતા અને અભીય સાથેનો વિકાસ.

ગાંધીજીના વિચારોને સમર્પિત વિકાસ

• ગાંધીજીએ આરોગ્યને પોતાની "સૌથી મોટી સંપત્તિ," તરીકે ગણ્યું હતું. તેમણે ઉલ્લેખ કર્યો હતો કે, ભૂખમરી નાબૂદ કરવામાટે વીકારો આરોગ્યપ્રદ આહાર લેવો જોઈએ. આ ધોષણ આપણી વર્તમાન અનુભૂતિ પહેલાની છે કે, જેમ જેમ આપણે ભૂખને નાબૂદ કરીએ છીએ, તેમ તેમ આપણે પોષણની ખાતરી કરવાની જરૂર છે, ખાસ કરીને બાળકો માટે.

• તે જ સમયે, મહાત્મા માનતા હતા કે શિક્ષણ એ પરિવર્તનનું નોંધપાત્ર ચાલકબળ છે, તેમના માટે. શિક્ષણ એ "જીવન-સામગ્રી ઘટના" છે. "નિરક્ષરતાને દૂર કરવી, તે જરૂરી નથી કે સંપૂર્ણ શિક્ષણ હોય." તેના માટે શિક્ષણનું માપ એ વ્યક્તિની આંતરિક ભાવઈ અથવા સંવાવનાઓની જોડેર થયેલી માત્રા હતી.

• આજકાલ, સામાન્ય રીતે અને ખાસ કરીને એસકીજીમાં આપણા વિકાસ પ્રવચનમાં જાતિય સમાનતા એ એક સુસ્થાપિત ધારણા છે. ગાંધીજીના દ્રષ્ટિકોણમાં પણ જાતિય સમાનતાની ચિંતા જીવા મળતી હતી. લગભગ એક સદી પહેલાં તેમણે કહ્યું હતું, "આપણે એવું ન કહેવું જોઈએ કે સ્ત્રીઓ પુરુષો કરતાં ઊતરતી કક્ષાની હોય છે, તે બદનસી હશે અને તે પાપ છે." હકીકતમાં, તેમણે સ્ત્રીઓ માટેના શિક્ષણ અને તેમની સમાજિક સ્થિતિ વિશે ખૂબ વિસ્તૃત વાત કરી. તેમણે ઉલ્લેખ કર્યો હતો કે, "જે દિવસે આપણે એમ કહી શકીશું કે આપણી મહિલાઓ રાત્રે રસ્તા પર સુરક્ષિત છે - એ જ દિવસે આપણે જાતિય સમાનતા પ્રાપ્ત કરી છે." તે જ બનાવે છે કે ગાંધીજી તેમના સમય કરતાં કેટલા આગળ હતા.

• સામાજિક આર્થિક વિકાસને આવક, રોજગારી, ટેકનોલોજી અને નવીનતાથી વગ મળે છે. "પૂર્ણ રોજગાર" અને "લખનના

સામગ્રિક શિક્ષણ

• ચરખો અને લઘુઉદ્યોગો પ્રત્યે ગાંધીજીની સ્પષ્ટ મોહ પણ યોગ્ય રીતે સમજવાની જરૂર છે. તેમના માટે ટેકનોલોજી અને નવીનતાનો ઉપયોગ લોકોની સેવામાં કરવો પડશે અને રોજગારીની વ્યાપક શક્યતાઓ ઊભી કરવી પડશે. લોકોને તેમની નીકરીઓમાંથી છૂટા કરવા અને શોષ લોકો માટે નફા પેદા કરવાના સાધન તરીકે તેનો ઉપયોગ ન થવો જોઈએ.

• તેમણે ગ્રામીણ રોજગાર અને નાના પાયના ઉદ્યોગોને ગરીબી નાબૂદીના સાધન તરીકે જોયા. ગ્રામીણ વિસ્તારોને શહેરી વિસ્તારોની સમકક્ષ વાળ્યા અને વધુ અગત્યનું "વિકાસને સ્થાનિક બનાવવું" ટેકનોલોજી અને નવીનતાની સંબંધિતતા પ્રત્યે સંવેદનશીલ રહેવું, તેમણે કહ્યું હતું કે, "પ્રકૃતિ અને તમામ સમાજની પ્રદાન કરવાની કે માત્ર કરવાની અમર્યાદિત ક્ષમતાનું ટેકનોલોજીકલ ઇનોવેશન માટેફતે સંપૂર્ણ પણે પરીણાજ કરવાનું બાકી છે."

• ગાંધીજી કાયદાના શાસન અને લોકતાંત્રિક રાજનીતિમાં દૃઢ વિશ્વાસ ધરાવતા હતા. તે દેશબંદ સામે લડ્યા હતા, તેના દ્વારા તે તેના પોતાના સંદર્ભમાં માનવાધિકાર સ્થાપિત કરવા મંત્રતા હતા. તેમના માટે, કાયદાનું શાસન અહિંસા, શાંતિપૂર્ણ સહઅસ્તિત્વ અને સહિમચૂતા દ્વારા પ્રગટ થયું હતું. તેમણે કહ્યું "જો તમે બૈરબર માનતા હો કે તમારા વિચારો બીજાઓ કરતાં વધુ સારા છે, તો તમારે બીજાના વિચારો સહન કરવા જોઈએ" આ વિચાર પણ, એસકીજીમાં પ્રતિબિંબિત થાય છે. વિકાસના નવા ચિત્રદાતો સમજને આપે છે કે કાયદાઓ અને જવાબદારીનું શાસન, માત્ર

દેશની અંદર જ નહીં પરંતુ દેશો વચ્ચે સ્થાપિત કરવું પડશે.

તારણ :

ગાંધીજીએ કહ્યું હતું કે, “જ્યારે તમે તેમના માટે કંઈક કરો છો ત્યારે તમારે સૌથી નબળા અને ગરીબ લોકોનો ધ્યાનમાં રાખવા જોઈએ.” તેઓ અહીં માલિકી, સશક્તિકરણ અને એકતા વિશે વાત કરે છે. એકતા અને ભાગીદારીનો ગાંધીવાદી વિચાર બીજા વિશ્વયુદ્ધ દરમિયાન ફાસીવાદ સામેની સંયુક્ત લડતના સંદર્ભમાં વસાહતી શક્તિ સાથેના તેમના સંબંધો દ્વારા શ્રેષ્ઠ રીતે વ્યક્ત કરવામાં આવે છે. વર્ષ 2030ની કાર્યસૂચિ હેઠળ, ગરીબી, ભેદભાવ અને અન્યાયના દુશ્મન સામે, વિકાસ અને શાસનભાગમાં કોઈ પણ પ્રકારના તકાવતને ધ્યાનમાં લીધા વિના, વિશ્વવસૈવ કુટુંબકમની ભાવના સાથે એક બને તેવું ઇચ્છનીય છે. મહાત્માગાંધીના મતે, દુનિયાને “સિદ્ધાંતો વિનાના રાજકારણ” અને “નૈતિકતા વિનાના વાણિજ્ય” થી દૂર કરવી પડશે અને શુભલાભના અર્થશાસ્ત્રને અપનાવવું પડશે. માનવતાને મહત્વ આપવું પડશે. એકંદરે ટકાઉ વિકાસના ખ્યાલમાં ગાંધીજીના વિચારો નો સમાવેશ થયેલો જોવા મળે છે. અસ્તુ

સંદર્ભ :

ભટ્ટદેવપ્રિયા (2019) “મહાત્મા ગાંધી અને સાતત્યપૂર્ણ વિકાસના વક્ષાકો, ગુજરાત વિદ્યાપીઠ

કોકારી, વિકૃતવાદ અને પટેલ અંબાલાલ (1977). ગુજરાતની તાલીમ સંઘ ગુજરાત વિદ્યાપીઠ

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NEW EDUCATION POLICY

Dr. Vandana G. Trivedi*

ABSTRACT

The outcome of teaching must be skill development of a student and achieve the holistic development of the student. In our present education system the number of educated people is increased, but on the other hand there are many burning problems which are still remain in the Economy. Number of students who are committed to suicide is increased. At this time, it is become more important to think about to bring reform in Education policy. Gandhiji (Ramakrishna, 2015) said that, "Literacy in itself is no education ". That means teaching means not to perceive a degree or making a career and earning money. But it is more than it. Keeping in the mind these all aspect New Education policy is formed. It will be implemented in the structure gradually.

Keywords: NEP, Skill Development, Teaching, Career, Economy.

Introduction

National Education policy (NEP) has launched in India on 29th July, 2020 with the goal of bringing transformation in school level and Higher Education. The old Education policy was introduced in 1986. After a long period of 34 years this is the first Education policy of 21st century. The policy will work in the direction of establishment of importance of Education in the new global Economy. Drucker (1993) and Porter (1990) emphasis the importance of Education on the basis of increase of productivity and expansion of the Economy by increase competitiveness national level NEP is based upon four main aspects like, Equality, Access, Quality and Accountability.

New Aspects in NEP

- 10TH and 12th board exam. Will introduce with reconstruction of the structure for the holistic development of the student.
- School examination will take for grade 3, 5 and 8 which will take appropriate Authority.
- A new National Assessment set up is introduced giving importance to as,(Performance assessment, review, and analysis of knowledge for holistic development) which is called "PARAKH"
- Scientific approach, Mathematical ability will get prioritize and coding will introduce from grade 6 onwards.
- The 10+2 structure will be replaced by 5+3+3+4
- In this new structure total 12 years will be of schooling and 3 years of pre-school/ Anganwadi.
- To promote entrepreneurship, vocational course will introduce from grade 6 in which internship is also included.

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- Mother tongue/ Regional language will be the medium of instruction till 5th grade. No language will be forced for students.
- Sanskrit will introduce as an optional language in schools and higher education.
- Literature of India and other classical language will be introduced as an option.
- Higher education will be more flexible, admission in multiple courses will be possible at a same period.
- Education and research will be multidisciplinary. Academic Bank of Credit (ABC) will help the students to choose subject as per their interest. They can earn credit and at the time of the completion of the degree the credit will be counted.
- The curricular in all subjects will reduce, practical and field work will be promoted.

Advantages

- The NEP is targeted to make possible the comeback of approximately Two crore students. This will make possible to achieve the objective of our constitution, "EDUCATION FOR ALL".
- Student's formative learning will increase because in NEP the 5+3+3+4 structure is applied. This 5+3+3+4 structure corresponds to ages from 3 to 8, 8 to 11, 11 to 14 and 14 to 18 years. In this entire process of education, there will be 12 years of schooling and 3 years of pre-school/ Anganwadi.
- Education in Mother tongue/ regional language will let down the early childhood stress of learning foreign language among the children. Researches shows that Mother tongue/ regional language are more efficient medium to learn new things.
- NCERT designed a frame work for early child care, a national level curricular and pedagogical framework for the students up to age 8. Which will promote the holistic development of students?
- Mission fundamental literacy and numeracy will be helpful o set up a strong foundation of fundamental literacy in the country.
- National book promotion policy will bring major benefits to the students.
- School level exams for grade 3, 5 and 8 will organize by appropriate authority. It is the good opportunity to check the student's ability of certain grade. If the student found weak, extra efforts can be made to upgrade them. 10th and 12th board exam. Will organize with modification this change will make easy the board exam. Stress of the students.
- "PARAKH" (Performance assessment, review, and analysis of knowledge for holistic development) policy will encourage the overall development of the students.
- The provision of Balbhavan (special day time boarding school) which will established in every state/ district of the country will encourage the participation of the students in sports, arts and other related activities.
- The provision of Academic Bank of Credit (ABC) will help the students to choose subject as per their interest. They can earn credit and at the time of the completion of the degree the credit will be counted. Multidisciplinary Education and research will bring a high level of intellectual rise in the country. Now there is no boundary of subject.
- Promotion of on line Education will make the student powerful in the use of technology. They can have knowledge of particular subject or topic from any corner of the world. On line education training will prepare the students to face any upcoming pandemic situation.

Challenges

National Education Policy has implemented many new policy which will definitely open up new direction for future India, but There are some challenges in the implementation of it. Like,

- To find out capable teachers who can teach in mother tongue will be difficult in initial stage of the implementation of "NEP".
- Teacher- student ratio is already problematic in the country, If the proper appointment of teacher will not be done, it will create other issues in Education.



- Majority of standard and valuable books regarding any discipline / subjects are available in English language, because since India's Independence English took place as an Important language. At the time of implementation of "NEP" it is the big challenge to make available material in mother tongue or regional language. To promote Education in mother tongue it is very necessary to translate all the material in regional language.
- In India private sector is actively work in the field of Education, there is a huge gap between the level of public school students and private school students. The government must take strong and effective steps to fulfill the gap.
- It may lead to lack of sufficient knowledge of any language in students.

Conclusion

Education is considering a powerful weapon to bring positive changes and to promote development in the country. "NEP" is applied in the country to bring overall development of the students and to build up skilled manpower through it. There are many significant steps are taken in "NEP". With the advantages of "NEP", there are also many challenges. We can hope that the crisis which will occur at the time of change in education system, will get set in few years. When any change take place, some part of the system get badly affected but with the step by step implementation it is become normal in the society. We can hope it for the "NEP" also.

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CORRIGENDUM

Priyankar Datta has been erroneously typed as **Priyanka Datta** in the article, "Applying Postcolonial Theory to Doris Lessing's *The Grass is Singing*" in *The Atlantic Critical Review*, Vol. 19, Nos. 1-4.

Ram Rajya and the Emergence of Indian Nationalism: The Significant Role of Gandhi

HARDEEPSINH RANJITSINH GOHIL

ART of modern political governance had experienced various forms of governance after the worst outcomes of World Wars. The whole world was in need of a saviour who would deliver the blessing of peace on humanity. During that time India came forward and gifted a mind which changed all the established concepts of governance. In the form of 'Man of Millennium', Mohandas Karamchand Gandhi bestowed the mankind with one of the most significant political ideas of the age. The idea was the concept of Ram Rajya. The age-old Indian tradition of democratic rule as described in one of the oldest epics of the world. It becomes very interesting to explore the concept as the need of an hour and contribution in generating the faith of common Indians regarding the vision of Independence and place of the concept in comparison of other prevailing concepts of nationalisms.

Nationalism in the Contemporary World

The intellectuals of the early 1980s and their opinions about the nation building, especially the contributions of thinkers like Benedict Anderson [*Imaging Communities: Reflections on the Origin and Spread of Nationalism* (1983)], Anthony D. Smith [*The Ethnic Origins of Nations* (1986)], Ernest Gellner [*Nations and Nationalism* (1983)] universally referred to the idea of nation as a late eighteenth century and early nineteenth century European intervention, closely related to the emergence of modern state, grounded in the popular sovereignty.

Almost all the citizens of the world bear the identity of their nationality. The world has not become a one nation and still we



live in the world which is at the height of nationalism. At the same time, we find political power of nationalism co-exists with its philosophical poverty. The political science of nationalism did not receive scholarly interest that it deserved until the 1960s. Till today we do not have final definition or consensus about it. For such inclusiveness Benedict Anderson observes,

All these uncertainties mean that any anthology mapping the terrain of nationalism finds the authors more often with their backs to one another, staring out at different, obscure horizons, than engaged in orderly hand-to-hand combat.²

At the same time in the Western tradition in the ancient Rome particularly, the Latin word *natio* mean 'a group of outsiders' in actual sense referred to the 'communities of outsiders' who lived in Rome as aliens and were not given the privilege of Roman citizenship. More than that, the term nation had a derogatory connotation. The term nation understood as 'a community of foreigners',³ which was applied to communities of students in medieval universities. These students rarely belonged to the place where the university was situated. This led to a modified understanding of 'nation' as a 'community of foreigners' to the 'community of opinion'. In the 16th century people of England understood it as a synonym of the 'people' and acquired its modern political meaning as a 'sovereign people'.⁴ Today, it refers exactly opposite to what Roman people termed it in the beginning. According to *Random House Dictionary*, the word Nation stands for "a body of people, associated with a particular territory, that is sufficiently conscious of its unity to seek or to possess a government particularly its own."⁵

Thinkers from the world over have opined differently about the nation. Raymond Williams in his one of the most discussed novels *Second Generation* (1964), talks about the term in post-colonial way as,

Nationalism is in this sense like class. To have it, and to feel it, is the only way to end it. If you fail to claim it, or give it up too soon. You will merely be cheated by other classes and other nations.⁶



In the last two hundred year, nationalism has amalgamated itself with various ideologies such as liberalism, socialism, and communalism and every time emerged with its victorious varieties. There are instances like fruitful battles of anti-colonial movements and disintegration of Soviet Union which proves the superiority of nationalism in comparison of any other contemporary ideology, there is a constant threat of being wiped out for nations in the peaceful multicultural heterogeneous world. At the same time nationalism provides protection to preserve the ethnic cultures and their values. Here nationalism becomes more important when under the garb of globalization there are constant and multidimensional attempts to homogenization of heterogeneous cultures. For such threat President of United States Thomas Jefferson in his inaugural address on 4 March 1801 reveals his trepidations as,

Peace, Commerce, and honest friendship with all nations—
entangling alliances with none.⁷

The Impact of Epics on Human Civilization

Under the impact of international pandemic Covid 19 what would be more important for us than the evaluation of what does it mean to be a human. From the West to the East, if human civilisation has ever produced best way to mould and measure the depth of humanity then perhaps it would have been the method of proliferating the age-old epics. The epics have always provided the rich resources of moral and ethics for the civilisations to flourish. In case of West *Iliad* and *Odyssey* have played a major role in qualifying information about value system of its ancient culture. For the thinkers like John Miles Foley the basic aspect 'for national identity, epic is foundational genre'.⁸ Similarly, *The Aeneid* stands for Roman civilisation, *Epic of Gilgamesh* for Sumerian civilisation, *Beowulf* for Old English, *Divine Comedy* for Italians, *Song of Roland* for France and *Nibelungenlied* for Germany have stood as foundation of their national representation as well as for their strong foundations. Such foundations have played their stronger roles during the rise of nationalism in the West during the late eighteenth and early nineteenth century. The way nineteenth century Serbian scholars had to play a pivotal role in establishing *Kosovo* as the



crucial subject of Siberian literature, culture and politics. By re-visiting the formation of the *Kosovo* epic in the collection of Vuk Karadzic, the founder of modern Siberian culture, one can observe his role in making *Kosovo* the foundational myth of the whole Serbian nation from the surge in romantic nationalism onwards. In case of India, *Ramayana* and *Mahabharat* have been continuously explored by researchers for their continuous capability to talk to the readers throughout various ages. In general, epics apart from talking about war and peace tries to explore the depths of human heart where lies the answers of many of our existential questions.

The Indian epics have tremendous influence upon subsequent literary traditions. In case of India, one can say that there is no need of separate spiritual book like the *Bible* as it is in the West. Both *Ramayana* and *Mahabharat* consist everything which is related to any spiritual search of the Indian reader. The influence of epics in India can be observed from the cinema to politics. Mega blockbuster movie like *Baahubali* and all the contemporary issues of Sri Ram Temple are evidence of that. In the contemporary time the bestselling authors like Amish Tripathi with his unique *Ram Chandra series* that consist *Ram: The Scion of Ikshvaku*, *Sita: The Warrior of Mithila*, or *Ravan: The Enemy of Aryavrat* has contributed to establish the significance of the epic. Similarly, Devdutt Pattanaik in his significant works like *Sita* or *Hanuman's Ramayana*, Chitra Banerjee Divakaruni in her *The Forest of Enchantments* proved the relevance of the epic among contemporary readers. In the past if we look at 'the conscience keeper' of Mahatma Gandhi, C. Rajagopalachari in his *Ramayana*, R.K. Narayan (one of the significant predecessors for novel writers in Indian Writing in English) the most celebrated writer of the time in his *The Ramayana* tried to deal with the significant aspect of the epic. In the same way, one can observe the multilayer influence of *Ramayana* be it society, religion, culture or Indian literature at large. Perhaps which maybe the central reason that Mahatma Gandhi constructed his idea of nation on the basis of *Ram Rajya*. Among other significant influence one can count the social influence of *Ramayana* on various aspects such as social harmony. It is quite visible in the episode of Kevat and Sabri.



The examples are relevant even today. There are quite a few schemes of Indian Government which are named after these characters. For the female gender Sita's patience and fidelity would always remain inspiration for the entire female gender from any corner of the earth. At the same time characters like Urmila and Ahalya represent unique sacrifices of feminine in case of building Indian civilisation so strong. Devotional duty of a brother to another brother is being reflected in case of Lakshman as well as in case Bharat, the role of ideal father can be observed in case of philosopher king Janak, the role of ideal mother being represented by Kaushalya, the qualities of ideal son for the long many generations to come in the form of Sri Ram only, the ideal of family life can also be traced from the influence of *Ramayana*. In this way, since ages *Ramayana* has provided the significant social ideals in real sense for India.

In case of religious influence what can be the most relevant topic then the vision of Saudi Prince Mohammed bin Salman's new vision for the education sector in Saudi Arabia, Vision 2030, where he advocates to introduce *Ramayana* as the text which can teach his subjects the lessons of social and religious harmony.⁹ The text which teaches lessons of cultural, ritual, religious, and various sacrifices to make one's religion acceptable for all and for all the times. Similarly, the lesson of love for one's mother nation is also the part of *Ramayana*. As Rishi Bharadwaj describes the most significant lesson to Sri Ram for love of one's mother land as,

मित्राणि धन धान्यानि प्रजानां सम्मतानि।

जननी जन्म भूमिश्च स्वर्गादपि गरीयसी॥

(Friends, riches and prosperity are always respected and adored in this world but the mother and mother land are always superior to heaven even.)¹⁰

Similarly, being educated in Britain, professionally working in Africa—Mohandas Gandhi came back to India and serve the mother nation with best of his services until his last breath. The passion and dedication can be observed in his all the actions in bringing the independence for the Jewel of the British Crown.

As a widespread influence upon Indian culture one can see that the ideal kingdom of Rama deals with significant



aspects that is the victory of virtue over sin, the importance of sacrificing for the sake of giving up greed, the idea of sacrifice for the morality of life, truthfulness, promise, and devotion to the duty and many more other qualities that makes one culture superior in its basic foundations can be found in Ramayana, especially with main character of the epic.

In case of Indian literature one can find the enormous amount of influence as we have seen in case of Indian writers in English one can search the influence of *Ramayana* upon almost all the languages of South Asian continent. *Puranas* like *Mahabharat*, *Agni*, *Vishnu*, *Skanda*, *Padma* and *Bhagavat Puran* as well has the mention of *Ramayana* within themselves. Along with Kalidas' masterpieces *Raghuvamsam*, *Meghdoot*, *Abhigyan Shakuntalam*, *Vikramorvasiyam* are greatly influenced by *Ramayana*. Bhasa's *Pratima* and *Abhishek* drama—Bhavbhuti's *Mahavir Charitra*, *Uttar Rama Charitham*—Kshemendra's *Ramayana Manjari*—Raj Shekhar's *Valramayana*, Jaydev's *Prasanna Raghav*, Bhoja's *Champu Ramayan* are some glaring example of bearing the influence of *Ramayana* in Indian literature. Perhaps this would be the major reason why Mahatma Gandhi would have selected the model for future independent India from *Ramayana* only.

The Concept of Nation in India

The theory of misconceptions that labelled against Indian Political Tradition has believed that there were no enquires regarding Theory of State, nature of Sovereignty, Structure of State and Society, Principle of obedience, Nature of Civil Society, Good Governance, Humanistic Politics, Law, Judicial System in ancient India. In case of Indian tradition of nationalism one can find very long etymological tradition for the word *Rajya* which stands for the word nation in the most ancient language of the world that is Sanskrit. Different treatises deal with the word with the unique objective. One can trace it back from *Rashtra Sukta* of Vedas where the qualities of the motherland have been introduced. One can find the references for *Rashtra* from various treatises such as *Ramayan* (the foundational text for Gandhi's *Ram Rajya*), *Mahabharat*, *Nitisashtra*, Kautilya's *Arthasashtra*, *Manusmriti*, *Mastyapuran*, *Dharmasutras*,



Smritis, and *Sukraniti* respectively.¹¹ It can be found one such example in *Vishnu Puran* where it talks about 'Bharat—that is India' in geographical sense as,

उत्तरं यत् समुद्रस्य हिमाद्रेश्चैव दक्षिणं।
वर्षं तद् भारतं नाम भारती यत्र संततिः॥

Vishnu Puran 2.3.1

One of the most debated texts from India—*Manusmriti* even talks about the concept of nation in a very unique way. It delineates seventy-two constituent parts of a *Rashtra* with suitable examples and explanation. One such example is for the duties of the king to protect his subject from calamities can be traced similar from various texts such as *Apstamb Dharmasutra* (II, 10-26).

As one of the most popular leaders of Indian struggle of Independence Mohandas Karamchand Gandhi was also cultivated in the same culture which was thickly weaved with the threads of such cultural ecosystem. From his significant treatises be it *Hind Swaraj*, *My Experiment with Truth* or *Gram Swaraj* one can find the reflection of ancient concept of *Ram Rajya* which was introduced in one of the most popular texts of the world *Sri Ramcharit Manas* by Goswami Tulsidas. The text which has been considered as 'the best and most trustworthy guide to the popular living faith of the Indian people'.¹² It is true in multiple sense. M.K. Gandhi as an international political figure found it more convincing to adopt and apply the idea of *Ram Rajya* to reach at the grass-root level of the world's oldest civilization. Though he had been in the direct contact of greatest phenomena of that time from Tolstoy to Charlie Chaplin, he realized that the applicability of *Ram Rajya* would be highly effective than any other idea of the time. He not only defeated his political rivals without a drop of blood but could struggle against the illegitimate and illegal presence of the British Empire in India. He successfully mobilized the Indian common man against the Empire. With the grand success of his non-violent theory he has been considered as the 'Man of the Millennium' for past millennium amongst legendary leaders of the world.



The Concept of Ram Rajya in Comparison of Other Ideal States of the World

If any one takes *Ramayana* as a part of the literature only—even then also one has to consider it as one of the most advanced text which consists within itself more elaborate Utopia than the *The Republic* (ca. 370-360 BC) by Plato, *Sacred History* (ca. 300 BC) by Euhemerus or eponymous text *Utopia* (1516) by Thomas More. Voltaire's *Candide: or All for the Best* (1759) also plays significant role in providing proper understanding about the philosophic vision of the writers regarding the ideals of the society. Whereas *A General Idea of the College of Mirania* (1753) by William Smith stands as an inspiration for a utopian educational system. This text was published in United States and delivered immense influence upon the methods of education have significant influence upon the future of the nation at large. More recently *Unioorder: Build Yourself Paradise* (2014), by Joe Oliver discuss about the possible utopian life with the help of computer.

As an anti-state protagonist Gonzalo in *The Tempest* (1610-1611), one of the final plays of William Shakespeare (contemporary of Tulsidas) imagines his Commonwealth as,

Gonzalo: Had I plantation of this isle, my lord....
 And were the king on't;
 What would I do?
 I' the common wealth I would by contraries
 Execute all things; for no kind of traffic
 Would I admit; no name of magistrate;
 Letters should not be known; riches, poverty,
 And use of service, none; contract, succession,
 Bourn, bound of land tilth vine yard, none;
 No use of metal corn, or wine or oil;
 No occupation, all men idle, all;
 And women too, but innocent and pure;
 No sovereignty—

Sebastian: Yet he would be king on't.



Antonio: The latter end of his commonwealth—
Forgets the beginning.

Gonzalo: All things in common nature should produce
Without sweat or endeavor. Treason, felony
Sword, pike, knife, gun, or need of any engine,
Would I not have; but nature should bring
forth,
Of its own kind all foison, all abundance,
To feed my innocent people.

[*The Tempest*, Act 2, Scene 1, 144-64]¹³

Gonzalo would have been disappointed, if he had lived long enough, till the arrival of the industrial era which increased the division of industrial labour in manifold thereby ensuring a long life for the state. State under the industrial influences was no longer an option; it became an undeniable necessity.

At the same time on the other part of the globe one of Shakespeare's contemporary Goswami Tulsidas in his concept of ideal kingdom Ram Rajya has rightly explained the qualities of the administration of the dream as,

राम राज बैठे त्रिलोका। हरषित भए गए सब सोका॥

बयरु न कर काहु सन कोई। राम प्रताप बिषमता खोई॥४॥¹⁴

(As Sri Ram established on the throne all the three world becomes ecstatic, all their miseries are wiped out, all have lost the feeling of animosity and even all have lost their reasons for difference.)

The very foundation of the Ram Rajya would be on the basis of zero reason for बिषमता or difference. Such quality will naturally eliminate the 'feeling of animosity' amongst its subject. Such absence of the 'difference' has been at the base of the one of the significant theories of the twentieth century known as Marxism. Perhaps, this may be the reason Mohandas Karamchand Gandhi was more attracted towards the concept of Ram Rajya than any other idea. To substantiate the idea clearly Tulsidas mentions his idea in the subsequent Chaupai very clearly that,



नहिं दरिद्र कोउ न दुखी न दीना॥
नहिं कोउ अबुध न लच्छन हीना॥3॥¹⁵

(No one would be living in the misery or no one would be living the life of a beggar. Nobody would be lacking in intellect or auspicious aspects.)

This chaupai clearly indicates that the vision of Ram Rajya was so advanced that it had clearly demarcated the draft of future necessities as well. It becomes evident to observe that apart from being an exclusive literary text it consists highest morals for the State and its subject. At the same time the text also includes the essential aspects regarding the ethics and morals of the state in very interesting style such as,

दंड जतिन्ह कर भेद जहँ नर्तक नृत्य समाज॥
जीतहु मनहि सुनिअ अब रामचंद्र के राज॥2॥¹⁶

(In the Ram Rajya punishment would be the authority of those only who have detached themselves from the bondages of the social life. At the same time the aspect known as difference would applied to the field of dance only as professionally they have to apply it for their various moves while performing. Moreover, the word victory would be applied to the victory of the conscious efforts to win one's inner soul only.)

In this way, the ideal of politics is based upon detachment, uniformity, and control of one's conscience only. The idea of such decision-making practice itself leads the authority to the height of any successful administration. Such ideal is applicable to the policymakers even today. The reason is—under the unbiased understanding of the subject matter only one can take a proper and unbiased decision. The truthful unbiased rule will have its impact upon the natural objects even. Tulsidas tries to explain it with the help of beautiful imagery as,

फूलहिं फरहिं सदा तरु कानन। रहहिं एक संग गज पंचानन॥
खग मुग सहज बयर बिसराई। सबन्हि परस्पर प्रीति बढ़ाई॥॥॥

(Flora and fauna are ever blooming in this forest. Even the lion and the elephant are living together harmoniously. Similarly, all the birds and animals have forgotten their animosity and developed love for each other under the reign of Ram Rajya.)

Such congruent existence of all the living entities on the planet makes it obvious to have a heaven on earth itself. At the same time, it is subsequently, comes out of the idea, though metaphorically, that in such state everyone is going to have their own existence without any amount of conflict. At the same time this has been the dream of Shakespeare, Marx or any other concerned thinker of human civilization.

Mohandas Karamchand Gandhi and the Concept of Ram Rajya

The name of Sri Ram has been introduced to Mohandas during his childhood in his family to empower him to walk alone in the darkness. Subsequently, this little boy happens to be the ultimate remover of the darkness of British Empire from the surface of the world with the vision of Ram Rajya. Be it the struggle of Nelson Mandela or strong struggle of President Obama—one common inspiration always empowers them all is that of Gandhian philosophy. One can try to investigate real concept of Gandhian Ram Rajya from his various writings that were published during different phases of his political career. The crux of the concern leads one to the significant base for the concrete philosophical foundation of the man who has influenced the present millennium the most.

From his different writing one can connect the dots for the vision of his ideal state in the form of Ram Rajya. The credit for understanding of his very identity as Hindu as well as the unique quality of respecting the various religions equally goes to his concept of Ram Rajya only. In one of his articles published in magazine called *Harijan* (especially published two months after Indian independence), he mentions that,

My Hinduism teaches me to respect all religions. In this lies the secret of Ramarajya. (*Harijan*, 19-10-1947, p. 378)¹⁷

More than the statement of the politician, sometimes the timing of the statement also plays the significant role in its unique impact upon the receivers. The independence of India was possible only on the division of nation on the basis of religion only. This statement by one of the most significant leaders of the nation makes the entire echo system perceivable for readers. The mention of Ram Rajya at the juncture reveals

importance of the concept as well as that of culture which has successfully preserved the ethos of the text.

In the category of his 'Imagined Community',¹⁸ Mohandas Gandhi had only one choice of Ram Rajya as the option. The explanation behind his option makes his argument more clear for the contemporary political theorists on the basis of his logical acceptance of the concept as Gandhi mentions in one of his earliest writings with proper explanation very categorically that,

Whether Rama of my imagination ever lived or not on this earth, the ancient ideal of Ramarajya is undoubtedly one of true democracy in which the meanest citizen could be sure of swift justice without an elaborate and costly procedure. (YI, 19-9-1929, p. 305)¹⁹

The time period between the World War I and World War II the world has faced worst outcomes of the nationalism. At the same time for the freedom struggle of India and its leaders it was the time to rejuvenate the nationalism in the minds of young Indians. Gandhi being the key figure had to introduced one of the most suitable forms of nationalism in India. In one of his significant discourses upon the future choice of administration in India just before World War II Mohandas in one of his journals *Young India* mentions his clear perception about the then political systems. In very pithy statement, he reveals the importance of Ram Rajya as,

By political independence I do not mean an imitation to the British House of commons, or the soviet rule of Russia or the Fascist rule of Italy or the Nazi rule of Germany. They have systems suited to their genius. We must have ours suited to ours. What that can be is more than I can tell. I have described it as Ramarajya i.e., sovereignty of the people based on pure moral authority. (H, 2-1-1937, p. 374)²⁰

The world history just after two years reveals the worst outcomes of prevailing nationalism on the earth. The successful journey of largest democracy on earth approximately after seventy-five years reveals the strength of not only Gandhian ideology but also the important base of Ram Rajya for its foundation.

Thus, it is really important to see the rise of nationalism of India and its leader's inclination towards one of the oldest concepts of nationalisms on the earth. The comparative analyses of utopian texts along with the impact of epics on human civilization brings forth the importance of *Ramayan* and the concept of Ram Rajya that is bestowed by the text. Mohandas Gandhi's steadfast faith and adamant adherence to the concept bestowed the nation with best of its significant tradition of political concept of democracy. The last words of Man of the Millennium reveal depth of ideological clarity of the leader.

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Changing Perception of Renaissance Politics: A Contemporary Evaluation of Final Plays by William Shakespeare

Hardeepsinh Ranjitsinh Gohil

As per the Moore's law in the age of 'Supernova', everything is changing exponentially faster than the imagination of mankind. In the time when goods, ideas, and art works are being exchanged between East and the West quicker and cheaper than ever before, there is nothing wrong in naming the era as the age of Asian Shakespeare 2.0 (Alexander Huang, 2011).¹ Merchant Ivory's production *Shakespeare Wallah* (1965)² exemplifies the changes that took place in the process of perceiving Shakespeare not only for minds of colonized subject but also in the perception of the British members of the troupe even (Dan Venning, 2011).³

The New Historicism in Renaissance Studies manufactured not searched; that literature is not only passive reflection of its historical 'context' but an agent in envisaging culture's sense of reality. For few critics significance of Shakespeare's vision for his own 'historical moment' lies in his interpretation. Even he had been enhanced by popular histories such as *A Mirror for Magistrates*, Holinshed's *Histories of England* and Tacitus' *Annals* (Hadfield, 2004);⁴ he never wrote plays with "obvious political purpose", rather by bestowing the audience "to sit in judgment on the action as it takes place" (Hadfield, 2004).

With the help of contemporary critical and theoretical approaches, one can study his final plays such as *Pericles*, *Cymbeline*, and *The Tempest* from various unexplored avenues for the contemporary global citizens. Gonzalo's 'Commonwealth' in *The Tempest* can cater a new dimension to the contemporary

debates on the nationalism. The relationship between the powerful Rome and subordinate Britain with the fresh air of patriotism can be observed in *Cymbeline*, national feud with political perplexity adorns the art of storytelling in *Pericles* as well.

The effort is worth encouragement because it opens unknown paths for mankind to understand the craft of Shakespeare with a new perspective that explores opportunities for further research and observation.

The age of Renaissance in England has been considered as the age of various oxymorons. One of them can be "liberties of the subject". At the same time religion has been observed as one of the defining characteristics of Elizabethan and Jacobean dramas in Particular and of English society in general. Going one step ahead the protestant literary culture has exemplified its antagonism with stagecraft which symbolized liberties of the Subject? Professor Donna Hamilton in her depiction of Shakespeare's treatment to Church-government and Church-State relation observes that Shakespeare as an artist, Involved himself in taking positions that posters the liberties of the subject.⁵

Perhaps it may be one of the reasons which instigate the Protestants to put restrictions upon the performances of the stagecraft. Critics like John Russell Brown opines that there were certain political issues which determines the administration and funding of Shakespeare's theatrical Production. After applying theories of 'behavioral ideology' and redeploying Elizabethan anti-stage literature John Drakakis observes that obvious danger of Renaissance theatre resides in its capacity to expose in rulers the politics of representations. Catherine Besley's observation of Shylock and the anti-Semitism portrayed in *The Merchant of Venice* turns to be cultural politics.⁶ Balz Engler as being observer of Shakespeare in the Trenches' highlights tercentenary celebrations of Shakespeare in England and in Germany and subsequent neglect of German scholars due to contentions assertion of national identity. Similarly, Shakespeare's close of *Henry V* in the content of treaty of Troy

is in the context of French History reveals Henry's expansionist and colonialist ambitions.

As being the Indians who are historically labeled as the victim of family feuds and disharmony. It may be an eye-opening experience to have firsthand understanding of English history through New Historicist criticism. The social history such as Paul Slack's *Poverty and Policy in Tudor and Stuart England 1540-1640* and *The Family, Sex and Marriage in England 1500-1800*, J.H. Jessie's *Memoirs of the Court of England* and King James' *The True Law of Free Monarchies* represent the true picture of Britain which can be visualized in plays of Shakespeare with the help of New Historicist way of reading.

The best possible impact of post-structuralism can be found in the form of changing very perception of history which emphasized the role of representation and discourse in social life. By the early 1980s at the University of California at Berkeley a group of young scholars Stephen Greenblatt, Louis Montrose (UC), Catherine Gallagher, D.A. Miller introduced the term 'return to history' in literary scholarship. Their prime focus in literature has been how such collective representational systems work in the production and contestation of social power. Their journal *Representations* reveals primary influence of Michel Foucault. Foucault shifted critical interiorly away from the micronarratives of politics and economics for the micro logical discursive practices and knowledge/power regimes that construct various forms of domination. Likewise Stephen Greenblatt emphasizes upon 'Cultural Poetics' which would study the social and cultural compromises, transactions and exchanges that resulted in the formation of a particular literary work.

It may be an attempt to analyze the cultural replacements, substitution and interchange during the Renaissance England in the form plays by its most celebrated literary phenomenon William Shakespeare. The New Historicist way to evaluate final plays such as *Cymbeline*, *Pericles*, *The Tempest*, and of *Henry VIII* would be an attempt to know the English culture during Renaissance period with the help of most celebrated creative art of the age. In the process, one can apply the 'Cultural Poetics'

to the plays written by Shakespeare at the most matured stage of his dramaturgy.

In the contemporary times when every nation of the world is concerned about its national identity it would be a useful to analyze the British Concern about its national identity in the time of its ascendancy. Produced as early as 1611 *Cymbeline*, *King of Britain* is set in Pre-Roman Britain based upon the King of Britain Cymbelinus, who controlled South-eastern Britain from the late first century BC until the 40s AD. The chronicles of Raphael Holinshed and Geoffrey of Monmouth's *Histaria Regum Britanniae*⁷ has roots for Shakespeare's plot construction. Whereas most significant sub-plots of the play such as Iachimo's hiding place inside a chest in order to gather details of Imogen's room has its origin in story II-9 of *Decameron* by Boccaccio.

The play reveals the perverted political treacheries that take place within the Royal Family at the national level and international extortion sought by Roman army from Britain in the form of tribute-kind of charge served to powerful nation by weaker on for a promise of non-aggression. The first family of Britain itself reveals here the complex social system prevailing in the country. The King Cymbeline has a daughter Imogen from his previous wife, who is pursued by Cloten a son of Queen from her former husband. There are number of events which provide important information about 'Cultural Values' of the then Britain. The exile of Posthumus stands for rigid social rituals.

On the political ground the banishment of Belarius and his insult also reflects the underlying political stratagem of Renaissance Britain. The rash judgments of the king and their implementations reveal one more quality of Renaissance England. New Historicist reader would compare it with the rule of James I of Scotland and his emphasis upon the absolute obedience to the Scepter. Shakespeare being very close to the scepter might have highlighted such issue of obedience to the audience with the help of popular medium, the medium of drama! In the Act 5, Scene V of *Cymbeline* Belarius in most rebellious manner reveals his act of obedience as,

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I, old Morgan,
 Am that Belarius whom you sometime banish'd
 Your pleasure was my mere offence, my punishment
 Itself, and all my treason; that I suffer'd
 Was all the harm I did. (333-37).⁸

Such revelation comes at the time when the honor of Britain itself have been protected by the rebellious person only! The king has no option but to forgive and honor such Knights of nations.

On the contrary to the act of real patriotism, the loquacious glorification about new political status of Britain Comes from the mouth of crafty Queen. In the Act 3, Scene I of the play, when Caius Lucius, an agent of Roman Empire comes to ask for Britain's tribute to the patronage in the presence of the king—the queen interrupts and insults the Empire and boasts about British political status as,

A kind of conquest
 Caesar made here; but made not here his brag
 Of 'came, and saw and overcome.' With shame
 (The first that ever touch'd him) he was carried
 From off our coast, twice beaten; (22-26)⁹

In the similar vein the King of Britain answers to the Roman ambassador as,

You must know,
 Till the injurious Romans did extort
 This tribute from us, we were free. (Act 3, Scene I, 45-47)¹⁰

The rising of patriotism and self-respect of Renaissance England resembles the inspirational line behind the freedom movement of world's oldest Democracy US. That is "No taxation, without presentation."

There is no need to iterate how this freedom movement of the oldest democracy influenced the largest democracy of the world! In many ways, the struggle as well as foundational stones behind both the democracy overlaps each other on several occasions. Perhaps the role of the Empire might have played crucial role in inculcating the rebellious argument.

The Tempest has been often discussed by the critics for possibilities of post-colonial interpretation especially in the case of occupation of an island by an outsider and dominating the dwellers especially Caliban and Ariel. The most popular lines from the mouth lines of Caliban,

You taught me language; and my profit on't
Is, I know how to curse. (364-67)¹¹

Perhaps the mentioned line is sufficient to introduce the theme of post-colonial interpretation of the text. Along with that the play also reveals the prevailing family feud with the example of the crafty plots of younger brother Sebastian and Antonio to dethrone and banish their elder brothers Alonso and King of Naples and Prospero, The Duke of Milan. It is character of Gonzalo, an honest old counselor of Prospero who saves the life of the Duke and his daughter against the treachery of the family members.

For the unique interpretation of the national administration, the vision of Gonzalo delivered on the island—When stranded with the others. It can be evaluated from multiple nationalistic interpretations as,

I the commonwealth I would by contraries
Execute all things, for no kind of traffic
Would I admit; no name of magistrate;
Letters should not be known; riches, poverty,
And use of service, none; contract, succession,
Bourn, bound of land, tilth, vineyard, none;
No use of metal, corn or wine or oil;
No occupation, all men idle, all;
And women too, but innocent and pure;
No sovereignty—(146-55)¹²

The Concept of Commonwealth in more than one ways a source of inspiration for the schools of Marxist, Democratic as well as contemporary awakening of Eco-nationalism—under pressure of which France has recently announced its coal less energy production by 2020. At the same time, recent initiatives by Government of India to enhance and promote the usage and production of renewable energy is also part of "No use of...fossil fuel" political policy only!

A play which demands exclusive rereading more than any is *King Henry VIII*, a historical drama, perhaps produced collaboratively by Shakespeare and Fletcher at the final stage of Bard's creative journey. The play deals with some of the most crucial issues of the time such as accusation and execution of the Duke of Buckingham, the most sensitive divorce of Queen Katharine, pride-fall and death of Cardinal Wolsey and futuristic image of the Queen Elizabeth has also been meticulously threaded here.

In case of contemporary progressing India, the biggest political issue may be the tax levied by the government. During the Renaissance England, when the country was under the process of development it had to face certain amount of frictions. To meet the expenses behind these frictions there were need of certain taxes. The play artistically deals with the matter of economy which is at the center of all the revolutions of present world. Duke of Norfolk in company of Duke of Buckingham raises question against the tax levied by Cardinal Wolsey in the name of French War. Queen Katharine as if supporting their stratagem 'loud' about the 'rebellion'. Norfolk threatens the King in his most cunning manner in very beginning of the play in Act 1, Scene II as,

Not almost appears,
It doth appear; for upon these taxations,
The clothiers all, not able to maintain
The many of them 'longing, have put of
The spinsters, carders, fullers, weavers, who
Unfit for other life, compell'd by hunger
And lack of other means, in desperate manner
Daring the event to the teeth, are all in uproar,
And danger serves among them. (29-36)¹³

The person who is reporting and the message of 'danger' reveals the affinity of intention behind political personality. The perception about 'taxation' and report about 'lack of other means' remind us of participation of international celebrities in the tax-related protest of Indian farmers in 'desperate manner'. The King subsequently convinced by Queen to withdraw the tax and invites the unwelcomed consequences in the play. The

play very tenderly tries to reveal political scenario of the then Britain. A critic like Farina rightly observes that, "The play dramatizes the concurrent births of the English Reformation and the Princess Elizabeth in 1533, as well as the intertwined conflicts surrounding these occurrences" (Farina 151).¹⁴

The Queen's remark at the time of the trial in the presence of the King reveals the psychological responsibility that lies upon the solders of the members of royal family in Act 2, Scene IV as,

Sir,
I am about to weep; but, thinking that
We are a queen, or long have dream'd so, certain
The daughter of a king, my drops of tears
I'll turn to sparks of fire. (69-73)¹⁵

Such words from 'the daughter of a king' (Spain) resulted in the futuristic 'Sparks' that takes the entire energy of the Britain get doused. Further when discussing about the cardinal Griffith, Gentleman-Usher to the Queen Katharine departs an eternal wisdom in very simple words in Act 4, Scene II as,

Noble madam,
Men's evil manners live in brass: their virtues
We write in water. (44-46)¹⁶

Similarly, before the epilogue of the play Cranmer expresses the futuristic characteristic of the Queen Elizabeth along with her virtues to the King in an eloquent manner possible. That reflects the political future of the princess along with the nation in a unique way as,

She shall be, to the happiness of England,
And aged princess; many days shall see her,
And yet no day without a deed to crown it,

.....
A most unspotted lily shall she pass
To the ground, and all the world shall mourn her. (56-62)¹⁷

The eulogy of play wright in the form of the Cranmer's opinion opens up multiple layers of investigations which can be applied to find real nature of relationship of the writer of the

time and their rules. Such detailed study may bring forth many information which can be helpful to the contemporary writers.

In case of *Pericles, the Prince of Tyre*, one can find two major threads to infer the then political situation of the Europe at that time. The first one is related to the incestuous relationship between king of Antioch and his daughter, another is the popular revolt against Dionyza. One can find lot of inter breeding throughout Europe, Spain and Portugal. They were at lowest level where marrying aunts, uncle, niece, and nephews found common. It was in trend whereas in the rest of the Europe they were usual amongst cousins. The significant spark behind WWI has been one of its outcomes only! The riddle in the Scene I, Act 1 describes one such evidence of Renaissance Europe as,

I am no viper. Yet I feed
On mother's flesh which did me breed.
I sought a husband in which labour
I found that kindness in a father:
He is father, son, and husband mild;
I mother, wife and yet his child.
How they may be, and yet in two,
As you will live, resolve it you. (64-71)¹⁸

It was such a situation that leads the prince of Tyre to run away from the Antioch to save his life. Maureen Quilligan in *Incest and Agency in Elizabeth's England* observes that incestuous criticism underlying Elizabeth's famed virginity.¹⁹

Another significant aspect that one need to iterate from the *Pericles* is the spirit of ingratitude displayed by Dionyza whom *Pericles* hand over the most needed stuff to feed their famine-affected subject. In return they were not able to even look after his daughter Marina. Because of that she had to go through the worst experiences of life including the time she spent in brothel house even! The consequent revolt of their subject can be seen as the public revolts in the Europe during the age against such fall of ethics. The underlying revolt against King James I can be referred in this connection.

Thus, on the basis of the final plays by Shakespeare one can understand the "cultural poetics" that went into the making of such classic plays such as *The Tempest*, *Cymbeline*, *Pericles*,

and *King Henry VIII*. With help of "textual traces" one can observe and analyze how various extra-textual representational systems of the European culture has been embedded seamlessly with the various evidences. For the Indian interpreter it may provide new avenues to evaluate the Renaissance England be it is court life, social life or life in nature, that is to say harmonious existence with the environment. At the same time such reading can help in rejuvenating the most needed aspect of self-respect for one's own civilization which had been brutally subjugated by the culture of the Empire. Yet there are multiple layers to be unearth for the better understanding of the true culture of the colonizers!

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Optimal and/or Efficient Cross-Over Designs Balanced for Carry-Over of Active Treatments

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Abstract

The experimenters have limited flexibility as far as the number of experimental units are concerned; this could be unsuitable in bioavailability/bioequivalence study. In cross-over design literature, most of the designs require an even number of subjects, few of them are available for 3, 9 or 15 subjects, but designs are not available for number of subjects like 5, 7, 11. A new class called active balanced cross-over designs is defined and constructed for carry-over models through a 5M active balanced computer search algorithm for addressing this gap in literature. The newly generated cross-over designs are more variance efficient under self and mixed carry-over model than the two treatments three periods cross-over designs. Many cross-over designs, which have been unavailable so far, are obtained for five carry-over models in this paper. A new optimal cross-over design in the class of balanced two treatments three periods cross-over designs is also generated. An exhaustive list of optimal and/or efficient cross-over designs have been provided for designs in 4 to 13 experimental units. In this list, 10 new included designs are optimal for one of the carry-over models and 7 new included designs are optimal and/or efficient when fitting to all four plausible carry-over models.

Keywords Self and mixed carry-over effect · Optimal and efficient design · Active treatment · Placebo treatment · Washout period

1 Introduction

Designs with a new therapy, standard therapy and a placebo/reference are sometimes referred as 'gold standard' trials. There are two kinds of objectives associated with these trials: compare two active treatments and compare each active

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treatment with placebo/reference. These research objectives are often carried out using cross-over designs (CODs) because within experimental unit treatment comparisons are more efficient than between experimental unit treatment comparisons. For example, [19] used a three treatment COD having three periods to compare the protective effect of single dose of a study therapy formoterol solution aerosol 12 mg (F12) with that of a standard therapy salbutamol suspension aerosol 100 mg (F100) and a placebo (P). The forced expiratory volume in one second (FEV1) of patients suffering from exercise-induced asthma are repeatedly measured after respective therapy defined in COD. Also, refer [3], to discover that COD was used to compare the bioavailability of two brands of phenytoin sodium tablets, considering eptoin as the reference.

In CODs, each experimental unit is measured according to a treatment sequence over successive periods of time, where the carry-over effects may sustain for different amounts of time. According to [16] if carry-over is present to any appreciable degree, then the usual statistical models provide no guaranteed protection against its effects. Owing to this reason, [17] investigated two treatments four periods CODs under traditional and steady state carry-over models and concluded that, statisticians cannot provide a general design and estimation strategy that gives guarantee to deal with carry-over. The steady state model assumes that the carry-over from the same treatment applied in the previous period ultimately vanishes to zero.

Koch et al. [10] proposed a two periods COD in ten sequences for comparison of two active treatments in presence of placebo. Jones and Donev [9] improved their design into a three-period design to optimize the active treatment comparison. However, both the authors assumed that the carry-over effects of active treatments and placebo are equal in magnitude but opposite in sign. Since proving optimality through combinatorial theory is tractable only for restricted class of designs, many authors such as, [8, 9, 15, 20] used a computer search algorithm to construct optimal CODs in two or more treatments for specific models.

A design optimal for one statistical model may not be optimal for another. Also, a design that estimates treatment contrasts under one model may not be able to estimate under another. It is therefore of interest to identify designs that provide efficient estimates of treatment contrasts (relative to an optimal design) for more than one model.

Several optimal and efficient CODs in two treatments or two active treatments and a placebo are discussed in literature, for example, [5–7, 9, 10, 14], etc. But, they are suitable only when the number of experimental units are available in multiples of two or three. This limits use of their designs in several experimental situations, particularly in the medical field, where utilization of every unit is crucial. For example, if exactly five experimental units are available, then the experimenter has to forgo getting information available on one of the units, because no design is available for five units. In general, no COD is available if the number of units is a prime number greater than three. This, of course, does not stop experimenter from using the design, but he either has to do away with less information, or capitalize on fund by cost incurred on one additional unit. The reason for the nonexistence of CODs for a prime number of units is a combinatorial one, as it is not possible to balance all possible pair occurrences of treatments for carry-over effects.



To overcome this limitation, this paper defines a new class of CODs called active balanced CODs (ABCODs). It is a class of three treatments CODs, consisting of one placebo and two active treatments, where the balancedness and uniformity on periods is to be managed only for active treatments, and not necessarily for placebo. Also, CODs in two active treatments and a placebo have an additional benefit in analysis [2]. These designs have been studied under five different models and an optimal design is given for each model. A computer search algorithm called 5M active balanced algorithm is given and used to construct active balanced CODs which are optimal and/or efficient for each of the five models. The newly generated CODs have a variance smaller than that of the two treatments three periods CODs under self and mixed carry-over model. For example, the cross-over design {2ABA, 2BAB} is shown to be optimal under self and mixed carry-over model by [7] for $COD(2, 4, 3)$ having a variance of 1.5 for treatment contrast whereas, for active an balanced cross-over design {APB, BPA, PAB, PBA}, it is 0.62. Interestingly, some more new CODs, efficient than the popular balanced two treatments three periods CODs are also generated. Our contribution is twofold. First, it provides a new optimal COD for each specific model, and second, it gives new CODs which are optimal and/or efficient CODs for all the five models. A COD which is either optimal for any one model and efficient for the remaining models or efficient for all five models is referred as an optimal and/or efficient COD.

2 New Definitions, Models and Optimality

2.1 New Definitions

Balanced COD is not possible when the number of experimental units is not a multiple of number of treatments. To overcome this limitation, we simplify the treatment pair occurrences and introduce two new terminologies, namely, *active uniform over periods* and *active balanced*.

Definition 1 A COD is called *active uniform over periods* if each active treatment occurs equally frequently in each period.

For example, the below COD is *active uniform over periods* because both active treatments A and B are applied once in the first and second period, and, twice in the third period.

Period	Subjects			
	1	2	3	4
1	A	B	P	P
2	P	P	A	B
3	B	A	B	A

Definition 2 A $COD(t, n, p)$ is said to be *active balanced* with respect to the set of treatments and first order carry-over effects if it is (i) active uniform over periods,

and (ii) in two successive periods, each ordered pair of active treatments, each self pair of active treatments, as well as, each pair of placebo followed by active treatments are given to equal number of units.

For example, the design given above is active balanced because each active treatment A and B is given to equal number of units in each period, also each ordered pair of active treatments AB and BA, each self-paired active treatments AA and BB, and each ordered pair, an active treatment followed by a placebo AP and BP, are given to equal number of units in two successive periods.

2.2 Models

The model known as no carry-over model in the COD literature is of the form,

$$y_{ijk} = \mu + \pi_k + \xi_{ij} + \tau_{d(k,j)} + \epsilon_{ijk}, \quad i = 1, \dots, s; \quad j = 1, \dots, n_i; \quad k = 1, 2, \dots, p, \quad (1)$$

where y_{ijk} denotes the response from sequence i , experimental unit j , in period k to which treatment $d(k, j)$ was assigned, μ is the general mean, $\tau_{d(k,j)}$ is the effect of treatment $d(k, j)$, π_k is the effect due to period k , ξ_{ij} is the effect due to experimental unit j having sequence i , every sequence replicated n_i times ($n_i \geq 1$), and the ϵ_{ijk} are independently normally distributed error terms with mean 0 and variance σ^2 .

When the response variable is also affected by the treatment applied in the previous period, then one more term of carry-over effect of the treatment should be added in the model. This model is generally called simple carry-over model or traditional model in optimal design literature, and is given by

$$y_{ijk} = \mu + \pi_k + \xi_{ij} + \tau_{d(k,j)} + \gamma_{d(k-1,j)} + \epsilon_{ijk}, \quad (2)$$

where $\gamma_{d(k-1,j)}$ is the carry-over effect of treatment $d(k-1, j)$ on the response observed on experimental unit j in period k . It is obvious that there is no carry-over effect in the first period, that is, $\gamma_{d(0,j)} = 0$. Sometimes, the carry-over due to the treatment preceded by it in the previous period is different than the treatment preceded by other. This view was first introduced by [1] and studied by [11, 12]. This self and mixed carry-over model is of the form,

$$y_{ijk} = \mu + \pi_k + \xi_{ij} + \tau_{d(k,j)} + \gamma_{1d(k-1,j)} + \gamma_{2d(k-1,j)} + \epsilon_{ijk}, \quad (3)$$

where $\gamma_{1d(k-1,j)}$ is the carry-over of treatment preceded by other treatment in the previous period and $\gamma_{2d(k-1,j)}$ is the carry-over of treatment preceded by itself in the previous period.

Practical situations where the purpose of the trial is to compare two treatments with help of a placebo/reference (For example, [13, 18]), the treatments are called active treatments. Accordingly, all the models considered in this paper are restricted to two active treatments and a placebo. As per medical knowledge, when a placebo is given to patients, in the patients' mind the psychology is that a drug is given to them, but in reality it is a placebo, so whatsoever psychological effects the patients have get measured as treatment effects of the placebo, and in the next period there is no carry-over of

the psychological effects. Therefore it is logical to assume that there is no presence of psychological carry-over and obviously, there is no pharmacological carry-over from the placebo treatment. As per the assumption that, a placebo has no carry-over effects, models 1–3 with active treatments A, B and placebo P are referred in this article by NCM (No Carry-over Model), TBM (Traditional Model where Both active treatments have carry-over) and SBM (Self and mixed Model where Both active treatments have carry-over) respectively. Also, when the purpose of a trial is to compare a new treatment with a standard treatment, the experimenter is usually aware of the washout period of the standard treatment. In this case, if the experimenter sets the length of washout period according to the standard treatment, then the standard treatment will not have carry-over effects. Regarding the complexity of the analysis of cross-over experiments for comparing a new treatment with a standard, the analysis also gets simplified by assuming that only the new treatment has carry-over effect. In this case, the traditional model is considered under the assumption that only treatment A having carry-over effect is model 2, with $\gamma_{d(k-1,j)} = 0$ if $d(k-1,j) = B$ or P. We will refer to this model as TSM (Traditional Model where Single active treatment has carry-over).

Similarly, a self and mixed model is considered under the assumption that only treatment A having carry-over effect is model 3 with $\gamma_{d(k-1,j)} = 0$ if $d(k-1,j) = B$ or P. We will refer to this model as SSM (Self and mixed Model where Single active treatment has carry-over). These five different fixed effect models, NCM, TSM, TBM, SSM and SBM for continuous response cover all the possibilities of occurrence of carry-over effect.

2.3 Optimality

Most commonly, the performance of a design is measured by its variance of treatment comparison, given by the variance of the least square estimates of the treatments. Usually a design d with larger information matrix, C_d , yields a smaller variance for an estimate of treatment, hence the central problem in the design of experiments is to find the design d such that the information matrix C_d is as large as possible. However, in general, matrices cannot be compared directly. To compare them for different designs, one has to define functions of C_d , which maps from the matrix space into one dimensional space. For the connected balanced designs, it suffices to compare variances of the treatment contrasts. Note that, the nature of treatment contrasts depends upon the objective of the study.

For comparison of two treatments, the objective is to estimate the difference of treatment effects. The design which minimizes its variance over all the possible designs for a specific class is referred to the optimal in the class [7, 9]. A specific class of COD is generally determined by fixing only one or two of the three parameters, the number of treatments, periods and experimental units, but preferably, it should be considered by fixing all the three parameters, because the design information matrix is affected by change in all three parameters.

Hedayat and Stufken [7] and Ozan and Stufken [14] ignored the number of experimental units in comparison of different designs, and thus missed several optimal designs available in specific number of experimental units, particularly in

Table 1 Variance for treatment contrast of CODs for class $COD(2 + 1, 5, 3)$

Design	n	NCM	TSM	TBM	SSM	SBM
AAB,ABB,BBA,BAA	4	0.3750	0.3871	0.3871	0.5714	2.0000
ABA,ABB,BAB,BAA	4	0.3750	0.4615	0.4615	0.7941	1.8750
ABB,ABB,BAA,BAA	4	0.3750	0.3750	0.3750	–	–
ABA,ABA,BAB,BAB	4	0.3750	1.5000	1.5000	1.5000	1.5000
APB,BPA,PAB,PBA	4	0.5000	0.5682	0.6154	0.5682	0.6154
ABB,APB,BAA,BPA,PPP	5	0.4286	0.4286	0.4286	0.5270	0.6364

Table 2 Optimal and/or efficient active balanced CODs for class $COD(2 + 1, 5, 3)$

Serial no.	Design	n	NCM	TSM	TBM	SSM	SBM
1	AAB,ABB,BBA,BAA	4	100	97	97	92	31
2	2ABB,2BAA	4	100	100	100	–	–
3	APB,BPA,PAB,PBA	4	75	66	61	93	100
4	ABB,APB,BAA,BPA,PPP	5	88	88	88	100	97

the presence of carry-over effects [5]. Also under SSM and SBM, comparison of active treatments with the help of a placebo reduces the variance of treatment contrast. From Table 1, it is clear that the designs {ABB,APB,BAA,BPA,PPP} and {APB,BPA,PAB,PBA} in two active treatments and a placebo has the least variance for treatment contrast under SSM and SBM respectively than the cross-over design {ABA,ABA,BAB,BAB} recommended by [4], the cross-over design {ABA, ABB, BAB, BAA} of [7] and the cross-over design {AAB,ABB,BBA,BAA} of [5]. These designs are now optimal under SSM and SBM, respectively. That is, $COD(t + 1, n, p)$ performs optimal than $COD(t, n, p)$ under SBM. Note that, class $COD(t + 1, n, p)$ contains all the CODs of t and $t + 1$ treatments having n or $n - 1$ experimental units in p periods. For simplicity, we used an abbreviated notation for the designs. For example, the active balanced cross-over design {ABB,ABB,BAA,BAA} is abbreviated as $cod(ab)2\{2ABB,2BAA\}$ as shown in Table 2. The number after $cod(ab)$ stands for the serial number of the COD in the Table. The number before the sequence denotes the replication of the sequence in the design. A design that is optimal under one model may not be optimal under another model. Then, the better choice is the design which is efficient under several models. The efficiency is the relative efficiency of a design, d , with respect to the optimal design for that class and the model. Efficiency is calculated by taking the ratio of the variance of least squares estimator of treatment contrast for the optimal design to the variance of design d . Thus, efficiency of a design optimal for a specified class and model is 100% but it may not be so in case of another models. From Table 2, it is clear that, $cod(ab)4\{ABB,APB,BAA,BPA,PPP\}$ is optimal and efficient for class $COD(2 + 1, 5, 3)$, because this design is optimal under SSM and efficient in other models. Variance of least squares estimator of treatment contrast of CODs shown in this paper is obtained through the said computer search algorithm.



2.4 Simulation Study

We demonstrate the performance adequacy of 5M algorithm via a simulation study. It was performed for each five models with results equivalent to those in Table 2. Suppose an experimenter wants to construct optimal and/or efficient CODs. Data shown in Table 3 for the *cod(ab)4* were simulated under SBM by fixing the parameters as $\mu = 15$, $\tau_A = 1$, $\tau_B = -1$, $\tau_P = 0$, $\gamma_{1A} = -1$, $\gamma_{1B} = 1$, $\gamma_{1P} = 0$, $\gamma_{2A} = -2$, $\gamma_{2B} = 2$, $\gamma_{2P} = 0$, $\pi_1 = -2$, $\pi_2 = 1$, $\pi_3 = 1$, $\xi_{11} = \xi_{31} = 1$, $\xi_{21} = \xi_{41} = -1$, $\xi_{51} = 0$ and $\sigma^2 = 1$. Estimates of the interested treatment contrast ($\hat{\tau}_A - \hat{\tau}_B$) in this case is 2.0563. It shows that an active treatment A has 2.0563 units more effects than B, which is very close to exact value 2 ($\tau_A - \tau_B$). Similarly, we simulated data for the *cod(ab)1* and *cod(ab)3* under SBM by fixing the parameters as shown above. Estimates of the interested treatment contrast ($\hat{\tau}_A - \hat{\tau}_B$) for the *cod(ab)1* is 5.7841 which is outlying from the exact value 2, whereas for the *cod(ab)3* is 2.0265 which is very close to exact value 2. So it is clear that *cod(ab)3* and *cod(ab)4* estimates treatment contrast more efficiently than other designs under SBM. We have repeated the above procedure 100 times for all the four designs under all five models and estimated treatment contrast ($\hat{\tau}_A - \hat{\tau}_B$) as shown by charts in the “Appendix”. Chart of *cod(ab)4* clearly shows that *cod(ab)4* performs efficient under all the models as compared to the *cod(ab)1-cod(ab)3*.

3 The 5M Active Balanced Algorithm

In this section, we present a computer algorithm for search of optimal and/or efficient ABCODs under the five models, namely, NCM, TSM, TBM, SSM and SBM. The algorithm involves making comparisons of variances of treatment effects among ABCODs of a class for a given model. Several computer algorithms have been given in literature [8, 9, 15, 20] for search of optimal and/or efficient CODs. The most common approach of these algorithms is that, they begin the search procedure with a ‘random’ design and attempt to improve it until it cannot be improved by applying further steps. Our computer search algorithm starts from a trivial possibility and proceeds systematically up to the last possibility, and provides globally optimum ABCOD by comparing every possible ABCOD of a specified class and model. Since, the algorithm makes an exhaustive search and returns optimal and/or efficient ABCODs for one or more of the five models, the programming was challenging. A broad outline of the 5M active balanced algorithm is given below.

Table 3 Simulated data for the *cod(ab)4* under SBM

Period	Seq	Data	Seq	Data	Seq	Data	Seq	Data	Seq	Data
1	A	14.4417	A	11.9743	B	11.3011	B	11.6992	P	11.5169
2	B	14.6886	P	13.0913	A	19.6076	P	16.2696	P	14.9797
3	B	17.4300	B	13.7901	A	15.8822	A	16.4943	P	15.5530

- (i) Set variance $V(m)$ = a high value (say, 99), for all models numbered $m = 1, \dots, 5$. Set parameters t, p and n .
- (ii) Generate all possible treatment sequences of t treatments in p periods.
- (iii) Generate a cross-over design d by considering n treatment sequences arbitrarily from those obtained in step (ii) including replications of the sequences.
- (iv) Perform an equal replication check for the generated design that is, $(np)/t$ occurrence of each treatment. If all the treatments are not equally replicated then return to step (iii).
- (v) Perform the balanced occurrence check for active treatments in each period that is, equal occurrence of each active treatment in each period. If the active treatments are not equally replicated in each period then return to step (iii).
- (vi) Perform the pair wise balanced occurrence of active treatments in two successive periods that is, each ordered pair of mixed active treatments, pair with self of active treatments, and mixed pair of active treatment and placebo are given to a constant number of units. If this condition is not satisfied then return to step (iii).
- (vii) Under NCM, TSM, TBM, SSM and SBM indexed, respectively $m = 1, 2, \dots, 5$.
 - (a) Perform the connectedness check for the design d , that is, calculate the rank of the design information matrix (C_d) under model m . If it is not connected, that is, rank of C_d is less than $t - 1$, then skip the next step and consider next model.
 - (b) Perform least variance check, that is, compute $V(d, m)$ which is variance of the least squares estimator of treatment contrast ($\tau_A - \tau_B$ for two active treatments A and B) under model m . If $(V(d, m) \geq 0 \ \& \ V(d, m) < V(m))$ then store $V(m) = V(d, m)$ and $optimaldesign(m) = d$.
- (viii) Finally, store the design with variance $V(d, m)$ and ranks of the design matrix under NCM, TSM, TBM, SSM and SBM, provided that the design is connected in all five models.
- (ix) Repeat (iii) to (viii) for all possible combinations of n treatment sequences.

This algorithm produces optimal ABCODs under each model along with their variances and ranks. All of this is stored in a spreadsheet for at a glance view of design statistics for optimal and/or efficient ABCODs under given model. Note that, the ABCODs optimal under NCM, TSM, TBM, SSM and SBM are stored respectively as the last five designs in the spreadsheet. A flowchart to present how the algorithm works is shown in “[Appendix](#)”.

3.1 Working of the 5M Active Balanced Algorithm

Consider an experimental situation where $t = 3$, $p = 3$, $n = 4$. Let the two active treatments be denoted by 1, 2 and placebo denoted by 3. Step (i) is set $V(m) = 99$, $m = 1, 2, \dots, 5$. Step (ii) generates all the possible sequences. Step (iii) generates a design say, $\{111, 111, 111, 111\}$. As per step (iv) treatment 2 is not



equally replicated as treatment 1 and 3, and hence, the algorithm returns to step (iii) and generates a second design say, {111, 111, 111, 112}. Again the algorithm shall return to step (iii) and generates designs, say, {111, 111, 111, 113}, {111, 111, 111, 121}, ..., {111, 122, 223, 333}. Now algorithm moves to step (v) but all the active treatments are not equally replicated in each period and hence the algorithm returns to step (iii) and generates the other designs, say, {111, 122, 231, 231}, {111, 122, 231, 232}, ..., {111, 122, 233, 233}. Now algorithm moves to step (vi) but the treatments are not active balanced in terms of carry-over and hence, algorithm returns to step (iii) and generates the other designs {111, 122, 233, 311}, ..., {111, 222, 331, 332}. Now this design satisfies the condition of steps (iv)–(vi). Hence, in step (vii), rank of C_d under NCM is calculated. Here the rank of the design matrix is three, which implies that the design is connected. In step (viii) variance of the least squares estimator of treatment contrast $(\tau_1 - \tau_2)$ under NCM is calculated. Also, variance of the least squares estimator of treatment contrast $(\tau_1 - \tau_2)$ is less than the set variance $V(1)$. Hence, the algorithm stores design {111, 222, 331, 332} as the optimal design along with its variance for treatment comparison. Similarly, the algorithm calculates C_d and variances of the least squares estimator of treatment contrast $(\tau_1 - \tau_2)$ under TSM, TBM, SSM and SBM one by one according to step (vii). Under all the other four models, the design is connected and hence algorithm stores design {111, 222, 331, 332} as the optimal design along with its variance under TSM, TBM, SSM and SBM. Also, this design is connected in all five models, hence the algorithm stores this design as design number 1 with its variance and rank. According to step (ix), the algorithm returns to step (iii) and generates other designs {111, 222, 331, 333}, ..., {112, 133, 221, 233}. Since this latest design yields a smaller variance of treatment contrast under all five models, hence this design is stored as optimal under all five models. Also, this design is connected in all five models. Hence this design is stored as design number 2 with its variance and rank. Similarly, the algorithm repeatedly works for other sequence combinations. Finally, the algorithm generates a spreadsheet having three sheets named as var, rank and design respectively, showing the variances of treatment contrast, the ranks of C_d matrix and the CODs, stored by the 5M active balanced algorithm.

4 Optimal and/or Efficient Active Balanced CODs

A COD in two active treatments and one placebo having three periods is given by some of these twenty seven treatment sequences AAA, BAA, PAA, ABA, BBA, PBA, APA, BPA, PPA, AAB, BAB, PAB, ABB, PBB, APB, BPB, PPB, AAP, BAP, PAP, ABP, BBP, PBP, APP, BPP and PPP. Due to increased options as compared to two treatments CODs, better and new optimal designs are obtained for two treatments comparison. Variance of treatment contrasts are estimable under all models for all classes that is, according to desirable number of experimental units. Also, now there are more options for designs. Before defining such a COD, let us consider a practical situation reported by [19] for a single center data from a multi-center trial, where such types of CODs are used. Here, an experimenter want to compare and establish the protective effect of a single dose of an experimental treatment, a

12 mg formoterol solution aerosol (say, treatment A), with that of a standard therapy, 100 mg salbutamol suspension aerosol (say, treatment B), and a placebo (say, treatment P) optimally, in patients suffering from exercise-induced asthma. A three periods three treatments double-blind crossover trial is used by giving the treatment sequences to patients and values of forced expiratory volume in one second (FEV1) after an exercise is measured.

For the above cross-over trial, any of the following three periods CODs would be useful according to the availability of experimental units and choice of the carry-over model. Naturally, an experimenter would prefer a design which is optimal under the most speculated carry-over model and simultaneously efficient under the possible models. For example, if experimenter have five patients of asthma, he should use the $cod(ab)11\{ABB, APB, BAA, BPA, PPP\}$ shown in Table 4, because, this design is optimal and efficient for class $COD(2 + 1, 5, 3)$. A suitable design could be a two treatments $COD(2, n, p)$ design or a two treatments with one placebo $COD(2 + 1, n, p)$ design. Note that, the former type requires an even number of experimental units, while the latter type is available in arbitrary number of experimental units. We know that, even and odd numbers occur consequently, if n is even, $n - 1$ is odd and vice-versa. To get an complete advantage of both types of CODs, the class of designs in n experimental units are compared within and across the class of designs in $n - 1$ experimental units. Therefore, both types of designs are evaluated and tabulated as belonging to common classes. A class is determined by the number of experimental units needed by an experiment. Table 4 restricts classes of designs up to thirteen experimental units, but more classes can be obtained using the 5M active balanced algorithm.

4.1 Optimal Cross-Over Design Under NCM, TSM and TBM

Although CODs in two treatments are optimal under NCM, TSM and TBM, they are not available for odd number of experimental units 5, 7, 9 and so on. However, comparison across two treatments and one placebo designs in odd number of experimental units show that, the two treatments designs having even numbers of units still performs better, as result of having a lower variance of treatment contrast under NCM, TSM and TBM. Across $COD(2, n - 1, 3)$ and $COD(2 + 1, n, 3)$, for $n = 5, 7$, each of the two treatments $cod(ab)9\{2ABB, 2BAA\}$ and $cod(ab)15\{3ABB, 3BAA\}$ are optimal under NCM, TSM and TBM. However, both the designs are unable to estimate treatment contrast under SSM and SBM. Similarly, each two treatment cross-over design, $cod(ab)35\{AAB, 4ABB, 4BAA, BBA\}$ and $cod(ab)45\{AAB, 5ABB, 5BAA, BBA\}$ are optimal under NCM, TSM and TBM for class $COD(2 + 1, 11, 3)$ and $COD(2 + 1, 13, 3)$, respectively.

4.2 Optimal Cross-Over Designs Under SSM

For every class, optimal ABCODs under SBM are not necessarily optimal under SSM. The designs are now evaluated assuming that the experimenter is sure about the model as SSM. Among designs in four experimental units, the active balanced



Table 4 Optimal and/or efficient active balanced cross-over design for classes $COD(2 + 1, 4, 3)$ to $COD(2 + 1, 13, 3)$

Serial no.	Design	n	NCM	TSM	TBM	SSM	SBM
1	AAB,ABB,BBA,BAA	4	100	97	97	99	31
2	ABA,ABB,BAB,BAA	4	100	81	81	72	33
3	2ABB,2BAA	4	100	100	100	–	–
4	2ABA,2BAB	4	100	25	25	38	41
5	APA,BAB,PBP	3	38	16	12	24	19
6	APB,BPA,PAB,PBA	4	75	66	61	100*	100 [®]
7	ABB,BAA,PAP,PBP	4	63	62	62	61	35
8	AAB,ABB,BBA,BAA	4	100	97	97	92	31
9	2ABB,2BAA	4	100	100	100	–	–
10	APB,BPA,PAB,PBA	4	75	66	61	93	100 [®]
11	ABB,APB,BAA,BPA,PPP	5	88	88	88	100*	97
12	AAB,ABA,ABB,BBA,BAB,BAA	6	100	81	81	78	39
13	AAB,2ABB,BBA,2BAA	6	100	99	99	96	22
14	ABA,2ABB,BAB,2BAA	6	100	92	92	100	24
15	3ABB,3BAA	6	100	100	100	–	–
16	ABP,BPA,PAB,APB,BAP,PBA	6	75	63	60	90	88
17	AAB,ABP,APB,BAP,BBA,BPA,PPP	7	83	74	73	95	87
18	ABB,ABP,APB,BAA,BAP,BPA,PPP	7	83	81	81	97	87
19	ABA,2APB,BAB,2BPA,PPP	7	83	70	68	100*	100 [®]
20	2AAB,2ABB,2BAA,2BBA	8	100	97	97	77	35
21	AAB,ABA,2ABB,2BAA,BAB,BBA	8	100	90	90	70	56
22	AAB,3ABB,3BAA,BBA	8	100	99	99	100	25
23	4ABB,4BAA	8	100	100	100	–	–
24	2APB,2BPA,2PAB,2PBA	8	75	66	61	77	100 [®]
25	ABA,ABP,APB,BAP,BPA,BPB,PAB,PAP,PBA	9	60	44	42	65	69
26	2ABB,APB,2BAA,BPA,PAP,PBP,PPP	9	60	60	60	70	54
27	2ABB,APB,BAA,BAP,BPA,PAA,PBP,PPP	9	58	58	57	71	61
28	AAB,ABB,APB,BAA,BBA,BPA,PAP,PBP,PPP	9	60	59	58	71	57
29	ABB,ABP,APB,BAA,BAP,BPA,PAA,PBB,PPP	9	55	55	55	66	68
30	AAB,4ABB,4BAA,BBA	10	100	100	100	94	20
31	2AAB,3ABB,3BAA,2BBA	10	100	99	99	100	43
32	AAA,2ABA,2ABB,2BAA,2BAB,BBB	10	80	66	66	66	61
33	ABP,2APB,BAP,2BPA,2PAB,2PBA	10	75	65	61	95	100 [®]
34	2ABB,2APB,2BAA,2BPA,2PPP	10	70	70	70	84	78
35	AAB,4ABB,4BAA,BBA	10	100	100	100	89	18
36	2AAB,3ABB,3BAA,2BBA	10	100	99	99	95	40
37	AAA,2ABA,2ABB,2BAA,2BAB,BBB	10	80	66	66	62	56



Table 4 (continued)

Serial no.	Design	n	NCM	TSM	TBM	SSM	SBM
38	ABP,2APB,BAP,2BPA,2PAB,2PBA	10	75	65	61	91	92
39	2ABB,2APB,2BAA,2BPA,2PPP	10	70	70	70	80	72
40	ABB,ABP,2APB,BAA,BAP,2BPA,PAB,PBA,PPP	11	80	76	75	97	92
41	ABP,3APB,2BAB,2BPA,PBA,2PPA	11	76	71	60	100*	86
42	ABA,3APB,BAB,BPA,2BPA,PAB,PBA,PPP	11	80	69	66	97	100 [@]
43	2AAB,ABA,3ABB,3BAA,BAB,2BBA	12	100	93	93	89	59
44	2AAB,4ABB,4BAA,2BBA	12	100	99	99	96	25
45	AAB,5ABB,5BAA,BBA	12	100	100	100	86	21
46	3AAB,3ABA,3BAB,3BBA	12	100	50	50	43	64
47	ABB,ABP,2APB,2BAA,BBA,BPA,PAB,PAP,PBP,PPP	12	69	67	66	78	63
48	2ABP,2APB,2BAP,2BPA,2PAB,2PBA	12	75	63	60	90	94
49	ABB,3APB,BAA,3BPA,2PAB,2PBA,PPP	13	79	76	75	100*	94
50	ABA,ABP,3APB,BAB,BAP,3BPA,PAB,PBA,PPP	13	79	67	64	95	100 [@]

Designs in bold denote new optimal and/or efficient ABCOD to class having n number of experimental units

*New optimal ABCOD under new defined model SSM

[@]New optimal ABCOD under SBM

$cod(ab)6\{APB, BPA, PAB, PBA\}$ has lesser variance of treatment contrast under SSM, than the two treatments $cod(ab)1\{AAB, ABB, BBA, BAA\}$. In the class of five experimental units $COD(2 + 1, 5, 3)$, the $cod(ab)11\{ABB, APB, BAA, BPA, PPP\}$ is more optimal than ABCOD of four experimental units, $cod(ab)10\{APB, BPA, PAB, PBA\}$, as well as, the two treatments $cod(ab)8\{AAB, ABB, BBA, BAA\}$ under SSM. Similarly, $cod(ab)19\{ABA, 2APB, BAB, 2BPA, PPP\}$, $cod(ab)41\{ABP, 3APB, 2BAB, 2BPA, PBA, 2PPA\}$ and $cod(ab)49\{ABB, 3APB, BAA, 3BPA, 2PAB, 2PBA, PPP\}$ is more optimal than the ABCOD having the same number of experimental units, as well as, the two treatments COD in even (preceding the odd) number of experimental units under SSM for the classes $COD(2 + 1, 7, 3)$, $COD(2 + 1, 11, 3)$ and $COD(2 + 1, 13, 3)$, respectively. However, the two treatments COD remains optimal in case of even number of experimental units except four. Each two treatments $cod(ab)22\{AAB, 3ABB, 3BAA, BBA\}$ and $cod(ab)31\{2AAB, 3ABB, 3BAA, 2BBA\}$ is more optimal than ABCOD under SSM respectively for the classes $COD(2 + 1, 8, 3)$ and $COD(2 + 1, 10, 3)$.

4.3 Optimal Cross-Over Designs Under SBM

Two treatments and one placebo designs have filled the gap of unavailability of optimal CODs under SBM for the cases of $n = 3, 9, 15$ and so on, as discussed in [5]. However, this does not include some cases as $n = 5, 7, 11, 13$. When these cases occur, statisticians generally exclude one experimental unit to use an optimal COD



in an even number of experimental units. Now there is no need to lose information, because ABCODs are available in given number of experimental units which are optimal under SBM. In the class $COD(2 + 1, 5, 3)$, $cod(ab)10\{APB, BPA, PAB, PBA\}$ is optimal under SBM. When the availability of experimental units is seven, $cod(ab)19\{ABA, 2APB, BAB, 2BPA, PPP\}$ is optimal and hence, useful under SBM. Similarly, in case of classes $COD(2 + 1, 11, 3)$ and $COD(2 + 1, 13, 3)$, respectively the $cod(ab)42\{ABA, 3APB, BAB, BPA, 2BPA, PAB, PBA, PPP\}$ and $cod(ab)50\{ABA, ABP, 3APB, BAB, BAP, 3BPA, PAB, PBA, PPP\}$ are optimal under SBM. In addition to the above cases, ABCODs are also more optimal than the two treatments CODs. For example, variance of treatment contrast for $cod(ab)4\{2ABA, 2BAB\}$ is 1.5, while that for $cod(ab)6\{APB, BPA, PAB, PBA\}$ is 0.6154, which resulted in gain of 59%. Hence, active balanced $cod(ab)6$ is optimal under SBM for the class $COD(2 + 1, 4, 3)$. Similarly, active balanced $cod(ab)24\{2APB, 2BPA, 2PAB, 2PBA\}$ is more optimal than the two treatments $cod(ab)21\{AAB, ABA, 2ABB, 2BAA, BAB, BBA\}$ and, $cod(ab)33\{ABP, 2APB, BAP, 2BPA, 2PAB, 2PBA\}$ is more optimal than the $cod(ab)32\{AAA, 2ABA, 2ABB, 2BAA, 2BAB, BBB\}$ for the classes $COD(2 + 1, 8, 3)$ and $COD(2 + 1, 10, 3)$, respectively. Further, $cod(ab)33$ is optimal under SBM than COD of [10] design (denoted as K), as well as [9] designs (denoted as $J1$ and $J2$) as shown in Table 5.

4.4 Efficient Cross-Over Designs Under NCM, TSM, TBM, SSM and SBM

From [2] and [5], it is clear that inclusion of placebo as an additional treatment not only improves the efficiency of active treatments comparison considerably, but also provides an additional benefit in the analysis. We evaluate optimal and/or efficient ABCODs in comparison to the two treatments CODs of [5], and the two treatments and one placebo CODs of [6]. For example, $cod(ab)6$ has the least variance for treatment contrast under SSM and SBM. This design is now optimal under both SSM and SBM; incidentally it is also efficient under the remaining three models. Hence, in the class $COD(2 + 1, 4, 3)$, now $cod(ab)6$ is more optimal and efficient than the cross-over design $\{2ABA, 2BAB\}$ recommended by FDA [4] for bioavailability/bioequivalence study, the cross-over design $\{ABA, ABB,$

Table 5 Efficiency of [10] and [9] cross-over design comparable to our cross-over design of Table 4 for class $COD(2 + 1, 10, 3)$

Serial no.	Design	n	NCM	TSM	TBM	SSM	SBM
cod(ab)30	AAB,4ABB,4BAA,BBA	10	100	100	100	94	20
cod(ab)31	2AAB,3ABB,3BAA,2BBA	10	100	99	99	100	43
cod(ab)32	AAA,2ABA,2ABB,2BAA,2BAB,BBB	10	80	66	66	66	61
cod(ab)33	ABP,2APB,BAP,2BPA,2PAB,2PBA	10	75	65	61	95	100
cod(ab)34	2ABB,2APB,2BAA,2BPA,2PPP	10	70	70	70	84	78
K	3ABB,3BAA,APP,PAA,BPP,PBB	10	70	70	70	42	35
J1	PAB,BAP,2PBA,3ABP,BPA,2BAB	10	80	49	46	72	75
J2	PAB,BAP,PBA,ABP,BAA,ABB,2ABA,2BAB	10	90	61	59	73	56

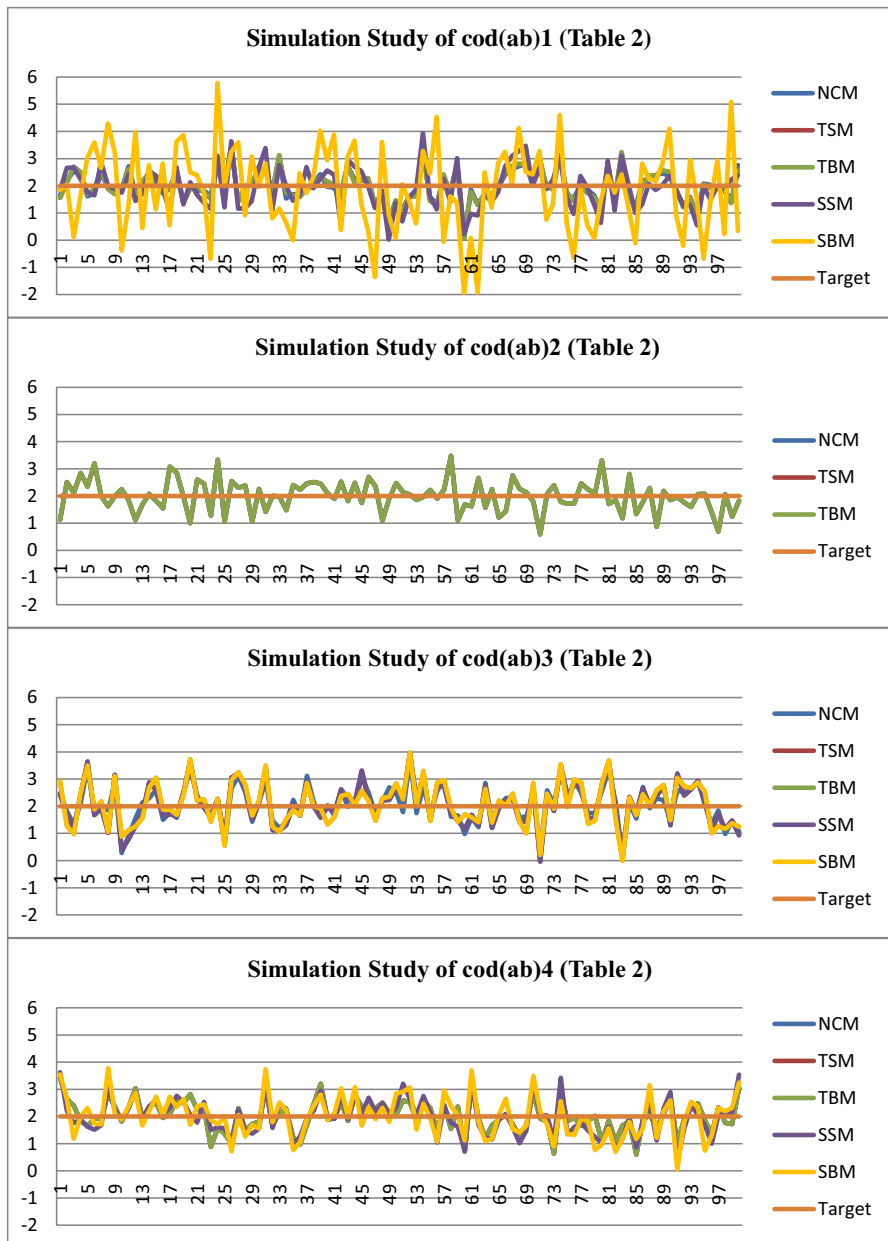
BAB, BAA} of [7], as well as the three experimental units $cod(ab)5\{APA, BAB, PBP\}$ of [6]. In the class $COD(2 + 1, 5, 3)$, two designs perform well, specifically speaking, when an experimenter originally was interested in the ensilability of SSM, then he should use $cod(ab)11\{ABB, APB, BAA, BPA, PPP\}$, because it is optimal under SSM and has an efficiency of more than 87% under other four models. Otherwise, it is better to use $cod(ab)10$, because it is optimal under SBM and efficient under the remaining models. In the class $COD(2 + 1, 7, 3)$, $cod(ab)18\{ABB, ABP, APB, BAA, BAP, BPA, PPP\}$ is more efficient than $cod(ab)19\{ABA, 2APB, BAB, 2BPA, PPP\}$, because this design has more than 80% efficiency in all five models, while the latter is optimal under SSM and SBM but has 83%, 70% and 68% efficiency under NCM, TSM and TBM, respectively. In the class $COD(2 + 1, 8, 3)$, $cod(ab)21$ is optimal under NCM and efficient under TSM, TBM and SSM but has poor efficiency of 56% under SBM, whereas active balanced $cod(ab)24\{2APB, 2BPA, 2PAB, 2PBA\}$ has an efficiency of more than 60% in all five models. In the class $COD(2 + 1, 10, 3)$, $cod(ab)33\{ABP, 2APB, BAP, 2BPA, 2PAB, 2PBA\}$ and $cod(ab)34\{2ABB, 2APB, 2BAA, 2BPA, 2PPP\}$ are efficient under all five models, with the former design being optimal under SBM and the latter being not optimal under any models, but has an efficiency of 70% and higher in all five models. Further, active balanced $cod(p)33$ is optimal under SBM and $cod(p)34$ is more efficient under all carry-over models than that of COD of [10] (denoted as K) and [9] (denoted as $J1$ and $J2$), as shown in Table 5. In class $COD(2 + 1, 11, 3)$, although a number of choices of designs are available, the three designs $cod(ab)40\{ABB, ABP, 2APB, BAA, BAP, 2BPA, PAB, PBA, PPP\}$, $cod(ab)41\{ABP, 3APB, 2BAB, 2BPA, PBA, 2PPA\}$ and $cod(ab)42\{ABA, 3APB, BAB, BPA, 2BPA, PAB, PBA, PPP\}$, give efficient estimations of treatment contrast under all five models. $cod(ab)42$ is optimal under SBM, $cod(ab)41$ is optimal under SSM and $cod(p)40$ has an efficiency of more than 74% in all five models. Similarly, in class $COD(2 + 1, 13, 3)$, two designs, $cod(ab)49\{ABB, 3APB, BAA, 3BPA, 2PAB, 2PBA, PPP\}$ and $cod(ab)50\{ABA, ABP, 3APB, BAB, BAP, 3BPA, PAB, PBA, PPP\}$ are efficient under all five models. However, $cod(ab)49$ is more efficient, because it is optimal under SSM with an efficiency of 75% and higher in the other four models, whereas $cod(ab)50$ is optimal under SBM with an efficiency of more than 63% in other models.

5 Conclusion

A new class of cross-over designs is introduced, called active balanced, which facilitate the experimenter to use cross-over designs even when the availability of the experimental units is a prime number. Through the 5M active balanced algorithm, the experimenter can generate an optimal active balanced cross-over design in three periods for any number of experimental units. It is advisable to use these designs instead of the balanced two treatments designs in two experimental situations: when the model under consideration is a self and mixed carry-over model and when the idea about nature of carry-over is vague.



Appendix



Flowchart to present how the algorithm works



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DEVELOPMENT OF BANKING SECTOR IN INDIA

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Abstract

From establishment of 1st bank i.e. Bank of Hindustan in 1770 to 2021 there is huge changes had been seen in the banking sector in India. In 1935 a central bank was established with name Reserve Bank of India. India's banking sector is sufficiently capitalised and well-regulated. The financial and economic conditions in the country are far superior to any other country in the world. The Indian banking system is well structured and divided into two parts namely banks and financial institutions. Very huge growth has been seen in banking deposits, credits, interest income, other income and banking assets in last 5 years from FY16 to FY22. Government Policies plays vital role in development of banking sector in India. Digitalization of banking transactions also increases through digital India. Different schemes like Pradhanmantri Jan Dhan Yojana, Atal Pension Yojana, Pradhan Mantri Suraksha Bima Yojana, Pradhan Mantri Jeevan Jyoti Bima Yojana, Capital Infusion scheme are well structured and very well famous among people of India. It gives boost up to banking sector in India.

Key words: RBI, banking deposits, banking credits, banking assets, Pradhanmantri Jan Dhan Yojana, Atal Pension Yojana, Pradhan Mantri Suraksha Bima Yojana

INTRODUCTION

Modern banking in India originated in the mid of 18th century. Among the first banks were the Bank of Hindustan, which was established in 1770 and liquidated in 1829–32; and the General Bank of India, established in 1786 but failed in 1791.¹

In India, the largest and the oldest bank which is still in existence is the State Bank of India (SBI). It originated and started working as the Bank of Calcutta in mid-June 1806. In 1809, it was renamed as the Bank of Bengal. This was one of the three banks founded by a presidency government; the other two were the Bank of Bombay in 1840 and the Bank of Madras in 1843. The three banks were merged in 1921 to form the Imperial Bank of India, which upon India's independence, became the State Bank of India in 1955. For many years, the presidency banks had acted as quasi-central banks, as did their successors, until the Reserve Bank of India² was established in 1935, under the Reserve Bank of India Act, 1934.

As per the Reserve Bank of India (RBI), India's banking sector is sufficiently capitalised and well-regulated. The financial and economic conditions in the country are far superior to any other country in the world. Credit, market and liquidity risk studies suggest that Indian banks are generally resilient and have withstood the global downturn well.

Indian banking industry has recently witnessed the roll out of innovative banking models like payments and small finance banks. RBI's new measures may go a long way in helping the restructuring of the domestic banking industry.

The digital payments system in India has evolved the most among 25 countries with India's Immediate Payment Service (IMPS) being the only system at level five in the Faster Payments Innovation Index (FPII).*

* according to an FIS report, Micro finances Institution Network

THE STRUCTURE OF INDIAN BANKING SECTOR

The Indian banking system is well structured under the Reserve Bank of India. It is mainly divided in two parts i.e. Banks and Financial Institutions. Banks are sub-divided into two parts i.e. Scheduled Commercial Banks and Cooperative Credit Institutions while Financial Institutions are sub-divided into three parts i.e. All India Financial Institutions, State level Institutions and other Institutions.

Classification of Banks

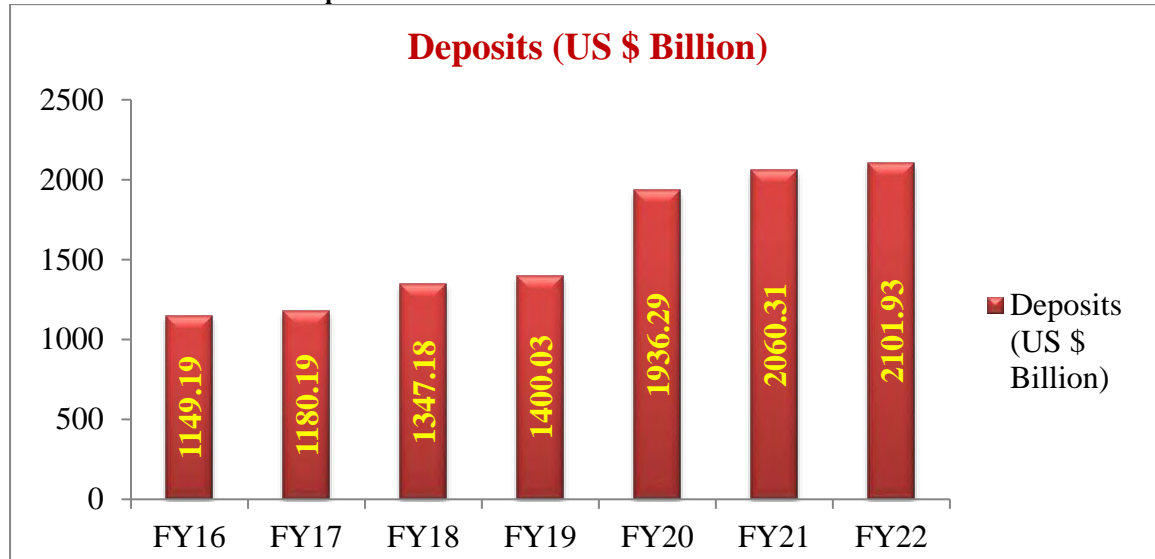
Bank	No. of Banks
Public Sector Banks	12
Private Sector Banks	22
Foreign Banks	46
Regional Rural Banks	56
Urban Cooperative Banks	1485
Rural Cooperative Banks	96000

The Indian banking system consists of 12 public sector banks, 22 private sector banks, 46 foreign banks, 56 regional rural banks, 1485 urban cooperative banks and 96,000 rural cooperative banks in addition to cooperative credit institutions.

DEVELOPMENT OF INDIAN BANKING SECTOR

In India, there is a huge development has been seen in bank deposits, bank credits, interest income and other income as well as in banking assets in last decade.

A. Growth in Bank Deposits:



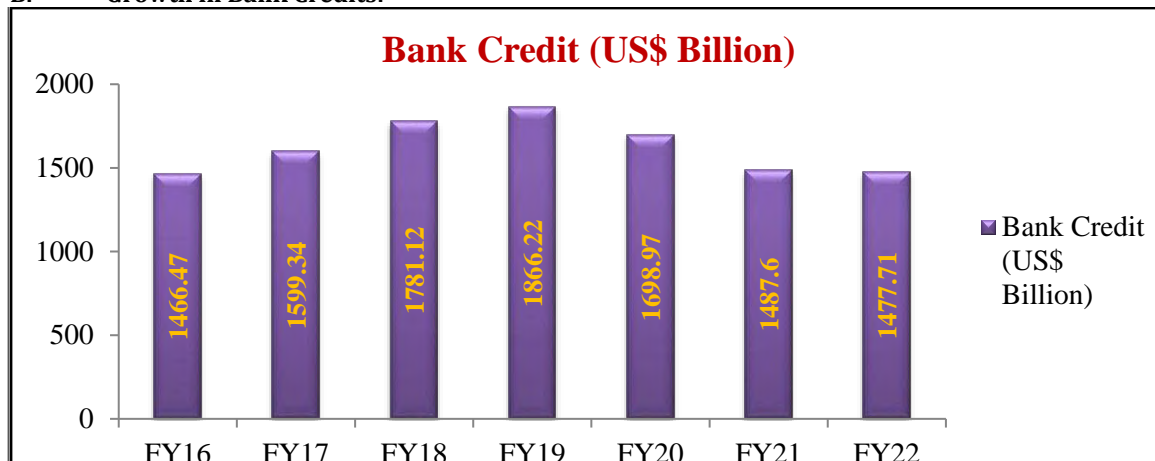
Source: Reserve Bank of India (RBI)

From the above graphical presentation we can sort out the following important points.

- Strong growth in savings amid rising disposable income levels are the major factors influencing deposit growth.
- Access to banking system has also improved over the years due to persistent effort from Government to promote banking technology and promote expansion in unbanked and non-metropolitan regions.
- At the same time, India's banking sector has remained stable despite global upheavals, thereby retaining public confidence over the years.
- According to RBI, the performance of Indian banking sector improved in FY20, as lenders reported a profit on an aggregate basis after two years of losses.
- According to the RBI, bank deposits stood at Rs. 157.12 trillion (US\$ 2.10 trillion) as of October 22, 2021.
- CAGR until October 22, 2021 is 12.38%.
- Opportunity:

Significant growth possible in private sector lending as credit disbursement by private sector banks is expected to increase.

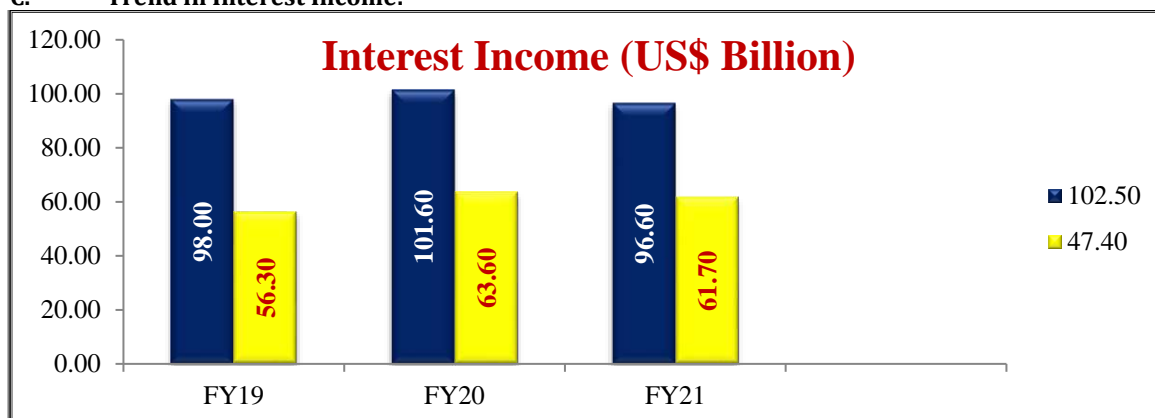
B. Growth in Bank Credits:



Source: Reserve Bank of India (RBI)

- Credit off-take has been surging ahead over the past decade, aided by strong economic growth, rising disposable incomes, increasing consumerism and easier access to credit.
- During FY16-FY21, bank credit increased at a CAGR of 0.29%. As of FY21, total credit extended surged to US\$ 1,487.60 billion.
- Demand has grown for both corporate and retail loans. Services, real estate, consumer durables and agriculture allied sectors have led the growth in credit.
- In August 2021, Barclays announced investment of Rs. 30 billion (US\$ 403.99 million) in India to expand its operations.
- In August 2021, RBI developed Financial Inclusion Index (FI-Index) to measure the level of financial inclusion across the country. The FI-Index increased from 43.4 in FY17 to 53.9 in FY21.
- In FY21, bank credit grew 5.56% and deposits by 11.4%.
- According to the RBI, bank credit stood at Rs. 110.46 trillion (US\$ 1.47 trillion) as of October 22, 2021.
- As of October 22, 2021, credit to non-food industries stood at Rs. 109.82 trillion (US\$ 1.46 trillion).
- CAGR until October 22, 2021 is 0.29%.

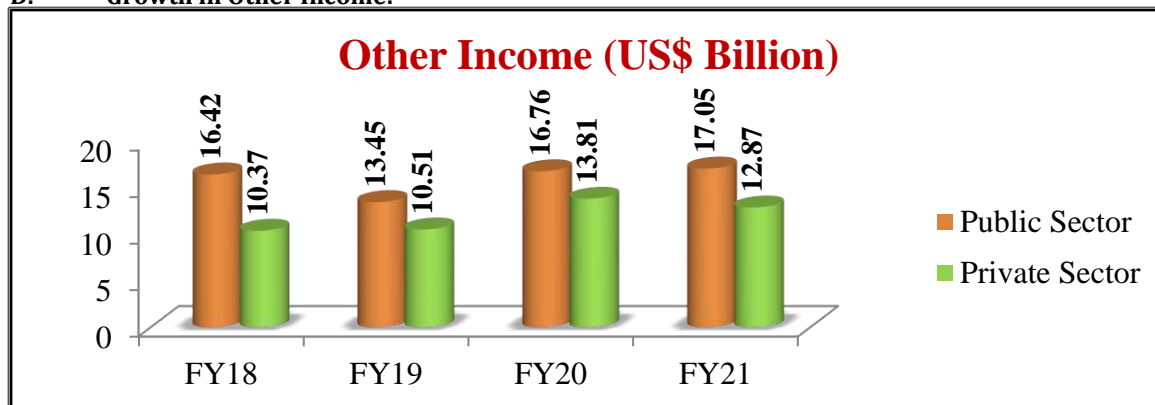
C. Trend in Interest Income:



Source: Indian Bank's Association

- Interest Income of Public Sector banks reached US\$ 96.60 billion in FY21 which shows decrease in interest income in comparison of FY18, FY19 and FY20 which is 102.50, 98.00 and 101.60 US\$ billion respectively.
- Interest Income of Private Sector banks reached 61.70 US\$ billion in FY21 which is decrease in comparison of 63.60 US\$ billion in FY20 while increase in comparison of FY18 and FY19 47.40 and 56.30 US\$ billion respectively.

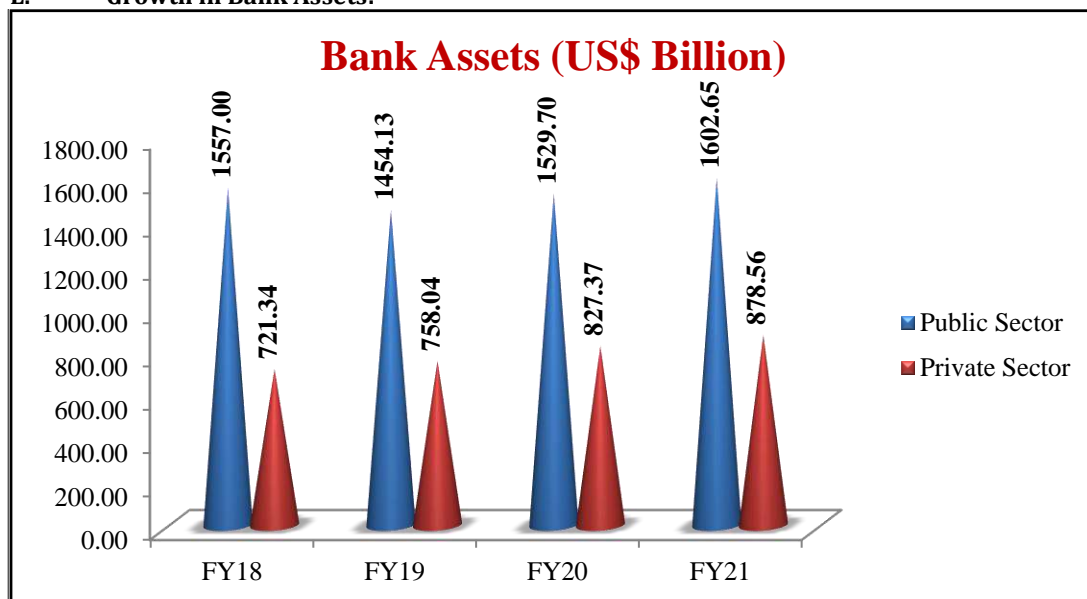
D. Growth in Other Income:



Source: Indian Bank's Association

- Other Income of Public Sector banks stood at US\$ 17.05 billion in FY21 which shows increase in other income in comparison of FY18, FY19 and FY20 which is 16.42, 13.45 and 16.76 US\$ billion respectively.
- Other Income of Private Sector banks reached 12.87 US\$ billion in FY21 which is decrease in comparison of 13.81 US\$ billion in FY20 while increase in comparison of FY18 and FY19 10.37 and 10.51 US\$ billion respectively.

E. Growth in Bank Assets:



Source: Indian Bank's Association

- In FY18-FY21, bank assets across sectors increase. Total assets across the banking sector increased to US\$ 2.48 trillion in FY21.
- In FY21, total assets in the public and private banking sectors were US\$ 1602.65 billion and US\$ 878.56 billion respectively which is increase in comparison to FY18 it was US\$ 1557.00 billion and US\$ 721.34 billion respectively.
- In FY21, assets of public sector banks accounted for 64.59% of the total banking assets.

• **Growth Drivers of Indian Banking Sector:**

1. Economic and Demographic drivers:

- It is favourable demographics and rising Income levels.
- India ranks among top 7 economies with a GDP of US\$ 2.73 trillion in 2018.
- The sector will benefit from structural economic stability and continued credibility of Monetary Policy.

2. Policy Support:

- The Government of India passed the Banking Regulation (Amendment) Bill 2017 to empower RBI to deal with NPAs in the banking sector.
- The Insolvency and Bankruptcy Code (Amendment) Ordinance, 2017 Bill was passed by the Rajya Sabha to give strength to the banking sector (as of Jan 2018).

3. Infrastructure Financing:

- India currently spends 6% of GDP on infrastructure. NITI Aayog expects this percentage to grow going ahead.
- As per the Union Budget 2019-20, Investment-driven growth requires access to low-cost capital, which requires an investment of Rs. 20 lakh crores (US\$ 300 billion) every year.

4. Open banking Eco-system:

- The open banking eco-system in India has now grown to include Non-Banking Financial Company (NBFC) and other fintech players that have created partnerships within the banking system.
- In 2003 Kotak Mahindra Finance Ltd. received a banking license from RBI and became the first NBFC to be converted into a bank.

5. Cross-border Payments:

- Visa Inc. has sought RBI's permission to offer a new cross-border payments system to process trade flows to and from India. It will be offering a potentially cheaper, quicker and block chain based solution now on trial.

6. Government Initiatives:

- The Government has smoothly carried out consolidation, reducing the number of public sector banks by eight.
- The Government of India will invest Rs. 48,239 crore (US\$ 6.78 billion) in 12 public sector banks in FY20 to help maintain regulatory capital requirements and financial growth in India.
- The Government of India will invest Rs.5,042 crore (US\$ 0.731 billion) in Bank of Baroda post its merger with two other public sector lenders, Dena Bank and Vijaya Bank.

- In November 2021, RBI launched the 'RBI Retail Direct Scheme' for retail investors to increase retail participation in government securities.
- The RBI introduced new auto debit rules with a mandatory additional factor of authentication (AFA), effective from October 01, 2021, to improve the safety and security of card transactions, as part of its risk mitigation measures.
- In September 2021, Central Banks of India and Singapore announced to link their digital payment systems by July 2022 to initiate instant and low-cost fund transfers.
- In August 2021, Prime Minister Mr. Narendra Modi launched e-RUPI, a person and purpose-specific digital payment solution. e-RUPI is a QR code or SMS string-based e-voucher that is sent to the beneficiary's cell phone. Users of this one-time payment mechanism will be able to redeem the voucher at the service provider without the usage of a card, digital payments app, or internet banking access.
- As per Union Budget 2021-22, the government will disinvest IDBI Bank and privatise two public sector banks.
- The following schemes are implemented by Government:
 - A. Pradhan Mantri Suraksha Bima Yojana:**
 - ❖ This scheme is mainly for accidental death Insurance cover for up to Rs. 2 lakh. (US\$ 2,983.29)
 - ❖ The premium amount is only Rs.12 (US\$ 0.18) per annum.
 - ❖ Risk coverage for accidental death and full disability is Rs. 2 lakh and for partial disability is Rs. 1 lakh.
 - ❖ Gross enrolment under the scheme reached 154 million in FY19.
 - B. Pradhan Mantri Jeevan Jyoti Bima Yojana:**
 - ❖ This scheme aims to provide life insurance cover.
 - ❖ The premium amount is only Rs. 330 (US\$ 4.92) per annum. It will be auto debited in one installment.
 - ❖ Risk coverage is Rs. 2 lakh (US\$ 2,983.29) in case of death for any reason.
 - ❖ Gross enrolment under the scheme reached 59 million in FY19.
 - C. Atal Pension Yojana:**
 - ❖ Under the scheme, subscriber would receive fixed pension up to Rs. 5,000 (US\$ 74.58) at the age of 60 years (depending on their contribution)
 - ❖ During FY21 more than 79 lakh new subscribers joined the Atal Pension Yojana.
 - ❖ Totalling more than 3.02 crore enrolments as of March 31, 2021.
 - D. Pradhan Mantri Jan Dhan Yojana:**
 - ❖ AS of November 03, 2021 the number of bank accounts opened under the government's flagship financial inclusion drive 'Pradhan Mantri Jan Dhan Yojana (PMJDY)' reached 43.81 crores.
 - ❖ Total deposits reached to more than Rs. 1.48 trillion (US\$ 19.89 billion) in Jan Dhan accounts.
 - ❖ Under the scheme, each & every citizen will be enrolled in a bank for opening a Zero balance account.
 - ❖ Each person getting into this scheme will get Rs. 30,000 (US\$ 447.49) life cover while opening the account.
 - ❖ Overdraft limit under such account is Rs. 5,000 (US\$ 74.58).
 - E. Capital Infusion Scheme:**
 - ❖ The Finance Ministry announced its plan to infuse Rs. 14,500 crore (US\$) as capital infusion in public sector banks in the fourth quarter of FY21.

ROAD AHEAD

Enhanced spending on infrastructure, speedy implementation of projects and continuation of reforms are expected to provide further impetus to growth in the banking sector. All these factors suggest that India's banking sector is poised for a robust growth as rapidly growing businesses will turn to banks for their credit needs.

Also, the advancement in technology has brought mobile and internet banking services to the fore. The banking sector is laying greater emphasis on providing improved services to their clients and upgrading their technology infrastructure to enhance customer's overall experience as well as give banks a competitive edge. India's digital lending stood at US\$ 75 billion in FY18 and is estimated to reach US\$ 1 trillion by FY23 driven by the five-fold increase in the digital disbursements. By 2025, India's fintech market is expected to reach Rs. 6.2 trillion (US\$ 83.48 billion).

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[7] Other references - Media Reports, Press releases, Reserve Bank of India, Press Information Bureau.
[8] Note: Conversion rate used in November 2021, Rs. 1 = US\$ 0.01336



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Digital Preservation of Library Resources: Strategic planning a Management perspective

Digital Preservation of Library Resources: Strategic planning A Management perspective

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Abstract

Our cultural heritage has been presented on many different materials, including stone, vellum, bamboo, silk, paper and etc. these all materials for information storage had been found in physical medias. That time the attention had been focused only on preserving physical media. Now a day a variety of information exists in digital forms, including emails, blogs, social networking websites, national elections websites, web photo albums, etc. US Library of Congress, had reported(1998) that 44% of the sites available on the internet. It means technology help us to access the cultural heritage from storage of digital memory. However technology creates some opportunity as well as raise challenges also. Libraries and information professionals are now being challenged by new technology; Like multimedia, internet, www, and other virtual computer technology. The environmental, legal, ethical and technological challenges create some major issues to retrieve and preserve the digital information. So the responsibility of librarian and information technology professionals has been wider. The paramount need is to create a well-organized digital preservation strategy for modern library. The researchers have tried to define digital preservation of library resources. The present paper flew the light on the challenges of digital preservation and recommends the suitable strategy implement for digital preservation. They also focus on proposed model for strategic planning for digital preservation.

Keywords:

Preservation, Digital Preservation, Challenges- Ethical, Political, Economical, Technical and Legal, Strategy for digital preservation , Proposed Model for Strategic Planning for Digital Preservation

Introduction:

The rapid growing technology has paved a revolutionary change in Library & information technology. Day by day information has taken place from physical media to digitized form. So, it is essential to know how to prevent it. Information created, stored and access digitally is at risk for loss in two important ways; obsolescence and physical damage. Obsolescence can affect hardware, software and even the arrangement of the data in a stored file. Physical damage can occur to multiple components required to access digital



information, namely hardware and media. Digital preservation seeks to achieve longevity of the digital object with all its original properties intact. The issue of long term preservation of digital data has become a critical issue with many diverse groups and organisations recognizing the need to preserve digital documents before they fall victim to digital obsolescence.

Scope of the paper

This paper seeks to address what is digital preservation. It focuses issues related to digital preservation like; environmental, ethical and legal. The issues covered in three steps. The first step is an overview of the background to preserving digital resources that has developed in response to the concerns of digital and research libraries. The second step will assess the challenges and the third will consider recommended mechanisms for libraries to develop strategies that support the long term retention of digitised data. The researchers have discussed on proposed model for strategic planning for digital preservation. The paper also highlights some policy matters on digital preservation. Researchers also tried to provide some historical background on digital preservation.

LITERATURE REVIEW

Digital preservation means, “the process of maintaining in a condition suitable for use, materials produced in digital format.(veer, 2009).

Digital preservation aims at taking steps to ensure the longevity of electronic documents. It applies to document that are either born digital and stored in online platform or CD/DVDs . it means digital preservation needs high range of strategic planning. There has been concern about preservation of primary research data and records in digital formats in the library community internationally as early as in the 1990s. In 1996 the Commission of Preservation and Access (CPA) and the Research Libraries Group (RLG) in the USA



published a joint report on *Preserving digital information* which identified problems, made recommendations and suggested areas for further research (Garrett et.al, 1996). In the UK, in November 1995, the Joint Information System Committee (JISC) of the Higher Education Funding Councils and the British Library addressed the question of the preservation of digital media by holding a national conference in Warwick, where a number of action points were identified (Fresco, 1996).

Since then extensive studies and collaborative efforts on preservation of digital data and records were undertaken by the library, archival and publishing communities in the UK. The first study (Bennett, 1997) developed a framework of data types and formats, in order to indicate the likely problems, requirements and responsibilities appropriate to each category, and to identify the most appropriate method of preservation.

The literature suggests that, within the Asia and Southeast Asian region, centralized data archives are yet to be established.

CASE STUDIES HAVE BEEN CARRIED OUT ON DIGITAL PRESERVATION IN VARIOUS PALCES OF UNITED KINGDOM:

DORSET HISTORY CENTRE

This case study discuss A local governments archive service, and its use of Preservica Cloud Edition - a cloud-based digital preservation service. It explains the organisational context of the archive, the nature of its digital preservation requirements and approaches, its one year pilot project using Preservica Cloud Edition, the archive's technical infrastructure, and the business case and funding for the pilot. It concludes with the key lessons they have learnt and future plans.



TATE GALLERY

This case study discusses the experience of developing a shared digital archive for the Tate's four physical locations (Liverpool, St. Ives, and two in London), powered by a commercial storage system from Arkivum. It explains the organisational context of the Gallery, the nature of their digital preservation requirements and approaches, and their rationale for selecting Arkivum's on-premise solution, OSCAR (On-Site Cloud ARchive) in preference to cloud-based offerings from Arkivum and others. It concludes with the key lessons learned, and discusses plans for future development.

BODLEIAN LIBRARY, UNIVERSITY OF OXFORD

This case study covers the Bodleian Library and the University of Oxford, and their provision of a "private cloud" local infrastructure for its digital collections including digitised books, images and multimedia, research data, and catalogues. It explains the organisational context, the nature of its digital preservation requirements and approaches, its storage services for research data, the technical infrastructure, and the business case and funding. It concludes with the key lessons they have learnt and future plans.

THE PARLIAMENTARY ARCHIVES

This case study covers the Parliamentary Archives and their experience of procuring via the G-Cloud framework and running public cloud storage as part of their digital preservation infrastructure. For extra resilience/an exit strategy they have selected two cloud service providers with different underlying storage infrastructures. The archive is not storing sensitive material in the cloud and is using local storage systems for that material. It has a locally installed preservation system (Preservica Enterprise Edition) which is integrated with cloud and local storage. As such it is an example of an archive using a hybrid set of storage



solutions part-public cloud and part-locally installed for digital preservation.

ARCHIVES & RECORDS COUNCIL WALES DIGITAL PRESERVATION CONSORTIUM

This case study discusses the experience of a cross-sectoral consortium of Welsh archives as they cooperated to pilot deployment of the open source Archivematica software with Microsoft's Windows Azure public cloud service. It explains the organisational context of the consortium, the varied nature of their digital preservation requirements and approaches, and their experience with selecting, deploying and testing Archivematica in the cloud. It concludes with the key lessons they learned, and discusses current proposals to secure grant funding in order to move this pilot into operation.

RESEARCH PROJECTS ON DIGITAL PRESERVATION

Voutssas (2012) argued that initially digital preservation projects in the past tended to focus on the endurance of CD's and DVD's, tapes and other storage devices, and its artificial aging and how to keep them safely. However in the later part of the 20th century, the literature suggested that large amount of writings were focusing on the issues of philosophical underpinnings and technical aspects of digital preservation.

Here researchers, have try to provide some past and present international projects list which was initiated in earlier on digital preservation, so the next generation would be benefited to be familiar with how the development has been made for digital preservation around the world. As mention below

Table 1. Past and Present International Projects on Digital Preservation

Research Projects	Year of Commencement
Victorian E-Records Strategy (VERS)	1990s



Exemplars in Digital Archives (CEDARS)	1990s
Creative Archiving at Michigan and Leeds: emulating the old on the new (CAMiLEON)	1990s
University of Pittsburg project	1990s
University of Indiana project	1990s
University of Yale project	1990s
Preserving access to digital information (PADI)	1998
The Dutch Digitale Bewaring (Digital Preservation testbed) project	2002
Network Excellence on Digital Libraries (DELOS)	2004-2007
The Long-Term Preservation Metadata for E- Records (LMER)	2005
Minnesota Historical Society	2005 - 2007
Effective Strategic Model for the Preservation and Disposal of Institutional Digital Assets (ESPIDA)	2005 - 2007
Clever Recordkeeping Metadata Project (CRKM)	2007
Life-Cycle Information for E-Literature (LIFE)	2007
Investigating Significant Properties of Electronic Content (InSPECT) Project	2007 - 2008
Digital Archiving in Flemish Institutions and	2007/2008



Administrations (DAVID)	
Managing the Digital University Desktop (MDUD)	2007/2008
Co-operative Development of a Long-term Digital Information Archives (KOPAL)	2007/2008
Cultural, Artistic and Scientific Knowledge for Preservation, Access and Retrieval (CASPAR)	2007/2008
Securing a Hybrid Environment for Research Preservation and Access Development Partner (SHERPA DP2)	2007/2008
Repository for Preservation of Authentic Digital Records (RODA)	2007/2008
Service-Oriented Architecture for Preservation and Ingest of Digital objects (SOAPI)	2007–2008
Digital Repository Infrastructure Vision for European Research (DRIVER)	2009
Preservation E-print Services (PRESERV)	2009
Exploring Collaborations to Harness Objects in a Digital Environment for Preservation (ECHO Depository)	2009
Data Preservation Alliance for the Social Science (Data-PASS)	2009
Preservation and Long-term Access through Networked Services (PLANETS)	2009
Metadata Encoding and Transmission	2009



Standard (METS)	
Image Spatial Data Analysis Group (ISDA/Ip2Learn)	2009
Digital Preservation Europe (DPE)	2009
International Research Project on Permanent Authentic Records in Electronic Systems (InterPARES 1, 2 & 3)	1996 - 2012
InterPARES 4- Trust and Digital Records in an Increasingly Networked Society	2013

Source : Irwan Kamaruddin (2014)

Definition of the terms:

Digital preservation

Digital preservation is the active safekeeping of digitally stored information. As a part of the formalized efforts of library and archival sciences, digital preservation includes the practices required to ensure that information is safe from medium failures as well as software and hardware obsolescence.

Preservation

Preservation includes all the managerial and financial considerations including storage and accommodation provisions, staffing levels, policies, techniques and methods involved in preserving library and archive materials and information contained in them.

Challenges

A challenge is something new and difficult which requires great effort and determination.



Strategies

Strategic means relating to the most important, general aspects of something such as a military operation or political policy, especially when these are decided in advance.

Why Worry About Digital Preservation?

Society's heritage has been presented on many different materials, including stone, vellum, bamboo, silk, paper and etc. Now a large quantity of information exists in digital forms, including emails, blogs, social networking websites, national elections websites, web photo albums, and sites which change their content over time. However, technologies create some opportunity as well as raise some challenges also. Therefore the responsibility of librarian and information professional has become wider in terms of techno savvy person. The paramount need is to create a well-organized digital preservation strategy for modern library.

What Is Digital Preservation?

Morrow defined preservation as “The action taken to prevent, stop or retard deterioration” it means Digital preservation...refers to all of the actions required to maintain access to digital materials beyond the limits of media failure or technological change. In other words Digital preservation refers to the series of managed activities necessary to ensure continued access to digital materials for as long as necessary.

What Digital PRESERVATION IS Not occur

- Reformatting from print to digital for access surrogates or product line expansion
- Back-up or byte storage on various media
- Mirror sites or networks designed for reliable delivery
- Carried out within delivery systems
- Active content management designed to ensure enduring usability, authenticity and accessibility over the very long-term



Core Requirements for Digital Preservation

Preservation of digital source is as important as collection development. So some key requirement needed for it. Following are the core requirement.

- Third-party with an organizational mission to carry out preservation
- A sustainable economic model able to support preservation activities over the targeted timeframe
- Technological infrastructure able to support selected preservation strategy and best practices
- Clear legal rights and relationships with content providers and (eventual) users
- Compliance with digital preservation standards and best practices
- OAIS: Open Archives Information Systems
- TRAC: Trustworthy Repositories Audit and Certification
- DRAMBORA: Digital Repository Audit Method Based on Risk Assessment

Aspects of Digital Preservation

According to Graham (1997), digital preservation problems are associated with three distinct aspects which are mention below.

- Medium preservation – the preservation of the physical media on which the bits and bytes of electronic information reside.
- Technology preservation – refreshing of technologies from old to new as they become available.
- Intellectual preservation – addressing the integrity and authenticity of the information as originally recorded.



Challenges of Digital Preservation

“The root of the digital preservation problem is technological, but any proposed solution also needs to take an account of organizational and economic issues. Almost all kinds of digital information need to be interpreted by machines before they can become intelligible to humans.”

Legal & Ethical Challenges

- (1) Digital preservation often occurs while materials are still under copyright – can we reproduce, reformat, or migrate these materials?
- (2) Many digital materials are obtained through license or subscription. These materials are outside custody of institutions with mandate to preserve – how can one preserve something that he/she doesn't really own?
- (3) Can we preserve Web sites hosted by others?

Economic challenges

- (1) Large sums of money are invested in digitizing materials, and these digital assets need to be managed and preserved.
- (2) Digital preservation is costly.
- (3) Economic sustainability – Digital preservation is not an one-off, short-term operation. It's a long-term obligation and continuous effort.

Organizational Challenges

Most of the challenges associated with digital preservation are organization – not technical, e.g.

- (1) Creators of digital information ≠ Owners of server space
- (2) Supporting infrastructure



- (3) Trusted and empowered organizations or repositories Certification process

Technical Challenges

- (1) Improve cost efficiency and affordability
- (2) Under standing how to préserve High-volume rapidly changing content
- (3) Anticipation of future contextes of use
- (4) Standards – and support for inter operability

Strategic planning

“Strategic planning is a management activity often used by businesses to better focus their energy, establish priorities, and strengthen operations to achieve targeted goals.”

Library have variety of resources which may needs to preserve or stored in digital format , so future generation can be utilize without any difficulty. As we know strategic planning is not a simple process. It is purely managerial activities. Here, researchers have tried to focus what strategies should be applied before and after digital preservation of library resources.

Table : 1 Proposed Model for Strategic Planning for Digital Preservation

Sr. No	Input of thoughts	Framing Activities	Out put
A	Top management Librarian and Authority	Technical structure	Final digitized product
B	Decision making on Tools to be used Financial assistance Technological	Build repo with humans and technology	Bibliographic data set
C	Allocation of resources Human Technology	Test trial version	Institutional repository



	Co-ordination Evaluation		
D	Develop alternate solution	Team work	High Satisfaction

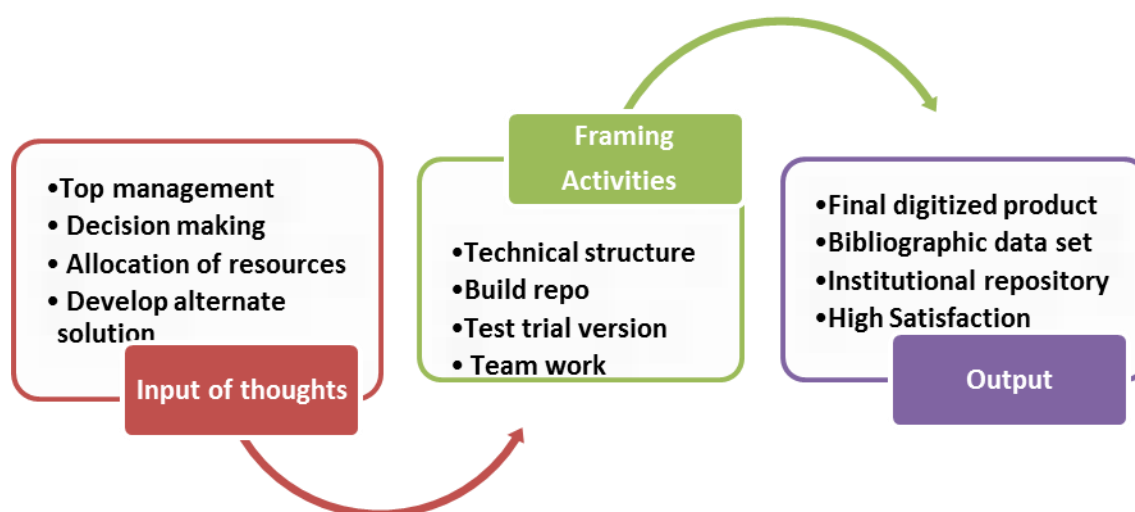


Figure 1. Proposed Model for Strategic Planning for Digital Preservation

Dr. S.R. Ranganathan's philosophy for classification works on three basic principles. The Idea Level, The verbal level and the Notational level. According to Dr. Ranganathan's philosophy human mind is the place of origin of ideas. The creators of ideas need self – communication within the mind in order to create more ideas. Language is the medium for communication of ideas. Written language made communication even more widespread than spoken language. This philosophy is rich in its content and leads towards more practical solution in today's era in a scientific way. As a professional when we frame the work situations according to these principle its look like



Idea plane



Verbal plane



Notational plane



Input of thoughts → Framing Activities → Output of product

Idea level planning: Input of thoughts

Let's discuss all in brief

Top Management (Librarian and Authority)

The vision, mission and goals of every institute or library have its own. The main function of library is to serve society information timely and take possible steps to conserve resources for future references. Here librarian's moral duty is to assure guarantee for preservation of documentary and non-documentary sources to easy access of future generation. As we know, Library is a social institution and dedicated to knowledge dissemination for providing better human civilization to society. Here, one question arise that, who is responsible for preservation of library resources? The answer is everybody is responsible for conserving and preserving the library resources who are directly or indirectly users of library resources or an employee of library or institutions. As an authority of the institution or library the director, HR person and an employees of this institution the all are responsible for enhancing library services. They should take responsibility and make possible arrangement for necessary equipment for library personal and person who are engaged with digital preservation work.

Decision Making:

Digital preservation involves series of activities and an organizational structure in all its dimensions. Librarian and authorities of institution should concentrate on decision making like.

- Tools to be used- for digital preservation which tools be useful should be categorised and arrange according to requirements.



- Financial assistance- assures and fixes the party or person who will be responsible for all the financial assistance whenever needed for the project. It is advisable to get advance payment at time of project approval.
- Technology –refers to which type of techniques, tools and software should be applied for digital preservation is considered must. When the project taken for digital preservation for “paper to digital” or “born digital” needs lots of efforts, tools techniques, equipment and hardware, software tools. It assumed that an employee’s having basic computer knowledge may be considered.

Allocation of resources

It is important to have clear ideas of digital preservation project among the staffs. Before starting any procedures the Authorized person should study the details information regarding the policies, operations in written documents. How they may be utilized to fulfill institutional goals and objectives. Let’s discuss

Human

The most preferable resources are humans; which will be utilized for preservation and digitalization of library resources. Selection of the person related to digitization work made by interview and observation. It is necessary to identify qualify and devoted person for this noble work. This activity creates awareness among the staff and made concentration on shared responsibilities of what to preserve and what extent the library will acquire and retain material would be digitization.



Technology

There is no definable strategy to used technology for digital preservation. It is defers

according to size of institutes , size of holding resources in library , the potential users and the amount of budget spent on the project on digital preservation. It's depending on logical decision taken by authorised person. The most convenient and preferable technological tools are describe as follows

Wide format scanner (8.5” * 14 or 8.5” *11.5)

Book scanner with V shaped cradle

Dark rooms with lighting

Servers with high storage capacity

Backup equipment's like; Tap Drives, hard drivers, DVD writers, Cloud and Virtual space

Computers, Hard ware and Software

Standards for Architecture: ISO/DIS 15489, AS 4390, DOD 5015.2 STD, OAIS

Standards for digital Content: PDF, XML, Dublin core, MARC, Z39.50

Standards for interoperability: ODMA, DMA,

Co-ordination

According to Merriam Webster “Co-ordination is the process of organizing people or groups so that they work together properly and well”

For library professionals and IT professional digital preservation is a big challenge to tackle with information technology and connect an employee as a human. Means proper co-ordination and command needs in written documents than they work smoothly. Here, library professionals and IT professionals experience as well as knowledge towards digital



preservation helps them to run the project step by step as smoothly.

Evaluation

As we discussed library is a mirror of knowledge society and serves for society. It is assumed that a small mistake can lead to wrong interpretation of documents or presentation which is digitized. Before completing whole library materials to be digitized, an evaluation process has been carried out after some content were digitized or born to digital. So the errors or small mistakes can be removed at the trial stage.

Develop alternate solution

When library or institute get approval for digitization of library holdings, it is necessary to work out future obstacles' also. Because

- When you are pioneering some activities it is going to be most costly, might be this cost effect the whole budget.
- Technology change is so rapid, might be outdated soon. Cost spent on technology may be worthless.
- Getting skilled employees for smooth running project for long term without any disturbance is a question mark for project directors.
- So, it is important ingredient for deciding how to develop alternate solutions. All these situations need an excellent project director to have expertise to handle critical situation.



Verbal level Planning: Framing Activities

Technical structure

The digitization project is run by the director who is in-charge of all operation related to digital preservation carried out by library or an institute. He/ she are the authority of co-ordinating, directing and guiding to employees. The project director reports to librarian, librarian reports to institutes head. As a project director he/ she have to fix vision, mission and fix the goals. According to this, project director have to plan and execute technical structure and co-ordinate their employees with their assign work. A working blue print has to prepared and gave demonstration in meetings also. This will creates awareness among the employee, colleague, librarian and the head of the institution. The main area of discussion considered follow items or content.

Find out sources to be digitized

Digital preservation concerns two types of documents namely “born digital documents” and “digital created documents”. As library have variety of collection in terms of printed and non-printed items like books, journals, newspaper, manuscript, documents and other grey literature. So, the pre-requisite is to identify the source (in terms of documents) which would go to be digitized. These activities ensure that the preserved digital materials are authentic and valuable. So, it is important to identify most preferable and valuable sources to be digitized. Like

- Costly books, most utilised books and articles
- Rare books which were going to out of print
- Most preferable items which were suggested by users, publishers, experts etc.



Observation and notified items

Digital preservation also concerns with preserving damaged and deteriorate items. So preservation of damaged and deteriorate physical media in to digital media, needs the basic requirements must have to checkout

- The condition of resources in terms of overall condition of require items
- Identified items which are especially poor in terms of (Torn items, rare items, stop publication)
- Identified the most risky and old collections
- What is the alternate and possible direction for preservation of materials?
- Duplication of items should be avoided

Combination of sources

Selection for digital preservation of items is multi-stage and contents range of activities. Every step needs different methods to proceed. It is necessary to select proper items which have longevity in terms of usage and storage. After selecting proper physical media or documents it is necessary to give identification to sources like

- Collection should be notifying with some identical codes or numbering patterns
- Make list accordingly
- Stored in different space or reserve separate cupboard for easily identify and labelled them
- Stop for transaction for this separate collection

Fix the source which would be adopt

Organizational structure is also important factor for acquiring funds or financial assistance.



Majority of libraries or institutions have its own powerful link with state government and national level bodies. As we know library is growing organism and not for profit making service factor. It is totally depends on government and public funds. Some autonomous institute have their own financial funding agencies. As related to preservation of library collection needs excessive library funds. Here the authority and project director plays vital role in creating most preferable source for financial assistance. Final decision depends on authority how they fix the sources without any interruption for financial needs.

Time management

“Time management” refers to the way that you organize and plan how long you spend on specific activities.”

How much time needs to digital preservation activities should be calculate for every stage and gave algorithm to staff for wok accordingly and make assure to follow the rules strictly. This will help out to get benefit in cost effective ways.

SWOT analysis

“SWOT (strengths, weaknesses, opportunities, and threats) analysis is a framework used to evaluate a company's competitive position and to develop strategic planning. SWOT analysis assesses internal and external factors, as well as current and future potential.”

When institute or library is working on this important project, it is essential to check out the possible strength, weakness, opportunity and traits also. This analysis will help to identify present situation and how the institute can take advantages of his strengths and moderate his weakness into opportunity to bring out new inventions, it would be helpful for smooth running for the said project. Ex. Books and documents damage is a weakness of any library. A clever project director can covert this weakness in opportunity and make possible



arrangement to traits financial and organizational barriers with strong funding agency. He creates digital platform and make best ROI (return on investment) through subscription base document delivery.

Notation level

After completing thinking process the project director should maintain all the files in written form, as specially workflow charts and coding language. This might be easier to follow and moderate all functions regarding digital preservation.

Execute Technical Process

Execute technical process in terms of operational level work assigned. The flow chart of assign work contents as follows

Codification of compiled items

Digital transformation needs lots of attention at time of scanning or image captured. A small mistake can overload the task of replication work. To survive with computers and information technology era, proper coding and interpretation of documents needed. Failing in this it is meaningless activities of “0” and “1” without interpretation. Means convert binary document from physical structure.

Digital preservation involves set of activities with access right for longevity of data. Proper identification and coding of electronic documents vice versa physical documents are primary activities of digitization of resources. Ex. A well define class numbers require same as physical and digital documents and they must be unique in nature. So everybody can identify easily.



Making decision for quality control

Digital contents needs quality in three phases, first at time designing workflow, second at time of digital image capture or scanning how it is selected and handled. Third one is access and downloads time with user's friendly in its nature. This may require quality control at every stage and gave guarantee for produce first product output as same level whenever and whatever time it will retrieve for usage. Means, maintain consistency in quality work despite the technological changes occur. It will be able migrate data in to other format also. Like word to PDF, mp3 to mp 4 and so on.

Special treatments of rare items

Form Stone Age to digital Age, library holdings gets variety of information sources like; manuscripts, clay books, paper books, original copies, Maps, charts, diagram, photographic materials, microfilms, films, documentary , recordings, CDs, DVDs, etc. all these materials needs to preserve from deteriorations of various hazards like Environmental, biological, chemical , natural and disasters , human related. All these hazards affect the original product and harm the quality of library holding.

Environmental factors- temperature, humidity, light and dust

Biological factors-fungi, Insects, other parasites

Chemical Factors- Chemical product used in production

Disasters and Natural Factors – Floods, Earth quack, Hurricane, Volcanic

Eruptions, Sand storm

All this printed and non-book materials needs special treatment like;

Treatment for environmental hazards: to maintain library resources properly, the environmental condition/ storage condition should scientific monitored. Proper lighting,



ventilation, Air and temperature should be maintained. Cleanliness of library resources, shelves should be maintained and check by periodically.

Treatment for Biological hazards: in order to biological hazards; strictly banned food and drinks inside the library. Prevent with insect used naphthalene bricks on the shelves, periodically spray dry neem powder and placed the camphor tablets inside the shelves for pest control.

Treatment for Chemical hazards: books/ documents kept indoors are better protected than books/documents kept outside. This will prevent records from dust, chemical reaction of papers used in paper making process and binding process. Torn and damaged resources should be maintained with lamination, re-binding, re-pairing and restoring with excellent quality equipment's.

Treatment for disasters and natural hazards: library should plan proper disasters management systems and this will checked and tracked on regular basis. The building maintenance, water and air facilities, drainage and flood resistance systems, fire alarm security should checked and maintained on periodic times. Certification, verification and updating of equipment's also are done by regular systems for preventive natural hazards. It advisable to get best quality scanning and digital output of library resources, the digital preservation process should be start after proper maintaining of physical library resources or documents.



Convert in to Meta data and Bibliographic work

Archiving and preserving of library resources/documents involves using standardized format of data captured and migration process. This will help out to recall deteriorate data. The fundamentals requirements is the validation of digital documents should be done with Meta data standards including EAD (encoding archives description for discovering guidelines and

EACs encoding archive materials). It advisable to get access of data put bibliographic work on local hard disks as well as institutional websites also.

Build repo with humans and technology

Working with technology needs suitable integration and collaboration with technology as well as humans. So the project director should make some guidelines for completing the task of digital preservation. This may include;

- Pin point key functions and task may drawn out for this project
- Provide manuals to project head, how the functional and organizational units would be worked with supporting staffs.
- Determine degrees of authority needed to manage each units
- Provide co-ordination among the functional and organizational units
- Negotiate with hard ware/ software agencies , which they are responsible for assigned work at every stages like; at the time of beginning, at time of completion and at time of execution of work, to get better result the policy should remain to maintain the continuity of work

Test trial version

To ensure access to digital materials, which are under process and repositories of particular institutions? It is advisable to test trial version first. After getting remarkable notification for successful operations of various levels it should be linked with institutional website.

Team work

Team work is essential elements for every institutions, industry or firm. As we know teamwork is the collaborative effort of a group to achieve a common goal or to complete a



task in the most effective and efficient way. In this regard when all employees work together, then and then the project director would be able to accomplish the digital preservation of library resources task.

Out put

Final digitized product

At the end of the digitization process, the final product achieved by institute is that documents are digitally produced. This may be in form of “digital born documents” or “digitally created documents”.

Bibliographic data set

After creating digital product, it is essential to have total bibliographic details on this digital product. So, beneficiary can easily retrieve the documents whenever they needed.

Institutional repository

The project director of the digital preservation can claim for the institutional repositories. Because the final product is planning, prepared, offered and maintain by the parental institute.

High Satisfaction

High Job- Satisfaction, Institutional satisfaction and work satisfaction itself can be derived through the successfully completion of digitization of library resources. It always reflects on smiles and working behaviours of employees and user’s feedback as well as institutions returns on Invests. ROI



Recommended Strategy for digital preservation

Medium preservation

- Media renewal or media refreshing like, Copying – transferring data from old storage
- Media to new storage media with the same format specification
- Authentication and accreditation
- Decrease in physical size & Increase in storage capacity

Technology preservation

- This approach intends to retain the needed original hardware and software
- May have an important role for the recovery of data from obsolete storage media and Platforms, but it is unlikely to become a viable long-term strategy
- Digital resources would be to preserve the original software and then to run this on
- Emulators that would mimic the behavior of the obsolete hardware and operating systems
- Digital data object together with the application software used to create or interpret it and a description of the required hardware environment that could be used as a specification for an emulator

Intellectual preservation

- Regarding existing législation (especially copyright & IPR)
- Awareness of the broader scope of the problem

Policy framework

Due to technological revolutions and seeking instant information more and more content are created, converted in digital format. To maintain Libraries and archival record those who are



actively related to digital assets realised for policy matters and intellectual property rights. Their Nobel prospects lead them to create policy framework for digital preservation.

Why policy on digital preservation:

As we discuss technological revolution made easy transformation of physical media in to digital media. Easy availability of information and plagiarism raised some issues towards Intellectual property rights and owners identity. Librarians, arc hivers and groups of society realize the policy framework on digital preservation. Based on previous studies some observation has been made as :

Lyman and Besser noted, "The long term preservation of information in digital form requires not only technical solutions and new organizational strategies, but also the building of a new culture that values and supports the survival of bits over time." Beagrie, Semple, Williams, and Wright reinforced the idea that "...any long-term access and future benefit may be heavily dependent on digital preservation strategies being in place and underpinned by relevant policy and procedures and that the digital preservation policy should be integrated into business drivers, activities and functions e.g. regulatory compliance, staff development, applied technology, academic excellence."

The Electronic Resource Preservation and Access Network's (ERPANET) Digital Policy Preservation Tool suggests that "A policy forms the pillar of a programme for digital preservation. It gives general direction for the whole of an organization, and as such it remains on a reasonably high level from an external point of view, a written policy is a sign that the organization takes the responsibility to preserve digital material."

Cloonan and Sanett noted, "The lack of preservation policies in place is a distinct gap in the research design of many of the projects and possibly reflects a lack of commitment among the stakeholders in institutions."



Conclusion

Preservation in the area of digital technology is a shared responsibility. Library and information technology professionals are playing vital role in developing strategies for this sustainable issues. The emerging need is to develop high storage medium & work collaboratively with professionals & community. It is also needed to create awareness on IPR & related issues. It is also require having a healthy coordination among the various parties who involved in digital preservation and increase staff expertise with issues of digital technology. In views of overall situation the satisfaction reflects on employee's behaviour and face of happy customers.

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A STUDY ON FINANCIAL PERFORMANCE OF SELECTED PSU STEEL COMPANIES

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ABSTRACT

With an output of 9.8 MT in October 2021, India was the second-largest producer of crude steel in the world. FY21 had a 102.49 MT of crude steel production, while the finished steel output was at 94.66%. India's crude steel output is expected to rise by 18 percent in FY22, to 120 million tonnes, due to increased demand from consumers. The availability of iron ore and low-cost labour in India has been a major driver of the steel industry's expansion in India. As a result, India's manufacturing output has benefited greatly from the steel industry. Modern steel mills in India's steel industry are state-of-the-art. It has always sought to improve the energy efficiency of its older facilities and modernise them. Primary, primary, and secondary producers all fall under the umbrella term "Indian steel industry." An analysis of financial data for the years 2016-17 to 2020-21 has been carried out by the researcher in this study.

KEYWORDS: Financial Performance, PSU, Steel.

INTRODUCTION:

With a crude steel output of 9.5 MT in September 2021, India was the world's second-largest producer. FY21 had a 102.49 MT of crude steel production, while the finished steel output was at 94.66%. India's crude steel output is expected to rise by 18 percent in FY22, to 120 million tonnes, due to increased demand from consumers. At 93.43 metric tonnes (MT), finished steel consumption in FY21 was a record high. Final steel output in May 2021 amounted to 7.8 MT. There was 1.30 MT of crude steel production and 1.27 MT of saleable steel production in June of 2021, SAIL's total output. On the heels of a 29 MT capacity addition, steel producers are looking to recommence growth projects. There was a total usage of 49.11 MT of finished steel between April 2021 and September 2021.

Steel consumption is predicted to rise by 17% to 110 million tonnes in FY22, primarily due to an increase in construction activity. It is expected that Tata Steel's yearly capacity will increase from 34 MTPA to 55 MTPA by 2030 in India. From 34 million tonnes per year to 55 million tonnes per year, Tata Steel plans to increase its annual capacity in India by 2030. Exports of finished steel totaled 7.75 MT while imports of finished steel totaled 2.37 MT in FY22 (until September 2021). As of April 2021, India's exports were up 121.6% year-over-year (YoY) over the prior year. A total of 8.24 MT of finished steel was exported from India in FY20.

Per capita steel consumption in India increased by 4.43 percent between FY08 and FY19, from 46 kilogrammes to 74 kilogrammes. According to the National Steel Policy 2017 and allowing 100% FDI in steel sector, the government has taken numerous measures to support this industry... Department for Promotion of Industry and Internal Trade (DPIIT) statistics shows a \$16.0 billion inflow of foreign direct investment (FDI) into Indian metallurgical sectors between April 2000 and June 2021.

To achieve a per capita steel consumption of 160 kg by 2030-31, the government has set a goal in its National Steel Policy 2017. In addition, the government has advocated a policy that requires notified steel goods covered by preferential procurement to have a minimum value addition of 15%. In an effort to cut down on imports, the government implemented a Steel Scrap Recycling Policy in 2019. Developments in many industries are also benefiting the industry. There will be a reduction in steel prices due to the Vehicle Scrappage policy because outdated vehicles can be recycled and reused under this new policy. The demand for oxygen cylinders for COVID patients is now outpacing the capacity of major steel producers. Steel Authority of India Limited (SAIL) would supply Indian Railways with approximately 11 lakh tonnes of steel in 2021 for the renewal and construction of new railway lines across the country.

Investment in a steel plant in Jammu and Kashmir by JSW Steel is expected to be completed by October 2021, with an investment of Rs. 150 billion (US\$ 19.9 million). By 2021, ArcelorMittal and Nippon Steel Corporation's joint venture steel firm in India would invest a total of Rs. 1 trillion (US\$ 13.34 billion) in expanding its activities in India over the next decade. The approved specialty steel production-linked incentive (PLI) scheme had its rules issued by the government in October 2021. In October 2021, India and Russia inked an agreement to conduct research and development in the steel industry and to generate coking coal (used in steel making). Steel companies have firmed up their plans to invest Rs. 60,000 crore (US\$ 8.09 billion) over the next three years, according to CII president and

MD of Tata Steel Mr. T.V. Narendran in an interview with The Telegraph in June 2021. Mr. Narendran stated that this was the largest private sector investment plan announced recently.

According to a MoC that was signed in January 2021, India and Japan agreed to work together to increase steel production through collaborative operations in accordance with the framework set up by the India-Japan Steel Dialogue. As of July 2021, the Union Cabinet has approved a PLI programme for special steel. An estimated investment of Rs. 400 billion (US\$ 5.37 billion) and an increase in specialty steel capacity of 25 million tonnes (MT) are envisaged as a result of the scheme. CARE Ratings predicts that crude steel output in FY22 would rise by 8-9 percent YoY to 112-114 MT. Economic recovery, government spending, and increased liquidity will fuel this demand. At \$5.54 lakh crore (US\$ 74.60 billion), the budget for capital expenditures (capex) has increased by 34.5 percent year-on-year. The budget aims to boost the economy by building infrastructure and industry. In addition, increased investments in critical areas like defence, rail, and roads, transportation, and highways would spur demand for steel.

LITERATURE REVIEW:

For public sector firms and Bharat Heavy Electricals Limited, Joshi (2000) attempted to examine the influence of ownership change on financial performance. BHEL's pre- and post-disinvestment financial performance has been evaluated using a variety of financial ratios. He also employed a SWOT analysis to support his choice of BHEL for his research. Joshi found in his research that disinvestment is a good answer for public sector enterprises like BHEL, which compete in a globally competitive environment, because it has resulted in greater profitability and operational efficiency.

"Financial Performance of Divest Central PSUs in India: An Empirical Study on Select Dimensions" by Gupta (2011) has revealed the financial performance of divested CPSEs in India from 1986-87 to 2009-10 on both pre and post-disinvestment basis. The author of this essay argues that CPSEs continue to suffer challenges even after disinvestment, which is why even a tiny amount of disinvestment has failed to provide the anticipated benefits. He also points out that these issues are caused by government involvement and delegation of operational and functional authority to managers, among other things, as well as excessive costs and a non-competitive industrial structure in operational efficiency.

"Disinvestment and Performance of Profit and Loss Making CPSEs in India" by Singh (2015) examines the influence of profit & loss making CPSE disinvestment on investment, employment, financial strength and corporate liquidity. The author of this paper came to the conclusion that, while staff efficiency in resource usage has increased in both profit- and loss-making CPSEs following disinvestment, profitability and operational efficiency have decreased in profit-generating CPSEs.

There was "A general study on public sector undertakings: growth of PSUs and how effectively financially managed our PSUs." Compared to private sector enterprises, the author found that PSUs can be successfully and fiscally managed. A brief history of PSUs, financial management in public sector enterprises (PSEs), the function of financial advisors in PSEs, and other topics are also covered in this article.



An analysis of 235 public sector undertakings (PSUs) by Gupta (2017) in his research paper "Public Sector Undertaking: Bharat's Other Ratna". The author points out that the PSUs are categorised into distinct 'Ratna' categories in order to enhance their performance. The author also noted that CPSEs can improve their performance through partial privatisation. 'Maharatnas,' the larger PSUs, outperform 'Navratnas,' the smaller PSUs, and private enterprises alike, according to the author. Gupta also advised that India raise funds through privatisation, disinvestment, and liquidation, which may be invests in public infrastructure through the National Infrastructure Investment Fund and not the budget as a revenue raising measure.

In her work "Partial Privatization and Firm Performance," Gupta (2006) asserts that partial privatisation was the starting point for the majority of the privatisation program's early stages. Partial privatisation is beneficial to profitability, production, and investment, as the author points out. There are times when the stock can be used to monitor and reward management performance, especially when the government owns most of the shares.

RESEARCH OBJECTIVE:

1. To analyse financial performance of selected PSUs steel companies
2. To compare the financial performance of selected PSUs steel companies

RESEARCH METHODOLOGY:

Sources of Data:

Secondary sources of data utilised for this proposed research study

Secondary data have been collected from Annual Reports.

Universe:

In the research study selected 2 PSUs steel companies.

Period of Data Coverage:

Five years of financial statements has been analysed for PSUs steel companies taken under study.

Analysis of Data:

The proposed statistical tools for the analysis of data are ratio analysis

DATA ANALYSIS:

Net Profit Margin

Company	2020-21	2019-20	2018-19	2017-18	2016-17
Steel Authority of India Ltd	5.57	3.27	3.25	-0.83	-6.37
NMDC Ltd	40.68	30.85	38.19	32.76	29.32

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2785.895	1	2785.895	121.3523	4.1E-06	5.317655
Within Groups	183.6567	8	22.95709			
Total	2969.551	9				

Based on above ANOVA table it is concluded that, P value is less than significant value 0.05. It is concluded that there is significant difference in net profit margin ratio of selected PSUs steel companies of India.

Asset Turnover Ratio

Company	2020-21	2019-20	2018-19	2017-18	2016-17
Steel Authority of India Ltd	58.98	49.28	57.51	50.4	41.72
NMDC Ltd	41.78	37.56	40.8	40.59	34.34

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	394.6352	1	394.6352	13.66042	0.006077	5.317655
Within Groups	231.1116	8	28.88895			
Total	625.7468	9				

Based on above ANOVA table it is concluded that, P value is less than significant value 0.05. It is concluded that there is significant difference in asset turnover ratio of selected PSUs steel companies of India.

Current Ratio

Company	2020-21	2019-20	2018-19	2017-18	2016-17
Steel Authority of India Ltd	0.78	0.91	0.78	0.68	0.55
NMDC Ltd	1.91	2.63	2.6	2.5	3.09

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8.15409	1	8.15409	83.17105	1.68E-05	5.317655
Within Groups	0.78432	8	0.09804			
Total	8.93841	9				

Based on above ANOVA table it is concluded that, P value is less than significant value 0.05. It is concluded that there is significant difference in current ratio of selected PSUs steel companies of India.

CONCLUSION:

From the above table it is concluded that NMDC Ltd has highest profit margin compare to SAIL through out last 5 years of study period. NMDC Ltd has more current ratio compare to SAIL which indicates that NMDC Ltd has more current assets to pay their current obligations. SAIL has utilised its assets more efficient way compare to NMDC Ltd.

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A STUDY OF FINANCIAL PERFORMANCE OF SELECTED PSU BANKS OF INDIA

Meet Bhavik Shah¹ | Dr. Prashant Joshi²

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ABSTRACT

The Reserve Bank of India and the Ministry of Finance are in charge of the country's vast array of governmental and private financial institutions. Competition, client demand, and banking reforms in India have made efficiency and profitability of the banking sector a primary concern. SBI, BOB, and BOI, three of India's biggest public sector banks, are the focus of this research. From 2016-17 through 2020-21, these banks have been analysed in terms of their financial performance. FRA (Financial Ratio Analysis) is a tool used to evaluate public sector banks' financial performance by looking at their ratios. Banks can benefit from the outcomes of this study.

KEYWORDS: Public Sector Banks, Financial Performance, Efficiency, Profitability.

INTRODUCTION:

There are numerous definitions of "bank" in the book Son of Economics and Commerce by various authors. To define a bank, you have to look at all of its functions and see how they fit into that definition. One of the reasons for the proliferation of different types of banks is the fact that each one has its own unique niche in the financial industry. It would be unscientific and probably impossible to come up with a single definition that encompasses all banking organisations. There should be a distinct definition for each type of bank, which explains its specific functions. As a result, the Bill of Exchange Act of 1882 (England) defines the term "bill of exchange."

"A bank includes a body of persons, whether incorporated or not, who carry on the business of banking"

More than 35 commercial banks in India compete for customers with dozens of international banks, as well as rural and cooperative lenders, in a highly fragmented banking market. Eighty percent of the market is dominated by state-owned banks, with only a minor portion controlled by private competitors.

By the end of February, 13.7 million Pradhanmantri Jan Dhan Yojna (PMJDY) accounts had been opened and 12.2 million RuPay debit cards had been issued. Since their opening, these new accounts have received deposits totaling Rs 12,694 crore (\$ 2.01 billion).

According to Standard & Poor's, credit growth in India's banking sector would increase from less than 10% in the second half of CY 14 to 12-13% in FY 16.

LITERATURE REVIEW:

According to Mayuri, J. Farmer's (2009) research, the financial performance of 27 nationalised banks in India from 1989 to 1998 was mostly dependent on secondary data. Analysis of the quantitative variables and their influence on profitability has been undertaken using a regression analysis. There has also been a thorough investigation into the profitability of two different banks, one of which is quite profitable and the other of which is extremely loss-making. It has been attempted to use the idea of Break Even Analysis to distinguish between a profit-making bank and a loss-making bank, and to offer suggestions for increasing the margin of safety.

Rachin Gulati and Sunil Kumar (2009) investigate the link between efficiency and profitability in 51 Indian domestic banks that were active in the 2006-2007 financial year.

The Indian domestic banking industry's efficient frontier is dominated by de novo private sector banks, according to empirical evidence. As a result of the efficient-profitability matrix, 22 banks in the "Question Mark" and "Sleepers quadrants" have a poor resource utilisation procedure and a lot of waste in their supply chains. On the efficiency and profitability dimensions, Tamil Nadu Mercantile Bank and Yes Bank can serve as a benchmark for the underperforming banks in the country.

Both Shankar Ravi and Roma Mitra (2008), In order for a country's economy to grow, it is necessary to have a well-functioning financial system. In this paper, the efficiency of 50 Indian banks is modelled and evaluated. Every unit evaluated can have its inefficiency analysed and quantified. It is the goal of this article to

estimate and compare the efficiency of India's banking system. Whether or whether banks are able to compete with global financial institutions will be determined by this study's findings. Results are useful to financial policy planners since it identifies areas where banks need to focus in order to achieve their goals. Banks' performance in India is evaluated in this article.

Private sector banks have a vital part in the development of the Indian economy, according to B. Satish Kumar (2008) in his work on an examination of their financial performance. There were considerable changes in the banking business after the liberalisation. The banking sector has completely changed as a result of the economic changes. In accordance with the Narashiman committee's recommendations, the RBI allowed the establishment of new private sector banks. Public sector banks dominated the Indian banking sector. New generation banks with technology and competent management have achieved a respectable position in the banking business, but, as circumstances have changed.

Bank performance is increasingly essential in the modern world, according to a 2006 study by Vradi, Vijay, Mauluri, Nagarjuna, and their colleagues.

It is necessary to look at key metrics such as profitability, productivity, assets, quality, and financial management for both public and private Indian banks over the years 2000 and 1999 to 2002-2003 in order to assess the efficiency of the financial system in India. We used development envelopment analysis to gauge bank efficiency and discovered that public sector banks in India outperform all others.

Petya Koeva (July 2003) in his study on the Performance of Indian Banks. New empirical information on the influence of financial liberalisation on the performance of Indian commercial banks was presented during Financial Liberalization. During the period of liberalisation, the study examines the costs and profits of bank intermediation. Observed increases in competition during financial liberalisation have been linked to decreased intermediation costs as well as higher profitability for Indian banks, according to the empirical findings.

RESEARCH OBJECTIVE:

1. To analyse financial performance of selected public banks of India
2. To compare the financial performance of selected PSU banks

RESEARCH METHODOLOGY:

Sources of Data:

Secondary sources of data utilised for this proposed research study

Secondary data have been collected from Annual Reports.

Universe:

In the research study selected 3 public banks.

Period of Data Coverage:

Five years of financial statements has been analysed for public banks taken under study.

Analysis of Data:

The proposed statistical tools for the analysis of data are ratio analysis



Loans Turnover					
Bank Name	2020-21	2019-20	2018-19	2017-18	2016-17
State Bank of India	0.11	0.12	0.12	0.12	0.12
Bank of India	0.11	0.12	0.12	0.11	0.11
Bank of Baroda	0.10	0.13	0.11	0.11	0.11
Net Profit Margin					
Bank Name	2020-21	2019-20	2018-19	2017-18	2016-17
State Bank of India	8.05	7.32	0.90	-1.98	0.10
Bank of India	0.11	0.12	0.12	0.11	0.11
Bank of Baroda	1.17	0.71	0.87	-5.57	3.27
Operating Expense / Total Funds					
Bank Name	2020-21	2019-20	2018-19	2017-18	2016-17
State Bank of India	3.27	3.19	2.99	2.66	2.61
Bank of India	2.64	3.61	3.40	2.74	3.39
Bank of Baroda	2.97	3.91	3.09	3.41	2.53

The Loans Turnover ratio table shows that State Bank of India has the highest value, followed by Bank of Baroda and finally Bank of India. As a result, the State Bank of India generates the most revenue, which is needed to repay its loans.

SBI, BOB, and BOI all keep a larger percentage of their revenue as net income, as can be seen from the Net Profit Margin ratio chart shown above.

This graph shows that BOB has the highest operational expenses / total funds average ratio in the past five years. It demonstrates that BOB has the best ability to use its average total resources to improve its main stream of operating expenses. To improve its main stream of operating expenses, SBI is unable to use its average total resources to the greatest extent.

CONCLUSION:

It's possible to deduce from ratio analyses of public sector banks that the net profit margin ratio was larger in previous years, i.e. banks retained a bigger percentage of their revenue as net income in the earlier years. Public sector banks have a lower loan turnover ratio than private sector banks, and public banks have a higher outstanding loan balance compared to revenues. The State Bank of India has the greatest potential to leverage its average total resources in order to improve its primary operating expenses stream. State Bank of India. The average total resources of public banks can be used to increase their primary source of operating interest income.

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A Study on Impact of Advertisement on Consumer Behaviour

• Parul C. Dave

Abstract- Advertising is an important component of marketing. Advertisement and consumer behavior have a strong relation. The role of advertisement is to influence the consumer decision-making process and influence consumer decisions in all stages based on the marketing and advertising goals. This study is intended to analyze the impact of advertisement on consumer behavior. Most of the respondents have taken advertising as promotional tools that can convince the customers towards the products. The study shows that the customers are highly affected by the advertisement as it creates curiosity on the customers and it provides information of the products, which is also important for the customers before buying any goods and services. So there is a positive impact of advertisement on consumer behavior.

Keywords- Impact, Advertisement, Consumer, Behavior

Introduction- The advertisement must show what the product is all about. It should, in a way give some kind of information about its price, benefits, usage, availability and so on. The influence of advertising in everyday life is greater than many people realize. This is because the effects of advertising often work in subtle ways, to the point that many people do not even realize that they are being marketed to when they alter their behavior after encountering advertisements. Advertising is such a powerful psychological tool that an entire field of study dedicated to unlocking how advertising influences consumer behavior has been developed and continues to be explored today. Advertisers also study consumers' behavior not only to reach them but also to get their feedback and their reactions toward the sold products. Consumer behavior focuses on how individuals make decisions to spend their available resources such as time, effort, money etc. on consumptions related items. That includes what they buy, when they buy, why they buy, where they buy, how often they buy, how often they use, how they evaluate after the purchase and use it and impact of evaluations on future purchase and how they dispose it (Schiffman & Kanuk, 2009). Consumer behavior is the study of the processes involved when individuals or groups select, purchase, use or dispose of products, services, ideas or experiences to satisfy needs and desires. Advertising is a way of communication to convince an audience for taking purchase decision about a product or service and delivering information to viewers (Niazi, Siddiqui, Shah, & Hunjra, 2012).

Statement of the Research Problem- It is important to catch the research problem. Present study was commenced with the following title: "A study on

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- 15 The "Sexual Politics" Involved
in the Concept of "The Angel in the House"
Sonal Singhvi Choudhary 134
- 16 The Magic of J.K. Rowling's Imagination:
a Lesson in Creative Writing
Satabdi Koley, Shubha Tiwari 138
- 17 The Importance of Tacit Knowledge in Libraries
Vijendra Kumar Gupta, Mohan Lal Kaushal 139
- 18 Relative Study of Personality among Bachelor
and Married Female Sportspersons
Nibu R Krishnan 145
- 19 A Study on Impact of Advertisement on
Consumer Behaviour
Parul C. Dave 152
- 20 The effect of Yoga on Mental Fitness level of
COVID-19 Men patients
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- 21 Effect of Psychological Pressure on Pole Vaulters
Perception about the judgment of Cross Bar Height
Nibu R Krishna 160
- 22 A Study of the Role of Mass Media
in Pro Kabaddi League: A Survey Study
Minaxi Patel 165
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on Kabaddi Players Vital Capacity
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- 24 The Effect of Asanas and Pranayama
on Physical Fitness level of COVID-19 Patients
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- 25 Comparative Effect of Two Types of Isotonic
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- 26 Antiviral activity of some medicinal plant
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Shyam Govind Singh 181
- 27 Effect of Microbial Activity
on Calcium Content of Sunflower Plants
Anup Kumar Mishra, Pushpendra K. Sharma 185
- 28 A Theoretical Study of Thermophysical and
Cohesive Properties of KI_3 , F, Mixed Alkali Halide 194

on consumer behavior. To fulfill the purpose of the study total 50 women were selected as a sample. Convenience sampling method was used for the study.

Research Method- The research method of present study was descriptive research method well as analytical method. Descriptive research design describes the way of overcoming the facts, problems.

Research Tool- The research is the collection of adequate, accurate, and reliable facts about the problem under investigation. Interview schedule was used as a research tool in present study.

Development of the Interview Schedule- For good communication and understanding researcher has taken prior appointments and briefly introduced the purpose of study and also discussed with them the importance of the study before conducting the personal interview. An appropriate interview schedule was developed on the basis of the formed objectives of the study and library research. The schedule consisted of different questions covering various aspects.

1. **The Part "A" of the Schedule dealt with-**the personal details: It included the personal details of the respondents like name of the person, age, birth date, religion, etc.
2. **The Part "B" deals with advertisement and consumer behaviour-** It included the questions pertaining to factors influenced on consumer behaviour, buying decisions and advertisement impact related questions.

Pre-testing of the Interview Schedule for the Present Study- To see the work ability of the prepared Interview Schedule a Pilot Study was carried out on some persons. The Interview Schedule was translated into Gujarati for easy communication and better understanding. The interview was conducted in Gujarati language and the responses were recorded in English. The pretesting revealed that the questionnaire was explicit and clear to the respondents. A few modifications in the Interview Schedule were necessary and made after pretesting to increase the validity of the Schedule. Those changes were mainly in phrasing and restructuring the sequence of the questions in interview schedule.

Data Collection- Data were collected through primary sources to obtain the objectives of the research. The data was collected through interview schedule. Comprehensive literature reviews was made to analyze the impact of advertisement in consumer behavior.

Data Analysis and Interpretation- The result and discussion have been presented under the following research questions:

Question no.1- What are the factors influencing consumer buying decisions?

According to respondents response there were so many factors that influenced the buying decision like economical factor, functional factor, individual or personal factor, mix factor, social factor and psychological factors. Most of women gave importance on economical factor and fashion factor.

Question no.2 -Does an advertisement have any impact on consumers'

impact of advertisement on consumer behavior"

Objectives of the study- The objectives of the study provide a direction to research and researcher also. On the basis of the objectives, researcher carried out data collection, data analysis, drawing interpretation and conclusion of the research. Research processes are dependent on the objectives. The objectives of the study are as follows:

1. To analyze the consumer buying behavior
2. To examine the impact of advertisement on consumer behavior

Research Questions- The study starts with the following questions:

1. What are the factors influencing consumer buying decisions?
2. Does an advertisement have any impact on consumers' buying decisions?
3. Which advertising media is most effective to convince the consumers?

Variables Included in the Study- There are some variables related to the research. It is necessary to identify these variables to know the relations between them. Following is the detail of the variables included in the present research.

Independent variable:	Advertisement	
Dependent variable:	Consumer Behaviour	
Controlled variable:	Year	2020-21
	Gender	Women
	Area	Ahmadabad City
	College	Grant in Aid

Scope of the Research- The scope of research of the present study was related with so many fields, which are given below-

1. Education
2. Commerce
3. Marketing
4. Advertisements
5. Research

Delimitations of the Study-

1. Present study is delimited to women only.
2. Present study is delimited to grant in aid commerce college only.
3. Present study is delimited to Ahmadabad city only.
4. Present study is delimited to academic year 2020-21 only.

Limitations of the Study-

1. Present study analyses only the effect of advertisement in consumer buying decisions.

Type of Research- Thus the type of present research was qualitative research according to its implementation form.

Population- Women who studied in grant in aid commerce colleges during the academic year 2020-21 were selected as population.

Sampling- Present study is intended to analyze the impact of advertisement

buying decisions?

From the response analysis from the respondents researcher have drawn the conclusion that advertisement can change and have impact on consumers' buying decision. Most of respondents said this advertisement have more impact on buying decisions.

Question no.3 - Which advertising media is most effective to convince the consumers?

There were vast different opinions get from responds, but everyone said the advertising media is most effective to convince the consumers. Most of women said they were more affected by TV advertisement and in the view of some women of them radio advertisement is more effective and some women said print media is more effective to convince the consumers.

Conclusion- The study has been done to analyze the consumer behavior in purchasing decision and examine the impact of advertisement in buying behavior of consumers. According to the respondents taken for the study there is positive impact of advertising on consumer behavior. Most of the respondents have taken advertising as promotional tools that can convince the customers towards the products and Sales promotion is taken as the key function of advertisement to attract them. According to the respondents, television is more effective media to influence and convince the audience towards the advertisement products. The study shows that the customers are highly accepted by the advertisement as it creates curiosity on the customers. There was positive impact of advertisement on consumer behaviour but according to the respondents most of the people also think about their needs before buying goods and services.

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Rachin Gulati and Sunil Kumar (2009) investigate the link between efficiency and profitability in 51 Indian domestic banks that were active in the 2006-2007 financial year.

The Indian domestic banking industry's efficient frontier is dominated by de novo private sector banks, according to empirical evidence. As a result of the efficient-profitability matrix, 22 banks in the "Question Mark" and "Sleepers quadrants" have a poor resource utilisation procedure and a lot of waste in their supply chains. On the efficiency and profitability dimensions, Tamil Nadu Mercantile Bank and Yes Bank can serve as a benchmark for the underperforming banks in the country.

Both Shankar Ravi and Roma Mitra (2008), In order for a country's economy to grow, it is necessary to have a well-functioning financial system. In this paper, the efficiency of 50 Indian banks is modelled and evaluated. Every unit evaluated can have its inefficiency analysed and quantified. It is the goal of this article to

estimate and compare the efficiency of India's banking system. Whether or whether banks are able to compete with global financial institutions will be determined by this study's findings. Results are useful to financial policy planners since it identifies areas where banks need to focus in order to achieve their goals. Banks' performance in India is evaluated in this article.

Private sector banks have a vital part in the development of the Indian economy, according to B. Satish Kumar (2008) in his work on an examination of their financial performance. There were considerable changes in the banking business after the liberalisation. The banking sector has completely changed as a result of the economic changes. In accordance with the Narashiman committee's recommendations, the RBI allowed the establishment of new private sector banks. Public sector banks dominated the Indian banking sector. New generation banks with technology and competent management have achieved a respectable position in the banking business, but, as circumstances have changed.

Bank performance is increasingly essential in the modern world, according to a 2006 study by Vradi, Vijay, Mauluri, Nagarjuna, and their colleagues.

It is necessary to look at key metrics such as profitability, productivity, assets, quality, and financial management for both public and private Indian banks over the years 2000 and 1999 to 2002-2003 in order to assess the efficiency of the financial system in India. We used development envelopment analysis to gauge bank efficiency and discovered that public sector banks in India outperform all others.

Petya Koeva (July 2003) in his study on the Performance of Indian Banks. New empirical information on the influence of financial liberalisation on the performance of Indian commercial banks was presented during Financial Liberalization. During the period of liberalisation, the study examines the costs and profits of bank intermediation. Observed increases in competition during financial liberalisation have been linked to decreased intermediation costs as well as higher profitability for Indian banks, according to the empirical findings.

RESEARCH OBJECTIVE:

1. To analyse financial performance of selected public banks of India
2. To compare the financial performance of selected PSU banks

RESEARCH METHODOLOGY:

Sources of Data:

Secondary sources of data utilised for this proposed research study

Secondary data have been collected from Annual Reports.

Universe:

In the research study selected 3 public banks.

Period of Data Coverage:

Five years of financial statements has been analysed for public banks taken under study.

Analysis of Data:

The proposed statistical tools for the analysis of data are ratio analysis



Loans Turnover					
Bank Name	2020-21	2019-20	2018-19	2017-18	2016-17
State Bank of India	0.11	0.12	0.12	0.12	0.12
Bank of India	0.11	0.12	0.12	0.11	0.11
Bank of Baroda	0.10	0.13	0.11	0.11	0.11
Net Profit Margin					
Bank Name	2020-21	2019-20	2018-19	2017-18	2016-17
State Bank of India	8.05	7.32	0.90	-1.98	0.10
Bank of India	0.11	0.12	0.12	0.11	0.11
Bank of Baroda	1.17	0.71	0.87	-5.57	3.27
Operating Expense / Total Funds					
Bank Name	2020-21	2019-20	2018-19	2017-18	2016-17
State Bank of India	3.27	3.19	2.99	2.66	2.61
Bank of India	2.64	3.61	3.40	2.74	3.39
Bank of Baroda	2.97	3.91	3.09	3.41	2.53

The Loans Turnover ratio table shows that State Bank of India has the highest value, followed by Bank of Baroda and finally Bank of India. As a result, the State Bank of India generates the most revenue, which is needed to repay its loans.

SBI, BOB, and BOI all keep a larger percentage of their revenue as net income, as can be seen from the Net Profit Margin ratio chart shown above.

This graph shows that BOB has the highest operational expenses / total funds average ratio in the past five years. It demonstrates that BOB has the best ability to use its average total resources to improve its main stream of operating expenses. To improve its main stream of operating expenses, SBI is unable to use its average total resources to the greatest extent.

CONCLUSION:

It's possible to deduce from ratio analyses of public sector banks that the net profit margin ratio was larger in previous years, i.e. banks retained a bigger percentage of their revenue as net income in the earlier years. Public sector banks have a lower loan turnover ratio than private sector banks, and public banks have a higher outstanding loan balance compared to revenues. The State Bank of India has the greatest potential to leverage its average total resources in order to improve its primary operating expenses stream. State Bank of India. The average total resources of public banks can be used to increase their primary source of operating interest income.

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A Study on Impact of Advertisement on Consumer Behaviour

•Parul C. Dave

Abstract- Advertising is an important component of marketing. Advertisement and consumer behavior have a strong relation. The role of advertisement is to influence the consumer decision-making process and influence consumer decisions in all stages based on the marketing and advertising goals. This study is intended to analyze the impact of advertisement on consumer behavior. Most of the respondents have taken advertising as promotional tools that can convince the customers towards the products. The study shows that the customers are highly affected by the advertisement as it creates curiosity on the customers and it provides information of the products, which is also important for the customers before buying any goods and services. So there is a positive impact of advertisement on consumer behavior.

Keywords- Impact, Advertisement, Consumer, Behavior

Introduction- The advertisement must show what the product is all about. It should, in a way give some kind of information about its price, benefits, usage, availability and so on. The influence of advertising in everyday life is greater than many people realize. This is because the effects of advertising often work in subtle ways, to the point that many people do not even realize that they are being marketed to when they alter their behavior after encountering advertisements. Advertising is such a powerful psychological tool that an entire field of study dedicated to unlocking how advertising influences consumer behavior has been developed and continues to be explored today. Advertisers also study consumers' behavior not only to reach them but also to get their feedback and their reactions toward the sold products. Consumer behavior focuses on how individuals make decisions to spend their available resources such as time, effort, money etc. on consumptions related items. That includes what they buy, when they buy, why they buy, where they buy, how often they buy, how often they use, how they evaluate after the purchase and use it and impact of evaluations on future purchase and how they dispose it (Schiffman&Kanuk, 2009). Consumer behavior is the study of the processes involved when individuals or groups select, purchase, use or dispose of products, services, ideas or experiences to satisfy needs and desires. Advertising is a way of communication to convince an audience for taking purchase decision about a product or service and delivering information to viewers (Niazi, Siddqui, Shah, & Hunjra, 2012).

Statement of the Research Problem- It is important to catch the research problem. Present study was commenced with the following title: "A study on

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- 15 The "Sexual Politics" Involved
in the Concept of "The Angel in the House"
Sonal Singhvi Choudhary 124
- 16 The Magic of J.K. Rowling's Imagination:
a Lesson in Creative Writing
Satabdi Koley, Shubha Tiwari 129
- 17 The Importance of Tacit Knowledge in Libraries
Vijendra Kumar Gupta, Mohan Lal Kaushal 137
- 18 Relative Study of Personality among Bachelor
and Married Female Sportspersons
Nibu R Krishnan 145
- 19 A Study on Impact of Advertisement on
Consumer Behaviour
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- 20 The effect of Yoga on Mental Fitness level of
COVID-19 Men patients
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on Kabaddi Players Vital Capacity
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Workout on Agility of Female Athletes
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- 26 Antiviral activity of some medicinal plant
Extracts against spotted wilt virus disease in tomato
Shyam Govind Singh 181
- 27 Effect of Microbial Activity
on Calcium Content of Sunflower Plants
Anup Kumar Mishra, Pushpendra K. Sharma 185
- 28 A Theoretical Study of Thermophysical and
Cohesive Properties of $KI_{1-x}F_x$ Mixed Alkali Halide 194



on consumer behavior. To fulfill the purpose of the study total 50 women were selected as a sample. Convenience sampling method was used for the study.

Research Method- The research method of present study was descriptive research method well as analytical method. Descriptive research design describes the way of overcoming the facts, problems.

Research Tool- The research is the collection of adequate, accurate, and reliable facts about the problem under investigation. Interview schedule was used as a research tool in present study.

Development of the Interview Schedule- For good communication and understanding researcher has taken prior appointments and briefly introduced the purpose of study and also discussed with them the importance of the study before conducting the personal interview. An appropriate interview schedule was developed on the basis of the formed objectives of the study and library research. The schedule consisted of different questions covering various aspects.

1. **The Part "A" of the Schedule dealt with-**the personal details:It included the personal details of the respondents like name of the person, age, birth date, religion, etc.
2. **The Part "B" deals with advertisement and consumer behaviour-** It included the questions pertaining to factors influenced on consumer behaviour, buying decisions and advertisement impact related questions.

Pre-testing of the Interview Schedule for the Present Study- To see the work ability of the prepared Interview Schedule a Pilot Study was carried out on some persons. The Interview Schedule was translated into Gujarati for easy communication and better understanding. The interview was conducted in Gujarati language and the responses were recorded in English. The pretesting revealed that the questionnaire was explicit and clear to the respondents. A few modifications in the Interview Schedule were necessary and made after pretesting to increase the validity of the Schedule. Those changes were mainly in phrasing and restructuring the sequence of the questions in interview schedule.

Data Collection- Data were collected through primary sources to obtain the objectives of the research. The data was collected through interview schedule. Comprehensive literature reviews was made to analyze the impact of advertisement in consumer behavior.

Data Analysis and Interpretation- The result and discussion have been presented under the following research questions:

Question no.1- What are the factors influencing consumer buying decisions?

According to respondents response there were so many factors that influenced the buying decision like economical factor, functional factor, individual or personal factor, mix factor, social factor and psychological factors. Most of women gave importance on economical factor and fashion factor.

Question no.2 -Does an advertisement have any impact on consumers'

impact of advertisement on consumer behavior”

Objectives of the study- The objectives of the study provide a direction to research and researcher also. On the basis of the objectives, researcher carried out data collection, data analysis, drawing interpretation and conclusion of the research. Research processes are dependent on the objectives. The objectives of the study are as follows:

1. To analyze the consumer buying behavior
2. To examine the impact of advertisement on consumer behavior

Research Questions- The study starts with the following questions:

1. What are the factors influencing consumer buying decisions?
2. Does an advertisement have any impact on consumers' buying decisions?
3. Which advertising media is most effective to convince the consumers?

Variables Included in the Study- There are some variables related to the research. It is necessary to identify these variables to know the relations between them. Following is the detail of the variables included in the present research.

Independent variable:	Advertisement	
Dependent variable:	Consumer Behaviour	
Controlled variable:	Year	2020-21
	Gender	Women
	Area	Ahmadabad City
	College	Grant in Aid

Scope of the Research- The scope of research of the present study was related with so many fields, which are given below-

1. Education
2. Commerce
3. Marketing
4. Advertisements
5. Research

Delimitations of the Study-

1. Present study is delimited to women only.
2. Present study is delimited to grant in aid commerce college only.
3. Present study is delimited to Ahmadabad city only.
4. Present study is delimited to academic year 2020-21 only.

Limitations of the Study-

1. Present study analyses only the effect of advertisement in consumer buying decisions.

Type of Research- Thus the type of present research was qualitative research according to its implementation form.

Population- Women who studied in grant in aid commerce colleges during the academic year 2020-21 were selected as population.

Sampling- Present study is intended to analyze the impact of advertisement

buying decisions?

From the response analysis from the respondents researcher have drawn the conclusion that advertisement can change and have impact on consumers' buying decision. Most of respondents said this advertisement have more impact on buying decisions.

Question no.3 - Which advertising media is most effective to convince the consumers?

There were vast different opinions get from responds, but everyone said the advertising media is most effective to convince the consumers. Most of women said they were more affected by TV advertisement and in the view of some women of them radio advertisement is more effective and some women said print media is more effective to convince the consumers.

Conclusion- The study has been done to analyze the consumer behavior in purchasing decision and examine the impact of advertisement in buying behavior of consumers. According to the respondents taken for the study there is positive impact of advertising on consumer behavior. Most of the respondents have taken advertising as promotional tools that can convince the customers towards the products and Sales promotion is taken as the key function of advertisement to attract them. According to the respondents, television is more effective media to influence and convince the audience towards the advertisement products. The study shows that the customers are highly accepted by the advertisement as it creates curiosity on the customers. There was positive impact of advertisement on consumer behaviour but according to the respondents most of the people also think about their needs before buying goods and services.

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DANGER OF DENGUE IN INDIA: A STATISTICAL OVERVIEW

Dr. Vandana G. Trivedi*

ABSTRACT

In present era, the world is facing a health crisis. Recently, Covid-19 is detected as a pandemic. Along with this, there are other diseases that cannot be taken lightly. Dengue is one of them. It is a tropical disease that is spread via mosquito. The death rate due to Dengue is very high in India. In this paper, we will discuss about the spread of this disease in India through state-wise statistical data. The paper will also indicate that in which state or Union territory the number of cases of Dengue was high during 2014 to 2018. In which state the death rate is higher during 2014 to 2018 in India. We shall also compare the change in the number of total cases of Dengue during in this time period. It will also inform us that in which region this disease had spread more rapidly. This study indirectly indicates the efforts taken by the state / UT to control the disease.

Keywords: Dengue, Disease, State Wise, Death.

Introduction

In India, there are many diseases which are spreading speedily. Malaria, chikungunya fever, Dengue, Kala Azar, acute Encephalitis syndrome, Japanese encephalitis, Cholera, acute Diarrheal disease, Typhoid, Respiratory infections, Tetanus, Diphtheria, Whooping Cough, and many more. These diseases are counted as communicable disease in National profile of health report Government of India. Dengue has become a worldwide health problem. The disease is spread through the bite of female *Aedes Aegypti* mosquito. Normally, it takes about 5 to 6 days to spread the disease in the entire body after the mosquito bite.

Dengue is a communicable disease as it can be spread from an infected person to a non infected person through mosquito bites. Dengue can be divided into two types, Classical Dengue fever (Black bone) and Dengue hemorrhagic fever (DHF). Dengue hemorrhagic fever is dangerous than the other as this disease attacks on everyone irrespective of their age or gender. This is generally spread after rainy season. Since the last two decades, Dengue expanded widely in India. As mentioned earlier, it has become a global health issue now. More than hundred countries have become the victim of Dengue. In India, medical science works for the treatment of this disease. Research is still going on to find out a particular cure to Dengue. The statistical data about cases and death due to Dengue shows that even after so many years, Dengue is still as a danger.

Objectives

- To examine the state wise spread of Dengue in India
- To examine the state wise death rate in India.
- To make comparison between states of India.

Review of Literature

- The research paper entitled "Dengue in India" by Nivedita Gupta, Sakshi shrivastava, Amita Jain, and Umesh Chaturvedi published in The Indian Journal of medical research 136 (3), 373-390, 2012. Explain the, Dengue disease creates highly complex Pathophysiological, economic and ecological problems. In India, many clinical efforts have been taken by the physicians to control Dengue, the paper also discussed about the scientific research and progress to control Dengue.



- The paper entitled, "India general health risks- Dengue" published in International Association for medical assistance to travelers. Discusses about the cause of Dengue, the risk of Dengue and the symptoms of the disease. It suggests the measures of prevention from the disease
- The paper by Anita chakravarti, Rohit Arora and christain Luxmberger entitled, "The transaction of the royal society of tropical medicine and hygiene reviewed the epidemiology of Dengue in India", also shows the picture of expansion of Dengue in last 50 years. It discusses about the medical efforts to prevent and control the disease. The paper mainly throws light on the reasons and strategy of the spread of the disease.
- The paper by Atanu Bhattacharji and Dibyojyoti Bhattacharji discusses about state wise ranking on the basis of the performance of the state dealing with death control. In this paper they tried to find out the real burden of the disease on the state via examining the death rate.
- The paper by Swati Sinha and co others entitled, "An Epidemiological study of Dengue and its co infections in Delhi." Explain the epidemiology of Dengue with reference to serological, demographic profile spatio-temporal distribution, vectors, circulating serotypes and co infections.

State / UT wise cases and deaths due to Dengue in India, 2014 to 2018 (P)

Sr. No.	State/UT	2014				2015				2016				2017				2018(P)			
		No. of Cases	%	No. of Deaths	%	No. of Cases	%	No. of Deaths	%	No. of Cases	%	No. of Deaths	%	No. of Cases	%	No. of Deaths	%	No. of Cases	%	No. of Deaths	%
1	Andhra Pradesh	1262	3.11	5	3.65	3159	3.16	2	0.91	3417	2.65	2	0.82	4525	2.61	0	0.00	4011	3.96	2	0.00
2	Arunachal Pradesh	27	0.07	0	0.00	1933	1.93	1	0.45	13	0.01	0	0.00	18	0.01	0	0.00	1	0.00	0	0.00
3	Assam	85	0.21	0	0.00	1076	1.08	1	0.45	6157	4.77	4	1.63	5024	2.67	1	0.31	166	0.16	0	0.00
4	Bihar	297	0.73	0	0.00	1771	1.77	0	0.00	1912	1.48	0	0.00	1854	0.98	0	0.00	2142	2.12	0	0.00
5	Chhattisgarh	440	1.08	9	6.57	364	0.38	1	0.45	356	0.28	0	0.00	444	0.24	0	0.00	2574	2.64	10	5.81
6	Goa	168	0.41	1	0.73	293	0.29	0	0.00	150	0.12	0	0.00	235	0.12	0	0.00	335	0.33	1	0.58
7	Gujarat	2320	5.72	3	2.19	5590	5.59	9	4.09	8078	6.22	14	5.71	4753	2.52	6	1.85	7579	7.49	5	2.91
8	Haryana	214	0.53	2	1.46	9921	9.93	13	5.91	2493	1.93	0	0.00	4550	2.42	0	0.00	1858	1.88	0	0.00
9	*Himachal Pradesh	2	0.00	0	0.00	19	0.02	1	0.45	322	0.25	0	0.00	452	0.24	0	0.00	4672	4.62	7	4.07
10	J & K	1	0.00	0	0.00	153	0.15	0	0.00	79	0.06	1	0.41	486	0.26	0	0.00	214	0.21	0	0.00
11	Jharkhand	36	0.09	0	0.00	102	0.10	0	0.00	414	0.32	1	0.41	710	0.38	5	1.54	463	0.46	1	0.58
12	Karnataka	3358	8.28	2	1.46	5077	5.08	9	4.09	6083	4.71	8	3.27	17644	9.47	10	3.08	4427	4.37	4	2.33
13	Kerala	2575	6.35	11	8.03	4075	4.08	25	11.36	7439	5.76	13	5.31	19694	10.61	37	11.38	4083	4.03	32	18.60
14	Madhya Pradesh	2131	5.25	13	9.49	2108	2.11	8	3.64	3150	2.44	12	4.90	2666	1.42	6	1.85	4506	4.45	5	2.91
15	Maharashtra	8573	21.13	54	39.42	4936	4.94	23	10.45	6762	5.26	33	13.47	7829	4.16	65	20.00	11011	10.88	55	31.98
16	Manipur	0	0.00	0	0.00	52	0.05	0	0.00	51	0.04	1	0.41	193	0.10	1	0.31	14	0.01	0	0.00

Source: Directorate of National Vector Borne Disease Control Program, Dte. GHS, Ministry of Health and Family Welfare

Data Analysis

2014

Odisha stood second in 2014 as the total numbers of cases were 6433 and the percent age share was 15.86 % and the death rate was 6.57 % in Odisha.

In Madhya Pradesh total numbers of cases were 2131 which was 5.25 % of total cases in the country but the death rate was 9.49 % which were very high.

In Kerala the total numbers of cases were 2575 which was 6.35 % of total number of cases in the country but death rate was 8.03 % in all over the country. It is also high.

Karnataka is performing well. The total numbers of cases were 3358 and the percent age share was 8.28 % and the death rate was 1.46 % in all over the country.

The case of Chhattisgarh was totally inversed from that of Karnataka as the total numbers of cases in Chhattisgarh were 440 and the percent age share was 1.08% while the death rate was very high. It was 6.57 % in all over the country.

The situation in Punjab was also likely to be same. The total cases were 472 which was just 1.16 % of total number of cases in the country while the death rate was high it was 5.84 %.

In Tamil Nadu, total cases were 2804 and % share was 6.9, and the death rate was 2.19 % in the state all over the country.

In Gujarat the total numbers of cases were 2320 and the % share was 5.72 while the death rate was 2.19.

During the five year analysis, in 2014, five major states in India where cases and death rates were highest were Maharashtra, Odisha, West Bengal, Karnataka and Tamil Nadu. In these states, numbers of Dengue cases were 8573, 6433, 3934, 3358 and 2804 respectively. It was also respective 21.13%, 15.86%, 9.7%, 8.28% and 6.91% of total cases in India. If we discuss about death due to Dengue in 2014 Maharashtra has total 54 deaths it is equal to 39.42% death in India.

2015

In 2015, cases in West Bengal doubled. The numbers of cases shot up to 8516. It was 8.52 % of total cases in India. Death rate was 6.36 %.

In 2015 Delhi came into highlight with total number of 15867 cases with 15.88 % of total cases of the country and 27.27 % death rate all over the country.

During 2015 there was a good control over the disease spread in Odisha with 2450 cases which was 2.45 % all over the country. Another thing to notice was reduced death rate which was 0.91 % all over the country.

In Punjab the situation was worsening. Total numbers of cases were 14128 which were 14.14 % in the country and death rate was 8.18 % all over the country.

In Karnataka total number of cases increased. They were 5077 which was 5.08 % of the total cases and death rate was 4.09 %.

In Kerala the total numbers of cases were increased and became 4075 with 4.08 % in India. Death rate was 11.36 which are very high.

In Maharashtra total numbers of cases decreased but were still very high with 4936 cases which were 4.94 % of total cases and the death rate were very high it was 10.45 % of total death in the country.

In Gujarat the numbers of cases were 5590 which was 5.59 % of total cases in the country and the death rate was 4.09 %.

2016

In 2016, in Assam, the total numbers of cases were 6157 which was 4.77 % of total cases in the country and the death rate was 1.63 %.

In Gujarat the total numbers of cases were 8028 which was 6.22 % of total cases in the country and death rate was 5.71 % in the country.

In Karnataka total numbers of cases were 6083 which was 4.71 % of total number of cases and death rate was 4.71 %.

In Kerala total number of cases was 7439 which was 5.76 % of total cases and the death rate was 5.31 %.

In Maharashtra total numbers of cases were 6792 which was 5.26 % of total cases and death rate was 13.47 of total death in the country.



In Odisha total numbers of cases were 8380 which was 6.49 % of total cases and death rate was 4.49 % of total death in the country.

In Punjab total numbers of cases were 10439 which were 8.08 % of total cases in the country and the death rate was 6.12 % of total number of death in the country.

In Uttar Pradesh total numbers of cases were 15033 which were 11.64 % of total cases and death rate was 17.14 % of total death in the country.

In West Bengal the total numbers of cases were 22865 which were 17.70 % of total cases in the country and death rate was 18.37 % which is highest among all the states.

The cases in Delhi had decreased compared to 2015.

2017

In 2017, in Karnataka there were 17844 cases of the disease which was 9.47 % of total cases in India and death rate was 3.08 % here we can notice that Karnataka has a big jump in the number of cases in compare to 2016. It is also remarkable that in Karnataka the death rate control was very good.

In Kerala the numbers of cases were 19994 which were 10.61 % of total numbers of cases and death rate was 11.38 %. In compare to 2016, in this state the number of cases doubled.

In Maharashtra total cases were 7829 which was 4.16 %. The total number of cases did not increase much but the death rate was very high in this state. It was 20 % of total deaths due to the disease.

In Punjab the total numbers of cases were 15398 which were 8.17 % of total cases and the death rate was 5.54 %.

In Tamil Nadu total numbers of cases were 23294 which were 12.36 % of India and death rate was 20 % which was very high.

In Uttar Pradesh total numbers of cases were 3092 which was 1.64 % and death rate was 8.62 % all over the country.

In West Bengal total cases were 37746 which were 20.03 % of total cases in the country and death rate was 14.15 % of the total death rate in the country. It shows that the cases are increased in compare of 2016 in this state.

In Delhi total numbers of cases were 9271 which was 4.92 % of total cases in the country and the death rate was 3.08 %.

2018

In 2018, total numbers of cases were 7575 in Gujarat which was 7.49 % of total cases in the country and death rate was 2.91 % of the country.

In Maharashtra total number of cases jumped to 11011 which was 10.88 % of total cases in the country and death rate was 31.98 which were very high. Both, the cases and death rate increased in Maharashtra compared to 2017.

In Punjab total numbers of cases were 14980 in Punjab which was 14.80 % of total cases of the country and death rate was 5.23 % of the country. There is a decrease in both, the total cases and death rate.

In Rajasthan total numbers of cases were 9587 which was 9.47 % of total cases in the country and death rate was 5.81 % of the country.

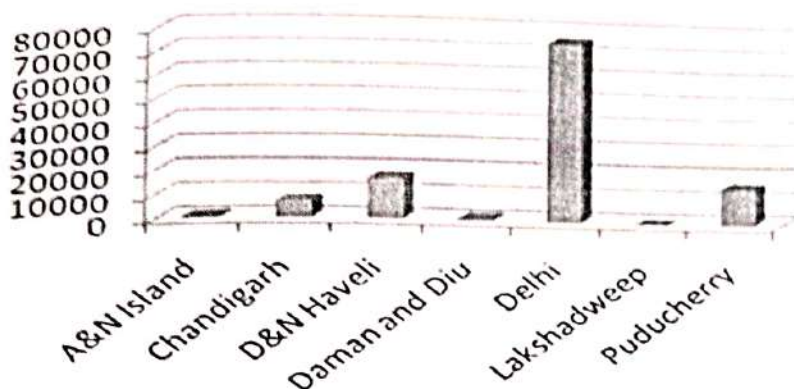
In Delhi total numbers of cases were 7136 which was 7.05 % of total cases and death rate was 2.33 % of India. Compared to 2017, the total number of cases and death rate decreased in Delhi in 2018.

Total number of Dengue cases in Union territory (2014-2018)

Sr. No.	UT	Total No. of Cases during 2014 to 2018
1	A&N Island	902
2	Chandigarh	7302
3	D&N Haveli	17026
4	Daman and Diu	1044
5	Delhi	75400
6	Lakshadweep	0
7	Puducherry	15486



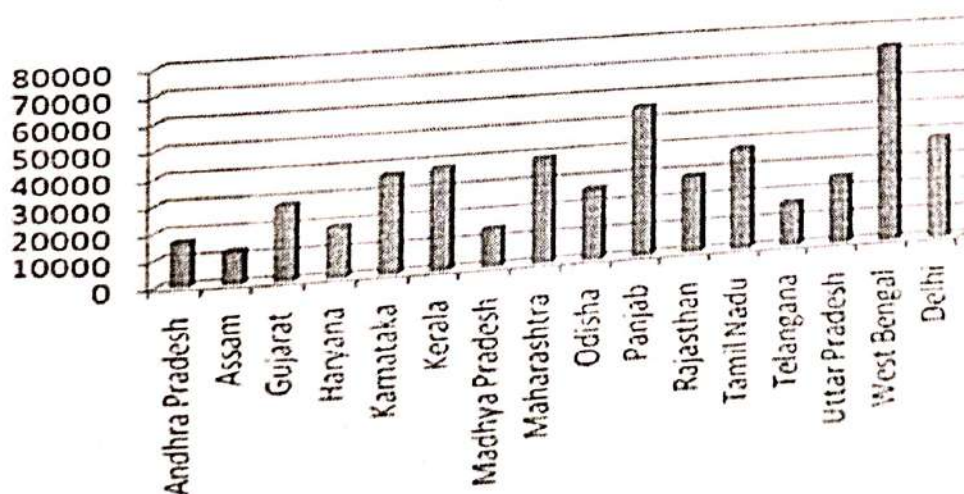
TOTAL NO. OF CASES DURING 2014 TO 2018 IN UT



■ TOTAL NO. OF CASES
DURING 2014 TO 2018

Sr. No.	State	Total No. of Cases during 2014 to 2018
1	Andhra Pradesh	33548
2	Assam	25016
3	Bihar	15952
4	Gujarat	56540
5	Haryana	38152
6	Himachal Pradesh	10934
7	Karnataka	73578
8	Kerala	76332
9	Madhya Pradesh	29122
10	Maharashtra	78282
11	Odisha	53238
12	Panjab	110834
13	Rajasthan	57184
14	Tamil Nadu	75300
15	Telangana	33066
16	Uttarakhand	10890
17	Uttar Pradesh	50092
18	West Bengal	146122

TOTAL CASES



■ TOTAL CASES



Sr. No.	Year	Total Cases of Dengue in India
1	2014	40571
2	2015	99913
3	2016	129166
4	2017	188401
5	2018(P)	101192

Conclusion

During the five year of analysis, 16 states exceeded more than 10,000 cases. Highest cases were in West Bengal. There were more than 60,000 during 2014 to 2018. Punjab is on second position during the time period.

Delhi, Maharashtra, Tamil Nadu, Rajasthan, Uttar Pradesh, Odisha, Kerala, Karnataka, and Gujarat had more than 20,000 cases during the time period.

Haryana, Madhya Pradesh, Telangana had more than 10,000 cases during the time period.

It was remarkable that no cases were registered in Lakshadweep during 2014 to 2018.

There were ups and downs in the number of cases in the most affected states. The major task was to control the death rate and prevent the spread of Dengue. Government is working to control the spread of the disease, but it not enough for the Government to work; the support of people plays an important part too. We should be aware and take precautions to stop the further spread of Dengue.

We must keep our surroundings clean and tidy, nor should we leave stagnant water around our residence. We should light diya with cow ghee and Camphor every evening in our home which stops the entry of mosquitoes in home. We should keep wet garbage separate and should destroy it timely.

In rainy season, the chance of spread of Dengue is higher and we must be more careful during the season. We should wear clothes that can cover our full body. We must close the doors and windows at evening. We should also take responsibility for our society. We must follow the rules of cleanliness.

We should follow the slogan, "*Be Healthy and Make Healthy*". It is very important to control and prevent the disease.

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DENGUE IN WEST BENGAL

Dr. Vandana G. Trivedi*

ABSTRACT

Dengue is a communicable disease that spreads by the bite of mosquito. After Second World War, dengue started spreading actively across the world. India is also facing this problem. Mortality rate of Dengue is also high in India. During the year of 2014 - 2018, the cases of dengue skyrocketed to be the highest in West Bengal compared to all the other states of India. In this paper, we will discuss about the spread of Dengue in West Bengal through 'district - wise statistical data'. The paper will also point out the data about district-wise number of cases of Dengue during the year 2012 - 2016, as well as mortality rate of Dengue during the same year, in India. We will compare the change in the number of total cases of Dengue during this time period. Also this paper will provide us the data regarding the rapid spread of Dengue in various regions. This study indirectly highlights the major efforts of the district to control the spread of disease.

Keywords: Dengue, Disease, State Wise, Death.

Introduction

Dengue is a serious disease. In India the spread of this disease is very fast. In my paper "Dengue in India" I discussed about the rapid spread of this disease in India and also discussed about the majorly affected states. I found that in West Bengal, the spread of the disease is very high. In this paper I have discussed about the condition of West Bengal. The number of cases of this disease and number of death in various districts of the state have been taken for this study.

Objectives

- To examine the district wise spread of dengue in West Bengal.
- To examine the district wise Mortality rate due to Dengue in West Bengal.
- To make comparison between districts of West Bengal.

Review of Literature

The paper published in Pub Med.gov written by A.K. Hati explains that Dengue occurred all over West Bengal, starting in 2005. The data was collected from various sources including Calcutta School of Tropical Medicine and Government of West Bengal. The study includes three years for investigation, 2005, 2006, and 2007. The cases were high in 2005 in the state. Highest cases were found in Kolkata. The cases were drastically reduced during 2006 and 2007.

The article written by Debjani Taraphdar, Arindam Sarkar, Bansi B. Mukhopadhyay and Shyamendu Chatterjee, published in The American Journal of Tropical Medicine and Hygiene, Volume-86, Issue - 4 discusses that people in West Bengal getting affected by dengue with chikungunya. Total 550 blood samples were taken to and investigated for the same. The paper shows that, in West Bengal not only Dengue but Chikungunya is also an emerging problem. It discusses about the common symptoms which appear in the patients affected by both Dengue and Chikungunya.

A research paper written by Minubharti and Dhiraj Saha published in PlosOne writing center discusses about the seriousness of the disease. The paper suggests the government to take strong action to prevent the rapid spread of the disease. Proper integrated vector management action is very needful in West Bengal.

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A paper published by Falguni Debnath, Manickam Ponniah, and Pralay Acharya, discusses about the situation of Baranagar municipality of North -24 parganas district of West Bengal. Six hundred and Seventy One cases were observed out of Thirty Four wards. They observed that all age groups were affected. In this paper, various symptoms of the disease were noticed. The paper recommended control measures. The study covers the time period of 2012 to 2015. They confirm outbreak and find out potential breeding sources.

Table 1: Reported cases of Dengue / DHF in West Bengal (2012 – 2016)

Sr. No.	District	2012		2013		2014		2015		2016		Total	
		Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths
1	Alipurduh												
2	Bankura	246	0	76	0	37	0	64	0	16	0	16	0
3	Birbhum	13	0	5	0	13	0	89	0	373	1	796	1
4	Bardhaman	169	0	89	1	64	0	129	1	442	1	562	1
5	Koch Bihar	4	0	0	0	4	0	26	0	480	0	931	2
6	Dakshindinajpur	23	0	93	0	55	0	72	0	37	0	71	0
7	Darjeeling	28	0	3560	1	190	0	65	0	1321	1	1564	1
8		243	0	27	0	145	1	138	1	165	0	4008	1
9	Haora	326	0	64	0	226	0	850	2	2160	1	2713	3
10	Jalpaiguri	31	0	760	0	35	0	82	0	2237	6	3703	8
11	Kolkata	3361	11	703	0	1741	2	3610	1	168	0	1076	0
12	Malda	129	0	20	0	42	0	109	0	1063	4	10478	18
13	Murshidabad	177	0	48	0	100	0	140	0	412	0	712	0
14	North 24 – parganas	750	0	216	2	815	0	2254	7	1070	0	1535	0
15	Nadia	405	0	23	0	78	1	118	1	8250	26	12285	35
16	PaschimMedinipur	155	0	64	0	59	0	137	0	1564	0	2188	2
17	PurabMedinipur	111	0	17	0	124	0	167	0	629	0	1044	0
18	Puruliya	4	0	5	0	5	0	4	0	424	1	843	1
19	South 24 – parganas	238	0	79	0	162	0	310	1	39	0	57	0
20	Uttar dinajpur	8	0	9	0	11	0	48	0	1722	2	2511	3
21	Other States	35	0	62	0	38	0	104	0	87	0	163	0
										206	0	445	0

Source: <https://www.wbhealth.gov.in/>

Table 2: Major districts of West Bengal affected by Dengue

Sr. No.	District	2012		2013		2014		2015		2016		Total	
		Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths
1.	Dakshin	23	0	93	0	55	0	72	0	1321	1	1564	1
2.	Darjeeling	28	0	3560	1	190	0	65	0	165	0	4008	1
3.	Hugli	243	0	27	0	145	1	138	1	2160	1	2713	3
4.	Haora	326	0	64	0	226	0	850	2	2237	6	3703	8
5.	Jalpaiguri	31	0	760	0	35	0	82	0	168	0	1076	0
6.	Kolkata	3361	11	703	0	1741	2	3610	1	1063	4	10478	18
7.	Murshidabad	177	0	48	0	100	0	140	0	1070	0	1535	0
8.	North 24 –parganas	750	0	216	2	815	0	2254	7	8250	26	12285	35
9.	Nadia	405	0	23	0	78	1	118	1	1564	0	2188	2
10.	Paschim Medinapur	155	0	64	0	59	0	137	0	629	0	1044	0
11.	South 24 – parganas	238	0	79	0	162	0	310	1	1722	2	2511	3

District	2012	2013	2014	2015	2016
Dakshin	23	93	59	72	1321
Darjeeling	28	3560	190	65	165
Hugli	243	27	145	138	2160
Haora	326	64	226	850	2237
Jalpaiguri	31	760	35	82	168
Kolkata	3361	703	1741	3610	1063
Murshidabad	177	48	100	140	1070
North 24 – parganas	750	216	815	2254	8250
Nadia	405	23	78	118	1564
PaschimMedinapur	155	64	59	137	629



South 24 – parganas	238	79	162	310	1722
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Table-3

Dengue cases in Dakshin

2012	
2013	
2014	23
2015	93
2016	55
	72
	1321



Table 4

Dengue cases in Darjeeling	
2012	28
2013	3560
2014	190
2015	65
2016	165

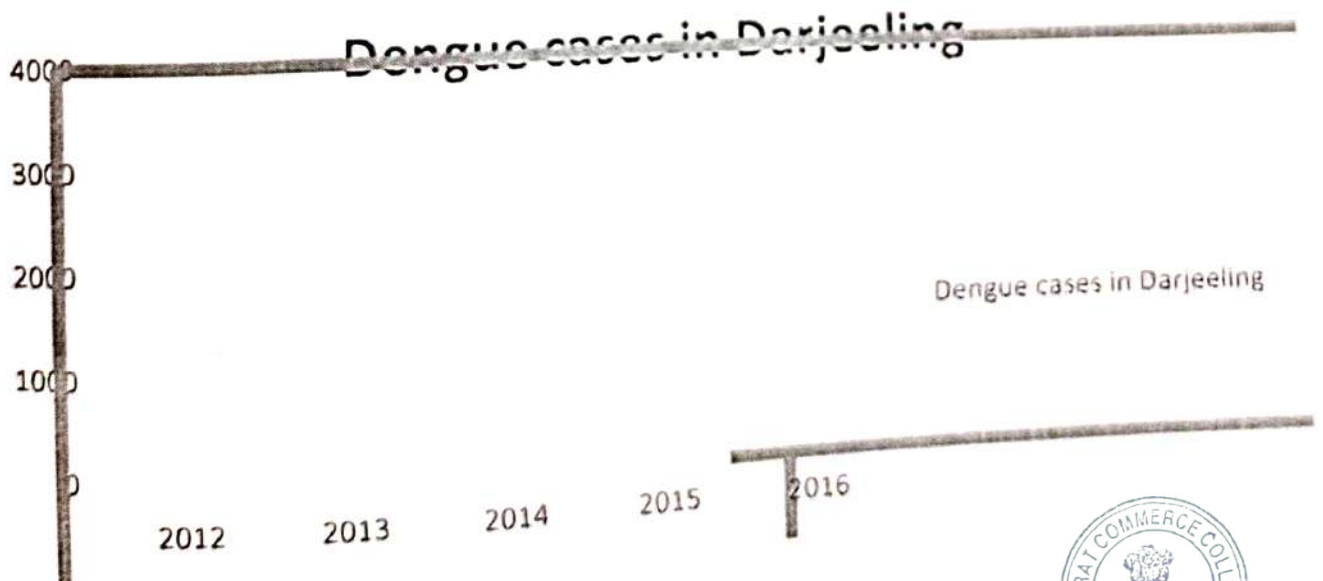


Table 5

Dengue cases in Hugli

2012	
2013	243
2014	27
2015	145
2016	138
	2160

Dengue cases in Hugli

2500
2000
1500
1000
500
0

2012 2013 2014 2015 2016

Dengue cases in Hugli

Table 6

Dengue Cases in Haora

	326
2012	64
2013	226
2014	850
2015	2237
2016	



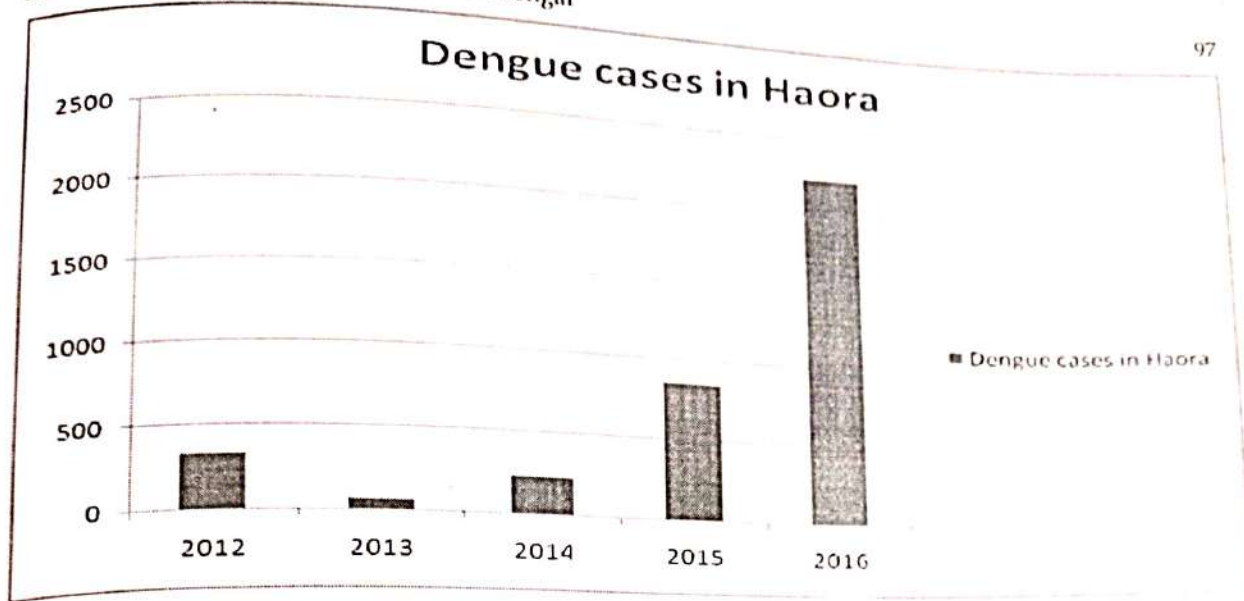


Table 7

Dengue cases in Jalpaiguri

Year	Dengue cases in Jalpaiguri
2012	31
2013	760
2014	35
2015	82
2016	168

Dengue cases in Jalpaiguri

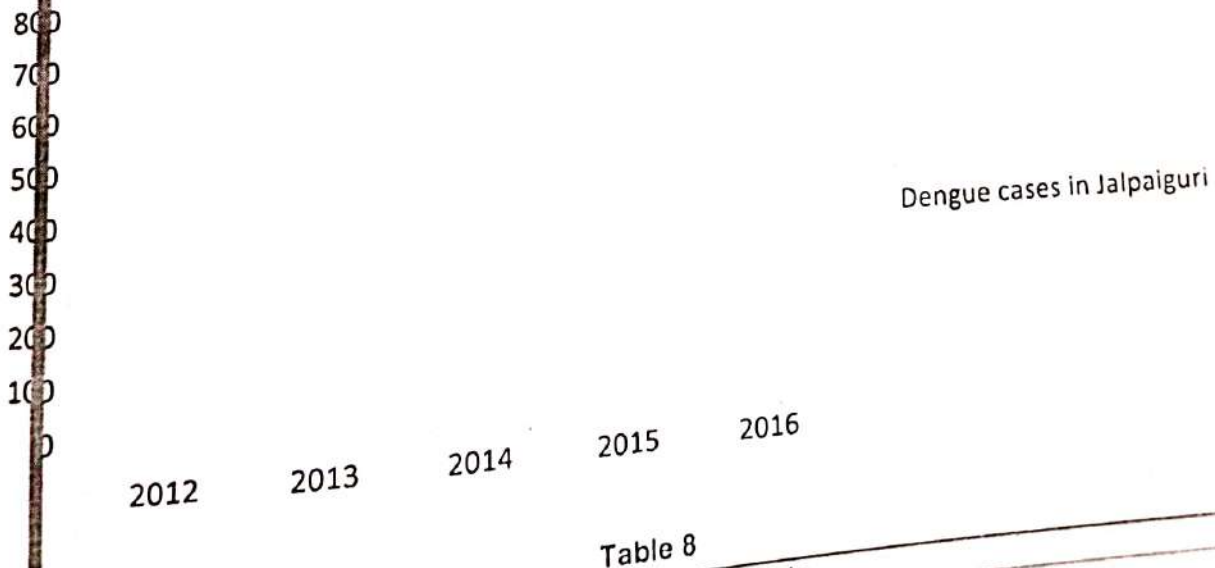


Table 8

Dengue cases in Kolkata

Year	Dengue cases in Kolkata
2012	3361
2013	703
2014	1741
2015	3610
2016	1063





Table 9

Dengue cases in North 24 - parganas	
2012	750
2013	216
2014	815
2015	2254
2016	8250

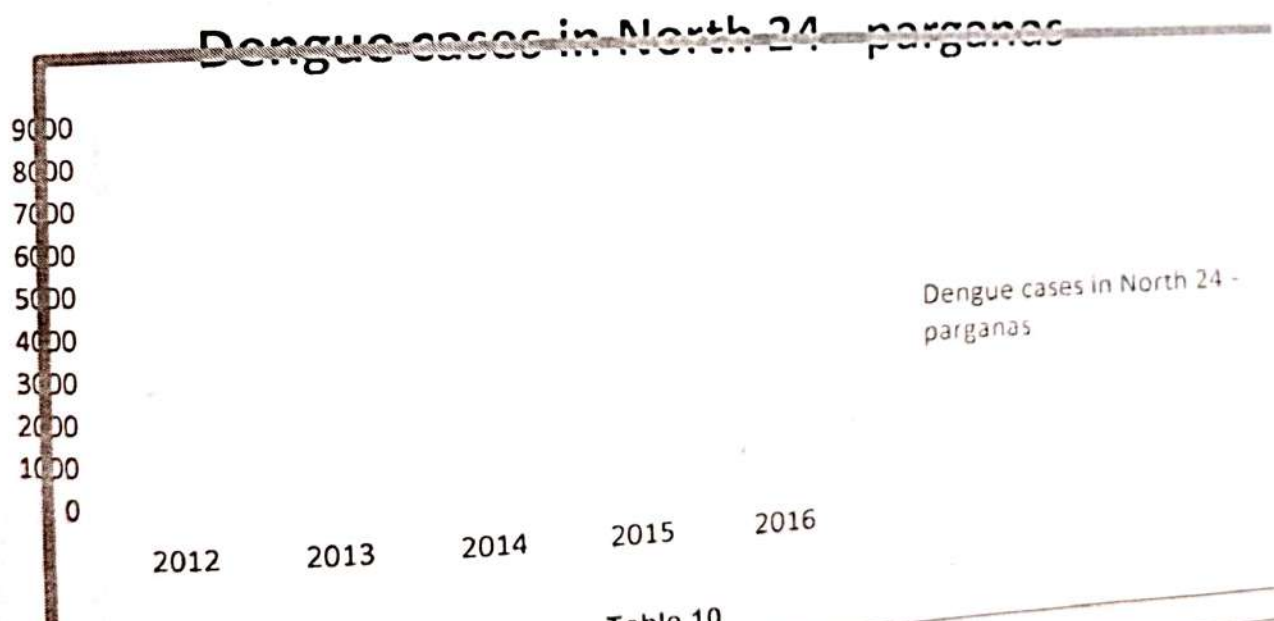


Table 10

Dengue cases in Nadia	
2012	405
2013	23
2014	78
2015	118
2016	1564



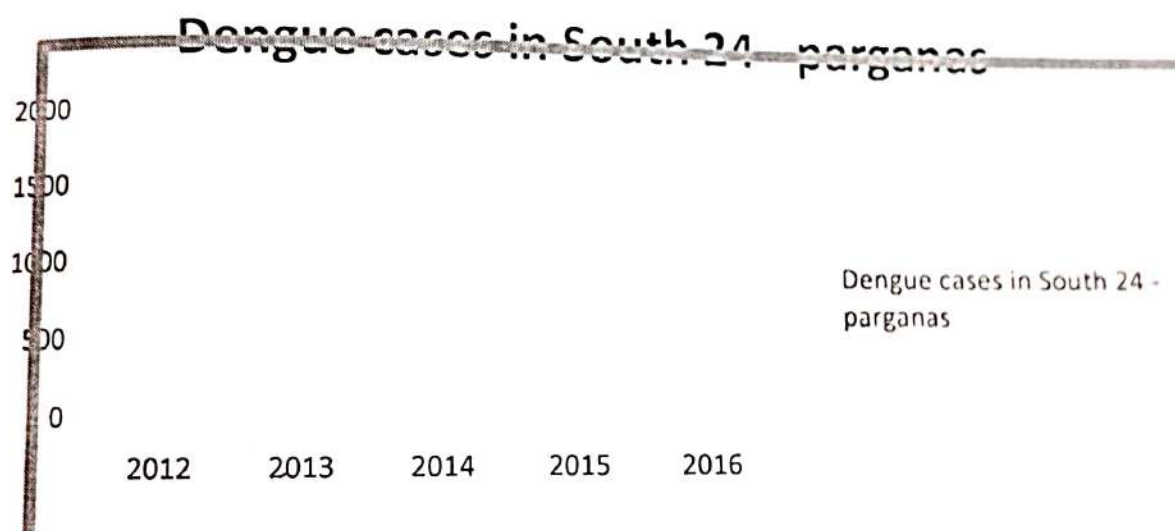
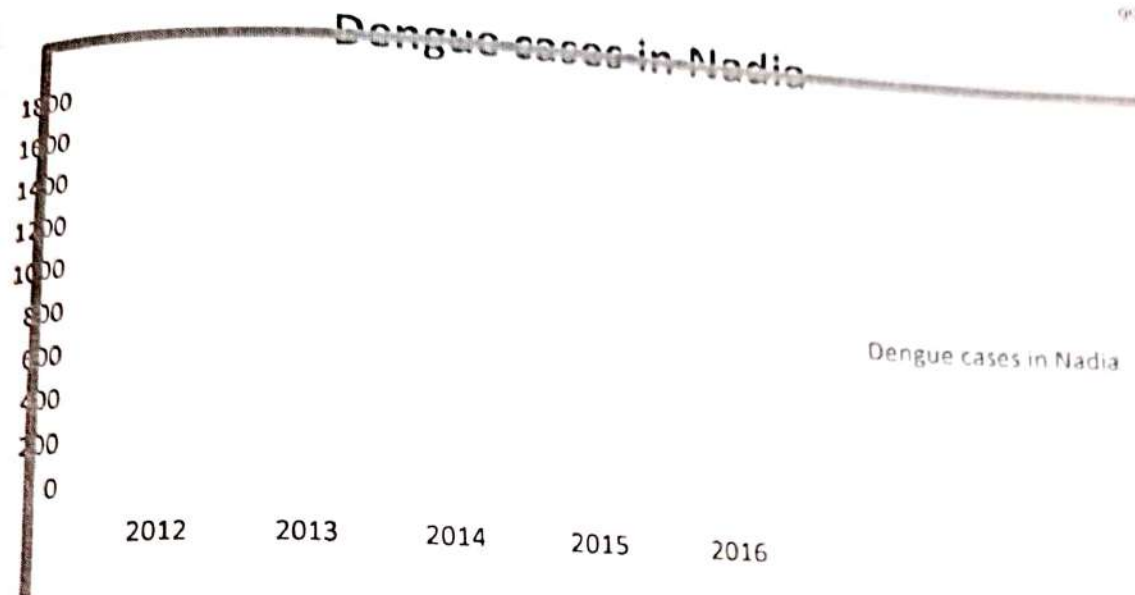


Table 11: Dengue cases in South 24 - parganas

2012	238
2013	79
2014	162
2015	310
2016	1722

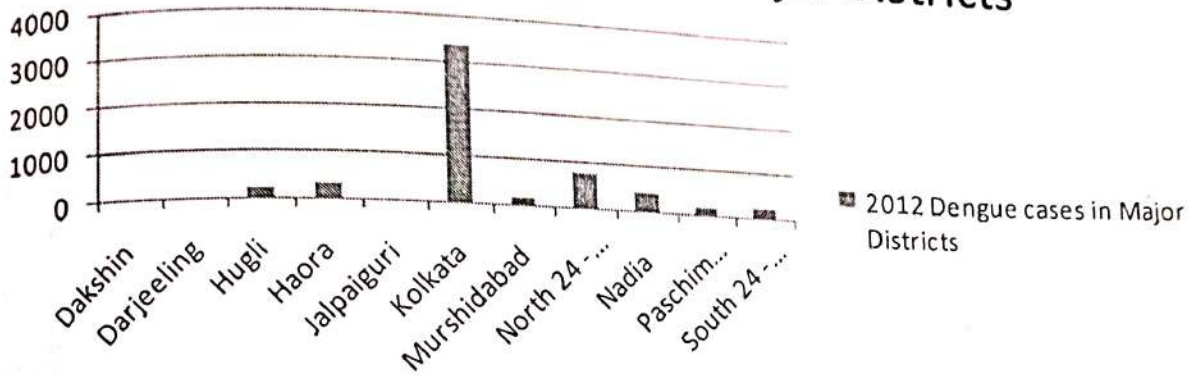
Table 12 : 2012 Dengue cases in Major Districts

Districts	2012 Dengue cases in Major Districts
Dakshin	23
Darjeeling	28
Hugli	243
Haora	326
Jalpaiguri	31
Kolkata	3361
Murshidabad	177
North 24 - parganas	750
Nadia	405



PaschimMedinapur	155
South 24 – parganas	238

2012 Dengue cases in Major Districts



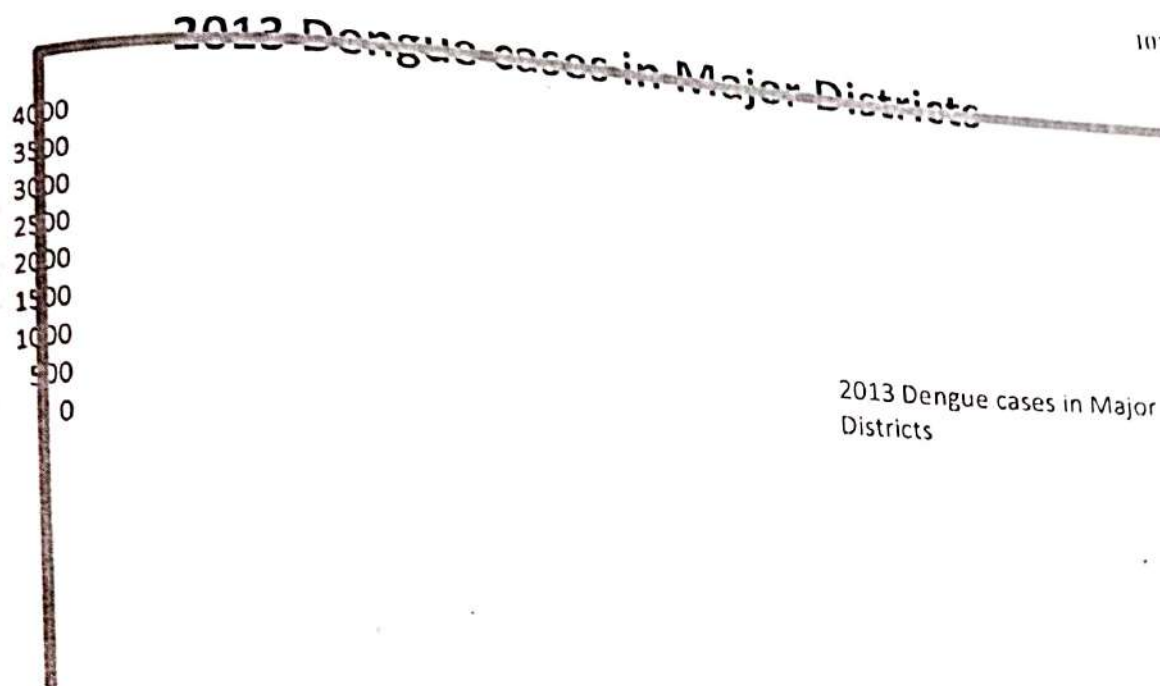
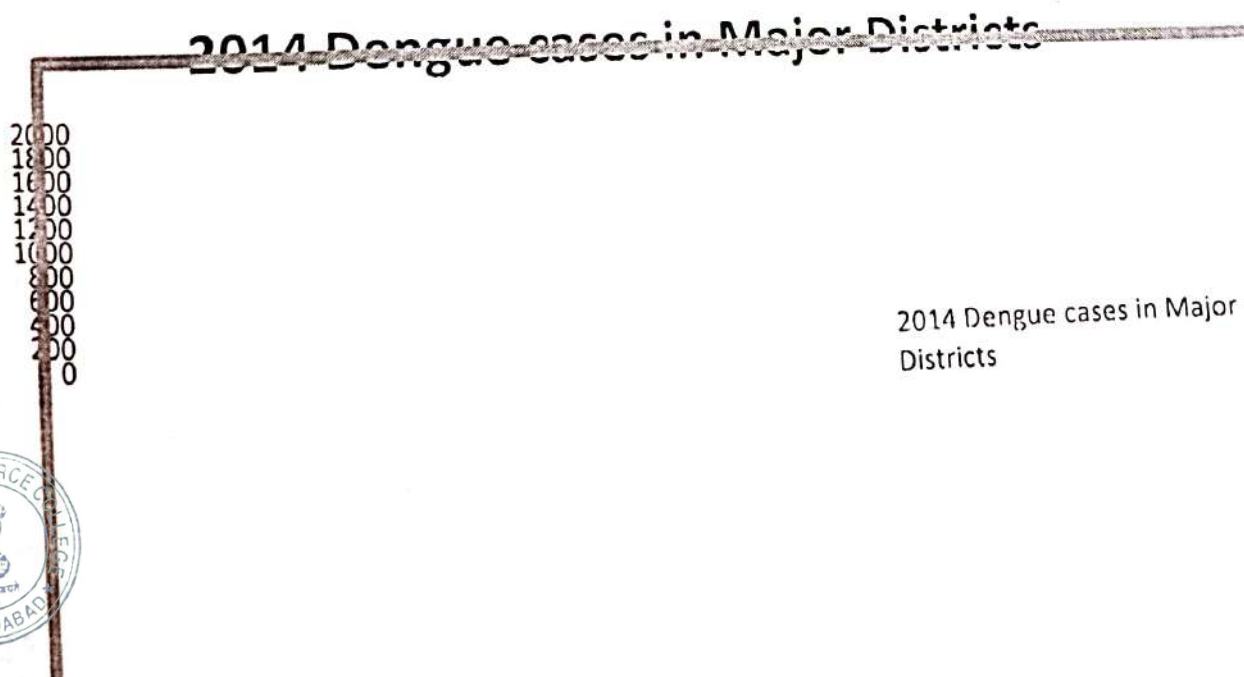


Table 13 : 2013 Dengue cases in Major Districts

Districts	2013 Dengue cases in Major Districts
Dakshin	93
Darjeeling	3560
Hugli	27
Haora	64
Jalpaiguri	760
Kolkata	703
Murshidabad	48
North 24 - parganas	216
Nadia	23
PaschimMedinapur	64
South 24 - parganas	79



2014 Dengue cases in Major Districts



Table 14 : 2014 Dengue cases in Major Districts

Districts	2014 Dengue cases in Major Districts
Dakshin	55
Darjeeling	190
Hugli	145
Haora	226
Jalpaiguri	35
Kolkata	1741
Murshidabad	100
North 24 – parganas	815
Nadia	78
PaschimMedinapur	59
South 24 - parganas	162

~~2015 Dengue cases in Major Districts~~

4000
3500
3000
2500
2000
1500
1000
500
0

2015 Dengue cases in Major
Districts



Table 15: 2015 Dengue cases in Major Districts

Districts	2015 Dengue cases in Major Districts
Dakshin	72
Darjeeling	66
Hugli	138
Haora	850
Jalpaiguri	82
Kolkata	3610
Murshidabad	140
North 24 – parganas	254
Nadia	118
PaschimMedinapur	137
South 24 - parganas	310

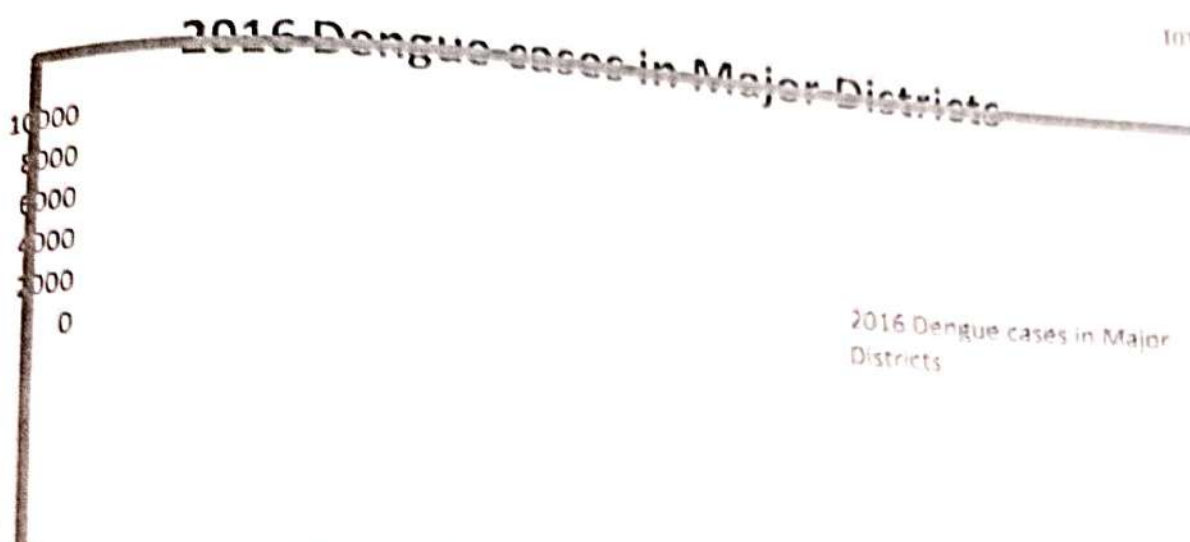


Table 16 : 2016 Dengue cases in Major Districts

Districts	2016 Dengue cases in Major Districts
Dakshin	1321
Darjeeling	165
Hugli	2160
Haora	2237
Jalpaiguri	168
Kolkata	1063
Murshidabad	1070
North 24 – parganas	8250
Nadia	1564
PaschimMedinapur	629
South 24 - parganas	1722

Table-1 shows the total cases and death due to Dengue, district wise during 2012 to 2016. Among the district of West Bengal, some districts were more affected by the disease. Dakshin, Darjeeling, Hugli, Haora, Jalpaiguri, Kolkata, Murshidabad, North-24 parganas, Nadia, Paschim medinipur and South-24 parganas had maximum cases of Dengue during the time period. This is showed in table-2.

Table-3 discusses the situation of Dakshin district. In this district the effect of the disease was highest in the year of 2016. Table-4 shows the situation of Darjeeling district it was affected badly in the year of 2013. Table-5 shows that Hugli district had maximum cases of Dengue in 2016. In table-6 the situation of haora district is given. The district had maximum cases in the year 2015, which were increased in 2016. Table-7 shows the picture of jalpaiguri district. The most cases were in the year of 2013. Table-8 shows the situation of Kolkata district. The situation of this district is very bad during the study years. Maximum cases were registered in the year of 2015. The situation in 2012 was also not good but during 2013 and 2014 the cases were decreased but again in 2015 the cases were increased rapidly which can get controlled in 2016.

Table-9 shows the picture of North-24 parganas. The cases were highest in the year of 2016. Table-10 shows the situation of Nadia district. The cases were highest in the year of 2016 in this year. Table-11 shows the situation of South-24 parganas. In this district the cases were highest in the year of 2016.

Conclusion

Among the 21 district, 11 districts are found to be most affected district by Dengue. In 2013, maximum cases of the disease were found in Darjeeling district. In 2014 Kolkata had maximum numbers of cases. In 2015 again Kolkata district found being most affected district of the state. In 2016, North- 24 parganas were affected maximum by Dengue.



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COLLABORATIVE ENVIRONMENT IN WORLD CLASS UNIVERSITY

Dr. Vandana G. Trivedi*

ABSTRACT

Development is the ultimate goal of each country of the world. To achieve the goal country applies various kinds of policies. Education is the most important part of social infrastructure. Higher Education plays very important role in the process of development of the young minds and make them able to think innovatively. Prepare them to be able to step-up with changing global scenario. Collaboration is a powerful way to bring magical changes in the standard of higher education. In present era Higher Education is facing many challenges. To upgrade a university on the level of world Class University is quite challenging task. The teachers of university and colleges must make continuous changes to be with the increasing need of change in their field. Student also makes their selves aware to acquire the changing scenario. Collaborative environment promotes the overall development of the university. In teaching institution majorly working style is common. This could be make innovative through collaborative practices. Collaborative practices promote innovative teaching techniques. Collaboration put force to come out of the comfort zones to the students and teachers. It promotes healthy environment among the students. Collaborative environment only became fruitful when the faculties get fully involved in the innovative practices.

Keywords: Collaborative, Environment, World Class University, Higher Education, e-Professionals.

Introduction

In collaborative Environment, teachers/ professor adapt new techniques of teaching. Work regardless of their own cultural or geographic environment. Majority of E- professionals use a collaborative working methods as they provide and share information regarding their profession.

Collaborative Environment in World Class University

Higher education is facing various kinds of challenges worldwide. It is a big challenge to set up Higher Education institute as capable to establish as a world class University. To fulfill the need of becoming world class the University should accept collaborative teaching environment. There is a continuous and rapid change in the field of Higher Education. To fulfill the objective of making a world class University. The faculties need to develop their caliber continuously. On the other hand, Higher Education institute has very limited resources for this purpose.

What is collaboration?

World Class Universities follows Collaborative techniques and creates collaborative teaching environment in their institution. The main question is here that why the Universities and teachers need to promote Collaboration. "an effective interpersonal process that facilitates the achievement of goals that cannot be reached when individual professionals act on their own" (Bronstein 2003, 299). In collaborative teaching environment everyone works together keeping the same goal in their mind. They convey their ideas and thoughts.

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Benefits of Collaborative Environment:

It promotes students to work together, we can also define it that to learn with the team, by co-operation of each other. In this teaching method, students provide mutual support to each other and assist to learn more and to understand the concept and idea. A teacher encourages the students for work in a team, this way a team spirit develops in the students and it will be very useful to them in their future. A study on the effect of collaborative teaching on students with disability shows the result that collaboration in teaching was highly effective and it leads towards success in the students with disabilities. (Margo A. mastropieri, 2005) It gives the chance to teacher and student to exchange their ideas. This method can be useful to bring the weak students on the same platform. The powerful and more active students can help them to clear the confusion. A survey was held and two third of teacher's report that they believe that more collaboration among teachers would greatly improve student's achievement. (Met Life, 2010). The teacher exchanges their ideas and thoughts about new teaching techniques and ideas this way collaborative teaching is very useful for effective teaching. (Vandana)

When collaboration is becoming successful?

In the method of collaborative learning some key elements are very important. First of all, the participants of the collaborative techniques or methods should have trust on each other (Kozza and Lewin 1998; Kelly, Schaan and Joncas 2002). If there is an environment of non-trust and rivalry, it will not get suitable for collaborative environment. When one of the partner has fear of being exploited, he/she will definitely not give their full contribution. Both the institution or individual must have trust on each other for an effective collaborative environment. Some studies show that the partners who have already worked together in past, have a good trust on each other and can work more effectively with each other (Cohen and Levinthal 1990). To bring out trust between two institution or individual quality based and frequently done communication is very useful. (Mohr and Spekman 1994) When all the participants of the collaborative work from a similar set of mind and similar circumstances it is become more fruitful. The responsibility to rich to the goal should be shared within all the participant so that they can work together without feeling over burden, and can participate fully in the process if the whole process is divided in some steps, it will be easy to put in practice the whole process. It should be divided like this,

- a shared vision,
- clearly defined goals,
- an agreed-upon mission and strategy,
- all parties engaged in the decision-making process,
- the ability to compromise (Bronstein 2003).

In the beginning of a collaborative work clarity of vision must be there. Everyone should aware about the goal. The plan and strategy of work should be clear in every one's mind. Everyone should get involved in the process of decision making process. Every one consider the work as their personal work and give their hundred percent efforts.

According to professor Hsiou Hsia Tai, National Chiao Tung University, some of the important features of world class universities are [<http://www.shanghairanking.com/wcu/wcu1/Tai.pdf>]

- World Class Universities are mostly public Universities. US is an exception of it because in US public and private both Universities are in the list of World Class University.
- The World Class Universities offers a wide range of Subjects.
- Research work of the University is Made It World Class University
- World Class Universities works in the area of Bio-medical and provide eminent research in this field majority of the World Class Universities have their medical colleges. Thus the university could do something more and different from other institution.

These are the basic characteristics of world Class University. Basically the World Class Universities are rich in the Infrastructure, they have best facilities and sufficient teaching as well as administrative staff. They offer variety of courses. The strongest point is, these Universities provide outstanding research in various field.

Collaboration Strategy and Methods in World Class University

To achieve the level of World Class University, the institute applies different kind of methods and practices of Collaboration.



- Commentating: World class universities select the method of co mentoring. In this method they give opportunity to junior faculty and senior faculty to work together. In this method they have chance to learn many things from each other.
- Scholarly consultation grants: Consultation
- Support for collaborative research.
- Research/student assistants. Beneficial collaborations are not always between faculty peers
- Field/interest-based conferences and workshops.
- Support for intellectual community.
- Leadership development

Challenges

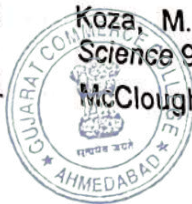
In the process of collaboration between two institutes or Individual some challenges also take place. Conflict difference in opinion is much common. It is a big challenge indeed to keep harmony and work together with different mind sets and ideas, but to achieve the benefit of collaborative teaching learning an Individual or Institute must develop the virtue of working together and maintain harmony. After all this is the main thing someone has to develop during the process of collaboration.

Conclusion

Institutions/ Individual has a very good tool of learning/teaching in the form of collaboration with the help of it they can develop their professional abilities. The process teach them strong coordination. In this process many new ideas and point of view can be shared with each other and everyone has the opportunity to work effectively. The entire teaching community has a golden opportunity of development in this process.


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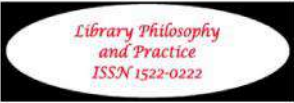
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Digital Preservation of Library Resources: Strategic planning a Management perspective

Digital Preservation of Library Resources: Strategic planning A Management perspective

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Abstract

Our cultural heritage has been presented on many different materials, including stone, vellum, bamboo, silk, paper and etc. these all materials for information storage had been found in physical medias. That time the attention had been focused only on preserving physical media. Now a day a variety of information exists in digital forms, including emails, blogs, social networking websites, national elections websites, web photo albums, etc. US Library of Congress, had reported(1998) that 44% of the sites available on the internet. It means technology help us to access the cultural heritage from storage of digital memory. However technology creates some opportunity as well as raise challenges also. Libraries and information professionals are now being challenged by new technology; Like multimedia, internet, www, and other virtual computer technology. The environmental, legal, ethical and technological challenges create some major issues to retrieve and preserve the digital information. So the responsibility of librarian and information technology professionals has been wider. The paramount need is to create a well-organized digital preservation strategy for modern library. The researchers have tried to define digital preservation of library resources. The present paper flew the light on the challenges of digital preservation and recommends the suitable strategy implement for digital preservation. They also focus on proposed model for strategic planning for digital preservation.

Keywords:

Preservation, Digital Preservation, Challenges- Ethical, Political, Economical, Technical and Legal, Strategy for digital preservation , Proposed Model for Strategic Planning for Digital Preservation

Introduction:

The rapid growing technology has paved a revolutionary change in Library & information technology. Day by day information has taken place from physical media to digitized form. So, it is essential to know how to prevent it. Information created, stored and access digitally is at risk for loss in two important ways; obsolescence and physical damage. Obsolescence can affect hardware, software and even the arrangement of the data in a stored file. Physical damage can occur to multiple components required to access digital



information, namely hardware and media. Digital preservation seeks to achieve longevity of the digital object with all its original properties intact. The issue of long term preservation of digital data has become a critical issue with many diverse groups and organisations recognizing the need to preserve digital documents before they fall victim to digital obsolescence.

Scope of the paper

This paper seeks to address what is digital preservation. It focuses issues related to digital preservation like; environmental, ethical and legal. The issues covered in three steps. The first step is an overview of the background to preserving digital resources that has developed in response to the concerns of digital and research libraries. The second step will assess the challenges and the third will consider recommended mechanisms for libraries to develop strategies that support the long term retention of digitised data. The researchers have discussed on proposed model for strategic planning for digital preservation. The paper also highlights some policy matters on digital preservation. Researchers also tried to provide some historical background on digital preservation.

LITERATURE REVIEW

Digital preservation means, “the process of maintaining in a condition suitable for use, materials produced in digital format.(veer, 2009).

Digital preservation aims at taking steps to ensure the longevity of electronic documents. It applies to document that are either born digital and stored in online platform or CD/DVDs . it means digital preservation needs high range of strategic planning. There has been concern about preservation of primary research data and records in digital formats in the library community internationally as early as in the 1990s. In 1996 the Commission of Preservation and Access (CPA) and the Research Libraries Group (RLG) in the USA



published a joint report on *Preserving digital information* which identified problems, made recommendations and suggested areas for further research (Garrett et.al, 1996). In the UK, in November 1995, the Joint Information System Committee (JISC) of the Higher Education Funding Councils and the British Library addressed the question of the preservation of digital media by holding a national conference in Warwick, where a number of action points were identified (Fresco, 1996).

Since then extensive studies and collaborative efforts on preservation of digital data and records were undertaken by the library, archival and publishing communities in the UK. The first study (Bennett, 1997) developed a framework of data types and formats, in order to indicate the likely problems, requirements and responsibilities appropriate to each category, and to identify the most appropriate method of preservation.

The literature suggests that, within the Asia and Southeast Asian region, centralized data archives are yet to be established.

CASE STUDIES HAVE BEEN CARRIED OUT ON DIGITAL PRESERVATION IN VARIOUS PALCES OF UNITED KINGDOM:

DORSET HISTORY CENTRE

This case study discuss A local governments archive service, and its use of Preservica Cloud Edition - a cloud-based digital preservation service. It explains the organisational context of the archive, the nature of its digital preservation requirements and approaches, its one year pilot project using Preservica Cloud Edition, the archive's technical infrastructure, and the business case and funding for the pilot. It concludes with the key lessons they have learnt and future plans.



TATE GALLERY

This case study discusses the experience of developing a shared digital archive for the Tate's four physical locations (Liverpool, St. Ives, and two in London), powered by a commercial storage system from Arkivum. It explains the organisational context of the Gallery, the nature of their digital preservation requirements and approaches, and their rationale for selecting Arkivum's on-premise solution, OSCAR (On-Site Cloud ARchive) in preference to cloud-based offerings from Arkivum and others. It concludes with the key lessons learned, and discusses plans for future development.

BODLEIAN LIBRARY, UNIVERSITY OF OXFORD

This case study covers the Bodleian Library and the University of Oxford, and their provision of a "private cloud" local infrastructure for its digital collections including digitised books, images and multimedia, research data, and catalogues. It explains the organisational context, the nature of its digital preservation requirements and approaches, its storage services for research data, the technical infrastructure, and the business case and funding. It concludes with the key lessons they have learnt and future plans.

THE PARLIAMENTARY ARCHIVES

This case study covers the Parliamentary Archives and their experience of procuring via the G-Cloud framework and running public cloud storage as part of their digital preservation infrastructure. For extra resilience/an exit strategy they have selected two cloud service providers with different underlying storage infrastructures. The archive is not storing sensitive material in the cloud and is using local storage systems for that material. It has a locally installed preservation system (Preservica Enterprise Edition) which is integrated with cloud and local storage. As such it is an example of an archive using a hybrid set of storage



solutions part-public cloud and part-locally installed for digital preservation.

ARCHIVES & RECORDS COUNCIL WALES DIGITAL PRESERVATION CONSORTIUM

This case study discusses the experience of a cross-sectoral consortium of Welsh archives as they cooperated to pilot deployment of the open source Archivematica software with Microsoft's Windows Azure public cloud service. It explains the organisational context of the consortium, the varied nature of their digital preservation requirements and approaches, and their experience with selecting, deploying and testing Archivematica in the cloud. It concludes with the key lessons they learned, and discusses current proposals to secure grant funding in order to move this pilot into operation.

RESEARCH PROJECTS ON DIGITAL PRESERVATION

Voutssas (2012) argued that initially digital preservation projects in the past tended to focus on the endurance of CD's and DVD's, tapes and other storage devices, and its artificial aging and how to keep them safely. However in the later part of the 20th century, the literature suggested that large amount of writings were focusing on the issues of philosophical underpinnings and technical aspects of digital preservation.

Here researchers, have try to provide some past and present international projects list which was initiated in earlier on digital preservation, so the next generation would be benefited to be familiar with how the development has been made for digital preservation around the world. As mention below

Table 1. Past and Present International Projects on Digital Preservation

Research Projects	Year of Commencement
Victorian E-Records Strategy (VERS)	1990s



Exemplars in Digital Archives (CEDARS)	1990s
Creative Archiving at Michigan and Leeds: emulating the old on the new (CAMiLEON)	1990s
University of Pittsburg project	1990s
University of Indiana project	1990s
University of Yale project	1990s
Preserving access to digital information (PADI)	1998
The Dutch Digitale Bewaring (Digital Preservation testbed) project	2002
Network Excellence on Digital Libraries (DELOS)	2004-2007
The Long-Term Preservation Metadata for E- Records (LMER)	2005
Minnesota Historical Society	2005 - 2007
Effective Strategic Model for the Preservation and Disposal of Institutional Digital Assets (ESPIDA)	2005 - 2007
Clever Recordkeeping Metadata Project (CRKM)	2007
Life-Cycle Information for E-Literature (LIFE)	2007
Investigating Significant Properties of Electronic Content (InSPECT) Project	2007 - 2008
Digital Archiving in Flemish Institutions and	2007/2008



Administrations (DAVID)	
Managing the Digital University Desktop (MDUD)	2007/2008
Co-operative Development of a Long-term Digital Information Archives (KOPAL)	2007/2008
Cultural, Artistic and Scientific Knowledge for Preservation, Access and Retrieval (CASPAR)	2007/2008
Securing a Hybrid Environment for Research Preservation and Access Development Partner (SHERPA DP2)	2007/2008
Repository for Preservation of Authentic Digital Records (RODA)	2007/2008
Service-Oriented Architecture for Preservation and Ingest of Digital objects (SOAPI)	2007–2008
Digital Repository Infrastructure Vision for European Research (DRIVER)	2009
Preservation E-print Services (PRESERV)	2009
Exploring Collaborations to Harness Objects in a Digital Environment for Preservation (ECHO Depository)	2009
Data Preservation Alliance for the Social Science (Data-PASS)	2009
Preservation and Long-term Access through Networked Services (PLANETS)	2009
Metadata Encoding and Transmission	2009



Standard (METS)	
Image Spatial Data Analysis Group (ISDA/Ip2Learn)	2009
Digital Preservation Europe (DPE)	2009
International Research Project on Permanent Authentic Records in Electronic Systems (InterPARES 1, 2 & 3)	1996 - 2012
InterPARES 4- Trust and Digital Records in an Increasingly Networked Society	2013

Source : Irwan Kamaruddin (2014)

Definition of the terms:

Digital preservation

Digital preservation is the active safekeeping of digitally stored information. As a part of the formalized efforts of library and archival sciences, digital preservation includes the practices required to ensure that information is safe from medium failures as well as software and hardware obsolescence.

Preservation

Preservation includes all the managerial and financial considerations including storage and accommodation provisions, staffing levels, policies, techniques and methods involved in preserving library and archive materials and information contained in them.

Challenges

A challenge is something new and difficult which requires great effort and determination.



Strategies

Strategic means relating to the most important, general aspects of something such as a military operation or political policy, especially when these are decided in advance.

Why Worry About Digital Preservation?

Society's heritage has been presented on many different materials, including stone, vellum, bamboo, silk, paper and etc. Now a large quantity of information exists in digital forms, including emails, blogs, social networking websites, national elections websites, web photo albums, and sites which change their content over time. However, technologies create some opportunity as well as raise some challenges also. Therefore the responsibility of librarian and information professional has become wider in terms of techno savvy person. The paramount need is to create a well-organized digital preservation strategy for modern library.

What Is Digital Preservation?

Morrow defined preservation as “The action taken to prevent, stop or retard deterioration” it means Digital preservation...refers to all of the actions required to maintain access to digital materials beyond the limits of media failure or technological change. In other words Digital preservation refers to the series of managed activities necessary to ensure continued access to digital materials for as long as necessary.

What Digital PRESERVATION IS Not occur

- Reformatting from print to digital for access surrogates or product line expansion
- Back-up or byte storage on various media
- Mirror sites or networks designed for reliable delivery
- Carried out within delivery systems
- Active content management designed to ensure enduring usability, authenticity and accessibility over the very long-term



Core Requirements for Digital Preservation

Preservation of digital source is as important as collection development. So some key requirement needed for it. Following are the core requirement.

- Third-party with an organizational mission to carry out preservation
- A sustainable economic model able to support preservation activities over the targeted timeframe
- Technological infrastructure able to support selected preservation strategy and best practices
- Clear legal rights and relationships with content providers and (eventual) users
- Compliance with digital preservation standards and best practices
- OAIS: Open Archives Information Systems
- TRAC: Trustworthy Repositories Audit and Certification
- DRAMBORA: Digital Repository Audit Method Based on Risk Assessment

Aspects of Digital Preservation

According to Graham (1997), digital preservation problems are associated with three distinct aspects which are mention below.

- Medium preservation – the preservation of the physical media on which the bits and bytes of electronic information reside.
- Technology preservation – refreshing of technologies from old to new as they become available.
- Intellectual preservation – addressing the integrity and authenticity of the information as originally recorded.



Challenges of Digital Preservation

“The root of the digital preservation problem is technological, but any proposed solution also needs to take an account of organizational and economic issues. Almost all kinds of digital information need to be interpreted by machines before they can become intelligible to humans.”

Legal & Ethical Challenges

- (1) Digital preservation often occurs while materials are still under copyright – can we reproduce, reformat, or migrate these materials?
- (2) Many digital materials are obtained through license or subscription. These materials are outside custody of institutions with mandate to preserve – how can one preserve something that he/she doesn't really own?
- (3) Can we preserve Web sites hosted by others?

Economic challenges

- (1) Large sums of money are invested in digitizing materials, and these digital assets need to be managed and preserved.
- (2) Digital preservation is costly.
- (3) Economic sustainability – Digital preservation is not an one-off, short-term operation. It's a long-term obligation and continuous effort.



Organizational Challenges

Most of the challenges associated with digital preservation are organization – not technical, e.g.

- (1) Creators of digital information ≠ Owners of server space
- (2) Supporting infrastructure

- (3) Trusted and empowered organizations or repositories Certification process

Technical Challenges

- (1) Improve cost efficiency and affordability
- (2) Under standing how to préserve High-volume rapidly changing content
- (3) Anticipation of future contextes of use
- (4) Standards – and support for inter operability

Strategic planning

“Strategic planning is a management activity often used by businesses to better focus their energy, establish priorities, and strengthen operations to achieve targeted goals.”

Library have variety of resources which may needs to preserve or stored in digital format , so future generation can be utilize without any difficulty. As we know strategic planning is not a simple process. It is purely managerial activities. Here, researchers have tried to focus what strategies should be applied before and after digital preservation of library resources.

Table : 1 Proposed Model for Strategic Planning for Digital Preservation

Sr. No	Input of thoughts	Framing Activities	Out put
A	Top management Librarian and Authority	Technical structure	Final digitized product
B	Decision making on Tools to be used Financial assistance Technological	Build repo with humans and technology	Bibliographic data set
C	Allocation of resources Human Technology	Test trial version	Institutional repository



	Co-ordination Evaluation		
D	Develop alternate solution	Team work	High Satisfaction

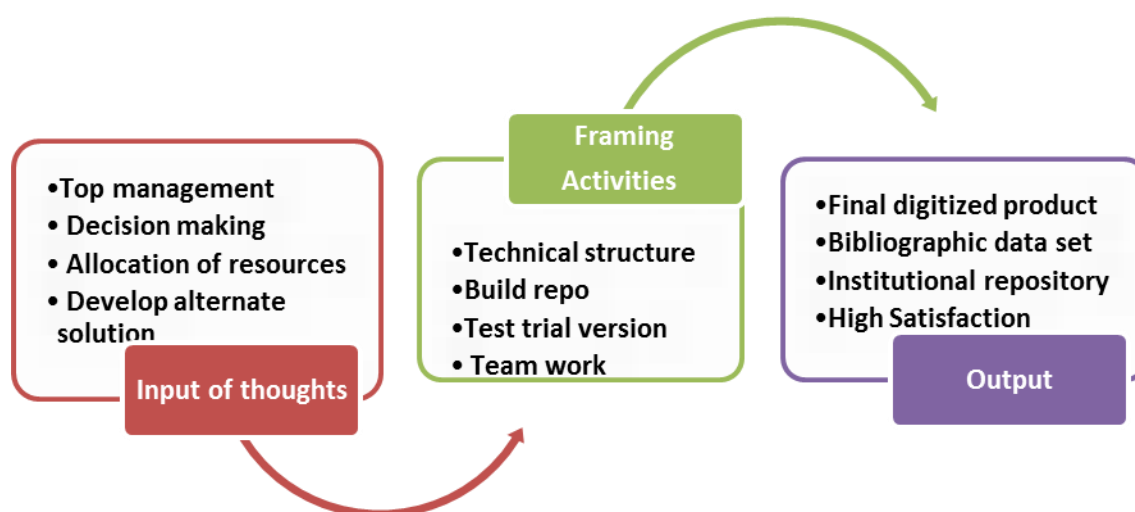


Figure 1. Proposed Model for Strategic Planning for Digital Preservation

Dr. S.R. Ranganathan's philosophy for classification works on three basic principles. The Idea Level, The verbal level and the Notational level. According to Dr. Ranganathan's philosophy human mind is the place of origin of ideas. The creators of ideas need self – communication within the mind in order to create more ideas. Language is the medium for communication of ideas. Written language made communication even more widespread than spoken language. This philosophy is rich in its content and leads towards more practical solution in today's era in a scientific way. As a professional when we frame the work situations according to these principle its look like



Idea plane



Verbal plane



Notational plane



Input of thoughts → Framing Activities → Output of product

Idea level planning: Input of thoughts

Let's discuss all in brief

Top Management (Librarian and Authority)

The vision, mission and goals of every institute or library have its own. The main function of library is to serve society information timely and take possible steps to conserve resources for future references. Here librarian's moral duty is to assure guarantee for preservation of documentary and non-documentary sources to easy access of future generation. As we know, Library is a social institution and dedicated to knowledge dissemination for providing better human civilization to society. Here, one question arise that, who is responsible for preservation of library resources? The answer is everybody is responsible for conserving and preserving the library resources who are directly or indirectly users of library resources or an employee of library or institutions. As an authority of the institution or library the director, HR person and an employees of this institution the all are responsible for enhancing library services. They should take responsibility and make possible arrangement for necessary equipment for library personal and person who are engaged with digital preservation work.

Decision Making:

Digital preservation involves series of activities and an organizational structure in all its dimensions. Librarian and authorities of institution should concentrate on decision making like.

- Tools to be used- for digital preservation which tools be useful should be categorised and arrange according to requirements.



- Financial assistance- assures and fixes the party or person who will be responsible for all the financial assistance whenever needed for the project. It is advisable to get advance payment at time of project approval.
- Technology –refers to which type of techniques, tools and software should be applied for digital preservation is considered must. When the project taken for digital preservation for “paper to digital” or “born digital” needs lots of efforts, tools techniques, equipment and hardware, software tools. It assumed that an employee’s having basic computer knowledge may be considered.

Allocation of resources

It is important to have clear ideas of digital preservation project among the staffs. Before starting any procedures the Authorized person should study the details information regarding the policies, operations in written documents. How they may be utilized to fulfill institutional goals and objectives. Let’s discuss

Human

The most preferable resources are humans; which will be utilized for preservation and digitalization of library resources. Selection of the person related to digitization work made by interview and observation. It is necessary to identify qualify and devoted person for this noble work. This activity creates awareness among the staff and made concentration on shared responsibilities of what to preserve and what extent the library will acquire and retain material would be digitization.



Technology

There is no definable strategy to used technology for digital preservation. It is defers

according to size of institutes , size of holding resources in library , the potential users and the amount of budget spent on the project on digital preservation. It's depending on logical decision taken by authorised person. The most convenient and preferable technological tools are describe as follows

Wide format scanner (8.5” * 14 or 8.5” *11.5)

Book scanner with V shaped cradle

Dark rooms with lighting

Servers with high storage capacity

Backup equipment's like; Tap Drives, hard drivers, DVD writers, Cloud and Virtual space

Computers, Hard ware and Software

Standards for Architecture: ISO/DIS 15489, AS 4390, DOD 5015.2 STD, OAIS

Standards for digital Content: PDF, XML, Dublin core, MARC, Z39.50

Standards for interoperability: ODMA, DMA,

Co-ordination



According to Merriam Webster “Co-ordination is the process of organizing people or groups so that they work together properly and well”

For library professionals and IT professional digital preservation is a big challenge to tackle with information technology and connect an employee as a human. Means proper co-ordination and command needs in written documents than they work smoothly. Here, library professionals and IT professionals experience as well as knowledge towards digital

preservation helps them to run the project step by step as smoothly.

Evaluation

As we discussed library is a mirror of knowledge society and serves for society. It is assumed that a small mistake can lead to wrong interpretation of documents or presentation which is digitized. Before completing whole library materials to be digitized, an evaluation process has been carried out after some content were digitized or born to digital. So the errors or small mistakes can be removed at the trial stage.

Develop alternate solution

When library or institute get approval for digitization of library holdings, it is necessary to work out future obstacles' also. Because

- When you are pioneering some activities it is going to be most costly, might be this cost effect the whole budget.
- Technology change is so rapid, might be outdated soon. Cost spent on technology may be worthless.
- Getting skilled employees for smooth running project for long term without any disturbance is a question mark for project directors.
- So, it is important ingredient for deciding how to develop alternate solutions. All these situations need an excellent project director to have expertise to handle critical situation.



Verbal level Planning: Framing Activities

Technical structure

The digitization project is run by the director who is in-charge of all operation related to digital preservation carried out by library or an institute. He/ she are the authority of co-ordinating, directing and guiding to employees. The project director reports to librarian, librarian reports to institutes head. As a project director he/ she have to fix vision, mission and fix the goals. According to this, project director have to plan and execute technical structure and co-ordinate their employees with their assign work. A working blue print has to prepared and gave demonstration in meetings also. This will creates awareness among the employee, colleague, librarian and the head of the institution. The main area of discussion considered follow items or content.

Find out sources to be digitized

Digital preservation concerns two types of documents namely “born digital documents” and “digital created documents”. As library have variety of collection in terms of printed and non-printed items like books, journals, newspaper, manuscript, documents and other grey literature. So, the pre-requisite is to identify the source (in terms of documents) which would go to be digitized. These activities ensure that the preserved digital materials are authentic and valuable. So, it is important to identify most preferable and valuable sources to be digitized. Like

- Costly books, most utilised books and articles
- Rare books which were going to out of print
- Most preferable items which were suggested by users, publishers, experts etc.



Observation and notified items

Digital preservation also concerns with preserving damaged and deteriorate items. So preservation of damaged and deteriorate physical media in to digital media, needs the basic requirements must have to checkout

- The condition of resources in terms of overall condition of require items
- Identified items which are especially poor in terms of (Torn items, rare items, stop publication)
- Identified the most risky and old collections
- What is the alternate and possible direction for preservation of materials?
- Duplication of items should be avoided

Combination of sources

Selection for digital preservation of items is multi-stage and contents range of activities. Every step needs different methods to proceed. It is necessary to select proper items which have longevity in terms of usage and storage. After selecting proper physical media or documents it is necessary to give identification to sources like

- Collection should be notifying with some identical codes or numbering patterns
- Make list accordingly
- Stored in different space or reserve separate cupboard for easily identify and labelled them
- Stop for transaction for this separate collection



Fix the source which would be adopt

Organizational structure is also important factor for acquiring funds or financial assistance.

Majority of libraries or institutions have its own powerful link with state government and national level bodies. As we know library is growing organism and not for profit making service factor. It is totally depends on government and public funds. Some autonomous institute have their own financial funding agencies. As related to preservation of library collection needs excessive library funds. Here the authority and project director plays vital role in creating most preferable source for financial assistance. Final decision depends on authority how they fix the sources without any interruption for financial needs.

Time management

“Time management” refers to the way that you organize and plan how long you spend on specific activities.”

How much time needs to digital preservation activities should be calculate for every stage and gave algorithm to staff for wok accordingly and make assure to follow the rules strictly. This will help out to get benefit in cost effective ways.

SWOT analysis

“SWOT (strengths, weaknesses, opportunities, and threats) analysis is a framework used to evaluate a company's competitive position and to develop strategic planning. SWOT analysis assesses internal and external factors, as well as current and future potential.”

When institute or library is working on this important project, it is essential to check out the possible strength, weakness, opportunity and traits also. This analysis will help to identify present situation and how the institute can take advantages of his strengths and moderate his weakness into opportunity to bring out new inventions, it would be helpful for smooth running for the said project. Ex. Books and documents damage is a weakness of any library. A clever project director can covert this weakness in opportunity and make possible



arrangement to traits financial and organizational barriers with strong funding agency. He creates digital platform and make best ROI (return on investment) through subscription base document delivery.

Notation level

After completing thinking process the project director should maintain all the files in written form, as specially workflow charts and coding language. This might be easier to follow and moderate all functions regarding digital preservation.

Execute Technical Process

Execute technical process in terms of operational level work assigned. The flow chart of assign work contents as follows

Codification of compiled items

Digital transformation needs lots of attention at time of scanning or image captured. A small mistake can overload the task of replication work. To survive with computers and information technology era, proper coding and interpretation of documents needed. Failing in this it is meaningless activities of “o” and “1” without interpretation. Means convert binary document from physical structure.

Digital preservation involves set of activities with access right for longevity of data. Proper identification and coding of electronic documents vice versa physical documents are primary activities of digitization of resources. Ex. A well define class numbers require same as physical and digital documents and they must be unique in nature. So everybody can identify easily.



Making decision for quality control

Digital contents needs quality in three phases, first at time designing workflow, second at time of digital image capture or scanning how it is selected and handled. Third one is access and downloads time with user's friendly in its nature. This may require quality control at every stage and gave guarantee for produce first product output as same level whenever and whatever time it will retrieve for usage. Means, maintain consistency in quality work despite the technological changes occur. It will be able migrate data in to other format also. Like word to PDF, mp3 to mp 4 and so on.

Special treatments of rare items

Form Stone Age to digital Age, library holdings gets variety of information sources like; manuscripts, clay books, paper books, original copies, Maps, charts, diagram, photographic materials, microfilms, films, documentary , recordings, CDs, DVDs, etc. all these materials needs to preserve from deteriorations of various hazards like Environmental, biological, chemical , natural and disasters , human related. All these hazards affect the original product and harm the quality of library holding.

Environmental factors- temperature, humidity, light and dust

Biological factors-fungi, Insects, other parasites

Chemical Factors- Chemical product used in production

Disasters and Natural Factors – Floods, Earth quack, Hurricane, Volcanic

Eruptions, Sand storm

All this printed and non-book materials needs special treatment like;

Treatment for environmental hazards: to maintain library resources properly, the environmental condition/ storage condition should scientific monitored. Proper lighting,



ventilation, Air and temperature should be maintained. Cleanliness of library resources, shelves should be maintained and check by periodically.

Treatment for Biological hazards: in order to biological hazards; strictly banned food and drinks inside the library. Prevent with insect used naphthalene bricks on the shelves, periodically spray dry neem powder and placed the camphor tablets inside the shelves for pest control.

Treatment for Chemical hazards: books/ documents kept indoors are better protected then books/documents kept outside. This will prevent records from dust, chemical reaction of papers used in paper making process and binding process. Torn and damaged resources should be maintained with lamination, re-binding, re-pairing and restoring with excellent quality equipment's.

Treatment for disasters and natural hazards: library should plan proper disasters management systems and this will checked and tracked on regular basis. The building maintenance, water and air facilities, drainage and flood resistance systems, fire alarm security should checked and maintained on periodic times. Certification, verification and updating of equipment's also are done by regular systems for preventive natural hazards. It advisable to get best quality scanning and digital output of library resources, the digital preservation process should be start after proper maintaining of physical library resources or documents.

Convert in to Meta data and Bibliographic work

Archiving and preserving of library resources/documents involves using standardized format of data captured and migration process. This will help out to recall deteriorate data. The fundamentals requirements is the validation of digital documents should be done with Meta data standards including EAD (encoding archives description for discovering guidelines and



EACs encoding archive materials). It advisable to get access of data put bibliographic work on local hard disks as well as institutional websites also.

Build repo with humans and technology

Working with technology needs suitable integration and collaboration with technology as well as humans. So the project director should make some guidelines for completing the task of digital preservation. This may include;

- Pin point key functions and task may drawn out for this project
- Provide manuals to project head, how the functional and organizational units would be worked with supporting staffs.
- Determine degrees of authority needed to manage each units
- Provide co-ordination among the functional and organizational units
- Negotiate with hard ware/ software agencies , which they are responsible for assigned work at every stages like; at the time of beginning, at time of completion and at time of execution of work, to get better result the policy should remain to maintain the continuity of work

Test trial version

To ensure access to digital materials, which are under process and repositories of particular institutions? It is advisable to test trial version first. After getting remarkable notification for successful operations of various levels it should be linked with institutional website.

Team work

Team work is essential elements for every institutions, industry or firm. As we know teamwork is the collaborative effort of a group to achieve a common goal or to complete a



task in the most effective and efficient way. In this regard when all employees work together, then and then the project director would be able to accomplish the digital preservation of library resources task.

Out put

Final digitized product

At the end of the digitization process, the final product achieved by institute is that documents are digitally produced. This may be in form of “digital born documents” or “digitally created documents”.

Bibliographic data set

After creating digital product, it is essential to have total bibliographic details on this digital product. So, beneficiary can easily retrieve the documents whenever they needed.

Institutional repository

The project director of the digital preservation can claim for the institutional repositories. Because the final product is planning, prepared, offered and maintain by the parental institute.

High Satisfaction

High Job- Satisfaction, Institutional satisfaction and work satisfaction itself can be derived through the successfully completion of digitization of library resources. It always reflects on smiles and working behaviours of employees and user’s feedback as well as institutions returns on Invests. ROI



Recommended Strategy for digital preservation

Medium preservation

- Media renewal or media refreshing like, Copying – transferring data from old storage
- Media to new storage media with the same format specification
- Authentication and accreditation
- Decrease in physical size & Increase in storage capacity

Technology preservation

- This approach intends to retain the needed original hardware and software
- May have an important role for the recovery of data from obsolete storage media and Platforms, but it is unlikely to become a viable long-term strategy
- Digital resources would be to preserve the original software and then to run this on
- Emulators that would mimic the behavior of the obsolete hardware and operating systems
- Digital data object together with the application software used to create or interpret it and a description of the required hardware environment that could be used as a specification for an emulator

Intellectual preservation

- Regarding existing législation (especially copyright & IPR)
- Awareness of the broader scope of the problem



Policy framework

Due to technological revolutions and seeking instant information more and more content are created, converted in digital format. To maintain Libraries and archival record those who are

actively related to digital assets realised for policy matters and intellectual property rights. Their Nobel prospects lead them to create policy framework for digital preservation.

Why policy on digital preservation:

As we discuss technological revolution made easy transformation of physical media in to digital media. Easy availability of information and plagiarism raised some issues towards Intellectual property rights and owners identity. Librarians, arc hivers and groups of society realize the policy framework on digital preservation. Based on previous studies some observation has been made as :

Lyman and Besser noted, "The long term preservation of information in digital form requires not only technical solutions and new organizational strategies, but also the building of a new culture that values and supports the survival of bits over time." Beagrie, Semple, Williams, and Wright reinforced the idea that "...any long-term access and future benefit may be heavily dependent on digital preservation strategies being in place and underpinned by relevant policy and procedures and that the digital preservation policy should be integrated into business drivers, activities and functions e.g. regulatory compliance, staff development, applied technology, academic excellence."

The Electronic Resource Preservation and Access Network's (ERPANET) Digital Policy Preservation Tool suggests that "A policy forms the pillar of a programme for digital preservation. It gives general direction for the whole of an organization, and as such it remains on a reasonably high level from an external point of view, a written policy is a sign that the organization takes the responsibility to preserve digital material."

Cloonan and Sanett noted, "The lack of preservation policies in place is a distinct gap in the research design of many of the projects and possibly reflects a lack of commitment among the stakeholders in institutions."



Conclusion

Preservation in the area of digital technology is a shared responsibility. Library and information technology professionals are playing vital role in developing strategies for this sustainable issues. The emerging need is to develop high storage medium & work collaboratively with professionals & community. It is also needed to create awareness on IPR & related issues. It is also require having a healthy coordination among the various parties who involved in digital preservation and increase staff expertise with issues of digital technology. In views of overall situation the satisfaction reflects on employee's behaviour and face of happy customers.

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મો યાન કૃત 'રેડ સોરધમ' માંથી પ્રગટ થતું વાસ્તવિક ચાઇનીઝ સમાજજીવન

વર્તમાન સમયના ચાઇનીઝ સાહિત્યના એક પ્રસિદ્ધ વિશેષજ્ઞ સબીના નાઈટની દૃષ્ટિએ ચીનના ત્રણ હજાર વર્ષોના સંઘર્ષ પાછળ તેના રાજકિય ઇતિહાસ કરતાં સાહિત્યિક પરંપરાએ અગત્યનો ભાગ ભજવ્યો છે. લિખિત ચાઇનીઝ સાહિત્યએ તાણાવગ્રસ્ત સમાજમાં નવસર્જનની પ્રેરણાને સતત જીવંત રાખવાની અગત્યની ભૂમિકા નિભાવી છે.

ચીનમાં ઐતિહાસિક ચિંતનની અગત્યતા ઝુઓ સામ્રાજ્ય (ઈ.સા.પૂર્વે 1027-256)ના અસ્ત કાળ દરમિયાન ખાસ અનુભવવામાં આવી.

આ સમય દરમિયાન શક્તિશાળી સશસ્ત્ર સંપન્ન રાજ્યોએ નજીકના નાના રાજ્યોને હડપવાના પ્રયત્નોને વેગવાન બનાવે છે.(ઈસા. પૂર્વે 475-221). કિન સામ્રાજ્યના ઉદય સાથે (ઈ.સ.પૂર્વે 221-207) ચીનમાં પ્રથમ સંયુક્ત શાસનનો ઉદભવ જોવા મળે છે. (અંગ્રેજી શબ્દ ચીન આ 'કિન' શબ્દનો અપભ્રંશ માત્ર છે.) કિન સામ્રાજ્યમાં અભ્યાસુ અમલદારોની કદર કરીને વિવિધ કાર્યભાર સોંપવાની શરૂઆત થયેલ, જેને આજપર્યંત સુધી જીવંત રાખવામાં આવેલ છે. આ પ્રકારના અભ્યાસુઓને રાજ્યાશ્રય મળ્યો અને જેના બદલામાં તેમના જ્ઞાનના આધારે રાજાઓએ પોતાની સત્તાને યથાર્થ સાબિત કરવાના પ્રયત્નો કરતા. જે અભ્યાસુઓએ અમલદારી ન કરી તેઓએ શિક્ષણનું કાર્ય સંભાળ્યું.

આ સમયગાળામાં બુદ્ધિઝમ દ્વારા જીવનને 'સત્' માર્ગ પર લઈ જવા માટે ચીનમાં ખુબ જ મોટું વૈચારિક બળ પૂરું પાડવામાં આવેલું. બુદ્ધિઝમે ચીનમાં તત્વજ્ઞાનની નવી ક્ષિતિજો ખોલી આપી. બુદ્ધિઝમની સાથોસાથ ભારતમાં લખાયેલી શરૂઆતના તબક્કાની અનેક રચનાઓ ચીનમાં પહોંચી. જેની અસર 'રેડ સોરધમ'માં ખાસ કરીને ગ્રેટ ગ્રાન્ડમાં દાઈ (દાઈ દાદીના) પાત્રમાં જોવા મળે છે.

આવી જ રીતે મેન્સીયસ (ઈસા. પૂર્વે 372-289) પોતાના આગવા વિચારોથી લોકોમાં ખુબ જ ઉમદા જીવન શૈલીનું આવાહન કરતા જોવા મળે છે. તેમના મત પ્રમાણે લોકો બીજા તરફની સદ્ભાવના, નૈતિક હિંમત, વિધિવિધાનની સાતત્યતા તેમજ સાચા ખોટાની સમજણથી આ વિશ્વને એક ઉમદા વિશ્વ બનાવી શકે છે. આ વિચારોનું ખંડન તેમના જ અનુયાયી ઝુંજી (ઈસા પૂર્વે 300-230) દ્વારા થતું જોવા મળે છે. ઝુંજી પોતાના ગુરૂ મેન્સીયસના વિચાર કે જેમાં મનુષ્યને જન્મથી જ સારો માનવામાં આવ્યો તે વિચારનું ખંડન કરી પોતાનો વિચાર રજૂ કરે છે અને કહે છે કે 'મનુષ્યને શિક્ષણ અને વિધિવિધાન દ્વારા સુસંસ્કૃત કરી સુદૃઢ સમાજની રચના તરફ અગ્રેસર કરી શકાય છે.'

આ વિચારને આગળ ધપાવતા માસ્ટર હેનફી (ઈસા. પૂર્વે 233)ના કાયદા તેમજ અમલદારશાહીવાળી એક સમાજ રચનાનો વિચાર રાખે છે. જેના દ્વારા બૌદ્ધિક પ્રવૃત્તિઓને વેગ મળી શકે. તેવો આ વિચાર આગળ વધતા 'લીગાલીઝમ' તરીકે ઓળખાય છે.

આ પ્રકારે ચીનના સાહિત્યિક જગતમાં અનેક વિચારધારાઓ વચ્ચે અનેક મતભેદો આજ પર્યંત ચાલી રહી છે, તેમાંથી એક નવી આગવી ઓળખનો ઉદભવ થતો જોવા મળે છે. જે આગવી ઓળખ આગળ જતાં ચાઇનીઝ સાહિત્યને તેના પ્રમુખ માર્ગ તરફ દોરી જાય છે.

ચાઇનીઝ સાહિત્યમાં નવલકથાને એક સ્વરૂપની દૃષ્ટિએ સમજવા આપણે મીંગ-કાળમાં લોકવાર્તાઓની સાથે ઉદભવેલ 'પ્રકરણવાળા કલ્પનો'ને પ્રાથમિકતા આપવી તે આવશ્યક રહેશે. આ કલ્પનો મુખ્યત્વે મૌખિક પરંપરાના વાર્તાકથનથી ખુબ જ પ્રભાવિત જોવા મળે છે. ઘણા વાચકોના મંતવ્ય પ્રમાણે આ નવલકથાઓ બુદ્ધિસ્ત વિચાર કે જેમાં 'ધુળનું વિશ્વ' અને તેની પેલી પારનો વિચાર કે જેમાં સમાજના દરેક તત્વનો સમાવેશ સમાન રીતે થાય છે, તેનું કલ્પન જોવા મળે છે. ખાસ કરીને બહારવટિયા, બળવાખોરો, નૈતિક મૂલ્યોને પડકારનાર પાત્રો કે જેમાં સામાજિક ત્રિજ્યાની બહાર રહેલ પાત્રોને મધ્ય(કિન્દ્ર)માં રાખીને (ખાસ કરેન મહિલાઓને) સમાજ વિશેનું વિશિષ્ટ ચિંતન કરવામાં આવેલ છે. આ મીંગ સામ્રાજ્યની મુખ્ય ચાર કૃતિઓને સાહિત્યની દૃષ્ટિએ ઉમદા કૃતિઓમાં ગણવામાં આવે છે. જેમાં ખાસ કરીને Romance of the Three Kingdoms, Water Margin અથવા તો Outlaws of the March, Journey to the West (પૂર્વીય એશિયાની લગભગ સૌથી વધુ ખ્યાતિ પ્રાપ્ત કૃતિ) કે જેમાં ઐતિહાસિક સંત ઝુઆંગ ઝેંગ અને તેમની ભારત યાત્રાનું વર્ણન છે. આ કૃતિમાં લેખક ભગવાન બુદ્ધ દ્વારા લખાયેલ પીઠીકાનું સરળ ભાષાંતર કરતા જોવા મળે છે. આ કૃતિ ઉપરથી ઘણી બધી કથાઓ સર્જવામાં આવેલ. મીંગ સામ્રાજ્યની ચોથી ખ્યાતનામ કૃતિ તરીકે The Plum in the Golden Vase એ પોતાના અશ્લીલ વિષયને કારણે ખુબ જ ચર્ચાસ્પદ બની રહેલ.

મો યાન દ્વારા ઈ.સ. 1983 માં લખાયેલ 'રેડ સોરધમ' આ કૃતિઓની અનુગામી કહી શકાય. 'રેડ સોરધમ' તેના શીર્ષકની દૃષ્ટિએ સાંપ્રત વિશ્વમાં પ્રવર્તતા વિચારોની દૃષ્ટિએ, પાત્રોના નિરૂપણની દૃષ્ટિએ તેમજ ભારતીય પરિપ્રેક્ષ્યમાં ચાઇનીઝ નવલકથાનું ખુબ જ ઉત્કૃષ્ટ પ્રતિનિધિત્વ કરે છે.

ઉત્તર પૂર્વીય ચીનના ગાઓમી વિસ્તારની પ્રમુખ ઉપજ તરીકે 'રેડ સોરધમ' પોતાના ઉપજાઉપણ તેમજ અગત્યના પ્રતિક સમાન ઉપસી આવે છે. (આ વિસ્તાર લેખકનું વતન પણ છે.) દાયકાઓના લોહિલુહાણ કત્તેઆમથી

ખરડાયેલા ઇતિહાસ વચ્ચે ‘રેડ સોરઘમ’ પોતાની અલગ ઉપજાઉપણાથી સતત જીવન જરૂરી ખોરાક, રહેઠાણ માટેની છત અને પીણું પણ પુરું પાડે છે. પ્રસ્તુત નવલકથા વિવિધ સામયિકોમાં ક્રમશઃ પ્રસિદ્ધ થયેલ. 1986માં આ અંકો Red Sorghum, Sorghum Wine, Dog Ways, Sorghum Funeral અને Strange Deathના નામો સાથે પ્રસિદ્ધ થયેલા.

‘રેડ સોરઘમ’ સાથેના જીવનની એકાત્મકતા દર્શાવવા લેખકે તેમની દાદીના મૃત્યુનું નિરૂપણ ખુબ સુંદર રીતે રજૂ કરે છે.

“It is the music of the universe and it emanates from red sorghum. She gazes at the Sorghum and through the dimness of her vision the stalks turn craftily and surpassingly beautiful, grotesque, and bizarre. They begin to moan, to writhe, to shout, to entwine her; they are demonic one minute, intimate the next and in her eyes, they coil like snakes.” (P.77)

“આ વૈશ્વિક સંગીત છે અને તેનું અવતરણ ‘રેડ સોરઘમ’થી થાય છે. તેણી સોરઘમ તરફ નજર માંડીને જુએ છે અને તેમાં પોતાની પ્રતિકૃતિની ઝાંખી થતી જુએ છે. આ દૃષ્ટિથી તેના પુડાઓને કલાત્મક અને આશ્ચર્યજનક રીતે સુંદર, વિલક્ષણ તેમજ વિક્ષિપ્ત થતા જુએ છે. તેણીને મળવા માટે તેઓ કણસવા, તળપવા તથા પોકારી ઉઠે છે; તેઓ એક ક્ષણે તામસીક તો બીજી જ ક્ષણે આત્મજન બની તેણીની આંખોમાં શાહીની જેમ વિંટળાઈ જાય છે.” (પૃ.77)

લેખક ‘રેડ સોરઘમ’ને ચીનના શાનદોંગ વિસ્તારની ઉત્તર-પૂર્વિય વિસ્તારમાં આવેલ ગાઓમી પરગણાના સમગ્ર જીવન સાથે જોડી, તેને પ્રકૃતિ સાથેના મનુષ્ય જીવનના અનુબંધ દ્વારા એક નવી જ ઓળખ આપે છે.

સાંપ્રત સમયમાં જ્યારે સંપૂર્ણ વિશ્વ ગ્લોબલ વોર્મીંગ અને ઔદ્યોગીકરણ જેવી ગંભીર સમસ્યાઓનો સામનો કરી રહ્યું છે ત્યારે ‘રેડ સોરઘમ’ અને તેની મનુષ્ય જીવન સાથેના એકબીજાના નિરૂપણને ‘ઈકોકીટીસીઝમ’ની દૃષ્ટિએ પણ એક ઉપલબ્ધિથી ઉતરતું નથી. વર્તમાન સમયમાં ઔદ્યોગીકરણને કારણે ચીન ઘણી બધી સમસ્યાઓનો સામનો કરી રહ્યું છે. આવી પરિસ્થિતિમાં મો યાન કુદરતને મુખ્ય પાત્ર બનાવીને ત્રણ પેઢીઓને વણી લેતી વાતને આપણી સમક્ષ રજૂ કરે છે. નવલકથાનો પ્લોટ શાનદોંગ પરિવારની ત્રણ પેઢીઓ વચ્ચેના ઈ.સ. 1923 અને ઈ.સ. 1976 સુધીના સમયગાળાના બનાવોને વર્ણવવા માટે થાય છે. આ કૃતિમાં નવલકથાકાર પોતાના પરિવારની સંઘર્ષની વાત આપણી સામે પ્રસ્તુત કરે છે. પ્રથમ સોરઘમની વાઈન બનાવવાની ભઠ્ઠીના માલિક તરીકે અને ત્યારબાદ દ્વિતીય ચીનો-જાપાનીઝ લડાઈના બડવાખોર લડવૈયા તરીકે. આ નવલકથામાં ચીનના આંતર વિગ્રહમાં રાજકિય સત્તા અને તેની હરીફ ટોળીઓ વચ્ચે ઉદભવતો આંતરવિગ્રહ દ્વારા ઉદ્ભવતો સઘર્ષ જોવા મળે છે. આ નવલકથામાં ચીનની સાંસ્કૃતિક ક્રાંતિ તેમજ ઈ.સ.1972માં ચીન અને જાપાન વચ્ચેના રાજનૈતિક સંબંધોની પુનઃસ્થાપનાની ઘટનાને પણ આવરી લેવામાં આવી છે.

નવલકથાના અંત ભાગમાં પ્રયોજાયેલ આત્મમંથનમાં લેખક પોતાની પરિસ્થિતિનો ચિંતાર આપે છે...

“Then a desolate sound comes from the heart of the land. It is both familiar and strange.... The ghosts of my family are sending me a message to point the way out of their labyrinth.” (P.378)

“આ ભૂમિના મધ્યમાંથી એક ઉદાસીન અવાજ આવતો સંભળાઈ છે, એ જાણીતો તેમજ અજાણ્યો પણ છે. મારા પરિવારનાં મૃતાત્માઓ મને આ ભૂલભૂલમણીમાંથી બહાર આવવાનો નિર્દેશ કરી રહ્યા છે.” (પૃ. નં.378)

આ આત્માઓમાં વિશેષ કરીને દાદા, દાદીનો સમાવેશ કરવામાં આવેલ છે. આ રીતે કથાનાયક ત્રણ પેઢીઓના અવાજને યોગ્ય વાચા આપવામાં સફળ બને છે. નવલકથાની આ વિશેષતા ‘રેડ સોરઘમ’ને ભારતીય પરિવાર ભાવનાની ખુબ જ નજીક લઈ આવે છે. ભારતથી હજારો કીલોમીટર દુર આવેલ ઉત્તર પૂર્વીય ચીનના શાનદોંગ પ્રાંતના ગાઓમી વિસ્તારનું ગ્રામ્ય જીવન ઘણી બધી રીતે ભારતીય ગ્રામ્ય જીવનને મળતું આવે છે. ‘રેડ સોરઘમ’ નવલકથા ઘણી બધી રીતે ચીનના સમાજ જીવનને વાચક સમક્ષ પ્રસ્તુત કરે છે. આ વિવિધ પાસાઓને ધ્યાને લેતા વાચકને ચીનના સમાજજીવન જેમ કે ત્યાંની લગ્ન પરંપરા, આર્થિક અસમાનતાને કારણે સર્જાતી પરિસ્થિતિઓ, સામ્રાજ્યવાદની આડઅસરો અને બળવાખોરો-બહારવટીયાઓની મા ભોમકાજે મરી મીટવાની ભાવના વગેરે જેવાં પાસાઓ ચીનના સામાન્ય જનજીવનને ઘણી બધી રીતે ભારતીય જીવનની નજીક લાવી આપે છે.

વિશ્વનો કોઈપણ સમાજ તેના દ્વારા નારીઓને અપાતા આદર સન્માનથી ઓળખાય છે. ‘રેડ સોરઘમ’ નવલકથાનું કેન્દ્રવર્તી પાત્ર દાઈ સ્વેંગલીઅન, લિટલ નાઈન અથવા તો દાદી સાથે બાલ્યકાળથી થતા વ્યવહારના તાદૃશ વર્ણન દ્વારા મો યાન ચીનના સમાજમાં નારીના સ્થાન અંગેનું નિરૂપણ કરે છે. માત્ર છ વર્ષની કુમણી વયથી તેના પગના પંજાઓ અંગેની દેખરેખ તેમજ સતત કાળજી દાદીની સુંદરતામાં વધારો કરવાની સાથોસાથ પુરુષ પ્રધાન સમાજ વ્યવસ્થામાં નારીના મર્યાદિત સ્થાન અંગેનો પણ ચિંતાર આપે છે. આટલું જ પર્યાપ્ત ન હોય. માત્ર 16 વર્ષની નાની વયે આ બાળાને આ પ્રાંતના ખ્યાતનામ વેપારી શાન તિગ્સ્યુના કોઢિયા પુત્ર શાન બીઆનલેંગ સાથે આર્થિક સહુરતાના કારણે પરણાવી દેવામાં આવે છે. આ ઘટના વૈશ્વિક સ્તરે નારીના જીવન પર પડનારી આર્થિક પરિબળોની અસરનું ઉત્કૃષ્ટ ઉદાહરણ પુરું પાડે છે. દાદી આ વિવાહનો દરેક રીતે પ્રતિકાર કરવાનો પ્રયત્ન કરે છે અને આખરે યુ જાન આશ્મ સાથેના પોતાના સંબંધોને પ્રતિપાદીત કરી પ્રસ્થાપિત સમાજ મૂલ્યો સામે એક પ્રકારનો બંડ પોકારે છે. પોતાના મૃત્યુ વેળાનું આત્મમંથન એમને વૈશ્વિક પ્રતિનિધિ તરીકે આપણી સમક્ષ રજૂ કર્યું છે-



“Have I sinned? Would it have been right to share my pillow with a leper and produce a misshapen, putrid monster to contaminate this beautiful world? What is chastity then? What is the correct path? What is goodness? What is evil? You never told me, so I had to decide on my own. I loved happiness, I loved strength, I loved beauty, it was my body and I used it as I thought fitting sin doesn't frighten me, nor does punishment.” (P.76)

“શું મેં પાપ કર્યું છે? શું એ ઉચિત હોત કે મે એક કોઢિયા સાથે મળીને એક વિકૃત, કોહવાયેલ રાક્ષસ સમાન બાળકને જન્મ આપીને આ સુંદર પૃથ્વીને કલુષીત કરી હોત? તો પછી સતીત્વ શું છે? સાચો માર્ગ કયો? સારું શું છે? અનિષ્ટ શું છે? તમોએ મને ક્યારેય માર્મદર્શિત ન કરી એટલા માટે મારે મારી રીતે વિચારવું પડેલું. મને પ્રસન્નતા પસંદ હતી, મને સામર્થ્ય પસંદ હતું, મને સુંદરતા પસંદ હતી, એ મારું શરીર હતું અને મેં તેનો યથાયોગ્ય ઉપયોગ કરેલ. પાપ મને ભયભીત નથી કરવો, કે ન તો સજા.” (પાન નં.76)

દાઈ ફ્લેંગ્લીઅનના ઈશ્વર સાથેના આ અંતિમ શબ્દો માત્ર ચીનની સંસ્કૃતિમાં ધરબાઈ રહીને સ્ત્રી સહજ આવેગોને જ રજુ નથી કરતી પરંતુ સંપૂર્ણ વિશ્વની નારીજગતના મનમાં રહેલ ભાવનાઓનું એક પ્રકારનું વ્યાપક પ્રસ્તુતીકરણ છે. સાંપ્રત નારીવાદીઓની દૃષ્ટિએ મોયાનનું આ માનસિક વિશ્લેષણ તેમને એક આગવી લેખન શૈલીનું આધિપત્ય પ્રદાન કરે છે. તેની સાથોસાથ હાંસિયા (માર્જીન)માં રહેલ વર્ગને મધ્ય (સેન્ટર)માં સ્થાન આપી લેખકે સમાજજીવનનાં અનેકવિધ પાસાઓનું સમન્વયયુક્ત સાયુજ્ય પ્રસ્તુત કરેલું છે.

આ નવલકથાની દૃષ્ટિએ ‘મો યાન’ અનેક પ્રકારે અને અનેક પ્રસંગે ચાઈનીઝ લેન્ડસ્કેપ પેઇન્ટિંગની કળાને નવલકથાના શબ્દોથી પ્રસ્તુત કરતા જોવા મળે છે. ‘રેડ સોરઘમ’માં આલેખાયેલ કથા એક રીતે તો જાપાન દ્વારા ઈ.સ. 1930ના દાયકામાં દ્વિતીય ચીનો-જાપાનીઝ યુદ્ધનું ઉપદ્રવી અને કત્વેઆમની ઘટનાઓનું એક વૃત્તાંત કહી શકાય તેવું છે. આ સમગ્ર કથા બહારવટિયા-આક્રમણકાર યુવાન આઓ (દાદા) તેમજ તેમની પત્ની દાઈ ફ્લેંગ્લીઅનની (દાદી) આસપાસ ગૂંથાયેલ જોવા મળે છે. નવલકથામાં કથા સમયની આગળ પાછળ થઈ દાદા અને દાદીના જીવનની નાની નાની ઘટનાઓને આપણી સમક્ષ યોજનબદ્ધ રીતે રજુ કરે છે, જે માટે નોબેલ અકાદમીએ મો યાનને પુરસ્કાર આપતી વેળાએ કહેલું કે લેખક તરીકે તેઓ,

“Who with hallucinatory realism merges folk tales, history and the contemporary.” (ભ્રમણાયુક્ત વાસ્તવિકતાને લોકવાર્તા, ઇતિહાસ અને સાંપ્રત સમય સાથે વણી લે છે.)

આમ, એક ચાઈનીઝ લેખક તરીકે મો યાન માનવીય જીવનના અનેકવિધ મૂલ્યોને અનેકવિધ રીતે સ્પર્શે છે અને તેનું ઉચિત નિરૂપણ પણ કરી આપે છે. આ કૃતિને સમગ્ર દૃષ્ટિએ જોતાં ‘રેડ સોરઘમ’ તેના ચરિત્રચિત્રણથી માંડી કથાસાર, વિચારધારાઓની એરણે ચાઈનીઝ સાહિત્યને સાંપ્રત વૈશ્વિક સાહિત્ય જગતમાં એક આગવું સ્થાન પ્રદાન કરે છે. તુલનાત્મક સાહિત્યની દૃષ્ટિએ ભારતીય સંશોધકો માટે આ નવલકથા નવી ક્ષિતિજો ઉઘાડી આપે છે તથા કૃતિમાંથી પ્રગટ થતો ભારતીય સમાજજીવન સાથેનો અનુબંધમાં એકાત્માક્તાનો ભાવ આ કૃતિ દ્વારા પામી શક્ય છે.

ડૉ. હરદિપસિંહ ગોહિલ, ગુજરાત કોમર્સ કોલેજ, એલિસબ્રિજ, અમદાવાદ

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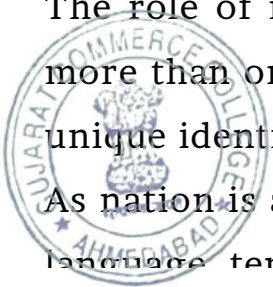
The Role of Media in Making Modern India

As the significant tool to make independence of India possible, media has played quintessential role in making modern India. In awakening the slumbering spirit of the nation, it stood as the foundational stone. It played the role of a catalyst for the power/paradigm shift from West towards East. It was a difficult task for thinkers of the slave countries to inject the most essential morale of self-esteem and independence inside the minds of the common citizens of their nation states. In case of country like India they were gracefully gifted with the gift of media. They utilised their education with the help of media to awaken the slumbering souls of the nation. Most of the prominent leaders

from India contributed to the 'Imagined Community'(Benedict Anderson) with their mediums of print publications such as, Dadabhai Naoroji through Rast Guftar, Balgangadhar Tilak through Kesari and Mahratta, Madan Mohan Malviya through Hindustan, Lala Lajapat Rai through Punjabi, Bande Mataram, and The People, Mohandas Karamchand Gandhi through Young India, Navjeevan, and Harijan, G. Subramania Aiyer through The Hindu and Sri Aurobindo dedicated his service towards mother nation by editing Bande Mataram, Dharma and Karma Yogin.

The Empire was compelled by these effective medium of mass awakening to bring forth as many as four different constitutional changes within short period of time, such as The Vernacular Press Act,1878 (Discrimination between English and vernacular Newspapers, no right to appeal!), Newspaper Act 1908 that empowers the magistrate to confiscate the property owned by the press, Indian Press Act 1910, and Indian Press (The Emergency Powers) Act 1931 to douse the Civil Disobedience Movement. At the same time for thinkers like Sophia Dobson it is, 'where no freedom of the press existed, and grievances consequently remained unrepresented and un-redressed, innumerable revolutions have taken place.' (Collet 406) According to Bhaha they help in creating 'hybridity' to rebel against "restrictive notions of cultural identity" by opening the avenues of change. This paper is an attempt to pay tribute to the Media which has played their role of foundational stones to make the dream of the contemporary India possible.

The role of media has played the significant role in making the uniformity of the slaved nation in more than one way. At the time when each thread of the nation bound together it came out to be the unique identity of nation. In terms of Lenin one can understand the phenomenon of a nation as, As nation is a historically constituted, stable community of people, formed on the basis of a common language territory, economic life and psychological makeup manifested in a common culture. (Lenin)



language, territory, economic life and psychological makeup manifested in a common culture. (Benny)

In case of India, the 'psychological makeup' in the form of 'a common culture' can be credited to the media and writers of the then popular media. If one takes up the examples of leading political leaders of the time most of them played vital role in writing for newspapers.

The most significant role of media in the constructing or destructing the nation can be studied from the Facebook Cambridge Analytica Scandal by Mark Zuckerberg, where personal data of millions of Facebook users was used without their permission for the political leverage. The result has been wondering and bewilderment for the entire world. It may have been the economic gain for any particular media but as a whole it has led on of the strongest democracy into unknown danger. (The term is lighter in its tone than what is being experienced by the Corona affected America today!) Ralph Schroeder in his significant research upon the role of media in the time of globalization mentions tacitly that,

Media elites translate the agenda of political elites, plus 'people', into the media agenda. These political elites consist not just a powerful leader, as Schudson (2011) has pointed out, for the vast bulk of sources of news are government officials. (Media Systems, Digital Media and Politics 28-59)

The aftermath of Wuhan incident has made it clear for entire world that however strong we believe that contemporary international media would be; it cannot penetrate inside the 'Wall' of 'government officials' created by the so called 'powerful leader' of the present time.

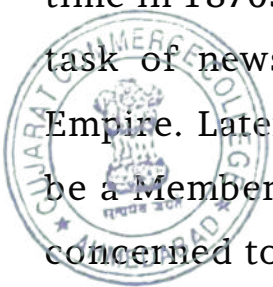
In case of India, when The British Crown took over the possession of Private Company (British East India Company), it was literally no entity to raise logical argument against such inhuman accession of power. As the company started facing difficulties in administrating population of different language



and culture (which was far superior and stronger than ever imagined by their 'intellectuals!'), the Crown constituted the English Education Act 1835 'to spend on education and literature in India' Lord Babington Macaulay lead the discussion of the Act. In his scathing argument projecting inferiority of Indian, especially Sanskrit education system he observed that, I feel...that it is impossible for us, with our limited means, to attempt to educate the body of the people. We must at present do our best to form a class who may be interpreters between us and the millions whom we govern – a class of persons Indian in blood and colour, but English in tastes, opinions, in morals and in intellect. To that class we may leave it to... convey knowledge to the great mass of the population. (Sharp)

The plan of the Crown was not full proof. There were certain lacunae which were focused upon and utilised to strengthen the future India by the same 'class' of interpreters. If one observes carefully, one finds that most of the Indian freedom fighters were well educated especially from Western education institutes only!

The 1851 riots between Parsi and Muslim communities in Bombay create the need to voice the grievances and pains of poor and middleclass Parsis. A leader rises to the occasion named Dadabhai Naoroji. He founds The Rast Goftar means 'The Truth Teller' with the help of Government subsidy. By 1858 its circulation rose from 432 to 852, which was quite considerable at the time. Along with the time in 1870s it was considered amongst one of four leading operating newspapers from Bombay. The task of newspaper helped him in raising questions against the draining of India' wealth by the Empire. Later, he becomes to be well known as the Grand Old Man of India. He was the first Indian to be a Member of British Parliament when the nation was still under the rule of Raj. In one of his most concerned tone about the nation he suggests to every Indian citizen that,

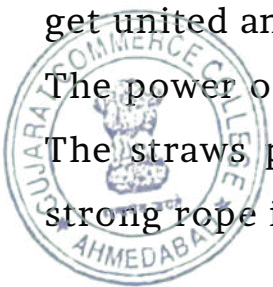


Be united, persevere, and achieve self-Government, so that the millions now perishing by poverty, famine, and plague may be saved, and India may once more occupy her proud position of yore among the greatest and civilized nations of the world. (Grover 231)

The genuine concern about the motherland can be experienced by the such patriotic lines by the Grand Old Man of India.

Similarly, the personality of Balgangadhar Tilak has influenced the entire nation. His writings and speeches have mesmerised not only common politicians but even the man of millennium Mohandas Karamchand Gandhi as well. At the time of paying tribute to his political teacher Mahatma opines that he admired Tilak as millions of his countrymen for 'his indomitable will, his vast learning, his love of country and above all the purity of his private life and great sacrifice. Of all men of modern times, he captivated the most the imagination of his people. He breathed into us the spirit of Swaraj.' It is well known that it was the struggle for Swaraj only which contributed the immense popularity to Mahatma as a freedom fighter. In a sense it was the coinage of Tilak that contributed the most in making of Mahatma. If one tries to examine it more closely, Tilak provided the basic foundational ideology for the nation to achieve freedom. As Brothers Sisir Kumar and Motilal started the Amrita Bazar Patrika in Bengal; Tilak introduces Keshari in Western part of the nation. The power of his inspirational thoughts can be experienced from one of his articles which tries to invigorate the common citizens to get united and fight against the injustices of the Empire as,

The power of public opinion lies in its resolute will. It cannot be gauged by the supporting numbers. The straws put together to make a big heap serve no purpose. But the same grass twisted into a strong rope is capable of subjugating even an intoxicated elephant. (Pandit 19)

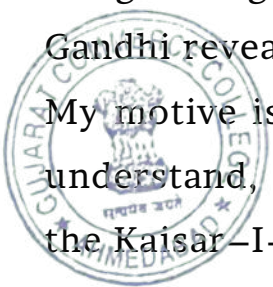


In a sense one can say that the straws of patriotic fervour have been articulated to domesticate the wild Elephant of the Empire! For such a noble cause one can observe that it was only the medium of newspaper Keshari. Such a burning torch was handed over to the final fighter of Indian independence Mohandas Gandhi.

In the similar way the founder of Banaras Hindu University, Shree Madan Mohan Malaviya contributed to the field of journalism with the spirit of nationalism. In the year 1908 the British Government passes one of the most objectionable Act in the form of the Press Act and Newspaper Act. In the company of Motilal Nehru, father of India's first Prime Minister Jawaharlal Nehru, Madan Mohan Malaviya started The Leader. The subjects of his publication remained focused upon the political upheavals of the time. The newspaper can be considered as the significant contributor to nationalistic fervour. One can find contributions of several political thinkers of the time including writings of Mahatma Gandhi as well.

The name of Mohandas Karamchand Gandhi would be immortal in the field of role of media in the field of nation construction. In more than one way he has revolutionised the field of newspaper writing. His subjects in media starts from the food habits till the fundamental rights and the ultimate responsibility of the government for its citizens. He contributed to Harijan and Young India with invigorating fervour of national freedom. In one of his articles to the Young India newspaper Mr. Gandhi reveals his identity with his intentions such as,

My motive is national service and that, too, so long as it is consistent with humanitarian dictates. I understand, because my South African work was considered to be humanitarian that I was awarded the Kaiser-I-Hind Gold Medal. (Gandhi, To Every Englishman)



The goal of serving the 'humanity' elevates his stature to the level of Man of Millennium. He has proved himself worthy of it at almost all the level of his political career. In that journey his articles in newspaper plays supporting pillar to make reach of his voice till the distanced dweller of the nation. The highest message of his political movement was also been conveyed through the use of media only. One can find his preaching about 'Truth' and 'Non-Violence' being edify through newspaper only as,

Therefore, Indian self-government not only means no menace to the world, but will be of the greatest benefit to humanity if she attains her end through those means (Truth and Non-violence) and those means alone. (Gandhi, Collected Works of Mahatma Gandhi, Vol. XXIII 361)

One can learn the central lesson of his political endeavour through these lines only. He clearly opines that the happiness of India in every sense would be instrumental to bring happiness of entire world in a very simple way possible. Selection of the political field also has been discussed in one of his articles in the Young India as,

My bent is not political but religious and I take part in politics because I feel that there is no department of life which can be divorced from religion and because politics touch the vital being of India almost at every point. (Gandhi, To G. S. Arundale)

In the same way the contribution of Sri Aurobindo can also be considered as one of the important cornerstones in the struggle of Indian independence. It was only because of his editorial task, he had to beseech immediate shelter at Puducherry. His erudition was par excellence which has not been matched by anyone till the date. In Bande Mataram of 17th December, 1907, he reveals his poetic craftsmanship while explaining how a nation would emerge as spirit in life formation and

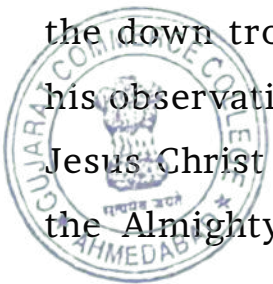


craftsmanship while explaining how a nation would emerge as spirit in the formation and, ... it is a law that all energies are forced to direct themselves, consciously or unconsciously, willingly or against their will, to the supreme work of the time . . . so now when the waters of a people's life are stirred and the formation of a great organic Indian state and nation has begun, the same law holds. (Ghose, Bande Mataram)

It was that 'law' of energy only which gifted independence of the nation on the birthday of Sri Aurobindo only! For the future of the nation, he provides a clear cut guide line as, The first work is to revive courage in the hearts of the people The next work is to give a stronger impetus to the boycott. . . The Third thing to be done is to spread National Education. . . . (Ghose, The Work Before Us)

In these three steps one can find the heart of rising India. In multiple ways India as a nation has been bestowed by the thinking minds like Sri Aurobindo. All such minds prepare a trajectory of a most spiritual and altruistic country in the world. One can easily observe the significance of such 'National Education' in times of globalised world as well.

The writings of Dr. Babasaheb Ambedkar was not limited to the concern of drafting the constitution of India only. If one analyses his writing corpus one can find variety mediums and subjects have been simply exhausted by him in multiple ways. As a researcher and one of the most influential persons of the down trodden class some of his writings possesses the significant value of their own. In one of his observation about the religions of the world and their comparative contributions he writes that, Jesus Christ and Mohammad Paygambar use to preach the world they are conveying the message of the Almighty and it is the ultimate Truth. The message delivered by Shri Krishna was itself the

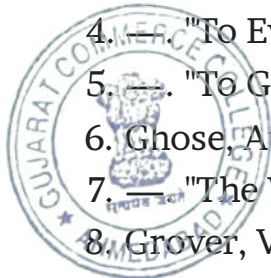


message of Almighty. There was no space for any doubt. But Bhagvan Buddha did not tell anything like that. He conveyed his message to his disciple Bhikkhu Anand and explained that his message is based upon experience. (Ambedkar)

Thus, the role of media and its contribution in the constructing India as nation is unique. Each and every leading freedom fighter has explored and endeavoured their talented personalities with the help of media available at the time. From writings of Dadabhai Naoroji till Dr. Babasaheb Ambedkar one can observe a continuum of media support for the bringing the morning of freedom for India. There has been British suppression in various form of Acts and regulations for the media. All such challenges in the contemporary scenario could create the situations where Facebook and Twitter provide the platform for the contemporary politicians to have their say in every walk of their life. The role of media in making India (Independent/developed) has been phenomenal, it can be observed that till the day media plays most significant role in making the nation.

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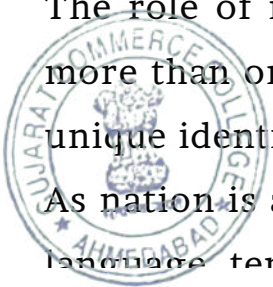
The Role of Media in Making Modern India

As the significant tool to make independence of India possible, media has played quintessential role in making modern India. In awakening the slumbering spirit of the nation, it stood as the foundational stone. It played the role of a catalyst for the power/paradigm shift from West towards East. It was a difficult task for thinkers of the slave countries to inject the most essential morale of self-esteem and independence inside the minds of the common citizens of their nation states. In case of country like India they were gracefully gifted with the gift of media. They utilised their education with the help of media to awaken the slumbering souls of the nation. Most of the prominent leaders

from India contributed to the 'Imagined Community'(Benedict Anderson) with their mediums of print publications such as, Dadabhai Naoroji through Rast Guftar, Balgangadhar Tilak through Kesari and Mahratta, Madan Mohan Malviya through Hindustan, Lala Lajapat Rai through Punjabi, Bande Mataram, and The People, Mohandas Karamchand Gandhi through Young India, Navjeevan, and Harijan, G. Subramania Aiyer through The Hindu and Sri Aurobindo dedicated his service towards mother nation by editing Bande Mataram, Dharma and Karma Yogin.

The Empire was compelled by these effective medium of mass awakening to bring forth as many as four different constitutional changes within short period of time, such as The Vernacular Press Act,1878 (Discrimination between English and vernacular Newspapers, no right to appeal!), Newspaper Act 1908 that empowers the magistrate to confiscate the property owned by the press, Indian Press Act 1910, and Indian Press (The Emergency Powers) Act 1931 to douse the Civil Disobedience Movement. At the same time for thinkers like Sophia Dobson it is, 'where no freedom of the press existed, and grievances consequently remained unrepresented and un-redressed, innumerable revolutions have taken place.' (Collet 406) According to Bhaha they help in creating 'hybridity' to rebel against "restrictive notions of cultural identity" by opening the avenues of change. This paper is an attempt to pay tribute to the Media which has played their role of foundational stones to make the dream of the contemporary India possible.

The role of media has played the significant role in making the uniformity of the slaved nation in more than one way. At the time when each thread of the nation bound together it came out to be the unique identity of nation. In terms of Lenin one can understand the phenomenon of a nation as, As nation is a historically constituted, stable community of people, formed on the basis of a common language territory, economic life and psychological makeup manifested in a common culture. (Lenin)



language, territory, economic life and psychological makeup manifested in a common culture. (Benny)

In case of India, the 'psychological makeup' in the form of 'a common culture' can be credited to the media and writers of the then popular media. If one takes up the examples of leading political leaders of the time most of them played vital role in writing for newspapers.

The most significant role of media in the constructing or destructing the nation can be studied from the Facebook Cambridge Analytica Scandal by Mark Zuckerberg, where personal data of millions of Facebook users was used without their permission for the political leverage. The result has been wondering and bewilderment for the entire world. It may have been the economic gain for any particular media but as a whole it has led on of the strongest democracy into unknown danger. (The term is lighter in its tone than what is being experienced by the Corona affected America today!) Ralph Schroeder in his significant research upon the role of media in the time of globalization mentions tacitly that,

Media elites translate the agenda of political elites, plus 'people', into the media agenda. These political elites consist not just a powerful leader, as Schudson (2011) has pointed out, for the vast bulk of sources of news are government officials. (Media Systems, Digital Media and Politics 28-59)

The aftermath of Wuhan incident has made it clear for entire world that however strong we believe that contemporary international media would be; it cannot penetrate inside the 'Wall' of 'government officials' created by the so called 'powerful leader' of the present time.

In case of India, when The British Crown took over the possession of Private Company (British East India Company), it was literally no entity to raise logical argument against such inhuman accession of power. As the company started facing difficulties in administrating population of different language

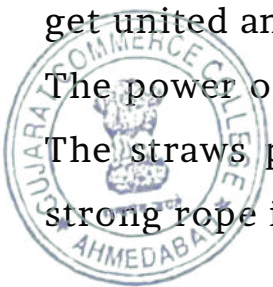


Be united, persevere, and achieve self-Government, so that the millions now perishing by poverty, famine, and plague may be saved, and India may once more occupy her proud position of yore among the greatest and civilized nations of the world. (Grover 231)

The genuine concern about the motherland can be experienced by the such patriotic lines by the Grand Old Man of India.

Similarly, the personality of Balgangadhar Tilak has influenced the entire nation. His writings and speeches have mesmerised not only common politicians but even the man of millennium Mohandas Karamchand Gandhi as well. At the time of paying tribute to his political teacher Mahatma opines that he admired Tilak as millions of his countrymen for 'his indomitable will, his vast learning, his love of country and above all the purity of his private life and great sacrifice. Of all men of modern times, he captivated the most the imagination of his people. He breathed into us the spirit of Swaraj.' It is well known that it was the struggle for Swaraj only which contributed the immense popularity to Mahatma as a freedom fighter. In a sense it was the coinage of Tilak that contributed the most in making of Mahatma. If one tries to examine it more closely, Tilak provided the basic foundational ideology for the nation to achieve freedom. As Brothers Sisir Kumar and Motilal started the Amrita Bazar Patrika in Bengal; Tilak introduces Keshari in Western part of the nation. The power of his inspirational thoughts can be experienced from one of his articles which tries to invigorate the common citizens to get united and fight against the injustices of the Empire as,

The power of public opinion lies in its resolute will. It cannot be gauged by the supporting numbers. The straws put together to make a big heap serve no purpose. But the same grass twisted into a strong rope is capable of subjugating even an intoxicated elephant. (Pandit 19)

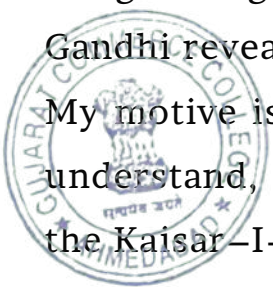


In a sense one can say that the straws of patriotic fervour have been articulated to domesticate the wild Elephant of the Empire! For such a noble cause one can observe that it was only the medium of newspaper Keshari. Such a burning torch was handed over to the final fighter of Indian independence Mohandas Gandhi.

In the similar way the founder of Banaras Hindu University, Shree Madan Mohan Malaviya contributed to the field of journalism with the spirit of nationalism. In the year 1908 the British Government passes one of the most objectionable Act in the form of the Press Act and Newspaper Act. In the company of Motilal Nehru, father of India's first Prime Minister Jawaharlal Nehru, Madan Mohan Malaviya started The Leader. The subjects of his publication remained focused upon the political upheavals of the time. The newspaper can be considered as the significant contributor to nationalistic fervour. One can find contributions of several political thinkers of the time including writings of Mahatma Gandhi as well.

The name of Mohandas Karamchand Gandhi would be immortal in the field of role of media in the field of nation construction. In more than one way he has revolutionised the field of newspaper writing. His subjects in media starts from the food habits till the fundamental rights and the ultimate responsibility of the government for its citizens. He contributed to Harijan and Young India with invigorating fervour of national freedom. In one of his articles to the Young India newspaper Mr. Gandhi reveals his identity with his intentions such as,

My motive is national service and that, too, so long as it is consistent with humanitarian dictates. I understand, because my South African work was considered to be humanitarian that I was awarded the Kaiser-I-Hind Gold Medal. (Gandhi, To Every Englishman)



The goal of serving the 'humanity' elevates his stature to the level of Man of Millennium. He has proved himself worthy of it at almost all the level of his political career. In that journey his articles in newspaper plays supporting pillar to make reach of his voice till the distanced dweller of the nation. The highest message of his political movement was also been conveyed through the use of media only. One can find his preaching about 'Truth' and 'Non-Violence' being edify through newspaper only as,

Therefore, Indian self-government not only means no menace to the world, but will be of the greatest benefit to humanity if she attains her end through those means (Truth and Non-violence) and those means alone. (Gandhi, Collected Works of Mahatma Gandhi, Vol. XXIII 361)

One can learn the central lesson of his political endeavour through these lines only. He clearly opines that the happiness of India in every sense would be instrumental to bring happiness of entire world in a very simple way possible. Selection of the political field also has been discussed in one of his articles in the Young India as,

My bent is not political but religious and I take part in politics because I feel that there is no department of life which can be divorced from religion and because politics touch the vital being of India almost at every point. (Gandhi, To G. S. Arundale)

In the same way the contribution of Sri Aurobindo can also be considered as one of the important cornerstones in the struggle of Indian independence. It was only because of his editorial task, he had to beseech immediate shelter at Puducherry. His erudition was par excellence which has not been matched by anyone till the date. In Bande Mataram of 17th December, 1907, he reveals his poetic craftsmanship while explaining how a nation would emerge as spirit in life formation and

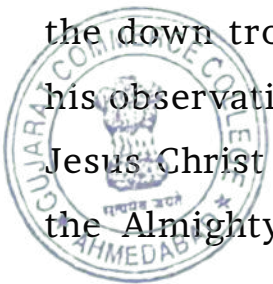


craftsmanship while explaining how a nation would emerge as spirit in the formation and, ... it is a law that all energies are forced to direct themselves, consciously or unconsciously, willingly or against their will, to the supreme work of the time . . . so now when the waters of a people's life are stirred and the formation of a great organic Indian state and nation has begun, the same law holds. (Ghose, Bande Mataram)

It was that 'law' of energy only which gifted independence of the nation on the birthday of Sri Aurobindo only! For the future of the nation, he provides a clear cut guide line as, The first work is to revive courage in the hearts of the people The next work is to give a stronger impetus to the boycott. . . The Third thing to be done is to spread National Education. . . . (Ghose, The Work Before Us)

In these three steps one can find the heart of rising India. In multiple ways India as a nation has been bestowed by the thinking minds like Sri Aurobindo. All such minds prepare a trajectory of a most spiritual and altruistic country in the world. One can easily observe the significance of such 'National Education' in times of globalised world as well.

The writings of Dr. Babasaheb Ambedkar was not limited to the concern of drafting the constitution of India only. If one analyses his writing corpus one can find variety mediums and subjects have been simply exhausted by him in multiple ways. As a researcher and one of the most influential persons of the down trodden class some of his writings possesses the significant value of their own. In one of his observation about the religions of the world and their comparative contributions he writes that, Jesus Christ and Mohammad Paygambar use to preach the world they are conveying the message of the Almighty and it is the ultimate Truth. The message delivered by Shri Krishna was itself the

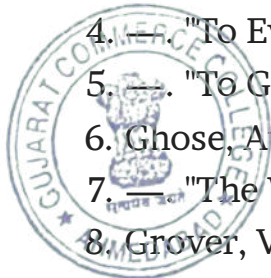


message of Almighty. There was no space for any doubt. But Bhagvan Buddha did not tell anything like that. He conveyed his message to his disciple Bhikkhu Anand and explained that his message is based upon experience. (Ambedkar)

Thus, the role of media and its contribution in the constructing India as nation is unique. Each and every leading freedom fighter has explored and endeavoured their talented personalities with the help of media available at the time. From writings of Dadabhai Naoroji till Dr. Babasaheb Ambedkar one can observe a continuum of media support for the bringing the morning of freedom for India. There has been British suppression in various form of Acts and regulations for the media. All such challenges in the contemporary scenario could create the situations where Facebook and Twitter provide the platform for the contemporary politicians to have their say in every walk of their life. The role of media in making India (Independent/developed) has been phenomenal, it can be observed that till the day media plays most significant role in making the nation.

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DOCUMENTS OF THE YEAR

2020



Some new generators to obtain efficient circular weakly balanced repeated measurements designs

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ABSTRACT

Minimal balanced repeated measurements designs (RMDs) are not possible to construct in several experimental situations. In these situations, weakly balanced RMDs are preferred which demand less experimental subjects without loss of efficiency. In this article, several generators are developed to construct the minimal circular weakly balanced RMDs in periods of (i) equal sizes, (ii) two different sizes, and (iii) three different sizes. All these constructions possess high efficiency and save the cost of experiments due to less number of experimental subjects.

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Treatment effects; residual effects; method of cyclic shifts; traditional model; efficiency of separability

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1. Introduction

In repeated measurements designs (RMDs), more than one measurement is taken on each subject/experimental unit. RMDs are widely used in the fields of medicine, pharmacology, animal sciences, and psychology where residual effects may exist. Minimal balanced RMDs (BRMDs) balance out these residual effects at low budget constraints. The situations for which minimal BRMDs cannot be constructed, weakly balanced RMDs (WBRMDs) are preferred. Some important definitions related to this study are:

Residual Effect: The effect which a treatment has during its period of application (treatment effect) may persist into the following period(s). If the effect persists only into the immediately following period the effect is called first-order carry over/residual effect.

Balanced RMD: RMD is balanced with respect to the first-order residual effects if each treatment is immediately preceded λ' times by each other treatment (excluding itself). This design will be minimal if $\lambda' = 1$.

Strongly Balanced RMD: RMD is strongly balanced with respect to the first-order residual effects if each treatment is immediately preceded λ' times by each other treatment (including itself).

RMD for v (treatments) and p_i (period sizes) is weakly balanced with respect to the first-order residual effects if each treatment is immediately preceded λ'_1 or λ'_2 times by each other treatment (excluding itself) where $|\lambda'_2 - \lambda'_1| = 1$.



Williams (1949) initiated for RMDs. Cheng and Wu (1980) constructed circular balanced and strongly balanced RMDs. Afsarinejad (1994) constructed minimal balanced and strongly balanced RMDs in periods of unequal sizes. Using method of cyclic shifts, (a) Iqbal and Jones (1994) constructed efficient RMDs and strongly BRMDs with periods of equal and unequal sizes, (b) Iqbal and Tahir (2009) constructed circular strongly BRMDs for some classes, (c) Iqbal, Tahir, and Ghazali (2010) constructed some first-order and second-order circular balanced and strongly balanced RMDs, (d) Rajab et al. (2018) developed some generators to obtain the circular BRMDs in periods of equal sizes, (e) Rasheed et al. (2018) developed some generators to obtain minimal circular strongly BRMDs in periods of three different sizes, (f) Bashir et al. (2018) presented circular BRMDs for $p = 3$. Some more references of the designs constructed through method of cyclic shifts can be found in Ahmed et al. (2020).

Bailey et al. (2017) constructed universally optimal WBRMDs for $p = v$. Khan et al. (2019) developed some generators to obtain minimal CWBRMDs for $p \leq v$ in periods of equal sizes. Hussain et al. (2019) developed some generators to obtain minimal CWBRMDs in periods of two different sizes for (i) $v = 2mi + s + 2$, $p_1 = 2m$, and $p_2 = s$ (even), (ii) $v = 2mi + s$, $p_1 = 2m$, and $p_2 = s$ (even), (iii) $v = 2mi + s + 1$, $p_1 = 2m$, and $p_2 = s$ (even) > 2 , (iv) $v = 2mi + s + 1$, $p_1 = 2m$, and $p_2 = s$ (odd) > 3 , (v) $v = 2mi + s - 1$, $p_1 = 2m$, and $p_2 = s$ (even) > 2 , (vi) $v = 2mi + s$, $p_1 = 2m$, and $p_2 = s + 1$, s even. In this article, some new generators are developed to obtain minimal CWBRMDs in periods of (i) equal sizes, (ii) two different sizes, and (iii) three different sizes.

The paper is organized as follows: the model, estimation of treatment and residual effects, and, its efficiency calculation is presented in Section 2. In Section 3, method of cyclic shifts is explained to construct CWBRMDs. New generators are discussed for minimal CWBRMDs in periods of equal sizes, two different sizes, and three different sizes in Section 3, in Section 4, and in Section 5, respectively.

2. Model and efficiency for circular RMDs

The model repeatedly discussed for RMDs in the literature is traditional model given by,

$$y_{ijk} = \mu + \tau_{d(k,j)} + \gamma_{d(k-1,j)} + \pi_k + \xi_{ij} + \varepsilon_{ijk} \quad (1)$$

where y_{ijk} is the observation from subject j having sequence i in period k to which treatment $d(k, j)$ is given, μ is the general mean, $\tau_{d(k,j)}$ is the effect of treatment $d(k, j)$, $\gamma_{d(k-1,j)}$ is the residual effect of treatment $d(k-1, j)$ in the period k which was applied in the period $k-1$ to the same subject, π_k is the effect of period k , ξ_{ij} is the effect of subject j having sequence i , ε_{ijk} are independently normally distributed error term with mean 0 and variance σ^2 .

2.1. Efficiency for residual effects

The joint information matrix of the treatment and residual effects for the Circular RMD is given by



$$C_{(\tau, \gamma)} = \begin{pmatrix} C_{11} & C_{12} \\ C'_{12} & C_{22} \end{pmatrix}$$

where C_{11} , C_{12} , and C_{22} in periods of two different sizes are given by

$$\begin{aligned} C_{11} &= rI - \frac{1}{n_1 + n_2} M_1 M'_1 - \frac{1}{n_1} M_2 M'_2 - \frac{1}{p_1} N_1 N'_1 - \frac{1}{p_2} N_2 N'_2 + \frac{r^2}{n_1 p_1 + n_2 p_2} J \\ C_{12} &= Z - \frac{1}{n_1 + n_2} M_1 \bar{M}'_1 - \frac{1}{n_1} M_2 \bar{M}'_2 - \frac{1}{p_1} N_1 \bar{N}'_1 - \frac{1}{p_2} N_2 \bar{N}'_2 + \frac{r\bar{r}}{n_1 p_1 + n_2 p_2} J \\ C_{22} &= \bar{r}I - \frac{1}{n_1 + n_2} \bar{M}_1 \bar{M}'_1 - \frac{1}{n_1} \bar{M}_2 \bar{M}'_2 - \frac{1}{p_1} \bar{N}_1 \bar{N}'_1 - \frac{1}{p_2} \bar{N}_2 \bar{N}'_2 + \frac{\bar{r}^2}{n_1 p_1 + n_2 p_2} J \end{aligned}$$

Here, n_1 subjects repeatedly measures up to p_1 periods, n_2 subjects repeatedly measures up to p_2 periods; M_1 is the incidence matrix of treatments versus 1 to p_2 periods; M_2 the incidence matrix of treatments versus $p_2 + 1$ to p_1 periods; \bar{M}_1 the incidence matrix of residual versus 1 to p_2 periods; \bar{M}_2 the incidence matrix of residual versus $p_2 + 1$ to p_1 periods; N_1 the incidence matrix of treatments versus 1 to n_1 subjects; N_2 the incidence matrix of treatments versus $n_1 + 1$ to $n_1 + n_2$ subjects; \bar{N}_1 the incidence matrix of residual versus 1 to n_1 subjects; \bar{N}_2 the incidence matrix of residual versus $n_1 + 1$ to $n_1 + n_2$ subjects. Similarly, C_{11} , C_{12} , and C_{22} in periods of three different sizes are given by

$$\begin{aligned} C_{11} &= rI - \frac{1}{n_1 + n_2 + n_3} M_1 M'_1 - \frac{1}{n_1 + n_2} M_2 M'_2 - \frac{1}{n_1} M_3 M'_3 - \frac{1}{p_1} N_1 N'_1 \\ &\quad - \frac{1}{p_2} N_2 N'_2 - \frac{1}{p_3} N_3 N'_3 + \frac{r^2}{n_1 p_1 + n_2 p_2 + n_3 p_3} J \\ C_{12} &= Z - \frac{1}{n_1 + n_2 + n_3} M_1 \bar{M}'_1 - \frac{1}{n_1 + n_2} M_2 \bar{M}'_2 - \frac{1}{n_1} M_3 \bar{M}'_3 - \frac{1}{p_1} N_1 \bar{N}'_1 \\ &\quad - \frac{1}{p_2} N_2 \bar{N}'_2 - \frac{1}{p_3} N_3 \bar{N}'_3 + \frac{r\bar{r}}{n_1 p_1 + n_2 p_2 + n_3 p_3} J \\ C_{22} &= \bar{r}I - \frac{1}{n_1 + n_2 + n_3} \bar{M}_1 \bar{M}'_1 - \frac{1}{n_1 + n_2} \bar{M}_2 \bar{M}'_2 - \frac{1}{n_1} \bar{M}_3 \bar{M}'_3 - \frac{1}{p_1} \bar{N}_1 \bar{N}'_1 \\ &\quad - \frac{1}{p_2} \bar{N}_2 \bar{N}'_2 - \frac{1}{p_3} \bar{N}_3 \bar{N}'_3 + \frac{\bar{r}^2}{n_1 p_1 + n_2 p_2 + n_3 p_3} J \end{aligned}$$

Here, n_1 subjects repeatedly measures up to p_1 periods; n_2 subjects repeatedly measures up to p_2 periods; n_3 subjects repeatedly measures up to p_3 periods; M_1 is the incidence matrix of treatments versus 1 to p_3 periods; M_2 the incidence matrix of treatments versus $p_3 + 1$ to p_2 periods; M_3 the incidence matrix of treatments versus $p_2 + 1$ to p_1 periods; \bar{M}_1 the incidence matrix of residual versus 1 to p_3 periods; \bar{M}_2 the incidence matrix of residual versus $p_3 + 1$ to p_2 periods; \bar{M}_3 the incidence matrix of residual versus $p_2 + 1$ to p_1 periods; N_1 the incidence matrix of treatments versus 1 to n_1 subjects; N_2 the incidence matrix of treatments versus $n_1 + 1$ to $n_1 + n_2$ subjects; N_3 the incidence matrix of treatments versus $n_1 + n_2 + 1$ to $n_1 + n_2 + n_3$ subjects; \bar{N}_1 the incidence matrix of residual versus 1 to n_1 subjects; \bar{N}_2 the incidence matrix of residual versus $n_1 + 1$ to $n_1 + n_2$ subjects; \bar{N}_3 the incidence matrix of residual versus $n_1 + n_2 + 1$ to $n_1 + n_2 + n_3$ subjects.



1 to $n_1 + n_2 + n_3$ subjects. Also we have r as the replication of treatment; \bar{r} the replication of residual; J the matrix with all elements as one. Then the information matrix of the treatment and residual effects are $C_\tau = C_{11} - C_{12}C_{22}^{-1}C_{21}$ and $C_\gamma = C_{22} - C_{21}C_{11}^{-1}C_{12}$, respectively. Note that, the information matrix in case of Circular RMD in periods of equal sizes (p) is obtain by substituting $p_1 = p$, $n_1 = n$ and $p_2 = n_2 = M_1 = \bar{M}_1 = N_2 = \bar{N}_2 = 0$ in C_{11} , C_{12} , and C_{22} . for periods of two different sizes.

The efficiency factor for residual effect can be regarded as the harmonic mean of non zero Eigen values of their respective information matrix, see James and Wilkinson (1971) and Pearce, Caliński, and Marshall (1974). The high value of E_r shows that design is suitable for the estimation of residual effects. Our developed generators provide the designs with high values of E_r , therefore, these designs are suitable for the estimation of residual effects.

2.2. Efficiency of separability

Every RMDs must be characterized for its ability of separating the treatment effects from residual effects. Divecha and Gondaliya (2014) provided simple formula of efficiency of Separability (ES) for the balanced RMDs. We have modified this formula according to the constraints of RMDs constructed in this paper is given by,

$$ES = \left[1 - \left\{ \frac{(l_1 + 4l_2)v - (l_1 + 2l_2)^2}{(v-1)(l_1 + 2l_2)^2} \right\}^{\frac{1}{2}} \right] \times 100\% \quad (2)$$

where l_1 is the number of a treatment immediately preceded by other treatment single time; l_2 is the number of a treatment immediately preceded by other treatment two times.

3. Method of cyclic shifts

Method of cyclic shifts is introduced by Iqbal (1991). Let we discuss Rule I and Rule II of method of cyclic shifts for the construction of CBRMDs and CWBRMDs.

Rule I. Let $S_1 = [q_{11}, q_{12}, \dots, q_{p_1-1}]$, $S_2 = [q_{21}, q_{22}, \dots, q_{p_2-1}]$, and $S_3 = [q_{31}, q_{32}, \dots, q_{p_3-1}]$ be the sets of shifts, where $1 \leq q_{ij} \leq v-1$. If each element $1, 2, \dots, v-1$ appears an equal number of times, say λ' in S^* , where $S^* = [\{q_{11}, q_{12}, \dots, q_{p_1-1}, v-(q_{11} + q_{12} + \dots + q_{p_1-1}) \bmod v\}, \{q_{21}, q_{22}, \dots, q_{p_2-1}, v-(q_{21} + q_{22} + \dots + q_{p_2-1}) \bmod v\}, \{q_{31}, q_{32}, \dots, q_{p_3-1}, v-(q_{31} + q_{32} + \dots + q_{p_3-1}) \bmod v\}]$ then design from it will be CBRMD in periods of sizes p_1, p_2 , and p_3 . If S^* contains all of $1, 2, \dots, v-1$ exactly λ'_1 times except a few of these which appear $\lambda'_1 - 1$ or $\lambda'_1 + 1$ times then it will be CWBRMD. Sum of any two, three, $\dots, (p-1)$ consecutive elements of a set should not be 0 (mod v). If so, reorder the elements of the corresponding set.

Example 3.1. Minimal CWBRMD for $v=20$, $p_1=8$, $p_2=6$, and $p_3=4$ can be constructed through the following sets of shifts.

$$S_1 = [1, 2, 3, 4, 19, 18, 17] \quad S_2 = [5, 6, 7, 15, 14] \quad S_3 = [8, 9, 12]$$



Table 1. Array obtained from $S_1 = [1, 2, 3, 4, 19, 18, 17]$.

p	Subjects																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	0
3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	0	1	2
4	6	7	8	9	10	11	12	13	14	15	16	17	18	19	0	1	2	3	4	5
5	10	11	12	13	14	15	16	17	18	19	0	1	2	3	4	5	6	7	8	9
6	9	10	11	12	13	14	15	16	17	18	19	0	1	2	3	4	5	6	7	8
7	7	8	9	10	11	12	13	14	15	16	17	18	19	0	1	2	3	4	5	6
8	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	0	1	2	3

Table 2. Array obtained from $S_2 = [5, 6, 7, 15, 14]$.

p	Subjects																			
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
2	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	0	1	2	3	4
3	11	12	13	14	15	16	17	18	19	0	1	2	3	4	5	6	7	8	9	10
4	18	19	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
5	13	14	15	16	17	18	19	0	1	2	3	4	5	6	7	8	9	10	11	12
6	7	8	9	10	11	12	13	14	15	16	17	18	19	0	1	2	3	4	5	6

Table 3. Array obtained from $S_3 = [8, 9, 12]$.

p	Subjects																			
	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
2	8	9	10	11	12	13	14	15	16	17	18	19	0	1	2	3	4	5	6	7
3	17	18	19	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
4	9	10	11	12	13	14	15	16	17	18	19	0	1	2	3	4	5	6	7	8

Proof. $S_1^* = [1, 2, 3, 4, 19, 18, 17, 16]$, $S_2^* = [5, 6, 7, 15, 14, 13]$, $S_3^* = [8, 9, 12, 11]$.

Hence $S^* = [1, 2, 3, 4, 19, 18, 17, 16, 5, 6, 7, 15, 14, 13, 8, 9, 12, 11]$. Here each of 1, 2, ..., 19 appears exactly once except 10 which does not appear. Hence given sets of shifts provide minimal CWBRMD for $v = 20$, $p_1 = 8$, $p_2 = 6$, and $p_3 = 4$. Systematic procedure to construct this CWBRMD is given below.

Take v experimental subjects for one set of shifts $S_1 = [1, 2, 3, 4, 19, 18, 17]$. Assign 0, 1, ..., $v - 1$ to each subject in first period respectively. To get the elements of second period for each subject, add 1 (mod 20) to each element of first period for all subjects. Then add 2 (mod 20) to each element of second period for all subjects of third period. Similarly, add 3, 4, 19, 18, and 17 as shown in Table 1.

Take v more experimental subjects for second set of shifts $S_2 = [5, 6, 7, 15, 14]$. Assign 0, 1, ..., 19 to each subject in first period respectively. To get the elements of second period for each subject, add 5 (mod 20) to each element of first period for all subjects. Then add 6 (mod 20) to each element of second period for all subjects of third period. Similarly add 7, 15, and 14 as shown in Table 2.

Take v more experimental subjects for third set of shifts and get the array from $S_3 = [8, 9, 12]$ in a similar way as shown in Table 3.

Tables 1–3 together produce minimal CWBRMD for $v = 20$, $p_1 = 8$, $p_2 = 6$, and $p_3 = 4$. □



Table 4. Array obtained from $S_1=[1,2,3,4,16,15,14]$.

p	Subjects																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	0
3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	0	1	2
4	6	7	8	9	10	11	12	13	14	15	16	0	1	2	3	4	5
5	10	11	12	13	14	15	16	0	1	2	3	4	5	6	7	8	9
6	9	10	11	12	13	14	15	16	0	1	2	3	4	5	6	7	8
7	7	8	9	10	11	12	13	14	15	16	0	1	2	3	4	5	6
8	4	5	6	7	8	9	10	11	12	13	14	15	16	0	1	2	3

Rule II. Let $S_a = [q_{a1}, q_{a2}, \dots, q_{a(p-1)}]$, $S_b = [q_{b1}, q_{b2}, \dots, q_{b(p-1)}]$, and $S_c = [q_{c1}, q_{c2}, \dots, q_{c(p-2)}]$ be the three sets of shifts, where $1 \leq q_i \leq v-2$. Then S^* will be $[q_{a1}, q_{a2}, \dots, q_{a(p-1)}, (v-1) - (q_{a1} + q_{a2} + \dots + q_{a(p-1)}) \bmod (v-1), q_{b1}, q_{b2}, \dots, q_{b(p-1)}, (v-1) - (q_{b1} + q_{b2} + \dots + q_{b(p-1)}) \bmod (v-1), q_{c1}, q_{c2}, \dots, q_{c(p-2)}]$. If each element $1, 2, \dots, v-2$ appears an equal number of times, say λ' in S^* then design from it will be CBRMD. If S^* contains all of $1, 2, \dots, v-2$ exactly λ'_1 time except a few of these which appear $\lambda'_1 - 1$ or $\lambda'_1 + 1$ times then it will be CWBRMD. Sum of any two, three, $\dots, (p-1)$ consecutive elements of a set should not be $0 \bmod (v-1)$. If so, reorder the elements of the corresponding set.

Example 3.2. Minimal CWBRMD for $v=18, p_1=8, p_2=6$, and $p_3=3$ can be constructed through the following sets of shifts.

$$S_1 = [1,2,3,4,16,15,14] S_2 = [5,6,7,12,11] S_3 = [8]t$$

Proof. $S_1^* = [1,2,3,4,16,15,14,13]$, $S_2^* = [5,6,7,12,11,10]$, $S_3^* = [8]$.

Hence $S^* = [1,2,3,4,16,15,14,13,5,6,7,12,11,10,8]$. Here each of $1, 2, \dots, 16$ appears exactly once except 9 which does not appear. Hence given sets of shifts provide minimal CWBRMD for $v=18, p_1=8, p_2=6$, and $p_3=3$. Systematic procedure to construct this CWBRMD is given below.

Take $v-1$ experimental subjects for first set of shifts $S_1 = [1,2,3,4,16,15,14]$. Assign $0, 1, \dots, v-2$ to each subject in first period, respectively. To get the elements of second period for each subject, add 1 (mod 17) to each element of first period for all subjects. Then add 2 (mod 17) to each element of second period for all subjects of third period. Similarly, add 3, 4, 16, 15, and 1 to complete the array as shown in Table 4.

Take more $v-1$ experimental subjects for second set of shifts $S_2 = [5,6,7,12,11]$. Assign $0, 1, \dots, v-2$ to each subject in first period, respectively. To get the elements of second period for each subject, add 5 (mod 17) to each element of first period for all subjects. Then add 6 (mod 17) to each element of second period for all subjects of third period. Similarly, add 7, 12, and 11 to complete the array as shown in Table 5.

Take more $v-1$ experimental subjects for third set of shifts $[8]t$. Assign $0, 1, \dots, v-2$ to each subject in first period respectively. To get the elements of second period for each subject, add 8 (mod 17) to each element of first period for all subjects. Then assign 17 to each element of third period for all subjects as shown in Table 6.

Tables 4–6 together produce minimal CWBRMD for $v=18, p_1=8, p_2=6$, and $p_3=3$. □



Table 5. Array obtained from $S_2 = [5, 6, 7, 12, 11]$.

p	Subjects																
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2	5	6	7	8	9	10	11	12	13	14	15	16	0	1	2	3	4
3	11	12	13	14	15	16	0	1	2	3	4	5	6	7	8	9	10
4	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	0
5	13	14	15	16	0	1	2	3	4	5	6	7	8	9	10	11	12
6	7	8	9	10	11	12	13	14	15	16	0	1	2	3	4	5	6

Table 6. Array obtained from $S_3 = [8]t$.

p	Subjects																
	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	41
1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2	8	9	10	11	12	13	14	15	16	0	1	2	3	4	5	6	7
3	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17

Table 7. CWBRMDs for $v = 2mi$, $p = 2m$, i integer.

v	p	Set(s) of shifts	E_r	E_s
16	8	$[1, 2, 3, 4, 15, 14, 13] + [6, 5, 7, 8, 11, 10, 9]$	0.93	0.91
20	10	$[1, 2, 3, 4, 5, 19, 18, 17, 16] + [6, 7, 8, 14, 9, 10, 13, 11, 12]$	0.945	0.93
24	12	$[1, 2, 4, 3, 6, 5, 23, 22, 21, 20, 19] + [7, 8, 10, 9, 11, 17, 12, 16, 15, 14, 13]$	0.955	0.94
28	14	$[1, 2, 6, 3, 4, 5, 27, 7, 26, 25, 24, 23, 22] + [8, 9, 13, 10, 11, 12, 14, 20, 19, 18, 17, 16, 15]$	0.96	0.95

4. Minimal CWBRMDs in periods of equal sizes

In this section, one generator is developed to generate minimal CWBRMDs in periods of equal sizes using method of cyclic shifts (Rule I).

Generator 4.1. Following i sets of shifts provide minimal CWBRMD for $v = 2mi$, $p = 2m$, i integer, and m (integer) > 2 . Here, ordered pairs $\{(0, v/2), (1, (v+2)/2), \dots, ((v-2)/2, v-1), (v/2, 0), ((v+2)/2, 1), \dots, (v-1, (v-2)/2)\}$ appear twice together as preceded values while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-(mj+1), v-(mj+2), \dots, v-(mj+m-1)] ; j=0, 1, \dots, i-1$$

Examples are given in Table 7.

5. Minimal CWBRMDs in periods of two different sizes

5.1. Minimal CWBRMDs in periods of two different sizes using Rule I

In this section, generators are developed to generate minimal CWBRMDs in periods of two different sizes using method of cyclic shifts (Rule I). Here i sets are for p_1 and two for p_2 .

Generator 5.1.1. Following $(i+2)$ sets of shifts provide minimal CWBRMD for $v = 2mi + 4s + 2$, $p_1 = 2m$, and $p_2 = 2s$, i integer, and m (integer) > 2 . Here, ordered pairs $\{(0, v/2), (1, (v+2)/2), \dots, ((v-2)/2, v-1), (v/2, 0), ((v+2)/2, 1), \dots, (v-1, (v-2)/2)\}$ do not appear together while all other appear once.



Table 8. CWBRMDs for $v = 2mi + 2s + 2$, $p_1 = 2m$, and $p_2 = s$ (even), i integer.

v	p_1	p_2	Sets of shifts	E_r	E_s
28	10	8	$[1,2,3,4,5,27,26,25,24] + [6,7,8,9,22,21,20] + [10,11,12,13,18,17,16]$	0.91	0.95
38	10	8	$[1,2,3,4,5,37,36,35,34] + [6,7,8,9,10,32,31,30,29] + [11,12,13,14,27,26,25] + [15,16,17,18,23,22,21]$	0.91	0.94
30	12	8	$[1,2,4,3,6,5,29,28,27,26,25] + [7,8,9,10,23,22,21] + [11,12,13,14,19,18,17]$	0.92	0.95
42	12	8	$[1,2,4,3,6,5,41,40,39,38,37] + [7,9,8,10,11,12,35,33,34,32,31] + [13,14,16,29,15,28,27] + [17,18,19,20,25,24,23]$	0.92	0.94

Table 9. CWBRMDs for $v = 2mi + 2s$, $p_1 = 2m$, and $p_2 = s$ (even), i integer.

v	p_1	p_2	Sets of shifts	E_r	E_s
22	10	6	$[1,2,3,4,5,21,20,19,18] + [6,7,8,16,15] + [9,10,11,13,12]$	0.90	0.93
32	10	6	$[1,2,3,4,5,31,30,29,28] + [6,7,8,9,10,26,25,24,23] + [11,12,13,21,20] + [14,15,16,18,17]$	0.90	0.96
28	12	8	$[1,2,4,3,6,5,27,26,25,24,23] + [7,8,9,10,21,20,19] + [12,11,13,14,17,16,15]$	0.92	0.95
30	14	8	$[1,2,3,4,5,6,7,29,28,27,26,25,24] + [9,8,10,11,21,22,20] + [13,12,14,15,18,17,16]$	0.93	0.95

$$S_{j+1} = [mj + 1, mj + 2, \dots, mj + m, v - (mj + 1), v - (mj + 2), \dots, v - (mj + m - 1)]; j = 0, 1, \dots, i - 1$$

$$S_{i+1} = [mi + 1, mi + 2, \dots, mi + s, v - (mi + 1), v - (mi + 2), \dots, v - (mi + s - 1)]$$

$$S_{i+2} = [mi + s + 1, mi + s + 2, \dots, mi + 2s, v - (mi + s + 1), v - (mi + s + 2), \dots, v - (mi + 2s - 1)]$$

Examples are given in Table 8.

Generator 5.1.2. Following $(i + 2)$ sets of shifts provide minimal CWBRMD for $v = 2mi + 4s$, $p_1 = 2m$, and $p_2 = 2s$, i integer, and m (integer) > 2 . Here, ordered pairs $\{(0, v/2), (1, (v + 2)/2), \dots, ((v - 2)/2, v - 1), (v/2, 0), ((v + 2)/2, 1), \dots, (v - 1, (v - 2)/2)\}$ appear twice together while all other appear once.

$$S_{j+1} = [mj + 1, mj + 2, \dots, mj + m, v - (mj + 1), v - (mj + 2), \dots, v - (mj + m - 1)]; j = 0, 1, \dots, i - 1$$

$$S_{i+1} = [mi + 1, mi + 2, \dots, mi + s, v - (mi + 1), v - (mi + 2), \dots, v - (mi + s - 1)]$$

$$S_{i+2} = [mi + s + 1, mi + s + 2, \dots, mi + 2s, v - (mi + s + 1), v - (mi + s + 2), \dots, v - (mi + 2s - 1)]$$

Examples are given in Table 9.

5.2. Minimal CWBRMDs in periods of two different sizes using Rule II

In this section, some generators are developed to obtain minimal CWBRMDs in periods of two different sizes using method of cyclic shifts (Rule II). Here i sets are for p_1 and two for p_2 .

Generator 5.2.1. Following $(i + 2)$ sets of shifts provide minimal CWBRMD for $v = 2mi + 4s + 1$, $p_1 = 2m$, and $p_2 = 2s$, where i integer, m (integer) > 4 . Here, ordered pairs $\{(0, (v + 1)/2), (1, (v + 3)/2), \dots, ((v - 5)/2, v - 2), ((v - 3)/2, 0), ((v - 1)/2, 1), \dots, (v - 2, (v - 1)/2)\}$ do not appear together while all other appear once.

$$S_{j+1} = [mj + 1, mj + 2, \dots, mj + m, v - 1 - (mj + 1), v - 1 - (mj + 2), \dots, v - 1 - (mj + m - 1)]; j = 0, 1, \dots, i - 1$$



Table 10. CWBRMDs for $v = 2mi + 2s + 1$, $p_1 = 2m$, and $p_2 = s$, where i integer, s (even) > 2 .

v	p_1	p_2	Sets of shifts	E_r	E_s
21	8	6	$[1,2,3,4,19,18,17] + [5,6,7,15,14] + [8,9,10,12]t$	0.99	0.93
23	10	6	$[1,2,3,4,5,21,20,19,18] + [6,7,8,16,15] + [9,10,11,13]t$	0.99	0.93
29	12	8	$[1,2,3,4,5,6,27,26,25,24,23] + [7,8,9,10,21,20,19] + [11,12,13,14,17,16]t$	0.91	0.95
31	14	8	$[1,2,3,4,5,6,7,29,28,27,26,25,24] + [9,8,10,11,21,22,20] + [13,12,14,15,18,17]t$	0.99	0.95

Table 11. CWBRMDs for $v = 2mi + 2s - 1$, $p_1 = 2m$, and $p_2 = s$, where i integer, s (even) > 2 .

v	p_1	p_2	Sets of shifts	E_r	E_s
19	8	6	$[1,2,3,4,17,16,15] + [5,6,13,7,12] + [8,9,10,10]t$	0.99	0.92
25	10	8	$[1,2,3,4,5,23,22,21,20] + [7,6,8,9,17,18,16] + [10,11,12,13,14,13]t$	0.99	0.94
27	12	8	$[1,2,4,3,6,5,25,24,23,22,21] + [7,8,9,10,19,18,17] + [11,12,13,14,15,14]t$	0.99	0.95
33	14	10	$[1,2,3,4,5,6,7,31,30,29,28,27,26] + [8,9,10,11,12,24,23,22,21] + [13,14,15,16,17,19,18,17]t$	0.99	0.96

$$S_{i+1} = [mi + 1, mi + 2, \dots, mi + s, v - 1 - (mi + 1), v - 1 - (mi + 2), \dots, v - 1 - (mi + s - 1)]$$

$$S_{i+2} = [mi + s + 1, mi + s + 2, \dots, mi + 2s, v - 1 - (mi + s + 1), v - 1 - (mi + s + 2), \dots, v - 1 - (mi + 2s - 2)]t$$

Examples are given in Table 10.

Generator 5.2.2. Following $(i + 2)$ sets of shifts provide minimal CWBRMD for $v = 2mi + 4s - 1$, $p_1 = 2m$, and $p_2 = 2s$, where i integer, m (integer) > 4 . Here, ordered pairs $\{(0, (v + 1)/2), (1, (v + 3)/2), \dots, ((v - 5)/2, v - 2), ((v - 3)/2, 0), ((v - 1)/2, 1), \dots, (v - 2, (v - 1)/2)\}$ appear twice together while all other appear once.

$$S_{j+1} = [mj + 1, mj + 2, \dots, mj + m, v - 1 - (mj + 1), v - 1 - (mj + 2), \dots, v - 1 - (mj + m - 1)]; j = 0, 1, \dots, i - 1$$

$$S_{i+1} = [mi + 1, mi + 2, \dots, mi + s, v - 1 - (mi + 1), v - 1 - (mi + 2), \dots, v - 1 - (mi + s - 1)]$$

$$S_{i+2} = [mi + s + 1, mi + s + 2, \dots, mi + 2s, v - 1 - (mi + s + 1), v - 1 - (mi + s + 2), \dots, v - 1 - (mi + 2s - 2)]t$$

Examples are given in Table 11.

6. Minimal CWBRMDs in periods of three different sizes

6.1. Minimal CWBRMDs in periods of three different sizes using Rule I

In this section, some generators are developed to generate minimal CWBRMDs in periods of three different sizes using method of cyclic shifts (Rule I).

Generator 6.1.1. If $v = 2mi + 2s + 2u + 2$, $p_1 = 2m$, $m > 3$ integer, $p_2 = 2s$, $s > 2$, and $p_3 = 2u$, $u > 1$, where $u < s < m$ then minimal CWBRMD can be constructed through the following $i + 2$ sets of shifts. Here i sets are for p_1 , one for p_2 , and also one for p_3 . In these designs, ordered pairs $\{(0, v/2), (1, (v + 2)/2), \dots, ((v - 2)/2, v - 1), (v/2, 0), ((v + 2)/2, 1), \dots, (v - 1, (v - 2)/2)\}$ do not appear together as preceded value while all other appear once.

$$S_{j+1} = [mj + 1, mj + 2, \dots, mj + m, v - (mj + 1), v - (mj + 2), \dots, v - (mj + m - 1)]; j = 0, 1, \dots, i - 1$$

$$S_{i+1} = [mi + 1, mi + 2, \dots, mi + s, v - (mi + 1), v - (mi + 2), \dots, v - (mi + (s - 1))]$$



Table 12. CWBRMDs for $v=2mi+2s+2u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

v	p_1	p_2	p_3	Sets of shifts	E_r	E_s
26	12	8	4	$[1,2,4,3,6,5,25,24,23,22,21] + [7,8,9,10,19,18,17] + [11,12,15]$	0.92	0.94
38	12	8	4	$[1,2,4,3,6,5,37,36,35,34,33] + [8,7,9,10,11,12,30,31,29,28,27] + [13,14,15,16,25,24,23] + [17,18,21]$	0.91	0.96
38	14	12	10	$[1,2,3,4,5,6,7,37,36,35,34,33,32] + [10,8,9,12,11,30,13,29,28,27,26] + [14,15,16,17,18,24,23,22,21]$	0.94	0.96
52	14	12	10	$[1,2,3,4,5,6,7,51,50,49,48,47,46] + [9,8,11,10,13,12,14,43,44,42,41,40,39] + [15,16,17,18,19,20,37,36,35,34,33] + [21,22,23,24,25,31,30,29,28]$	0.94	0.97

Table 13. CWBRMDs for $v=2mi+4s+2u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

v	p_1	p_2	p_3	Sets of shifts	E_r	E_s
36	12	8	6	$[1,2,4,3,6,5,35,34,33,32,31] + [7,8,9,10,29,28,27] + [11,12,25,13,14,24,23] + [15,16,17,21,20]$	0.90	0.96
48	12	8	6	$[1,2,4,3,6,5,47,46,45,44,43] + [7,8,9,10,11,12,41,40,39,38,37] + [13,14,15,16,35,34,33] + [17,18,19,20,31,30,29] + [21,22,23,27,26]$	0.91	0.97
38	14	8	6	$[1,2,3,4,5,6,7,37,36,35,34,33,32] + [8,9,10,30,11,29,28] + [12,13,14,15,26,25,24] + [16,17,18,22,21]$	0.91	0.96
52	14	8	6	$[1,2,3,4,5,6,7,51,50,49,48,47,46] + [9,8,11,10,13,12,14,43,44,42,41,40,39] + [15,16,17,18,37,36,35] + [19,20,21,22,33,32,31] + [23,24,25,29,28]$	0.92	0.97

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+s+u, v-(mi+s+1), v-(mi+s+2), \dots, v-(mi+s+u-1)]$$

Examples are given in Table 12.

Generator 6.1.2. If $v=2mi+4s+2u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$, where $u<s<m$ then minimal CWBRMD can be constructed through the following $(i+3)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and one for p_3 . In these designs, ordered pairs $\{(0, v/2), (1, (v+2)/2), \dots, ((v-2)/2, v-1), (v/2, 0), ((v+2)/2, 1), \dots, (v-1, (v-2)/2)\}$ do not appear together as preceded value while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-(mj+1), v-(mj+2), \dots, v-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-(mi+1), v-(mi+2), \dots, v-(mi+(s-1))]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-(mi+s+1), v-(mi+s+2), \dots, v-(mi+(2s-1))]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-(mi+2s+1), v-(mi+2s+2), \dots, v-(mi+2s+u-1)]$$

Examples are given in Table 13.

Generator 6.1.3. If $v=2mi+4s+4u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$, where $u<s<m$ then minimal CWBRMD can be constructed through the following $(i+4)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and also two for p_3 . In these designs, ordered pairs $\{(0, v/2), (1, (v+2)/2), \dots, ((v-2)/2, v-1), (v/2, 0), ((v+2)/2, 1), \dots, (v-1, (v-2)/2)\}$ do not appear together as preceded value while all other appear once.



Table 14. CWBRMDs for $v=2mi+4s+4u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

v	p_1	p_2	p_3	Sets of shifts	E_r	E_s
32	10	6	4	$[1,2,3,4,5,31,30,29,28] + [6,7,8,26,25] + [9,10,11,23,22] + [12,13,20] + [14,15,18]$	0.86	0.95
40	10	8	6	$[1,2,3,4,5,39,38,37,36] + [6,7,8,9,34,33,32] + [10,11,12,13,30,29,28] + [14,15,16,26,25] + [17,18,19,23,22]$	0.88	0.96
42	12	8	6	$[1,2,4,3,6,5,41,40,39,38,37] + [7,8,9,10,35,34,33] + [11,12,13,14,31,30,29] + [15,16,17,27,26] + [18,19,20,24,23]$	0.89	0.97
50	12	10	8	$[1,2,4,3,6,5,49,48,47,46,45] + [7,8,9,10,11,43,42,41,40] + [12,13,14,15,16,38,37,36,35] + [17,18,19,20,33,32,31] + [21,22,23,24,29,28,27]$	0.91	0.97

Table 15. CWBRMDs for $v=2mi+2s+2u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

v	p_1	p_2	p_3	Sets of shifts	E_r	E_s
24	12	8	4	$[1,2,4,3,6,5,23,22,21,20,19] + [7,8,17,9,10,16,15] + [11,12,13]$	0.91	0.94
36	12	8	4	$[1,2,4,3,6,5,35,34,33,32,31] + [7,8,9,10,11,12,29,28,27,26,25] + [13,14,15,16,23,22,21] + [17,18,19]$	0.91	0.96
26	14	8	4	$[4,1,3,2,6,5,7,25,24,23,22,21,20] + [8,9,10,11,18,17,16] + [12,13,14]$	0.92	0.94
40	14	8	4	$[1,2,3,4,5,6,7,39,38,37,36,35,34] + [8,9,11,10,13,12,14,32,31,30,29,28,27] + [15,16,17,18,25,24,23] + [19,20,21]$	0.92	0.96

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-(mj+1), v-(mj+2), \dots, v-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-(mi+1), v-(mi+2), \dots, v-(mi+(s-1))]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-(mi+s+1), v-(mi+s+2), \dots, v-(mi+(2s-1))]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-(mi+2s+1), v-(mi+2s+2), \dots, v-(mi+2s+u-1)]$$

$$S_{i+4} = [mi+2s+u+1, mi+2s+u+2, \dots, mi+2s+2u, v-(mi+2s+u+1), v-(mi+2s+u+2), \dots, v-(mi+2s+2u-1)]$$

Examples are given in Table 14.

Generator 6.1.4. If $v=2mi+2s+2u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+2)$ sets of shifts. Here i sets are for p_1 , one for p_2 , and also one for p_3 . In these designs, ordered pairs $\{(0, v/2), (1, (v+2)/2), \dots, ((v-2)/2, v-1), (v/2, 0), ((v+2)/2, 1), \dots, (v-1, (v-2)/2)\}$ appear twice together as preceded values while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-(mj+1), v-(mj+2), \dots, v-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-(mi+1), v-(mi+2), \dots, v-(mi+(s-1))]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+s+u, v-(mi+s+1), v-(mi+s+2), \dots, v-(mi+s+u-1)], \text{ for } u>1$$

Examples are given in Table 15.

Generator 6.1.5. If $v=2mi+4s+2u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+3)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and one for p_3 . In these designs, ordered pairs



Table 16. CWBRMDs for $v=2mi+4s+2u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

v	p_1	p_2	p_3	Sets of shifts	E_r	E_s
38	12	10	6	$[1,2,4,3,6,5,37,36,35,34,33] + [9,7,8,10,11,30,31,29,28] + [12,13,14,16,15,26,25,24,23] + [17,18,19,21,20]$	0.92	0.96
50	12	10	6	$[1,2,4,3,6,5,49,48,47,46,45] + [8,7,9,10,11,12,42,43,41,40,39] + [13,14,15,16,17,37,36,35,34] + [18,19,20,21,32,22,31,30,29] + [23,24,25,27,26]$	0.92	0.97
40	12	10	8	$[1,2,4,3,6,5,39,38,37,36,35] + [7,8,9,10,11,33,32,31,30] + [12,13,14,15,16,28,27,26,25] + [18,17,19,20,23,22,21]$	0.92	0.96
52	12	10	8	$[1,2,4,3,6,5,51,50,49,48,47] + [7,8,9,10,11,12,45,44,43,42,41] + [13,14,15,16,17,39,38,37,36] + [18,19,20,21,22,34,33,32,31] + [24,23,25,26,29,28,27]$	0.92	0.97

$\{(0, v/2), (1, (v+2)/2), \dots, ((v-2)/2, v-1), (v/2, 0), ((v+2)/2, 1), \dots, (v-1, (v-2)/2)\}$ appear twice together as preceded values while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-(mj+1), v-(mj+2), \dots, v-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-(mi+1), v-(mi+2), \dots, v-(mi+(s-1))]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-(mi+s+1), v-(mi+s+2), \dots, v-(mi+(2s-1))]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-(mi+2s+1), v-(mi+2s+2), \dots, v-(mi+2s+u-1)]$$

Examples are given in Table 16.

Generator 6.1.6. If $v=2mi+4s+4u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+4)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and also two for p_3 . In these designs, ordered pairs $\{(0, v/2), (1, (v+2)/2), \dots, ((v-2)/2, v-1), (v/2, 0), ((v+2)/2, 1), \dots, (v-1, (v-2)/2)\}$ appear twice together as preceded values while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-(mj+1), v-(mj+2), \dots, v-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-(mi+1), v-(mi+2), \dots, v-(mi+(s-1))]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-(mi+s+1), v-(mi+s+2), \dots, v-(mi+(2s-1))]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-(mi+2s+1), v-(mi+2s+2), \dots, v-(mi+2s+u-1)]$$

$$S_{i+4} = [mi+2s+u+1, mi+2s+u+2, \dots, mi+2s+2u, v-(mi+2s+u+1), v-(mi+2s+u+2), \dots, v-(mi+2s+2u-1)]$$

Examples are given in Table 17.

6.2. Minimal CWBRMDs in periods of three different sizes using Rule II

In this section, generators are developed to obtain minimal CWBRMDs in periods of three different sizes using method of cyclic shifts (Rule II).

Generator 6.2.1. If $v=2mi+2s+2u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u+1$, u integer then minimal CWBRMD can be constructed through the following



Table 17. CWBRMDs for $v=2mi+4s+4u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

v	p_1	p_2	p_3	Sets of shifts	E_r	E_s
40	12	8	6	$[1,2,4,3,6,5,39,38,37,36,35] + [7,8,9,10,33,32,31] + [11,12,13,14,29,28,27] + [15,16,17,25,24] + [18,19,20,22,21]$	0.89	0.96
52	12	8	6	$[1,2,4,3,6,5,51,50,49,48,47] + [7,8,9,10,11,12,45,44,43,42,41] + [13,14,15,16,39,38,37] + [17,18,19,20,35,34,33] + [21,22,23,31,30] + [24,25,26,28,27]$	0.91	0.97
50	14	10	8	$[1,2,3,4,5,6,7,49,48,47,46,45,44] + [8,9,10,11,42,12,41,40,39] + [13,14,15,16,17,37,36,35,34] + [18,19,20,21,32,31,30] + [23,22,24,25,28,27,26]$	0.92	0.97
64	14	10	8	$[1,2,3,4,5,6,7,63,62,61,60,59,58] + [8,9,11,10,13,12,14,56,55,54,53,52,51] + [15,16,17,18,19,49,48,47,46] + [20,21,22,23,24,44,43,42,41] + [25,26,27,28,39,38,37] + [30,29,31,32,35,34,33]$	0.92	0.98

Table 18. CWBRMDs for $v=2mi+2s+2u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u+1$.

v	p_1	p_2	p_3	Sets of shifts	E_r	E_s
19	8	6	3	$[1,2,3,4,17,16,15] + [5,6,13,7,12] + [8]t$	1.0	0.90
21	8	6	5	$[1,2,3,4,19,18,17] + [5,6,7,15,14] + [8,9,12]t$	1.0	0.91
25	10	8	5	$[1,2,3,4,5,23,22,21,20] + [7,6,8,9,17,18,16] + [10,11,14]t$	1.0	0.93
29	12	10	5	$[1,2,4,3,6,5,27,26,25,24,23] + [7,8,9,10,11,21,20,19,18] + [12,13,16]t$	1.0	0.94

$(i+2)$ sets of shifts. Here i sets are for p_1 , one for p_2 , and also one for p_3 . In these designs some ordered pairs do not appear together while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+s+u, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+s+u-1)]t$$

Examples are given in Table 18.

Generator 6.2.2. If $v=2mi+4s+2u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u+1$, u integer then minimal CWBRMD can be constructed through the following $(i+3)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and one for p_3 . In these designs some ordered pairs do not appear together while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+2s-1)]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-1-(mi+2s+1), v-1-(mi+2s+2), \dots, v-1-(mi+2s+u-1)]t$$

Examples are given in Table 19.

Generator 6.2.3. If $v=2mi+2s+2u+1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+2)$ sets of shifts. Here i sets are for p_1 , one for p_2 , and also one for p_3 . In these designs some ordered pairs do not appear together while all other appear once.



Table 19. CWBRMDs for $v=2mi+4s+2u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u+1$.

V	p_1	p_2	p_3	Sets of shifts	E_r	E_s
24	8	6	3	$[1,2,3,4,22,21,20] + [5,6,7,18,17] + [8,9,10,15,14] + [11]t$	0.99	0.94
26	8	6	5	$[1,2,3,4,24,23,22] + [5,6,7,20,19] + [8,9,10,17,16] + [11,12,14]t$	0.99	0.94
32	10	8	5	$[1,2,3,4,5,30,29,28,27] + [6,7,8,9,25,24,23] + [10,11,12,13,21,20,19] + [14,15,17]t$	0.99	0.95
38	12	10	5	$[1,2,4,3,6,5,36,35,34,33,32] + [7,8,9,10,11,30,29,28,27] + [12,13,14,15,16,25,24,23,22] + [17,18,20]t$	0.99	0.96

Table 20. CWBRMDs for $v=2mi+2s+2u+1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

V	p_1	p_2	p_3	Sets of shifts	E_r	E_s
23	10	8	4	$[1,2,3,4,5,21,20,19,18] + [6,7,8,9,16,15,14] + [10,11]t$	1.00	0.93
25	10	8	6	$[1,2,3,4,5,23,22,21,20] + [7,6,8,9,17,18,16] + [10,11,12,14]t$	1.00	0.94
31	12	10	8	$[1,2,4,3,6,5,29,28,27,26,25] + [7,8,9,10,23,11,21,22,20] + [12,13,14,15,18,17]t$	0.95	0.95
37	14	12	10	$[1,2,3,4,5,6,7,35,34,33,32,31,30] + [8,9,10,11,12,28,13,27,25,26,24] + [14,15,16,17,18,22,21,20]t$	1.00	0.96

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)];$$

$$j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+s+u, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+s+u-2)]t$$

Examples are given in Table 20.

Generator 6.2.4. If $v=2mi+4s+2u+1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+3)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and one for p_3 . In these designs some ordered pairs do not appear together while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)];$$

$$j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+2s-1)]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-1-(mi+2s+1), v-1-(mi+2s+2), \dots, v-1-(mi+2s+u-2)]t$$

Examples are given in Table 21.

Generator 6.2.5. If $v=2mi+4s+4u+1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+4)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and also two for p_3 . In these designs some ordered pairs do not appear together while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)];$$

$$j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+2s-1)]$$



Table 21. CWBRMDs for $v=2mi+4s+2u+1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

V	p_1	p_2	p_3	Sets of shifts	E_t	E_s
31	10	8	4	$[1,2,3,4,5,29,28,27,26] + [6,7,8,24,9,23,22] + [10,11,12,13,20,19,18] + [14,15]t$	0.99	0.95
33	10	8	6	$[1,2,3,4,5,31,30,29,28] + [6,7,8,9,26,25,24] + [10,11,12,13,22,21,20] + [14,15,16,18]t$	0.99	0.96
41	12	10	8	$[1,2,4,3,6,5,39,38,37,36,35] + [7,8,9,10,11,33,32,31,30] + [12,13,14,15,16,28,27,26,25] + [17,18,19,20,23,22]t$	0.94	0.96
49	14	12	10	$[1,2,3,4,5,6,7,47,46,45,44,43,42] + [8,9,10,11,12,13,40,39,38,37,36] + [15,14,16,17,18,19,33,34,32,31,30] + [20,21,22,23,24,28,27,26]t$	0.99	0.97

Table 22. CWBRMDs for $v=2mi+4s+4u+1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

V	p_1	p_2	p_3	Sets of shifts	E_t	E_s
35	10	8	4	$[1,2,3,4,5,33,32,31,30] + [6,7,8,9,28,27,26] + [10,11,12,13,24,23,22] + [14,15,20] + [16,17]t$	0.96	0.96
39	10	8	6	$[1,2,3,4,5,37,36,35,34] + [6,7,8,9,32,31,30] + [10,11,12,13,28,27,26] + [14,15,16,24,23] + [17,18,19,21]t$	0.97	0.96
48	12	10	8	$[2,1,4,3,46,5,6,45,44,42,43] + [7,8,9,10,11,41,40,39,38] + [13,12,14,15,16,36,33,35,34] + [17,18,19,20,31,30,29] + [21,22,23,24,27,26]t$	0.84	0.94
59	14	12	10	$[1,2,3,4,5,6,7,57,56,55,54,53,52] + [8,9,10,11,12,13,50,49,48,47,46] + [14,15,16,17,18,19,44,43,42,41,40] + [20,21,22,23,24,38,37,36,35] + [25,26,27,28,29,33,32,31]t$	0.98	0.97

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-1-(mi+2s+1), v-1-(mi+2s+2), \dots, v-1-(mi+2s+u-1)]$$

$$S_{i+4} = [mi+2s+u+1, mi+2s+u+2, \dots, mi+2s+2u, v-1-(mi+2s+u+1), v-1-(mi+2s+u+2), \dots, v-1-(mi+2s+2u-2)]t$$

Examples are given in Table 22.

Generator 6.2.6. If $v=2mi+2s+2u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u+1$, u integer then minimal CWBRMD can be constructed through the following $(i+2)$ sets of shifts. Here i sets are for p_1 , one for p_2 , and also one for p_3 . In these designs some ordered pairs appear twice together while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+s+u, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+s+u-1)]t$$

Examples are given in Table 23.

Generator 6.2.7. If $v=2mi+4s+2u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u+1$, u integer then minimal CWBRMD can be constructed through the following $(i+3)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and one for p_3 . In these designs some ordered pairs appear twice together while all other appear once.



Table 23. CWBRMDs for $v=2mi+2s+2u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u+1$.

V	p_1	p_2	p_3	Sets of shifts	E_r	E_s
16	8	6	3	$[1,2,3,4,14,13,12] + [5,6,7,10,9] + [8]t$	1.00	0.91
18	8	6	5	$[1,2,3,4,16,15,14] + [5,6,7,12,11] + [8,9,9]t$	0.92	0.92
22	10	8	5	$[1,2,3,4,5,20,19,18,17] + [6,7,9,15,8,14,13] + [10,11,11]t$	0.94	0.94
26	12	10	5	$[1,2,4,3,6,5,24,23,22,21,20] + [7,8,9,10,11,18,17,16,15] + [12,13,13]t$	0.94	0.95

Table 24. CWBRMDs for $v=2mi+4s+2u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u+1$.

V	p_1	p_2	p_3	Sets of shifts	E_r	E_s
22	8	6	3	$[1,2,3,4,20,19,18] + [5,6,7,16,15] + [8,9,10,13,12] + [11]t$	0.99	0.94
24	8	6	5	$[1,2,3,4,22,21,20] + [5,6,7,18,17] + [8,9,10,15,14] + [11,12,12]t$	0.90	0.94
30	10	8	5	$[1,2,3,4,5,28,27,26,25] + [6,7,8,9,23,22,21] + [10,11,12,13,19,18,17] + [14,15,15]t$	0.92	0.95
36	12	10	5	$[1,2,4,3,6,5,34,33,32,31,30] + [7,8,9,10,11,28,27,26,25] + [12,13,14,15,23,16,22,21,20] + [17,18,18]t$	0.93	0.96

Table 25. CWBRMDs for $v=2mi+2s+2u-1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

V	p_1	p_2	p_3	Sets of shifts	E_r	E_s
19	10	6	4	$[1,2,3,4,5,17,16,15,14] + [6,7,8,12,11] + [9,10]t$	1.0	0.93
23	10	8	6	$[1,2,3,4,5,21,20,19,18] + [6,7,8,9,16,15,14] + [10,11,12,12]t$	1.0	0.94
27	12	10	6	$[1,2,4,3,6,5,25,24,23,22,21] + [7,8,9,10,11,19,18,17,16] + [12,13,14,14]t$	1.0	0.95
29	12	10	8	$[1,2,4,3,6,5,27,26,25,24,23] + [7,8,9,10,11,21,20,19,18] + [12,13,14,15,16,15]t$	1.0	0.95

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+2s-1)]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-1-(mi+2s+1), v-1-(mi+2s+2), \dots, v-1-(mi+2s+u-1)]t$$

Examples are given in Table 24.

Generator 6.2.8. If $v=2mi+2s+2u-1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+2)$ sets of shifts. Here i sets are for p_1 , one for p_2 , and also one for p_3 . In these designs some ordered pairs appear twice together while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+s+u, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+s+u-2)]t$$

Examples are given in Table 25.

Generator 6.2.9. If $v=2mi+4s+2u-1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+3)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and one for p_3 . In these designs some ordered pairs appear twice together while all other appear once.



Table 26. CWBRMDs for $v=2mi+4s+2u-1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

V	p_1	p_2	p_3	Sets of shifts	E_r	E_s
29	10	8	4	$[1,2,3,4,5,27,26,25,24] + [6,7,8,9,22,21,20] + [10,11,12,13,18,17,16] + [14,15]t$	0.99	0.95
31	10	8	6	$[1,2,3,4,5,29,28,27,26] + [6,7,8,24,9,23,22] + [10,11,12,13,20,19,18] + [14,15,16,16]t$	0.99	0.95
39	12	10	8	$[1,2,4,3,6,5,37,36,35,34,33] + [8,7,9,10,11,30,31,29,28] + [12,13,14,16,15,26,25,24,23] + [17,18,19,20,21,20]t$	0.99	0.96
41	14	10	8	$[1,2,3,4,5,6,7,39,38,37,36,35,34] + [8,9,10,11,12,32,31,30,29] + [13,14,15,16,17,27,26,25,24] + [18,19,20,21,22,21]t$	0.99	0.97

Table 27. CWBRMDs for $v=2mi+4s+4u-1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

V	p_1	p_2	p_3	Sets of shifts	E_r	E_s
33	10	8	4	$[1,2,3,4,5,31,30,29,28] + [6,7,8,9,26,25,24] + [10,11,12,13,22,21,20] + [14,15,18] + [16,17]t$	0.96	0.96
37	10	8	6	$[1,2,3,4,5,35,34,33,32] + [6,7,8,9,30,29,28] + [10,11,12,26,25,13,24] + [14,15,16,22,21] + [17,18,19,19]t$	0.97	0.96
43	12	10	6	$[1,2,4,3,6,5,41,40,39,38,37] + [7,8,9,10,11,35,34,33,32] + [13,12,14,15,16,29,30,28,27] + [17,18,19,25,24] + [20,21,22,22]t$	0.97	0.97
47	12	10	8	$[1,2,4,3,6,5,45,44,43,42,41] + [7,8,9,10,11,39,38,37,36] + [13,12,14,15,16,34,33,32,31] + [17,18,19,20,29,28,27] + [21,22,23,24,25,24]t$	0.98	0.97

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+2s-1)]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-1-(mi+2s+1), v-1-(mi+2s+2), \dots, v-1-(mi+2s+u-2)]t$$

Examples are given in Table 26.

Generator 6.2.10. If $v=2mi+4s+4u-1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+4)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and also two for p_3 . In these designs some ordered pairs appear twice together while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+2s-1)]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-1-(mi+2s+1), v-1-(mi+2s+2), \dots, v-1-(mi+2s+u-1)]$$

$$S_{i+4} = [mi+2s+u+1, mi+2s+u+2, \dots, mi+2s+2u, v-1-(mi+2s+u+1), v-1-(mi+2s+u+2), \dots, v-1-(mi+2s+2u-2)]t$$

Examples are given in Table 27.



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Optimal minimal balanced crossover designs in first and second carryover effects

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ABSTRACT

Crossover designs balanced in first and second order carryover effects discussed in literature often require large number of experimental units. In practice experiments demand fewer experimental units where minimal balanced crossover designs are desirable. In this paper, a simple method of construction of minimal balanced crossover designs through a new form of terrace is presented. A new form of terrace constructs one series of crossover designs having less number of periods than the number of treatments and two series of crossover designs having more periods than the treatments. Crossover designs possess good efficiency of separability and optimal for the estimation of treatment effects.

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Crossover; treatment effect; minimal; terrace; second order carryover effect

1. Introduction

A crossover design is an arrangement of experiment in which experimental units are used repeatedly by exposing them according to a sequence of treatments over a span of time. Apparently each unit is influenced by the effect of current treatment and carryover effects of the previously applied treatments. The main advantage of a crossover design is that the treatments are compared within experimental units and such studies allow a more precise comparison of treatments. Some real life applications of the crossover designs are discussed by Taka and Armitage (1983) and Matthews (1989). Literature review of the applications of the three types of crossover designs shows that each of them has specific applications. The crossover designs with number of periods less than the treatments are suitable in clinical trials and pharmaceutical studies. The crossover designs with number of periods equal to the number of treatments so that each unit receives every treatment once are employed in agriculture and for the sensory evaluation of food and products. The crossover designs having periods more than the number of treatments are useful in animal nutrition and educational experiments (e.g., Gill 1978).

Crossover designs suitable for estimation of model with first order carryover effects have been discussed by many authors. However, the experimental studies like Thorough QT studies (ICH Guidance 2005; Ring et al. 2010, etc.), diet study, asthma study (Brusasco et al. 2002) etc. in which multi period crossover design is profitably used, it is

possible that carryover effects do not die unexpectedly after one period as commented by Jones and Quenouille (1977, 198). Only four authors discussed crossover designs suitable for such experiments which require balanced crossover design in first and second carryover. Patterson (1952) gave the conditions for carryover treatment effects designs balanced for first and second order carryover effects. Sharma (1977) presented a method of construction of crossover designs with complete balance for first and second order carryover effects. Collombier and Merchermek (1993) studied optimal crossover experimental designs for higher order carryover effects. Bose and Mukherjee (2000) constructed multi period crossover designs suitable for such studies. Their designs are optimal for estimation of treatment effects under non additive, higher order carryover model with correlated errors (Bose and Mukherjee 2003) for a specific correlation structure that, every two observations from a unit are identically correlated. Aggarwal, Deng, and Jha (2006) constructed balanced carryover treatment effects designs of first and second order using balanced incomplete block designs (BIBDs), balanced ternary designs and mutually orthogonal Latin squares (MOLS).

Bailey (1984) defined the term “terrace” and constructed Quasi-complete Latin squares. Morgan (1988) generalized the idea of terrace to m-terrace and constructed balanced polycross designs. Divecha and Gondaliya (2014) given modified forms of terrace called complementary pair of terraces and complementary trio of terraces and provided four series of minimal balanced crossover designs suitable for first order carryover model. Gondaliya (2019) provided a computer program that meet the practical need of experimenters/users through variety of terraces and crossover designs for the same class. The present paper introduces modified form of terrace called $terrace(t, g_1, g_2)$ and provides a simple method for the construction of three new series of minimal balanced crossover designs suitable for the optimal estimation of treatment effects. The $terrace(t, g_1, g_2)$ constructs two series of crossover designs for the case of more number of periods than the number of treatments while one series of crossover designs for the case of less number of periods than the number of treatments. All the designs are minimal balanced in first and second carryover and possess good efficiency of separability. Section 2 presents the model and characterization of crossover designs. Construction of three new series of crossover designs through $terrace(t, g_1, g_2)$ is discussed and illustrated by examples in Section 3. Newly constructed designs are compared with literature through efficiency.

2. Characterization and model

2.1. Characterization of crossover design

A crossover design for t treatments in n experimental units repeatedly measured for p periods is denoted by $COD(t, n, p)$.

Definition 2.1. A $COD(t, n, p)$ is said to be *balanced* with respect to the set of treatment, first and second order carryover effects if (i) in each period, each treatment is given to λ_1 units (ii) in two successive periods, each ordered pair of distinct treatments is given to λ_2 units, while, each pair of treatments with itself is given to λ_3 units, and



(iii) in two periods at distance of two position, each ordered pair of distinct treatments is given to λ_4 units, where integer $\lambda_1, \lambda_2, \lambda_4$ are positive and λ_3 is non negative.

Consequently, a balanced crossover design satisfies the following parametric relations,

$$n = \lambda_1 t \quad (1)$$

$$n(p-1) = (\lambda_2(t-1) + \lambda_3)t \quad (2)$$

$$n(p-2) = t(t-1)\lambda_4 \quad (3)$$

A minimal balanced crossover design is a design in which the number of experimental units that receive each treatment in each period (λ_1) is as small as possible. From (1), (2) and (3), Definition 2.2 follows.

Definition 2.2. A balanced $COD(t, n, p)$ is said to be *minimal* balanced crossover design if λ_1 is the smallest integer such that

$$(\lambda_1(p-1) - \lambda_3) \equiv 0(\text{modulo}(t-1)) \quad (4)$$

$$(\lambda_1(p-2)) \equiv 0(\text{modulo}(t-1)) \quad (5)$$

In addition of the characteristic minimal balanced, a crossover design must be characterized for its ability of separating the treatment effects from first and second order carryover effects. A measure called efficiency of separability (ES) is calculated on the basis of observed frequencies of treatment with first and second order carryover and the expected frequencies from an independent model. Following Hanford (2005), a measure of ES of treatment from first and second order carryover effects for balanced crossover designs is calculated by

$$ES = \left[1 - \left\{ \frac{(t-1)\lambda_4(\lambda_3 - \lambda_2)^2 + \lambda_4^2(\lambda_3 + (t-1)\lambda_2)}{(\lambda_3 + (t-1)\lambda_2)(t-1)\lambda_4(\lambda_1 + \lambda_3 + (t-1)\lambda_2 + (t-1)\lambda_4)} \right\}^{\frac{1}{2}} \right] \times 100\% \quad (6)$$

For example, the ES of the $COD\{AAB, BBA\}$ calculated by substituting $\lambda_1 = 1, \lambda_2 = 1, \lambda_3 = 1$ and $\lambda_4 = 1$ in the Equation (6) is 50%. The low ES indicates unsuitability while the high ES indicates suitability of crossover design for the estimation of treatment, first and second order carryover effects under model 7.

2.2. Model

The model with an addition of second order carryover effects to the simple carryover model is known as second order carryover model given by,

$$y_{ijk} = \mu + \pi_k + \xi_{ij} + \tau_{d(k,j)} + \gamma_{1d(k-1,j)} + \gamma_{2d(k-2,j)} + \epsilon_{ijk} \quad (7)$$

where, y_{ijk} is the observation from sequence i having experimental unit j in period k in which treatment $d(k, j)$ was given, μ is the general mean effect, π_k is the effect due to period k , ξ_{ij} is the effect due to experimental unit j having sequence i , $\tau_{d(k,j)}$ is the effect of treatment $d(k, j)$ in the period in which it is applied, $\gamma_{1d(k-1,j)}$ is the first order carryover effect of treatment $d(k-1, j)$ in the period k which was applied



in the period $k - 1$ to the same unit, $\gamma_{2d(k-1,j)}$ is the second order carryover effect of treatment $d(k-2,j)$ in the period k which was applied in the period $k - 2$ to the same unit and the ϵ_{ijk} are independently normally distributed error term with mean 0 and variance σ^2 . It is obvious that there is no first order carryover effect in the first period and second order carryover effect in first and second period, that is, $\gamma_{1d(0,j)} = \gamma_{2d(-1,j)} = \gamma_{2d(0,j)} = 0$.

The joint information matrix of the treatment effects and first and second order carryover effects for the balanced crossover design d is given by

$$C_{d(\tau, \gamma_1, \gamma_2)} = \begin{pmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{pmatrix}$$

where,

$$\begin{aligned} C_{11} &= R - \frac{1}{n}L_1L'_1 - \frac{1}{p}L_2L'_2 + \frac{r^2}{np}J, C_{12} = M_1 - \frac{1}{n}L_1E'_1 - \frac{1}{p}L_2N'_1 + \frac{rr_1}{np}J, \\ C_{13} &= M_2 - \frac{1}{n}L_1E'_2 - \frac{1}{p}L_2N'_2 + \frac{rr_2}{np}J, C_{22} = R_1 - \frac{1}{n}E_1E'_1 - \frac{1}{p}N_1N'_1 + \frac{r_1^2}{np}J, \\ C_{23} &= M_3 - \frac{1}{n}E_1E'_2 - \frac{1}{p}N_1N'_2 + \frac{r_1r_2}{np}J, C_{33} = R_2 - \frac{1}{n}E_2E'_2 - \frac{1}{p}N_2N'_2 + \frac{r_2^2}{np}J, \\ C_{21} &= C'_{12}, C_{31} = C'_{13}, C_{32} = C'_{23} \end{aligned}$$

Here, R is incidence matrix of observations vs treatments; R_1 incidence matrix of observations vs first order carryover; R_2 incidence matrix of observations vs second order carryover; M_1 is the incidence matrix of treatments vs first order carryover; M_2 the incidence matrix of treatments vs second order carryover; M_3 the incidence matrix of first order carryover vs second order carryover; L_1 the incidence matrix of treatments vs periods; L_2 the incidence matrix of treatments vs units; E_1 the incidence matrix of first order carryover vs periods; E_2 the incidence matrix of second order carryover vs periods; N_1 the incidence matrix of first order carryover vs units; N_2 the incidence matrix of second order carryover vs units. Also we have r is the replication of treatment; r_1 the replication of first order carryover; r_2 the replication of second order carryover; J the matrix with all elements unity.

3. Construction of crossover designs

Construction of crossover design balanced in first and second order carryover effects through only two simple steps is discussed in this section. Define a *terrace* (t, g_1, g_2) in form of $p \times s$ matrix and add all the numbers $0, 1, \dots, t - 1$ to it.

Step 1: Define terrace (t, g_1, g_2)

Let X be a $p \times s$ matrix for some positive integer $s = \frac{n}{t}$ having numbers from $Z_t = \{0, 1, \dots, t - 1\}$ in which repeats and non occurrences of the numbers are accepted during arrangement of numbers. Let $X^{(1)}$ and $X^{(2)}$ be the $(p - 1) \times s$ and $(p - 2) \times s$ matrices respectively contain difference of the numbers in following manner,



$$X^{(1)} = \begin{pmatrix} x_{21} - x_{11} & x_{22} - x_{12} & \dots & x_{2s} - x_{1s} \\ x_{31} - x_{21} & x_{32} - x_{22} & \dots & x_{3s} - x_{2s} \\ \vdots & \vdots & \vdots & \vdots \\ x_{p1} - x_{(p-1)1} & x_{p2} - x_{(p-1)2} & \dots & x_{ps} - x_{(p-1)s} \end{pmatrix} \text{ modulo } t$$

$$X^{(2)} = \begin{pmatrix} x_{31} - x_{11} & x_{32} - x_{12} & \dots & x_{3s} - x_{1s} \\ x_{41} - x_{21} & x_{42} - x_{22} & \dots & x_{4s} - x_{2s} \\ \vdots & \vdots & \vdots & \vdots \\ x_{p1} - x_{(p-2)1} & x_{p2} - x_{(p-2)2} & \dots & x_{ps} - x_{(p-2)s} \end{pmatrix} \text{ modulo } t$$

Definition 3.1. A $p \times s$ matrix X from Z_t is said to be a *terrace* (t, g_1, g_2) for some positive integer g_1 and non negative integer g_2 if $X^{(1)}$ contains each non zero numbers of Z_t exactly g_1 times, zero exactly g_2 times and $X^{(2)}$ contains each non zero number of Z_t exactly g_1 times.

Step 2: Write crossover design by adding all the numbers $0, 1, \dots, t-1$ to *terrace* (t, g_1, g_2)

A $p \times n$ matrix where $n = ts$ is obtained by adding all the numbers of Z_t to each elements of X modulo t in following way produces the specified crossover design.

$$\left(\begin{array}{cccc|cccc} x_{11} + 0 & x_{12} + 0 & \dots & x_{1s} + 0 & \dots & x_{11} + (t-1) & x_{12} + (t-1) & \dots & x_{1s} + (t-1) \\ x_{21} + 0 & x_{22} + 0 & \dots & x_{2s} + 0 & \dots & x_{21} + (t-1) & x_{22} + (t-1) & \dots & x_{2s} + (t-1) \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{p1} + 0 & x_{p2} + 0 & \dots & x_{ps} + 0 & \dots & x_{p1} + (t-1) & x_{p2} + (t-1) & \dots & x_{ps} + (t-1) \end{array} \right) \text{ modulo } t$$

Here, rows of the matrix are periods and columns are experimental units. From the definition of *terrace* (t, g_1, g_2) , it is clear that $\lambda_3 = g_2$ because occurrence of same number in two successive positions in same column of X contribute zero in $X^{(1)}$. Now, from the Equations (1)–(3), $\lambda_1 = \frac{n}{t}$, $\lambda_2 = \frac{n(p-1)-g_2t}{t(t-1)}$ and $\lambda_4 = \frac{n(p-2)}{t(t-1)}$.

Case 3.1. For $s = 2$, $p = \frac{t+3}{2}$ for odd t (> 3), $g_1 = 1$ and $g_2 = 2$, a *terrace* $(t, 1, 2)$ in $p \times 2$ matrix produces a series of minimal balanced $COD(t, 2t, \frac{t+3}{2})$ by adding all the numbers of Z_t to each elements of X reduced modulo t .

Here, $\lambda_3 = g_2 = 2$ and hence from the Equations (1)–(3), $\lambda_1 = 2$, $\lambda_2 = 1$ and $\lambda_4 = 1$. Now, substituting $\lambda_1 = 1$ in Equation (4), $(\lambda_1(p-1) - \lambda_3) = \frac{t-3}{2}$, which is not divisible by $t-1$. However, substituting $\lambda_1 = 2$ in Equations (4) and (5) respectively, $(\lambda_1(p-1) - \lambda_3) = t-1$ and $\lambda_1(p-2) = t-1$, which is divisible by $t-1$. Hence, $COD(t, 2t, \frac{t+3}{2})$ is minimal balanced, because, $\lambda_1 = 2$ is the smallest integer which satisfies both the conditions of minimal balanced. Let l_{ij} be occurrence of the number i in column j of matrix $X_{p \times s}$; n_{ij} occurrence of the number i in column j of matrix $X_{(p-2) \times s}$, then, following theorem must hold.

Theorem 3.1. If *terrace* $(t, 1, 2)$ have minimum value of $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2$ and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2$ among all possible *terrace* $(t, 1, 2)$, then design d^* with $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2 = t+7$ and



$\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2 = t-1$ from $\text{terrace}(t, 1, 2)$ is universal optimal for treatment effects over $\text{COD}(t, 2t, \frac{t+3}{2})$.

Proof 3.1. After considerable algebra using properties of matrices, it may be shown that under model 7, for any balanced crossover design d in $\text{COD}(t, 2t, \frac{t+3}{2})$, the coefficient matrix C_d of the reduced normal equations for τ is given by

$$\begin{aligned} C_d &= C_{11} - [C_{12} \ C_{13}] \begin{bmatrix} C_{22} & C_{23} \\ C_{32} & C_{33} \end{bmatrix}^{-1} \begin{bmatrix} C_{21} \\ C_{31} \end{bmatrix} \\ &= \left(\frac{rp - \sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2 + p}{p} I + \frac{r^2 - np - \lambda_1^2 p^2}{np} J \right) - \left(-\lambda_4 I + \frac{rr_2 + \lambda_4 np - \lambda_1^2 p(p-2) - np}{np} J \right) \\ &\quad \left(\frac{p}{r_2 p - \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2} I + \frac{-rp(r_2^2 - \lambda_1^2 p(p-2))}{n(r_2 p - \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2)(pr_2^2 - \lambda_1^2 p^2(p-2) + rr_2 p - r \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2)} J \right) \\ &\quad \left(-\lambda_4 I + \frac{rr_2 + \lambda_4 np - \lambda_1^2 p(p-2) - np}{np} J \right) \\ &= \left(\frac{rp - \sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2 + p}{p} - \frac{p}{r_2 p - \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2} \right) I + \\ &\quad \left(\frac{r^2 - np - \lambda_1^2 p^2}{np} + \frac{rp(r_2^2 - \lambda_1^2 p(p-2))}{n(r_2 p - \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2)(pr_2^2 - \lambda_1^2 p^2(p-2) + rr_2 p - r \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2)} \right) J \end{aligned}$$

Hence, C_d is completely symmetric. Now, the trace of C_d is maximum if and only if the $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2$ and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2$ are minimum. Minimization of $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2$ and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2$ subject to $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij} = 2p$ and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij} = 2(p-2)$ respectively leads to,

$$\begin{aligned} \text{tr} C_d &= t \left(\frac{rp - \sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2 + p}{p} - \frac{p}{r_2 p - \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2} \right) \\ &\quad + t \left(\frac{r^2 - np - \lambda_1^2 p^2}{np} + \frac{rp(r_2^2 - \lambda_1^2 p(p-2))}{n(r_2 p - \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2)(pr_2^2 - \lambda_1^2 p^2(p-2) + rr_2 p - r \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2)} \right) \\ &\leq \frac{t(rp - p - 4)}{p} - \frac{tp}{r_2 p - 2p + 4} + \frac{t(r^2 - np - 4p^2)}{np} \\ &\quad + \frac{trp(r_2^2 - 4p(p-2))}{n(r_2 p - 2p + 4)(pr_2^2 - 4p^2(p-2) + rr_2 p - 2rp + 4r)} \\ &= \text{tr} C_{d^*} \end{aligned}$$

Hence, d^* satisfies the sufficient conditions for universal optimality as given by Kiefer (1975) and the theorem is proved.

Example 3.1. For $t=5$ in the series $\text{COD}(t, 2t, \frac{t+3}{2})$, arranging eight numbers from the group $Z_5 = \{0, 1, 2, 3, 4\}$ in 4×2 matrix as,



$$X = \begin{pmatrix} 0 & 1 \\ 4 & 2 \\ 1 & 0 \\ 1 & 0 \end{pmatrix}$$

gives terrace(1, 2, 5) because $X^{(1)}$ contains each non zero numbers of Z_5 exactly one time, zero exactly two times and $X^{(2)}$ contains each non zero number of Z_5 exactly one time as shown below.

$$X^{(1)} = \begin{pmatrix} 4 & 1 \\ 2 & 3 \\ 0 & 0 \end{pmatrix} \quad \text{and} \quad X^{(2)} = \begin{pmatrix} 1 & 4 \\ 2 & 3 \end{pmatrix}.$$

Note that, $1 \equiv -4$ (modulo 5), $2 \equiv -3$ (modulo 5), $3 \equiv -2$ (modulo 5) and $4 \equiv -1$ (modulo 5). Adding each number 0, 1, 2, 3 and 4 of Z_5 to the matrix X reduced modulo 5 constructs the minimal balanced $COD(5, 10, 4)$ given by

		<i>Experimental units</i>									
		<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>10</i>
<i>Periods</i>	<i>1</i>	0	1	1	2	2	3	3	4	4	0
	<i>2</i>	4	2	0	3	1	4	2	0	3	1
	<i>3</i>	1	0	2	1	3	2	4	3	0	4
	<i>4</i>	1	0	2	1	3	2	4	3	0	4

Note that, $\lambda_1 = 2, \lambda_2 = 1, \lambda_3 = 2, \lambda_4 = 1$ and $ES = 81\%$. Also, $(\sum_{i=0}^{t-1} l_{i1}^2 + \sum_{i=0}^{t-1} l_{i2}^2) = 12$ and $(\sum_{i=0}^{t-1} n_{i1}^2 + \sum_{i=0}^{t-1} n_{i2}^2) = 4$, hence design is optimal.

Example 3.2. For $t=7$ in the series $COD(t, 2t, \frac{t+3}{2})$, arranging ten numbers from the group $Z_7 = \{0, 1, 2, 3, 4, 5, 6\}$ in 5×2 matrix X gives terrace(1, 2, 7) because $X^{(1)}$ contains each non zero numbers of Z_7 exactly one time, zero exactly two times and $X^{(2)}$ contains each non zero number of Z_7 exactly one time as shown below.

$$X = \begin{pmatrix} 0 & 0 \\ 1 & 6 \\ 4 & 3 \\ 2 & 5 \\ 2 & 5 \end{pmatrix} \quad X^{(1)} = \begin{pmatrix} 1 & 6 \\ 3 & 4 \\ 5 & 2 \\ 0 & 0 \end{pmatrix} \quad \text{and} \quad X^{(2)} = \begin{pmatrix} 4 & 3 \\ 1 & 6 \\ 5 & 2 \end{pmatrix}.$$

Adding each number of Z_7 to the matrix X reduced modulo 7 constructs the minimal balanced $COD(7, 14, 5)$ given by

	Experimental units														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Periods	1	0	0	1	1	2	2	3	3	4	4	5	5	6	6
	2	1	6	2	0	3	1	4	2	5	3	6	4	0	5
	3	4	3	5	4	6	5	0	6	1	0	2	1	3	2
	4	2	5	3	6	4	0	5	1	6	2	0	3	1	4
	5	2	5	3	6	4	0	5	1	6	2	0	3	1	4



Note that, $\lambda_1 = 2, \lambda_2 = 1, \lambda_3 = 2, \lambda_4 = 1$ and $ES = 86\%$. Also, $(\sum_{i=0}^{t-1} l_{i1}^2 + \sum_{i=0}^{t-1} l_{i2}^2) = 14$ and $(\sum_{i=0}^{t-1} n_{i1}^2 + \sum_{i=0}^{t-1} n_{i2}^2) = 6$, hence design is optimal.

Case 3.2. For $s = 1, p = t + 1, g_1 = 1$ and $g_2 = 1$, a $terrace(t, 1, 1)$ in $p \times 1$ matrix produces a series of minimal balanced $COD(t, t, t + 1)$ by adding all the numbers of Z_t to each elements of X reduced modulo t .

Here, $\lambda_3 = g_2 = 1$ and hence from the Equations (1)–(3), $\lambda_1 = 1, \lambda_2 = 1$ and $\lambda_4 = 1$. Now, substituting $\lambda_1 = 1$ in Equations (4) and (5) respectively, $(\lambda_1(p - 1) - \lambda_3) = t - 1$ and $\lambda_1(p - 2) = t - 1$, which is divisible by $t - 1$. Hence, $COD(t, t, t + 1)$ is minimal balanced, because, $\lambda_1 = 1$ is the smallest integer which satisfies both the conditions of minimal balanced.

Theorem 3.2 . If $terrace(t, 1, 1)$ have minimum value of $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2$ and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2$ among all possible $terrace(t, 1, 1)$, then design d^* with $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2 = t + 7$ for odd t , $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2 = t + 5$ for even t and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2 = t + 1$ from $terrace(t, 1, 1)$ is universal optimal for treatment effects over $COD(t, t, t + 1)$.

Proof 3.2. Under model 7, for any balanced crossover design d in $COD(t, t, t + 1)$, the coefficient matrix C_d of the reduced normal equations for τ is same as shown in Theorem 3.1. Hence, C_d is completely symmetric. Now, the trace of C_d is maximum if and only if the $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2$ and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2$ are minimum. Minimization of $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2$ and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2$ subject to $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij} = t + 1$ and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij} = t - 1$ respectively leads to, for odd t ,

$$\begin{aligned} trC_d &\leq t \left(\frac{rp - (t + 7) + p}{p} - \frac{p}{r_2p - (t + 1)} \right) \\ &\quad + t \left(\frac{r^2 - np - p^2}{np} + \frac{rp(r_2^2 - p(p - 2))}{n(r_2p - (t + 1))(pr_2^2 - p^2(p - 2) + rr_2p - r(t + 1))} \right) \\ &= trC_{d^*} \end{aligned}$$

for even t ,

$$\begin{aligned} trC_d &\leq t \left(\frac{rp - (t + 5) + p}{p} - \frac{p}{r_2p - (t + 1)} \right) + \\ &\quad t \left(\frac{r^2 - np - p^2}{np} + \frac{rp(r_2^2 - p(p - 2))}{n(r_2p - (t + 1))(pr_2^2 - p^2(p - 2) + rr_2p - r(t + 1))} \right) \\ &= trC_{d^*} \end{aligned}$$

Hence, d^* satisfies the sufficient conditions for universal optimality as given by Kiefer (1975) and the theorem is proved.

Example 3.3. For $t = 6$ in the series $COD(t, t, t + 1)$, arranging seven numbers from the group $Z_6 = \{0, 1, 2, 3, 4, 5\}$ in 7×1 matrix $X = (0 \ 1 \ 5 \ 5 \ 2 \ 1 \ 3)'$ gives $terrace(1, 6)$ because $X^{(1)}$ contains each non zero numbers of Z_6 exactly one time, zero exactly one time and $X^{(2)}$



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A Study of Optimum Timing of Laparoscopic Cholecystectomy in Patients Presenting with Acute Cholecystitis

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ABSTRACT

BACKGROUND

Laparoscopic cholecystectomy is difficult in acute cholecystitis because the gall bladder is usually thick walled and tensely distended. If the inflammation of the gall bladder extends to the porta hepatis the dissection becomes difficult. The normally thin minimally adherent tissue that invest the cystic duct and artery is markedly thickened and oedematous and may not readily separate from these structures with the usual blunt dissection technique. The duct wall also may be oedematous, thus making its external diameter similar to gall bladder neck and common bile duct. Moreover, operative difficulty substantially increases with time. It is believed that laparoscopic cholecystectomy in acute cholecystitis is having more operative time, more conversion rate and more chance of injury.

METHODS

We did an observational study to determine the safety, benefits and drawbacks of laparoscopic cholecystectomy within 72 hours of symptoms (and beyond that).

RESULTS

Total 325 patients underwent laparoscopic cholecystectomy in acute cholecystitis. Among them 110 patients were operated within 72 hours of appearance of symptoms while 215 patients were operated upon after 72 hours of appearance of symptoms. The mean duration of surgery was significantly ($p < 0.001$) less in early surgery group. There was no conversion. There was no serious intra operative complication (injury) in early group. There was no statistically significant post-operative complication in either group. Post-operative stay was significantly less ($p < 0.004$) in early laparoscopic cholecystectomy group. Period of return to work was also significantly less ($p < 0.001$) in early group.

CONCLUSIONS

Early (within 72 hours of appearance of symptoms) laparoscopic cholecystectomy can be safely advocated in patients of acute cholecystitis. It does not result in increased conversion rate or increased intra operative complication. Moreover it offers benefits shorter post-operative hospital stay and early return to work than laparoscopic cholecystectomy after 72 hours of appearance of symptoms.

KEY WORDS

Cholecystectomy, Laparoscopic, Cholecystitis, Acute

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BACKGROUND

The advent of laparoscopic cholecystectomy has been a significant milestone not only in the treatment of gallstone disease, but also in the evolution of surgical treatment by minimal access. Anecdotal reports of laparoscopic procedure related death and bile duct related injury necessitate viewing laparoscopic cholecystectomy with cautious enthusiasm.⁽¹⁾ With growing experience overcoming the learning curve, selection criteria for this surgery has become more liberal. Most of previous contraindications such as morbid obesity, previous upper abdominal surgery and acute cholecystitis are no longer absolute contraindications. Studies involving open cholecystectomy have suggested that performing surgery within the first 3 days of onset of symptoms reduced the length of hospital stay and recovery time without increasing complications.⁽²⁾ The appropriate timing for cholecystectomy in the treatment of acute cholecystitis still remains controversial. Reports suggested that early laparoscopic surgery for acute cholecystitis was associated with increased complication rates, prolonged operation times and increased conversion rates.⁽³⁾ As a consequence, initial conservative management with subsequent elective laparoscopic cholecystectomy became the accepted practice.⁽⁴⁾ Delayed cholecystectomy potentially increases the chances of further gallstone related complications and thus farther hospital admission.⁽⁵⁾

How early cholecystectomy is 'early' is not clear in the literature, as this parameter has not been effectively tested in controlled randomized trials. Optimal timing of laparoscopic cholecystectomy for acute cholecystitis still remains under debate.⁽⁶⁾ The aim of this study is to evaluate the results of laparoscopic cholecystectomy for acute cholecystitis when laparoscopy is carried out early (within 72 hours from the onset of the symptoms) and late (after 72 hours from the onset of the symptoms). The objective of this study is to determine optimal timing of surgery with regard to patient safety in cases of acute cholecystitis.

The degree of operative difficulty increases substantially over time in acute cholecystitis and surgeons have typically used 72 hours as an arbitrary cut off in degree of difficulty of dissection. Generally, in the first 48 to 72 hours of symptoms the tissue planes are oedematous, but structures are identifiable, and the tissue planes separate without much difficulty. After 72 hours, the tissues become more friable and separate less well, the important structures are less likely to be seen well and there is often more obscure bleeding. For these reasons it is important to consider operating early in acute cholecystitis. Often patients present late after many days of symptoms or the gallbladder appears extremely oedematous and thick walled on ultrasound. Generally, all of these patients should be considered for laparoscopic cholecystectomy unless they are extremely ill or significant comorbidities exist. If the patient goes to the operating room, an attempt at exposure of the Calot's triangle and a trial dissection should be undertaken. If it is determined that safe laparoscopic cholecystectomy cannot be performed, two potential options exist: 1. Conversion to open surgery or 2. Cholecystostomy tube placement. An open operation might not offer much additional benefit to a very experienced laparoscopic surgeon and many recently trained surgeons

today do not have a great deal of experience performing open cholecystectomy, so that conversion may not be that beneficial to the surgeon or the patient.

METHODS

The study was conducted at department of surgery, SMIMER hospital from September 2013 to December 2015 on patients presented and hospitalised with acute cholecystitis, of all age groups and gender. Thus, patients taken under this study are based on consecutive sampling and purposive sampling (With purpose of patients having acute cholecystitis). Diagnosis of acute cholecystitis was established on following parameters: 1) clinical presentation which included; a) pain in abdomen. b) Tenderness in right hypochondrium. c) Contraction of the abdominal wall in right upper quadrant. d) With or without fever. e) With or without nausea and vomiting. 2) Contributory laboratory findings. 3) Abdominal ultrasonographic confirmation of the diagnosis by presence of gallstones, gallbladder wall oedema, pericholecystic fluid collection. 4) Intra-operative findings 5) histopathologic examination. All cases undergone laparoscopic cholecystectomy, were studied under two categories: Group A: laparoscopic cholecystectomy performed within 72 hours of onset of symptoms of acute cholecystitis. Group B: laparoscopic cholecystectomy performed after 72 hours of onset of symptoms of acute cholecystitis. The following parameters were analysed: 1) demographic information, laboratory tests and ultrasonographic features. 2) Duration of surgery. 3) Duration of postoperative hospital stay. 4) Incidence of major biliary injury and injury to other organs. 5) Conversion of laparoscopic surgery to open surgery.

Laparoscopic cholecystectomy was performed using standard technique under general anaesthesia. It is an observational study with consecutive and purposive sampling. All patients registered from September 2013 to December 2015 who were hospitalised with acute cholecystitis, of all age groups and gender are considered as sample of study. So, the sample size is 325 patients. Amongst them 110 patients were operated within 72 hours of diagnosis and 215 patients were operated after 72 hours of diagnosis. So, study is based on two non-randomized groups. (Group A: 110 patients, group B: 215 patients).

Statistical Analysis

Descriptive and Inferential statistics have been carried out in the study. Using descriptive statistics, results on quantitative data are presented in mean (+/-) standard deviation and results on qualitative data are presented in percentage (%). Using inferential Statistics, significance is assessed at 95% level of significance. Student t test (two tailed, independent) has been used to find the significance of study parameters on continuous scale between two groups on metric parameters. Chi-square test, Fisher exact test and Yate's correction has been used to find the significance of study parameters on categorical scale between two groups. Data analysis is done using open EPI software. Microsoft Word and Microsoft Excel used to generate graphs, tables etc.



RESULTS

33.84% patients were operated upon within 72 hours of onset of symptoms and included in group A. 66.16% patients were operated upon after 72 hours of onset of symptoms and included in group B. Mean age (Mean \pm SD) for group A is 37.94 \pm 12.82 years and for group B it is 40.13 \pm 13.92 years. Group A included 18.19% males and 81.81% females; Group B included 24.65% males and 75.35% females. Most common presenting complaint was pain in abdomen which was seen in all patients. 46.36% of patients in group A and 43.25% of patients in group B were febrile at the time of presentation. One third of the patients (35.6%) presented within 24 hours of onset of complaints. Eleven percent of patients were found to have raised temperature (>100°F). Only 2.5% of patients had pulse rate more than 100 per minute. All patients presented with tenderness in right hypochondrium. Guarding was present in 71.81% of group A and 78.60% of patients of group B. Lump was palpable in 12.30% cases (13.63% in group A and 11.62% in group B).

Total WBC count between 11000-15000/cmm was noted in 45.45% of patients in group A and 55.34% of patients in group B. Total 18 (5.54%) patients had serum bilirubin levels more than 2 mg/dl (2.73% patients in group A and 6.98% in group B). Serum AST, serum ALT and serum ALP levels were found to be elevated only in 13.3%, 17.5% and 11.4 % patients respectively (In 11.82%, 16.37% and 8.19% patients respectively in group A, while in 13.96%, 18.14% and 13.03% respectively in group B). Majority of patients (72%) had multiple gallbladder calculi (71.81% in group A and 72.09% in group B) while pericholecystic fluid was present in 1.5% of cases (0.9% in group A and 1.86% in group B). Wall thickening was present in 72% of patients (58.18% in group A and 79.06% in group B). Common bile duct was normal in 98.5% of patients (99.09% in group A and 98.14% in group B).

Particulars	Group A	Group B	Particulars	Group A	Group B
N	110	215	WBC (11000-15000/cmm) (in %)	45.45	55.34
Percentage	34.92	68.25	Serum bilirubin levels (>2 mg/dl) (in %)	2.73	6.98
Mean	37.94	40.13	Serum AST (in %)	11.82	13.96
S.D.	12.82	13.92	Serum ALT (in %)	16.37	18.14
Male (%)	18.19	24.65	Serum ALP (in %)	8.19	13.03
Female (%)	81.81	75.35	Multiple gallbladder calculi (in %)	71.81	72.09
Febrile at the time of presentation (%)	46.36	43.25	Presence of pericholecystic fluid (in %)	0.9	1.86
Guarding (%)	71.81	78.6	Wall thickening (in %)	58.18	79.06
Lump	13.63	11.62	Normal Common bile duct (in %)	99.09	98.14
Mean Duration of Surgery	75.55	94.16	Standard Deviation of Duration of Surgery	10.47	13.47

Table 1. Descriptive Analysis (Pre Operation)

	N	Mean	S.D.	t-test	p-Value	Conclusion
Group A	110	75.55	10.47	12.281	0.000	Mean duration of surgery of group A is significantly less than group B.
Group B	215	94.16	13.47			

Table 2. Comparison of Mean Duration of Surgery Using Independent t Test

No patient in group A needed to be converted from laparoscopic to open procedure. In group B, laparoscopic surgery had to be converted in open surgery in 3 patients, due to intra-operative bleeding in 1 patient, due to difficult anatomy in 1 patient and due to adhesions in 1

patient. Duration of surgery was 75.55 \pm 10.87 minutes in group A, while it was 94.16 \pm 13.87 minutes in group B. The P value is less than 0.001. It shows that mean duration of surgery in patients operated under group A was significantly less than those operated under group B.

Most patients (95.38 %) had oedematous gallbladder (96.36% in group A and 95.38% in group B). Adhesions were present in 90.70% cases (90% in group A and 90.47% in group B) while cystic duct was normal in 96.92% cases (98.19% in group A and 96.28% in group B). Intraoperative bleeding was noted in 1.81% of cases in group A and 7.44% of cases in group B. Gallbladder perforation was noted in 1.81 % patients in group A and 7.44% patients in group B. Gallbladder aspiration was done in 2 cases. Bile duct injury occurred in 2 cases of group B. Stone spillage occurred in 0.9% of cases in group A and 4.18 % of cases in group B.

	Group A		Group B		p	Total Patients	% of Total
	No.	%	No.	%			
Bile Leak - Yes	-	-	1	00.46	1	1	00.40
Bile Leak - No	110	100	214	99.54		324	99.60
Icterus - Yes	-	-	3	01.39	0.5763	3	00.92
Icterus - No	110	100	212	98.61		322	90.08
Uncontrolled BP	-	-	3	01.39	0.5763	3	00.92
Uncontrolled Sugar	1	0.90	4	01.86	0.8547	5	01.53
Wound infection	1	0.90	9	4.18	0.2011	10	03.08

Table 3. Post-Operative Complications

	N	Mean	S.D.	t-test	p	Conclusion
Group A	110	4.46	3.73	2.884	0.004	Mean duration of postoperative stay of group A is significantly less than group B.
Group B	215	5.92	5.26			

Table 4: Comparison of Mean Duration of Postoperative Stay Using Independent T Test

Bile leak found postoperatively in one patient of group B. Icterus observed in 3 cases of group B. Surgical site infection occurred in 0.9% cases in group A and 3.08% of group B cases. P value is > 0.05 for all parameters including bile leak, icterus, uncontrolled blood pressure, uncontrolled blood sugar and wound infection. It means there is no statistically significant difference in occurrence of postoperative complications between group A and group B.

Most of the patients (50.15 %) were discharged within 3 days after surgery (60% in group A and 45.16 % in group B) while 24.92 % patients were discharged between 4 to 7 days after surgery. 55.15% of patients (60 % from group A and 45.16 % from group B) were discharged within 3 days of surgery. 20.9 % of patients from group A and 26.97 % of patients from group B (Total 24.92 %) were discharged within 4-7 days. 19.08% (17.27% from group A and 20% from group B) of patients were discharged in second week. Total of 19 (5.85%) patients (2 in group A and 17 in group B) were discharged after 2 weeks. Three of them had uncontrolled hypertension, four had uncontrolled sugar and nine of them had surgical site infection. Mean post-operative stay is 4.46 \pm 3.73 days in group A and 5.92 \pm 5.26 days in group B. The P value is p< 0.004. It shows that mean duration of postoperative stay in group A was significantly less than that in group B. Return to work was calculated from the day of surgery.

97.27% of patients in group A while 69.76% of patients in group B returned to work in first week of surgery. Of remaining patients of group B, 25.58 % returned to work in second week and 4.64 % in third week of surgery. P value is

$p < 0.001$. It shows that period for return to work is significantly less for patients in group A than for those in group B. About two third of the patients, 217 patients (66.80%) were found to have acute on chronic cholecystitis on histopathology report (91.81 % in group A and 53.95% in group B).

DISCUSSION

Several authors have reported performing laparoscopic cholecystectomy in the face of acute inflammation with success but with a higher conversion rate than for elective laparoscopic cholecystectomy.^(7,8,9,10) Lo et al in their prospective study reported that despite longer operative times and postoperative stays for early laparoscopic cholecystectomy (treatment within 5 days) versus delayed laparoscopic cholecystectomy (initial conservative treatment followed by laparoscopic cholecystectomy 3 to 4 months later), the advantage of early laparoscopic cholecystectomy was the reduction in the total hospital stay, from 15 to 7 days.⁽¹¹⁾ Another prospective study of 105 patients randomized to early laparoscopic cholecystectomy (within 24 hours of diagnosis of acute cholecystitis) versus delayed laparoscopic cholecystectomy (6 to 8 weeks later), reported no significant difference in conversion rate (Early 21% vs. delayed 24%), postoperative analgesic requirement or number of postoperative complications. The early group did have a longer operative time (123 min vs 107 min, $p = 0.04$); but total hospitalization was shorter (8 days v/s 12 days; $p = 0.001$).⁽¹²⁾

Rattner et al attempted laparoscopic cholecystectomy for acute cholecystitis and examined factors that were predictive of a successful procedure.⁽¹³⁾ Seven of the 20 patients (35%) required conversion to open cholecystectomy. The interval from admission to cholecystectomy in the successful cases was 0.6 days versus 5 days in the cases requiring conversion to open cholecystectomy. Chahin et al examined the relationship between the success rates for laparoscopic surgery and the time from onset of acute cholecystitis symptoms to surgery. The success rate has dropped significantly after the first 4 days.⁽¹⁴⁾ These results have been confirmed in more recent studies. In the study by Shamim disturbed anatomy at Calot's triangle accounted for more than one half of conversions (54.32%); The reasons of obscured anatomy were acute inflammation (52.27%), chronic cholecystitis (36.36%) and aberrant anatomy (11.36%).⁽¹⁰⁾ In 6.17% patients, dense adhesions were found between gallbladder and bowel. (3 with the stomach and 2 with the transverse colon). They were difficult to separate laparoscopically, so conversion to open surgery was made. With increasing laparoscopic experience, an inverse trend in conversion rates is seen.

CONCLUSIONS

Cholecystectomy for acute cholecystitis can be safely advocated in patients presenting within 72 hours of onset symptoms. This does not result in increased major

complication rates and conversion rates. Early laparoscopic cholecystectomy is not associated with more conversion to open procedures. Decreased conversion rates result in shorter post-operative hospital stay. Early cholecystectomy is beneficial as patients tend to return to work earlier.

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A COMPARATIVE TREND ANALYSIS OF CASH MANAGEMENT PERFORMANCE OF SELECTED INDIAN PHARMACEUTICAL COMPANIES

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Abstract

Efficient and well design cash management is important for growth and profit of the firm. Proper cash management is also helpful in good working capital management. This study attempts to analyze the trends of cash management through different cash ratios and find out its impact on firm's liquidity. Here researcher took Cash liquidity ratio and cash conversion cycle ratio for trend analysis. The researcher has taken a sample of ten Indian pharmaceutical companies which are listed in Bombay Stock Exchange for the period of ten years i.e. 2008 to 2017. This paper focus on to examine that how selected Indian Pharmaceutical companies managed their liquidity through cash management.

Keywords : Liquidity, Cash management, Trend analysis, Pharmaceutical companies

INTRODUCTION

According to (Financial Management, 2005) Cash is the most liquid asset of the entire current asset. Cash it may be in hand or in bank. Cash is the life blood of the business firm. Company can meet its daily obligations and short term liabilities only from cash. So, there is need of proper cash management for the solvency of the firm. Cash is in different form in the business i.e. raw material inventory to account receivables and converted into cash after completing one operating cycle of the company. Cash is also important for running the business. Higher cash shows that company is more liquid but result is in lower profitability as excess cash will not contribute in profit. Company should try to invest excess cash in other fixed assets so, profitability will be increase. Lower cash indicate that company is not more liquid but it also shows that company has higher profitability. Lower cash ratio shows that company has cash crises and it will be disrupt the daily business activities. The healthy and steady circulation of cash throughout the year is requiring for continuous business activities. So, company should try to lay right amount of cash at the right cost and at a right time. Efficient cash management means to find out that the cash from where it is to where it is needed to be. Adequate cash balance is good for working capital requirement. Efficient cash management tries to minimize investment in cash without damage to the liquidity of the firm. The ultimate goal of management of cash is to maintain minimum cash balance, which supply the firm sufficient liquidity to meet its short term obligations.





A Comparative Study of the Performance of Selected Indian Pharmaceutical Companies with the Reference of Liquidity

ABSTRACT:

The aim of this paper is to measure the liquidity indicators of ten selected Indian pharmaceutical companies, through Kruskal Wallis Test. The main object of this paper is to find the answer of question that different liquidity indicators of different selected pharmaceutical companies are significantly different or not? Liquidity ratios, performance ratios and efficiency ratios are used to measure the liquidity position of the selected companies. Researcher applied Kruskal-Wallis Test. This study is based on secondary data, which collected from Ace Knowledge, for the period of 2008 to 2017 of selected Indian pharmaceutical companies. The result of this study shows that different liquidity indicators of different selected pharmaceutical companies are significantly different.

KEY WORDS: *Liquidity, Profitability, Kruskal Wallis Test, Pharmaceutical companies.*

INTRODUCTION:

Liquidity plays a vital role in the successful functioning of business. Liquidity shows the ability of the firm to pay its current obligation on time. Profitability shows the excess of income over expenses. Liquidity and profitability are two important variables to measure the performance of the firm. Liquidity and profitability have inverse relationship. Higher the liquidity lower will be the profitability. The liquidity focuses on short-term assets which generate low profit and contain low risk. Every firm tries to maximize its profitability by maintaining liquidity. However, increasing profit at the cost of liquidity may cause of firm financial insolvency and goodwill. But excessive liquidity on one hand indicates the accumulation of ideal funds that don't earn any profit for the firm. So, company should maintain balance between liquidity and profitability.

REVIEW OF LITERATURE:

(Barad, 2010) Researcher studied the liquidity management, profitability, receivable management and cash management of steel industry in India for the period of 199-2000 to 2007-2008. The aim of this study was to measured effectiveness and efficiency in the use of resources available in the steel industries. Researcher used different techniques for the data analysis such as trend analysis through different ratios, average, one-way ANOVA, index and standard deviation. Current ratio of showed that selected steel industries had poor liquidity position. The position of current ratio to total assets ratio was not good. Working capital turnover ratio was not satisfactory. ANOVA analysis shown that there was difference is insignificance. Profitability ratios were good and satisfactory.

(Noor & Lodhi, 2015) The aim of this paper was to find out how can liquidity effect on profitability. Researcher took five automobile sector companies in Karachi for the period of 2010 to 2014. Researcher used some liquidity ratios and to find out the relation between liquidity and profitability. Descriptive statistics, correlation regression and ANOVA test was apply to data analysis. Result





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THE CONSTRUCTION OF EFFICIENT MINIMAL BALANCED CROSS-OVER DESIGNS USING MATLAB

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Abstract : Several field/area demands various minimal balance cross-over designs based on relation between treatment, period and subject. However, its construction is sometimes difficult, particularly for the non-mathematician experimenter. The present paper provides a MATLAB program for construction of the minimal balanced cross-over design. This program meets the practical needs of experimenters/users in the application of cross-over design because it provides a variety of cross-over designs for the same class by inputting only two user specified parameters, number of treatments, and number of periods. The MATLAB program constructs cross-over designs for any combination of treatments and periods with its efficiency of separability. Theoretical construction is difficult when number of treatments or periods is large, but through this program experimenter/user easily constructs number of cross-over designs. This program also constructs recently investigated cross-over designs.

Key words : Cross-over, Minimal balanced, Directed m-terrace, Carry over effect, MATLAB.

1. Introduction

A cross-over design is an experimental design where every subject is measured repeatedly by applying different treatments over period and these treatments are given in a randomly assigned sequence. However, due to implementation of more than one treatment on same subjects, every subject is also affected by carry over effects of treatment applied in previous period. Many authors, Carriere (1993), Collombier and Merchermek (1993), Dey *et al.* (1983), Divecha and Gondaliya (2014), Grizzle (1965), Jones and Donev (1996), Jones and Kenward (2003), Kunert (1984), Kushner (1997), Martin and Eccleston (1998) and others have discussed cross-over design with carry over effects under certain assumptions.

Several field/area uses cross-over design for the comparison of treatments. Taka and Armitage (1983), Matthews (1989) have discussed some real life applications of the cross-over designs. Based on the experimental needs, cross-over designs can be divided in three types and each of them has a specific

applications. Clinical trials as well as pharmaceutical studies generally demand the cross-over designs with fewer periods than the number of treatments. Agriculture and the field of the sensory evaluation of food and products generally use cross-over designs with periods equal to the treatments. Animal nutrition as well as educational experiments [Gill (1978)] requires cross-over designs with more periods than the treatments. However, in all above three cases, cross-over designs balanced in minimum number of subjects called minimal balanced are preferable [Hedayat and Afsarinejad (1975)].

Bailey (1984) has given the terrace for the construction of Quasi-complete Latin squares. Morgan (1988) defined m-terrace for the construction of balanced polycross designs. Divecha and Gondaliya (2014) provided new series of cross-over designs through new defined terraces as complementary pair of terraces and a complementary trio of terraces. The method of construction of the Divecha and Gondaliya (2014) is very simple, but to define terraces are very

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difficult, particularly for the non-mathematician experimenters/users. The goal of the present work is to construct cross-over design including new series using MATLAB Math Works (2012) so that non-mathematician experimenters/users easily constructs it for specified combination of the number of treatments and periods. The present paper introduces MATLAB program that constructs minimal balanced cross-over design with its efficiency of separability. MATLAB program is written in such a way that experimenters/users need to input only two parameters as the number of treatments and number of periods. This program is also able to construct the cross-over designs for any combination of treatments and periods. MATLAB program gives flexibility to experimenter according to requirement of the experiment by producing all possible minimal balanced cross-over designs for the specified class. The paper is organized as follows. The Section 2 presents the review on construction of cross-over design. Computer algorithm is presented for the construction of efficient cross-over designs in Section 3. A general MATLAB program for the construction of cross-over designs and the relevant procedures is discussed in Section 4. In Section 5, example is given to illustrate the procedure of the MATLAB program. A conclusion is provided in Section 6.

2. Review on Construction of Cross-over Design through terraces

We begin this section with the model for the cross-over design. Let y_{ijk} denotes the observation from j th subject of i th sequence in k th period to which treatment $d(k, j)$ is given, μ is the general mean, $\tau_{d(k, j)}$ is $\{d(k, j)\}$ th treatment effect, π_k is k th period effect, ξ_{ij} is j th subject effect having i th sequence. Then the carry over model repeatedly discussed in optimal cross-over design literature is traditional carry over model given by

$$y_{ijk} = \mu + \tau_{d(k, j)} + \gamma_{d(k-1, j)} + \pi_k + \xi_{ij} + \varepsilon_{ijk} \quad (1)$$

Where, ε_{ijk} are independently normally distributed error term with mean 0 and variance σ^2 . The another model is self and mixed carry over model given by

$$y_{ijk} = \mu + \tau_{d(k, j)} + \gamma_{1d(k-1, j)} + \gamma_{2d(k-1, j)} + \pi_k + \xi_{ij} + \varepsilon_{ijk} \quad (2)$$

Where, $\gamma_{1d(k-1, j)}$ is the carry over effect of the treatment preceded by other treatment in the previous period and $\gamma_{2d(k-1, j)}$ is the carry over effect of treatment preceded by itself in the previous period. Also, we denote cross-over design of t treatments in n subjects and p periods by COD (t, n, p) . All the cross-over designs

constructed in this paper are suitable for estimation of all the effects included in model (1) as well as (2). Let, we discuss some important definitions.

“A COD (t, n, p) is said to be balanced with respect to the set of treatment and first order carry over effects if (i) in each period, each treatment is given to λ_1 units, and (ii) in two successive periods, each ordered pair of distinct treatments is given to λ_2 units, while, each pair of treatments with itself is given to λ_3 units, where integer λ_1, λ_2 are positive and λ_3 is non-negative”. If $\lambda_2 = \lambda_3$, then a balanced cross-over design is said to be strongly balanced. “A balanced COD (t, n, p) is said to be minimal if λ_1 is the smallest integer and satisfy the following condition”.

$$(\lambda_1(p-1) - \lambda_3) = 0 \pmod{t-1} \quad (3)$$

Construction of cross-over design

In this subsection, simple form of construction of five series of minimal balanced cross-over design of Divecha and Gondaliya (2014) has been shown.

$$\text{First series COD} \left(t, 2t, \frac{t+1}{2} \right)$$

For the construction of a minimal balanced cross-over design from the series COD $\left(t, 2t, \frac{t+1}{2} \right)$ for odd t , first, write two set of numbers $a = (a_1, a_2, \dots, a_p)$ and $b = (b_1, b_2, \dots, b_p)$ from group $Z_t = (0, 1, \dots, t-1)$ such that $(a_2 - a_1, a_3 - a_2, \dots, a_p - a_{p-1}, b_2 - b_1, b_3 - b_2, \dots, b_p - b_{p-1})$ modulo t contains every number of the set $(1, \dots, t-1)$ single time. Second, write $p \times t$ matrix by adding 0, 1, $\dots, t-1$ to the set a and b shown below constructs cross-over design for t treatments in $2t$ subjects and $\frac{t+1}{2}$ periods.

		Subjects						
		1	2	3	4	...	$2t-1$	$2t$
Periods	1	a_1+0	b_1+0	a_1+1	b_1+1	...	a_1+t-1	b_1+t-1
	2	a_2+0	b_2+0	a_2+1	b_2+1	...	a_2+t-1	b_2+t-1
	\vdots	\vdots	\vdots	\vdots	\vdots	...	\vdots	\vdots
	p	a_p+0	b_p+0	a_p+1	b_p+1	...	a_p+t-1	b_p+t-1
		modulo t						

where, $p = \frac{t+1}{2}$. Here, $\lambda_1 = 2, \lambda_2 = 1, \lambda_3 = 0$ and

$$ES = \left[1 - \left\{ \frac{1}{t^2 - 1} \right\}^{\frac{1}{2}} \right] \times 100\%.$$



Second series COD $\left(t, 2t, \left(\frac{t}{2}\right)+1\right)$

For the construction of a minimal balanced cross-over design from the series COD $\left(t, 2t, \left(\frac{t}{2}\right)+1\right)$ for even t , first, write two set of numbers $a = (a_1, a_2, \dots, a_p)$ and $b = (b_1, b_2, \dots, b_p)$ from group $Z_t = (0, 1, \dots, t-1)$ such that $(a_2-a_1, a_3-a_2, \dots, a_p-a_{p-1}, b_2-b_1, b_3-b_2, \dots, b_p-b_{p-1})$ modulo t contains every numbers of the set $(0, 1, \dots, t-1)$ single time. Second, write $p \times t$ matrix by adding $0, 1, \dots, t-1$ to the set a and b shown below constructs cross-over design for t treatments in $2t$ subjects and $\left(\frac{t}{2}\right)+1$ periods.

	Subjects						
	1	2	3	4	...	$2t-1$	$2t$
1	a_1+0	b_1+0	a_1+1	b_1+1	...	a_1+t-1	b_1+t-1
2	a_2+0	b_2+0	a_2+1	b_2+1	...	a_2+t-1	b_2+t-1
\vdots	\vdots	\vdots	\vdots	\vdots	...	\vdots	\vdots
p	a_p+0	b_p+0	a_p+1	b_p+1	...	a_p+t-1	b_p+t-1

where, $p = \left(\frac{t}{2}\right)+1$. Here, $\lambda_1 = 2$, $\lambda_2 = 1$, $\lambda_3 = 1$ and $ES = 100\%$.

Third series COD $\left(t, 3t, \frac{t}{2}\right)$

For the construction of a minimal balanced cross-over design from the series COD $\left(t, 2t, \frac{t}{2}\right)$ for even t (≥ 4), first, write three set of numbers $a = (a_1, a_2, \dots, a_p)$, $b = (b_1, b_2, \dots, b_p)$ and $c = (c_1, c_2, \dots, c_p)$ from group $Z_t = (0, 1, \dots, t-1)$ such that $(a_2-a_1, a_3-a_2, \dots, a_p-a_{p-1}, b_2-b_1, b_3-b_2, \dots, b_p-b_{p-1}, c_2-c_1, c_3-c_2, \dots, c_p-c_{p-1})$ modulo t contains every numbers of the set $(1, \dots, t-1)$ single time and zero $\frac{3}{2}(t-2)-(t-1)$ times. Second, write $p \times t$ matrix by adding $0, 1, \dots, t-1$ to the set a, b and c shown below constructs cross-over design for t treatments in $3t$ subjects and $\frac{t}{2}$ periods.



	Subjects						
	1	2	3	...	$3t-2$	$3t-1$	$3t$
1	a_1+0	b_1+0	c_1+0	...	a_1+t-1	b_1+t-1	c_1+t-1
2	a_2+0	b_2+0	c_2+0	...	a_2+t-1	b_2+t-1	c_2+t-1
\vdots	\vdots	\vdots	\vdots	...	\vdots	\vdots	\vdots
p	a_p+0	b_p+0	c_p+0	...	a_p+t-1	b_p+t-1	c_p+t-1

where, $p = \frac{t}{2}$. Here, $\lambda_1 = 3$, $\lambda_2 = 1$,

$$\lambda_3 = \frac{3}{2}(t-2)-(t-1)$$

$$\text{and } ES = \left[1 - \left\{ \frac{(0.5t-3)}{2.25t(t-1)} \right\}^{\frac{1}{2}} \right] \times 100\%.$$

Fourth series COD (t, t, t)

For the construction of a minimal balanced cross-over design from the series COD (t, t, t) , first, write a set of numbers $a = (a_1, a_2, \dots, a_t)$ from group $Z_t = (0, 1, \dots, t-1)$ such that $(a_2-a_1, a_3-a_2, \dots, a_t-a_{t-1})$ modulo t contains every numbers of the set $(1, \dots, t-1)$ single time. Second, write $p \times t$ matrix by adding $0, 1, \dots, t-1$ to the set a shown below constructs cross-over design for t treatments in t subjects and t periods.

	Subjects			
	1	2	...	t
1	a_1+0	a_1+1	...	a_1+t-1
2	a_2+0	a_2+1	...	a_2+t-1
\vdots	\vdots	\vdots	...	\vdots
p	a_p+0	a_p+1	...	a_p+t-1

Here, $\lambda_1 = 1$, $\lambda_2 = 1$, $\lambda_3 = 0$ and

$$ES = \left[1 - \left\{ \frac{1}{t(t-1)} \right\}^{\frac{1}{2}} \right] \times 100\%.$$

Fifth series COD $\left(t, t, 1 + \frac{m(t-1)}{2}\right)$

For the construction of a minimal balanced cross-over design from the series COD $\left(t, t, 1 + \frac{m(t-1)}{2}\right)$ for even m (≥ 4), first, write a set of numbers $a = (a_1, a_2, \dots, a_p)$ from group $Z_t = (0, 1, \dots, t-1)$ such that $(a_2-a_1, a_3-a_2, \dots, a_t-a_{t-1})$ modulo t contains every

numbers of the set $(1, \dots, t-1)$ exactly $\frac{m}{2}$ times.

Second, write $p \times t$ matrix by adding $0, 1, \dots, t-1$ to the set a shown below constructs cross-over design for t

treatments in t subjects and $1 + \frac{m(t-1)}{2}$ periods.

		Subjects			
		1	2	...	t
Periods	1	$a_1 + 0$	$a_1 + 1$...	$a_1 + t - 1$
	2	$a_2 + 0$	$a_2 + 1$...	$a_2 + t - 1$
	\vdots	\vdots	\vdots	...	\vdots
	p	$a_p + 0$	$a_p + 1$...	$a_p + t - 1$

where, $p = 1 + \frac{m(t-1)}{2}$. Here, $\lambda_1 = 1$, $\lambda_2 = \frac{m}{2}$, λ_3

$$= 0 \text{ and } ES = \left[1 - \left\{ \frac{m}{(t-1)(2+m(t-1))} \right\}^{\frac{1}{2}} \right] \times 100\%.$$

Here, it is clear that, for every series, the method of construction is very simple however to define the sets (terraces) is very difficult and sometime it is impossible for large number of treatments or periods. Computer program helps to define the sets and to construct such cross-over design. Let, we discuss algorithm for the computer program in next section.

3. Algorithm

In this section, computer algorithm is presented for the construction of efficient cross-over designs under the model (1) and (2). A broad outline of the algorithm is given below

1. Input parameters t and p .
2. Generate all possible treatment sequences of t treatments in p periods.
3. If p is less than t and is equal to $\text{int}\left(\frac{t}{2}\right) + 1$, then go to case 1 of step 4, else if p is less than t (≥ 4) and is equal to $\left(\frac{t}{2}\right)$ or $\left(\frac{t}{2}\right) + 1$, then go to case 2 of step 4, else if p is equal to t or $t+1$, then go to case 3 of step 4, else if $t-1$ divides $p-1$ or $p-2$, then go to case 4 of step 4, else, go to case 5 of step 4.

4. Case 1 : Generating cross-over designs from series

$$\text{COD} \left(t, 2t, \left(\frac{t}{2} \right) + 1 \right).$$

- (i) Consider two treatment sequences (say, (a, b)) arbitrarily from those obtained in step 2.
- (ii) Define $(a_2 - a_1, a_3 - a_2, \dots, a_p - a_{p-1}, b_2 - b_1, b_3 - b_2, \dots, b_p - b_{p-1})$ modulo t (say (a^*, b^*) modulo t).
- (iii) Check (a^*, b^*) modulo t for containing number $(1, \dots, t-1)$ single time in case of odd t , whereas, every number $(0, 1, \dots, t-1)$ single time in case of even t . If it does not contain then return to step (i).
- (iv) Repeat step (i) to (iii) until combinations of two treatment sequence does not satisfy the condition (iii).
- (v) Construct COD (t, n, p) by adding each number $(0, 1, \dots, t-1)$ one after another to (a, b) reduced modulo t and calculate its efficiency of separability.
- (vi) Produce COD (t, n, p) with its efficiency of separability.
- (vii) Repeat step (i) to (vi) if experimenter requires alternative cross-over designs or all possible cross-over designs in the class, otherwise, terminate the program.

Case 2 : Generating cross-over designs from series

$$\text{COD} \left(t, 3t, \frac{t}{2} \right) \text{ for even } t (\geq 4).$$

- (i) Consider three treatment sequences (say, (a, b, c)) arbitrarily from those obtained in step 2.
- (ii) Define $(a_2 - a_1, a_3 - a_2, \dots, a_p - a_{p-1}, b_2 - b_1, b_3 - b_2, \dots, b_p - b_{p-1}, c_2 - c_1, c_3 - c_2, \dots, c_p - c_{p-1})$ modulo t (say (a^*, b^*, c^*) modulo t).
- (iii) Check (a^*, b^*, c^*) modulo t for containing number $(1, \dots, t-1)$ single time and zero $3/2(t-2) - (t-1)$ times. If it does not contain then return to step (i).
- (iv) Repeat step (i) to (iii) until combinations of three treatment sequences does not satisfy the condition (iii).
- (v) Construct COD (t, n, p) by adding each number $(0, 1, \dots, t-1)$ one after another to (a, b, c) reduced modulo t and calculate its efficiency



of separability.

- (vi) Produce COD (t, n, p) with its efficiency of separability.
- vii. Repeat step (i) to (vi) if experimenter requires alternative cross-over designs or all possible cross-over designs in the class, otherwise, terminate the program.

Case 3 : Generating cross-over designs from series COD (t, t, t) .

- (i) Consider a treatment sequence (say, a) from those obtained in step 2.
- (ii) Define $(a_2 - a_1, a_3 - a_2, \dots, a_p - a_{p-1})$ modulo t (say a^* modulo t).
- (iii) Check a^* modulo t for containing number $(1, \dots, t-1)$ single time. If it does not contain then return to step (i).
- (iv) Repeat step (i) to (iii) until a treatment sequence does not satisfy the condition (iii).
- (v) Construct COD (t, n, p) by adding each number $(0, 1, \dots, t-1)$ one after another to a reduced modulo t and calculate its efficiency of separability.
- (vi) Produce COD (t, n, p) with its efficiency of separability.
- (vii) Repeat step (i) to (vi) if experimenter requires alternative cross-over designs or all possible cross-over designs in the class, otherwise, terminate the program.

Case 4 : Generating cross-over designs from series

$$\text{COD} \left(t, t, 1 + \frac{m(t-1)}{2} \right) \text{ for even } m (\geq 4).$$

- (i) Consider a treatment sequence (say, a) from those obtained in step 2.
- (ii) Define $(a_2 - a_1, a_3 - a_2, \dots, a_p - a_{p-1})$ modulo t (say a^* modulo t).
- (iii) Check a^* modulo t for containing number $(1, \dots, t-1)$ exactly $m/2$ times. If it does not contain then return to step (i).
- (iv) Repeat step (i) to (iii) until a treatment sequence does not satisfy the condition (iii).
- (v) Construct COD (t, n, p) by adding each number $(0, 1, \dots, t-1)$ one after another to a reduced modulo t and calculate its efficiency of separability.

- (vi) Produce COD (t, n, p) with its efficiency of separability.

- (vii) Repeat step (i) to (vi) if experimenter requires alternative cross-over designs or all possible cross-over designs in the class, otherwise, terminate the program.

Case 5 : Cross-over design does not possible for the inputted combination of the parameters t and p . Terminate the program by showing the message 'Unexpected combination of t and p . No design created'.

By following the steps of the above algorithm, users/experimenters can generate the cross-over designs in several programming system like SAS, R, MATLAB etc. MATLAB program is given in the following section.

Table 1: List of treatments and periods less than twenty of possible cross-over designs through MATLAB program.

t	p
2	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20
3	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20
4	2,3,4,5,7,8,10,11,13,14,16,17,19,20
5	3,4,5,6,9,10,13,14,17,18
6	3,4,5,6,7,11,12,16,17
7	4,5,7,8,13,14,19,20
8	4,5,6,8,9,15,16
9	5,6,9,10,17,18
10	5,6,7,10,11,19,20
11	6,7,11,12
12	6,7,8,12,13
13	7,8,13,14
14	7,8,9,14,15
15	8,9,15,16
16	8,9,10,16,17
17	9,10,17,18
18	9,10,11,18,19
19	10,11,19,20
20	10,11,12,20

4. MATLAB Program

In this section, MATLAB program is described including the input parameters, the way to run the program and the output of the program.

Input Parameters

The computer program is simple in terms of the



input parameters for the construction of cross-over designs in specified combination of parameters. This program is written in such a way that experimenter/user has to input only two parameters for the construction of the cross-over design. First input parameter is number of treatments and second is number of periods. This program works for most of the combination of treatments and periods. List of the combinations of treatments and periods between two also available through E-mail on request to the author.

```

t=input('Enter number of treatments:');
p=input('Enter number of periods:');
%
ts=0; altdesign=1; rlp=0;
if (p==floor(t/2+1) & p~=t) || (p==floor(t/2+1)+1 & p~=t & p~=t+1)
    theorem=1;
    if p==floor(t/2+1)+1
        p=p-1; rlp=1;
    end
else if (p==t/2 & t>=4) || (p==t/2+1 & t>=4 & p~=t & p~=t+1)
    theorem=2;
    if p==t/2+1
        p=p-1; rlp=1;
    end
else if p==t || p==t+1
    theorem=3;
    if p==t+1
        p=p-1; rlp=1;
    end
else if mod(p-1,t-1)==0 || mod(p-2,t-1)==0
    if mod(p-2,t-1)==0
        p=p-1; rlp=1;
    end
    mby2=(p-1)/(t-1); theorem=4;
else
    theorem=5;
end
end
end
end

```

to twenty are shown in Table 1 for which cross-over designs are possible through this program. To have a clear exposition on the working of the program, consider the following subsection.

Running the Program

The program given below constructs cross-over designs for the several combinations of treatments and periods, including listed in the Table 1. The m-file is



```

conA(1:t^p,1:p)=0; astar(1:t^p,1:p-1)=0;
if (theorem~=5)
    for con1=1:p
        k=1;
        for conj=1:t^p
            conA(conj,con1)=k-1; ts=ts+1;
            if (mod(conj,t^(p-con1))==0)
                k=k+1;
            end
            if k>t
                k=1;
            end
        end
    end
end
switch theorem
case 1
    for con1=1:p-1
        astar(:,con1)=mod(conA(:,con1+1)-conA(:,con1),t);
    end
    for con1=1:t^p
        for conj=con1+1:t^p
            if mod(t,2)==0
                oddevet=1; allele=0; lambda3=1;
            else
                oddevet=2; allele=1; lambda3=0;
            end
            for conl=oddevet:t
                for conk=1:p-1
                    if (astar(con1,conk)==conl-1 || astar(conj,conk)==conl-1)
                        allele=allele+1;
                        break
                    end
                end
            end
        end
    end
    if allele==t
        cod(1:p,1:2*t)=0; cta=conA(con1,:); ctb=conA(conj,:);
        cod(:,1)=cta'; cod(:,2)=ctb'; codsub=3;
    end
end

```



```

for conm=1:t-1
    cod(:,codsub)=cta'+conm; cod(:,codsub+1)=ctb'+conm;
    codsub=codsub+2;
end
crossoverdesign(1:p,1:2*t)=0; crossoverdesign=mod(cod,t);
if rlp==0
    crossoverdesign=mod(cod,t); lambda1=2; lambda2=1;
else
    crossoverdesign=mod(cod,t);
    crossoverdesign(p+1,:)=crossoverdesign(p,:);
    lambda1=2; lambda2=1; lambda3=lambda3+2;
end
ES=round(100*(1-sqrt((lambda3-lambda2)^2/((lambda3+(t-1)*
lambda2)*(lambda1+lambda3+(t-1)*lambda2)))));
disp('Crossover Design is:'); crossoverdesign
disp('Efficiency of Separability (in "%") is:'); ES
if altdesign==1
    altdesign=input('Press 1 to generate alternative design,
Press 2 to generate all possible designs, otherwise Press 0:');
end
end
if altdesign==0
    break
end
end
if altdesign==0
    break
end
end
case 2
for con1=1:p-1
    astar(:,con1)=mod(conA(:,con1+1)-conA(:,con1),t);
end
lambda3=1.5*(t-2)-(t-1);
for con1=1:t^p
    for conj=con1+1:t^p
        for conh=conj+1:t^p
            if lambda3==0

```



```

        oddevet=2; allele=1;
    else
        oddevet=1; allele=0;
    end
    for conl=oddevet:t
        for conk=1:p-1
            if (astar(coni,conk)==conl-1 || astar(conj,conk)==conl-1 ||
                astar(conh,conk)==conl-1)
                allele=allele+1;
                break
            end
        end
    end
    if allele==t
        cod(1:p,1:3*t)=0; cta=conA(coni,:); ctb=conA(conj,:);
        ctc=conA(conh,:); cod(:,1)=cta'; cod(:,2)=ctb';
        cod(:,3)=ctc'; codsub=4;
        for conm=1:t-1
            cod(:,codsub)=cta'+conm; cod(:,codsub+1)=ctb'+conm;
            cod(:,codsub+2)=ctc'+conm; codsub=codsub+3;
        end
        crossoverdesign(1:p,1:3*t)=0;
        if rlp==0
            crossoverdesign=mod(cod,t); lambda1=3; lambda2=1;
        else
            crossoverdesign=mod(cod,t);
            crossoverdesign(p+1,:)=crossoverdesign(p,:);
            lambda1=3; lambda2=1; lambda3=lambda3+3;
        end
        ES=round(100*(1-sqrt((lambda3-lambda2)^2/((lambda3+(t-1)*
            lambda2)*(lambda1+lambda3+(t-1)*lambda2)))));
        disp('Crossover Design is:'); crossoverdesign
        disp('Efficiency of Separability (in "%") is:'); ES
        if altdesign==1
            altdesign=input('Press 1 to generate alternative design,
                Press 2 to generate all possible designs, otherwise Press 0:');
        end
    end
end

```



```

        if altdesign==0
            break
        end
        end
        if altdesign==0
            break
        end
        end
        if altdesign==0
            break
        end
        end
    end
case 3
    for con1=1:p-1
        astar(:,con1)=mod(conA(:,con1+1)-conA(:,con1),t);
    end
    lambda3=0;
    for con1=1:t^p
        allele=1;
        for conl=2:t
            for conk=1:p-1
                if (astar(con1,conk)==conl-1)
                    allele=allele+1;
                    break
                end
            end
        end
    end
    if allele==t
        cod(1:p,1:t)=0; dirter=conA(con1,:); cod(:,1)=dirter';
        codsub=2;
        for conm=1:t-1
            cod(:,codsub)=dirter'+conm; codsub=codsub+1;
        end
        crossoverdesign(1:p,1:t)=0;
        if rlp==0
            crossoverdesign=mod(cod,t); lambda1=1; lambda2=1;
        else
            crossoverdesign=mod(cod,t);

```




```

crossoverdesign(p+1,:)=crossoverdesign(p,:);
lambda1=1; lambda2=1; lambda3=1;
end
ES=round(100*(1-sqrt((lambda3-lambda2)^2/((lambda3+(t-1)*
lambda2)*(lambda1+lambda3+(t-1)*lambda2)))));
disp('Crossover Design is:');
crossoverdesign
disp('Efficiency of Separability (in “%”) is:');
ES
if altdesign==1
altdesign=input('Press 1 to generate alternative design,
Press 2 to generate all possible designs, otherwise Press 0:');
end
end
if altdesign==0
break
end
end
case 4
for con1=1:p-1
astar(:,con1)=mod(conA(:,con1+1)-conA(:,con1),t);
end
lambda3=0;
for con1=1:t^p
allele=0;
rep(1:1,1:t-1)=0;
for conl=2:t
for conk=1:p-1
if (astar(con1,conk)==conl-1)
allele=allele+1; rep(1,conl-1)=rep(1,conl-1)+1;
end
end
if rep(1,conl-1)~=mby2
break
end
end
if rep(1:1,1:t-1)==mby2*ones(1,t-1)
m=2*mby2; cod(1:p,1:t)=0; dirmter=conA(con1,:);

```



```

cod(:,1)=dirmter'; codsub=2;
for conm=1:t-1
    cod(:,codsub)=dirmter'+conm; codsub=codsub+1;
end
crossoverdesign(1:p,1:t)=0;
if rlp==0
    crossoverdesign=mod(cod,t); lambda1=1; lambda2=m/2;
else
    crossoverdesign=mod(cod,t);
    crossoverdesign(p+1,:)=crossoverdesign(p,:);
    lambda1=1; lambda2=m/2; lambda3=lambda3+1;
end
ES=round(100*(1-sqrt((lambda3-lambda2)^2/((lambda3+(t-1)*
lambda2)*(lambda1+lambda3+(t-1)*lambda2)))));
disp('Crossover Design is:'); crossoverdesign
disp('Efficiency of Separability (in "%") is:'); ES
if altdesign==1
    altdesign=input('Press 1 to generate alternative design,
Press 2 to generate all possible designs, otherwise Press 0:');
    end
end
if altdesign==0
    break
end
end
end

```



otherwise
 warning('Unexpected combination of t and p. No design created.');

end

Executing the program given above in the MATLAB, it asks for two user specified parameters, first, the number of treatments, second, number of periods. Once input these two parameters, program search the cross-over design for the defined combination. If cross-over design is possible in any number of the subjects, then the program generates the cross-over design with its efficiency of the separability (ES) as per the form shown in following subsection. Then the program asks for the further procedure by showing the message Press 1 to generate alternative design, Press 2 to generate all possible

designs, otherwise Press 0: If experimenter presses 1, then the program generates the alternative design in the same class and again shows the same message. This procedure continues until experimenter press 1 as experimenter does not get the satisfactory cross-over design. If experimenter presses 2, then the program generates the all possible remaining cross-over designs in the defined class so that experimenter has choices to select a suitable cross-over design which fulfill the essential requirements of the experiment. If experimenter presses 0, then the program will stop to search the cross-over design.

Output

The output of the execution of the above program is a cross-over design in the specified parameters and efficiency of separability. Rows of the generated cross-

over design are periods and columns of the design are subjects. For example, output given below is of the experimental situation, $t = 4$ and $p = 3$. Here, first treatment sequence is 001 represents treatment label 0 is given to first subject in period one and two, and, treatment label '1' is given to period three. For each cross-over design, program generates the efficiency of separability. Here, in following output efficiency of the cross-over design is 100%.

Cross-over Design is

Cross-overdesign =

0 0 1 1 2 2 3 3

0 2 1 3 2 0 3 1

1 1 2 2 3 3 0 0

Efficiency of Separability (in “%”) is

ES =

100

5. Illustrative example

Consider an experimental situation where $t = 4$ and $p = 3$. Cross-over design of 4 treatments in 3 periods can be constructed by following steps.

1. Run program in MATLAB
2. Press 4 for the argument 'Enter number of treatments:' and press enter
3. Press 3 for the argument "Enter number of periods:" and press enter. The program generates following output,

Crossover Design is:

crossoverdesign =

0 0 1 1 2 2 3 3

0 2 1 3 2 0 3 1

1 1 2 2 3 3 0 0

Efficiency of Separability (in “%”) is:

ES =

100

Press 1 to generate alternative design, Press 2 to generate all possible designs, otherwise Press 0:

4. If press 1 and press enter, then program gives alternative cross-over design as given below,

Crossover Design is:

crossoverdesign =

0 0 1 1 2 2 3 3

0 3 1 0 2 1 3 2

1 1 2 2 3 3 0 0

Efficiency of Separability (in “%”) is:

ES = 100

Press 1 to generate alternative design, Press 2 to generate all possible designs, otherwise Press 0:

5. If press 2 and press enter, then the program gives remaining all possible 188 cross-over designs in which first and last is,

Cross-over Design is:

cross-overdesign =

0 1 1 2 2 3 3 0

0 0 1 1 2 2 3 3

1 2 2 3 3 0 0 1

Efficiency of Separability (in “%”) is:

ES =

100

.

.

.

Crossover Design is:

crossoverdesign =

3 3 0 0 1 1 2 2

2 3 3 0 0 1 1 2

3 1 0 2 1 3 2 0

Efficiency of Separability (in “%”) is:

ES =

100

6. Then the program automatically stops to run. The above design is minimal balanced cross-over design denoted as COD (4, 8, 3) with 100% ES. The four treatments are denoted as 0, 1, 2 and 3. Note that, here only first and last design of 188 is shown because it is not possible to show all.

6. Conclusion

The article presents a MATLAB program to construct all three types of minimal balanced cross-over designs as number of treatments is less, equal and



more than the number of periods. This program solves the problem of construction of cross-over design for non-mathematician experimenter/user by constructing cross-over design through inputting only two user specified parameters, first, number of treatments and second, number of periods. Recently investigated minimal balanced cross-over designs are also constructed with its efficiency of separability by the program. Now, construction is also possible for a large number of treatments and periods which is generally difficult for experimenter/user. Sometime, it may not be convenient or possible in the experiment to use the certain sequences or periods of the cross-over design. Outcome of this article would solve this problem to a certain extent by constructing a variety of cross-over design in the same class.

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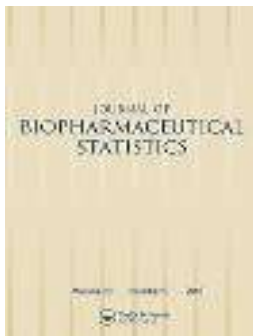
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Optimal and/or efficient three treatment crossover designs for five carryover models

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ABSTRACT

The additional benefits in the analysis of crossover designs with two active treatments and a placebo motivated us to study these kinds of designs. These designs have been studied through a computer search algorithm, called 5M balanced algorithm, in two to four periods for different number of units, which resulted in optimal and/or efficient crossover designs. The new two periods crossover designs having two active treatments and a placebo, enables the estimation of treatment contrasts, unlike the classic two treatments two periods crossover which fails to estimate the treatment contrasts under self and mixed carryover model. The crossover designs having three or four periods in two active treatments and a placebo, estimate treatment contrasts more efficiently under self and mixed carryover model than the usual two treatments crossover designs. An exhaustive list of optimal and/or efficient crossover designs has been provided for designs in two periods having 6–21 subjects, three periods having 3–20 subjects and four periods having 3–14 subjects. In this list, 35 new designs are optimal for one of the established carryover models and 26 new designs are optimal and/or efficient to all four plausible carryover models.

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Self and mixed carryover effect; optimal design; active treatment; placebo treatment; washout period



1. Introduction

Designs with a new therapy, standard therapy and a placebo are sometimes referred as “gold standard” trials. There are two kinds of objectives associated with these trials: first, compare two active treatments and, second, compare active treatments with placebo. These research objectives are carried out using crossover designs (CODs) because within subject treatment comparisons are more efficient than between subject treatment comparisons. For example, Tsoy et al. (1990) used three-period crossover design in three treatments as double-blind gold standard trial on patients suffering from exercise-induced asthma. They used data values of forced expiratory volume (FEV1) obtained after an exercise challenge for comparing the protective effect of a single dose of a study therapy formoterol solution aerosol 12 mg (F12), with a single dose of standard therapy salbutamol suspension aerosol 100 mg (F100) and with a placebo (P).

In crossover designs, each subject is measured according to a treatment sequence over successive periods of time, the carryover effects may sustain for different amounts of time. According to Senn (1992) if carryover is present to any appreciable degree then the usual statistical models provide no guaranteed protection against its effects. Owing to this reason, Senn and Lambrou (1998) investigated two treatments four periods CODs under traditional and steady state carryover models and concluded that statisticians cannot provide a general design and estimation strategy that give guarantee to deal with carryover. The steady state model assumes that the carryover from the same treatment applied in the previous period ultimately vanishes to zero.

Koch et al. (1989) proposed a two periods COD in 10 sequences for comparison of two active treatments in presence of placebo. Jones and Donev (1996) improved their design into three periods design to optimize the active treatment comparison. However, both the authors have assumed that carryover effects of active treatments and placebo are equal in magnitude but opposite in sign. Since proving optimality through combinatorial theory is tractable only for restricted class of designs, many authors, Jones and Donev (1996), John et al. (2004), Yang and Stufken (2008) and Satpati et al. (2012) used computer search algorithm to construct optimal CODs in two or more treatments for specific models.

A design optimal for one statistical model may not be optimal for another. Also, a design that estimate treatment contrasts under one model may not estimate under another. It is therefore of interest to identify designs that provide efficient estimates of treatment contrasts (relative to an optimal design) for more than one model.

Hedayat and Stufken (2003) studied CODs in t treatments having two to four periods under two carryover models and identified optimal and efficient CODs. Ozan and Stufken (2010) assessed the impact of carryover effects on the variances of the estimators of treatment differences in CODs for several models. They suggested that one should use a design that produces estimates with smaller values of variance relative to other designs with the same number of treatments and periods for all or most of the models under consideration. However, these authors did not consider the number of subjects while comparing different designs, which in fact is an important parameter and has a significant impact, not only on the choice of an optimal design but also in the execution of a crossover experiment. In particular, for experiments comparing a new treatment with a standard treatment, two more kinds of carryover models are likely to exist: the traditional carryover model and the self and mixed carryover model with only new treatment yielding carryover effect. Gondaliya and Divecha (2018) constructed two treatments CODs in various number of subjects for five different models, and contributed several new optimal and/or efficient CODs. However, there exist no two treatments two periods COD which can estimate treatment contrast under self and mixed carryover model. On the other hand, CODs in two active treatments and a placebo have additional benefit in analysis (Divecha and Gondaliya (2019)). These two reasons motivated us to study CODs in two active treatments and a placebo with a view to facilitate user with CODs in variety of the number of subjects under arbitrary carryover assumptions.

In this paper, optimal and/or efficient CODs of two active treatments and a placebo in two to four periods for different number of subjects under four plausible carryover models have been constructed through a 5M balanced algorithm. A COD which is either optimal for any one model and efficient for the remaining models or efficient for all five models is referred as optimal and/or efficient COD. The three and four periods CODs having two active treatments in presence of a placebo estimate treatment contrasts more efficiently under self and mixed carryover model than the two treatments CODs. For example, the design {ABA, ABA, ABA, BAB, BAB, BAB} having two active treatments in three periods and six subjects denoted as COD(2, 6, 3) shown to be optimal by Hedayat and Stufken (2003) has variance 1 of treatment contrast, whereas, our design {ABP, BPA, PAB, APB, BAP, PBA} having two active treatments in presence of placebo has variance 0.42. Hence, {ABP, BPA, PAB, APB, BAP, PBA} is new optimal COD under self and mixed carryover model. The new two periods CODs having two active treatments and a placebo enables the estimation of treatment contrasts under self and mixed carryover model. Our contribution is twofold. One is new optimal COD to specific model and second is new optimal and/or efficient COD to all five models. A list of new optimal and/or efficient two periods CODs in 6–21 subjects, three periods CODs in 3–20 subjects, and four periods CODs in 3–14 subjects have been provided.

2. Models and optimality

2.1. Models

The model known as no carryover model in the COD literature is of the form,

$$y_{ijk} = \mu + \pi_k + \xi_{ij} + \tau_{d(k,j)} + \epsilon_{ijk}, \quad i = 1, \dots, s; j = 1, \dots, n_i; k = 1, 2, \dots, p, \quad (1)$$



where y_{ijk} denotes the response from sequence i , subject j , in period k to which treatment $d(k, j)$ was assigned, μ is the general mean, $\tau_{d(k, j)}$ is the effect of treatment $d(k, j)$, π_k is the effect due to period k , ξ_{ij} is the effect due to subject j having sequence i , every sequence replicated n_i times ($n_i \geq 1$), and the ϵ_{ijk} are independently normally distributed error terms with mean 0 and variance σ^2 .

When the response variable is also affected by the treatment applied in the previous period, then one more term of carryover effect of the treatment should be added in the model. This model is generally called simple carryover model or traditional model in optimal design literature, and is given by

$$y_{ijk} = \mu + \pi_k + \xi_{ij} + \tau_{d(k, j)} + \gamma_{d(k-1, j)} + \epsilon_{ijk}, \quad (2)$$

where $\gamma_{d(k-1, j)}$ is the carryover effect of treatment $d(k-1, j)$ on the response observed on subject j in period k . It is obvious that there is no carryover effect in the first period, that is, $\gamma_{d(0, j)} = 0$. Sometimes, the carryover due to the treatment preceded by it in the previous period is different than the treatment proceeded by other. This view was first introduced by Afsarinejad and Hedayat (2002) and studied by Kunert and Stufken (2002, 2008)). This self and mixed carryover effect is of the form,

$$y_{ijk} = \mu + \pi_k + \xi_{ij} + \tau_{d(k, j)} + \gamma_{1d(k-1, j)} + \gamma_{2d(k-1, j)} + \epsilon_{ijk}, \quad (3)$$

where $\gamma_{1d(k-1, j)}$ is the carryover of treatment preceded by other treatment in the previous period and $\gamma_{2d(k-1, j)}$ is the carryover of treatment preceded by itself in the previous period.

Practical situations where purpose of the trial is to compare two treatments called active treatments with help of a placebo (for example, Laurell and Tornros (1986) and Tornros and Laurell (1990)). Accordingly, all the models considered in this paper are restricted to two active treatments and a placebo. As per medical knowledge, when a placebo is given to patients, in the patients' mind the psychology is that a drug is given to them, but in reality it is a placebo, so whatsoever psychological effects the patients have get measured as direct effects of the placebo, and in the next period there are no carryover of the psychological effects. Therefore, it is logical to assume no presence of psychological carryover and obviously, there is no pharmacological carryover from the placebo treatment. As per the assumption that, a placebo has no carryover effects, models 1–3 with active treatments A, B and placebo P are referred in this article by NCM (No Carryover Model), TBM (Traditional Model where Both active treatments have carryover), and SBM (Self and mixed Model where Both active treatments have carryover), respectively. Also, when the purpose of a trial is to compare a new drug with a standard drug, the experimenter is usually aware of the washout period of the standard treatment. In this case, if the experimenter set the length of washout period according to the standard treatment then the standard treatment will not have carryover effects. Regarding to the complexity of the analysis of crossover experiments for comparing new treatment with a standard, the analysis also gets simplified by assuming that only the new treatment has carryover effect. In this case, the traditional model with the assumption that only treatment A having carryover effect is model 2, with $\gamma_{d(k-1, j)} = 0$ if $d(k-1, j) = B$ or P . We will refer this model as TSM (Traditional Model where Single active treatment has carryover).

Similarly, self and mixed model with the assumption that only treatment A having carryover effect is model 3 with $\gamma_{d(k-1, j)} = 0$ if $d(k-1, j) = B$ or P . We will refer to this model as SSM (Self and mixed Model where Single active treatment has carryover). These five different fixed effect models, NCM, TSM, TBM, SSM, and SBM for continuous response cover all the possibilities of occurrence of carryover effect.

2.2. Optimality

Most commonly, the performance of a design is measured by its variance of treatment comparison, given by the variance of the least square estimates of the treatments. Usually, a design d with larger information matrix, C_d , yields a smaller variance for estimate of treatment, hence the central problem in the design of experiments is to find the design d such that the information matrix C_d is as large as possible. However,



matrices cannot be compared directly in general. To compare them for different designs, one has to define functions of C_d , which maps from the matrix space into one-dimensional space. For the connected balanced designs, it suffices to compare variances of the treatment contrasts. Note that the nature of treatment contrasts depends upon the objective of the study.

For comparison of two treatments, the objective is generally estimating the difference of treatment effects. The design which minimizes its variance over all possible designs for a specific class is referred to the optimal in the class (Jones and Donev (1996), Hedayat and Stufken (2003)). A specific class of COD is generally determined by fixing only one or two of the three parameters, the number of treatments, periods, and subjects, but preferably, it should be considered by fixing all the three parameters.

Hedayat and Stufken (2003) and Ozan and Stufken (2010) ignored the number of subjects in comparison of different designs, and thus missed several optimal designs available in specific number of subjects, particularly in the presence of carryover effects (Gondaliya and Divecha (2018)). Also under SBM, comparison of active treatments with the help of a placebo reduces the variance of treatment contrast. From Table 1, it is clear that, under SBM, the optimal design for six subjects {ABP, BPA, PAB, APB, BAP, PBA} given two active treatments and a placebo in three periods has 53% more efficiency as compared to the design {ABA, ABA, ABB, BAB, BAB, BAA} of two active treatments. That is, $COD(t+1, n, p)$ performs optimal than $COD(t, n, p)$ under SBM. Note that, class $COD(t+1, n, p)$ contains all the COD of t and $t+1$ treatments having n or $n-1$ subjects in p periods. For simplicity, we used an abbreviated notation for the designs. For example, the design {ABA, ABA, ABB, BAB, BAB, BAA} abbreviated as $cod(p)3\{2ABA, ABB, 2BAB, BAA\}$. The number after $cod(p)$ stands for serial number of the COD in the table. The number before the sequence denotes the replication of the sequence in the design. A design that is optimal under one model may not be optimal under another model. Then, the better choice is the design which is efficient under several models. The efficiency is the relative efficiency of a design, d , with respect to the optimal design for that class and the model. Efficiency is calculated by taking ratio of the variance of least squares estimator of treatment contrast for the optimal design to the variance of design d . Thus, efficiency of a design optimal for a specified class and model is 100% but it may not be so in case of another models. From Table 1, it is clear that, $cod(p)6\{ABP, BPA, PAB, APB, BAP, PBA\}$ is optimal and efficient for class $COD(2+1, 6, 3)$, because this design is optimal under SBM and efficient in other models. Variance of least squares estimator of treatment contrast of CODs shown in this paper, is obtained through the said computer search algorithm.

2.3. Simulation study

We demonstrate the performance adequacy of 5M algorithm via a simulation study. It was performed for each five models with results equivalent to those in Table 1. Suppose an experimenter wants to construct a balanced design which should be optimal under SBM and efficient for rest of the models. Data shown in Table 2 for the $cod(p)6$ were simulated by fixing the SBM parameters as $\mu = 15$, $\tau_A = 2$, $\tau_B = -2$, $\tau_P = 0$, $\gamma_{1A} = -1$, $\gamma_{1B} = 1$, $\gamma_{1P} = 0$, $\gamma_{2A} = -2$, $\gamma_{2B} = 2$, $\gamma_{2P} = 0$, $\pi_1 = -2$, $\pi_2 = 2$, $\pi_3 = 0$, $\xi_{11} = \xi_{21} = \xi_{31} = 1$, $\xi_{41} = \xi_{51} = \xi_{61} = -1$, and $\sigma^2 = 1$. Estimate of the interested treatment contrasts ($\hat{\tau}_A - \hat{\tau}_B$) in this case is 4.0171. It shows that an active treatment A has 4.0171

Table 1. Optimal and/or efficient balanced CODs for class $COD(2+1, 6, 3)$.

Serial no.	Design	n	NCM	TSM	TBM	SSM	SBM
1	AAB,ABA,ABB,BBA,BAB,BAA	6	100	81	81	78	45
2	AAB,2ABB,BBA,2BAA	6	100	99	99	96	25
3	2ABA,ABB,2BAB,BAA	6	100	67	67	62	47
4	ABA,2ABB,BAB,2BAA	6	100	92	92	100	28
5	3ABB,3BAA	6	100	100	100	—	—
6	ABP,BPA,PAB,APB,BAP,PBA	6	75	63	60	90	100



Table 2. Simulated data for the $cod(p)6$ under SBM.

Period	Seq	Data	Seq	Data	Seq	Data	Seq	Data	Seq	Data	Seq	Data
1	A	15.5736	B	10.1938	P	13.7637	A	12.7639	B	9.6881	P	10.3028
2	B	15.8896	P	20.0247	A	19.0187	P	14.9498	A	19.2214	B	13.4013
3	P	17.6498	A	18.8252	B	12.2304	B	11.6113	P	12.7027	A	16.4767

units more effects than B which is very close to exact value 4 ($\tau_A - \tau_B$). Similarly, we have simulated data for the $cod(p)1$ to $cod(p)4$ under SBM by fixing the parameters as shown above. Estimates of the interested treatment contrasts ($\hat{\tau}_A - \hat{\tau}_B$) in this cases are 7.4691, -1.6963 , 6.6107, and -1.0718 , respectively which is outlying from the exact value 4. So, it is clear that $cod(p)6$ estimates treatment contrasts more efficiently than the other designs under SBM. We have repeated the above procedure 100 times for all the six designs under all five models and estimated treatment contrast ($\hat{\tau}_A - \hat{\tau}_B$) as shown by charts in the Appendix. Chart of $cod(p)6$ clearly shows that $cod(p)6$ performs efficient under all the models as compared to the $cod(p)1$ - $cod(p)5$.

3. The 5M balanced algorithm

In this section, we present a computer algorithm for search of optimal and/or efficient CODs under the five models, namely, NCM, TSM, TBM, SSM, and SBM. The algorithm involves making comparisons of variances of direct effects among CODs of a class for a given model. Several computer algorithms have been given in literature (Jones and Donev (1996), John et al. (2004), Yang and Stufken (2008), Satpati et al. (2012)) for search of optimal and/or efficient CODs. The most common approach of these algorithms is that, they begin the search procedure with a “random” design and attempt to improve it until it cannot be improved by applying further steps. Our computer search algorithm starts from a trivial possibility and proceeds systematically up to the last possibility, and provides globally optimum COD by comparing every possible CODs of a specified class and model. Since, the algorithm makes exhaustive search and returns optimal and/or efficient crossover designs for one or more of the five models, the computer programming was challenging.

A broad outline of the 5M balanced algorithm is given below.

- (1) Set variance $V(m) = a$ high value (say, 99), for all models numbered $m = 1, \dots, 5$. Set parameters t , p , and n .
- (2) Generate all possible treatment sequences of t treatments in p periods.
- (3) Generate a crossover design d by considering n treatment sequences arbitrarily from those obtained in step 2 including replications of the sequences.
- (4) Perform equal replication check for the generated design that is, $(np)/t$ occurrence of each treatment. If all the treatments are not equally replicated then return to step 3.
- (5) Perform balanced occurrence check for treatments in each period that is, n/t occurrence of each treatment in each period. If all the treatments are not equally replicated in each period then return to step 3.
- (6) Perform pair-wise balanced occurrence of active treatments in two successive periods that is, each ordered pair of mixed, self active treatments, and mixed pair of active treatments and placebo are given to a constant number of units. If this condition is not satisfied then return to step 3.
- (7) Under NCM, TSM, TBM, SSM, and SBM indexed, respectively, $m = 1, 2, \dots, 5$.
 - (a) Perform connectedness check for the design d , that is, calculate the rank of the design information matrix (C_d) under model m . If it is not connected, that is, rank of C_d is less than $t - 1$, then skip the next step and consider next model.



- (b) Perform least variance check, that is, compute $V(d, m)$ which is variance of the least squares estimator of treatment contrast $(\tau_A - \tau_B)$ for two active treatments A and B under model m . If $(V(d, m) > 0 \& V(d, m) < V(m))$ then store $V(m) = V(d, m)$ and $optimaldesign(m) = d$.
- (8) Finally, store the design with variance $V(d, m)$ and ranks of the design matrix under NCM, TSM, TBM, SSM, and SBM, provided that the design is connected in all five models.
- (9) Repeat steps 3–8 for all possible combinations of n treatment sequences.

This algorithm produces optimal CODs under each model along with their variances and ranks. All this is stored in a spreadsheet for at a glance view of design statistics for optimal and/or efficient CODs under given model. Note that the CODs optimal under NCM, TSM, TBM, SSM, and SBM are stored, respectively, as the last five designs in the spreadsheet.

3.1. Working of the 5M balanced algorithm

Consider an experimental situation where $t = 3$, $p = 3$, and $n = 3$. Let the two active treatments be denoted by 1, 2, and placebo denoted by 3. Step 1 is set by $V(m) = 99, m = 1, 2, \dots, 5$. Step 2 generates all the possible sequences. Step 3 generates a design say, $\{111, 111, 111\}$. As per step 4, treatment 2 is not equally replicated as treatments 1 and 3, and hence, the algorithm returns to step 3 and generates a second design say, $\{111, 111, 112\}$. Again the algorithm shall return to step 3 and generates designs say, $\{111, 111, 113\}, \{111, 111, 121\}, \dots, \{111, 222, 333\}$. Now algorithm moves to step 5 where all the treatments are equally replicated in each period and hence, algorithm moves to step 6 but the treatments are not balanced in terms of carryover and hence, algorithm returns to step 3 and generates the other designs $\{111, 223, 223\}, \dots, \{121, 232, 313\}$. Now this design satisfies the condition of steps 4–6. Hence, in step 7(a), rank of C_d under NCM is calculated. Here rank of the design matrix is two, which implies that the design is connected. In step 7(b) variance of the least squares estimator of treatment contrast $(\tau_1 - \tau_2)$ under NCM is calculated. Also, variance of the least squares estimator of treatment contrast $(\tau_1 - \tau_2)$ is less than the set variance $V(1)$. Hence, the algorithm stores design $\{121, 232, 313\}$ as the optimal design along with its variance for treatment comparison. Similarly, the algorithm calculates C_d and variances of the least squares estimator of treatment contrast $(\tau_1 - \tau_2)$ under TSM, TBM, SSM, and SBM one by one according to step 7. Under all the other four models, the design is connected and hence algorithm stores design $\{121, 232, 313\}$ as the optimal design along with its variance under TSM, TBM, SSM, and SBM. Also, this design is connected in all five models, therefore the algorithm stores this design as design number 1 with its variance and rank. According to step 9, the algorithm returns to step 3 and generates other designs. Similarly, the algorithm repeatedly works for other sequence combinations. Since, all fail to yield smaller variance of treatment contrast under TSM and SSM except the design $\{131, 212, 323\}$, hence, this design is stored as optimal. Also, this design is connected in all five models. Hence, this design is stored as design number 2 with its variance and rank. Finally, the algorithm generates a spreadsheet having three sheets named as var, rank, and design, respectively, showing the variances of treatment contrast, the ranks of C_d matrix and the CODs, stored by the 5M balanced algorithm.

4. Two active treatments and one placebo CODs in two periods

Recall that in the class of two treatments two periods CODs, only a few designs are available which can estimate treatment contrasts superiorly. Considering crossover designs in two active treatments and one placebo will increase the availability of such designs. This is because the resultant design is a collection of replicates from the nine possible sequences, AA, AB, AP, BA, BB, BP, PA, PB, and PP. Before defining such CODs, let us consider a practical situation discussed by Senn (2003), where such types of CODs have application.



Example 4.1 This concerns a double-blind placebo controlled crossover trial, designed to measure the onset of action of two doses of formoterol solution aerosol: 12 and 24 μg . For practical reasons, it was decided that the patients could only be studied during four visits. Since each treatment day was to be preceded by a general medical evaluation, this meant that only 2 treatment days were possible. Blindness was maintained using dummy loading and each patient used two aerosols at each of visits 2 and 4, taking one puff from each. The aerosols were matched and depending on whether both aerosols were formoterol solution 12 μg , both placebo or one of each, the patient received 24, 0, or 12 μg formoterol. The wash-out period between visits 2 and 3 was approximately 1 week.

For the above crossover trial, a two treatment two period COD with placebo is required according to the availability of subjects and possibility of a carryover model. Naturally, an experimenter would prefer a design which is optimal under the most speculated carryover models and simultaneously efficient under other possible models. A class is determined by the number of subjects needed by an experiment. Note that sometimes two treatments designs are economical and efficient over two treatments—one placebo designs and vice versa. Thus, an experimenter has the choice to reduce the cost of trial by an amount incurred by one or two subjects, or not. Here, two treatments—one placebo designs having subjects in multiples of three have been evaluated and compared with two treatments CODs (Table 3 shows CODs having number of subjects from 6 to 21).

4.1. Optimal CODs under NCM, TSM, and TBM

Since the CODs in two active treatments and one placebo allocate the active treatments to less number of subjects than the corresponding two (active) treatments designs, the latter design will have a smaller variance for treatment contrasts under NCM, TSM, and TBM. Thus, two treatments designs are optimal under NCM, TSM, and TBM but are unable to estimate treatment contrast under SBM. Moreover, COD in two treatments is not possible in odd number of subjects. For example, for the class $COD(2, 9, 2)$, no two treatments design is possible but $COD(2 + 1, 9, 2)$ exists. However, when the experimenter is sure about his model to be NCM, TSM, or TBM, then it is better to use $COD(2, 8, 2)$ than $COD(2 + 1, 9, 2)$. Similarly, for the class $COD(2 + 1, 15, 2)$, optimal COD under NCM is $\text{cod}(p)28\{7AB, 7BA\}$ and under TSM and TBM is $\text{cod}(p)29\{3AA, 4AB, 4BA, 3BB\}$. For the class $COD(2 + 1, 21, 2)$, optimal COD under NCM is $\text{cod}(p)48\{10AB, 10BA\}$ and under TSM and TBM is $\text{cod}(p)44\{5AA, 5AB, 5BA, 5BB\}$.

4.2. Optimal CODs under SSM and SBM

Remember that no two treatments two periods COD exists which can estimate treatment contrast under SBM. Table 3 shows optimal COD under SSM and SBM for varying number of subjects n . Incidentally, optimal design under SSM is also optimal under SBM in two periods cases. From study of Table 3, it is clear that there exists two general constructions of optimal CODs under SSM and SBM for varying number of subjects.

For the class $COD(t + 1, n, p)$, when $n \equiv 0 \pmod{6}$, consider $n/6$ replications of the $\text{cod}(p)10\{AB, AP, BA, BP, PA, PB\}$ and, when $n \equiv 3 \pmod{6}$, use $(n - 3)/6$ replications of $\text{cod}(p)10$ along with $\{AA, BB, PP\}$. Under SSM and SBM, COD in two active treatments and a placebo has lesser variance of treatment contrast than that of COD in two treatments. Just as $\text{cod}(p)15\{AA, AB, AP, BA, BB, BP, PA, PB, PP\}$ is optimal under SSM and SBM in class $COD(2 + 1, 9, 2)$, accordingly $\text{cod}(p)31\{AA, 2AB, 2AP, 2BA, BB, 2BP, 2PA, 2PB, PP\}$ and $\text{cod}(p)50\{AA, 3AB, 3AP, 3BA, BB, 3BP, 3PA, 3PB, PP\}$ are optimal under SSM and SBM in their respective classes $COD(2 + 1, 15, 2)$ and $COD(2 + 1, 21, 2)$. Also note that, $\text{cod}(p)16\{AA, AB, AP, BA, BB, BP, PA, PB, PP\}$ is optimal under SSM and SBM in the class $COD(2 + 1, 10, 2)$. Also, this saves experimental resources on one subject. Similarly,



Table 3. Optimal and/or efficient balanced CODs for classes $COD(2 + 1, 6, 2)$ to $COD(2 + 1, 21, 2)$.

Serial no.	Design	n	NCM	TSM	TBM	SSM	SBM
7	3AB,3BA	6	100	—	—	—	—
8	2AA,AB,BA,2BB	6	33	100	100	72	—
9	AA,2AB,2BA,BB	6	67	100	100	72	—
10	AB, AP, BA, BP, PA, PB	6	50	69	56	100*	100 [@]
11	3AA,AB,BA,3BB	8	25	75	75	63	—
12	2AA,2AB,2BA,2BB	8	50	100	100	83	—
13	AA,3AB,3BA,BB	8	75	75	75	63	—
14	4AB,4BA	8	100	—	—	—	—
15	AA, AB, AP, BA, BB, BP, PA, PB, PP	9	38	86	75	100*	100 [@]
16	AA, AB, AP, BA, BB, BP, PA, PB, PP	9	30	71	63	100*	100 [@]
17	2AA,3AB,3BA,2BB	10	60	100	100	100	—
18	AA,4AB,4BA,BB	10	80	67	67	67	—
19	5AB,5BA	10	100	—	—	—	—
20	3AA,3AB,3BA,3BB	12	50	100	100	81	—
21	2AA,4AB,4BA,2BB	12	67	89	89	72	—
22	AA,5AB,5BA,BB	12	83	56	56	45	—
23	6AB,6BA	12	100	—	—	—	—
24	2AA,AB,AP,BA,2BB,BP,PA,PB,2PP	12	25	69	62	72	50
25	2AB, 2AP, 2BA, 2BP, 2PA, 2PB	12	50	62	50	100*	100 [@]
26	2AA,5AB,5BA,2BB	14	71	83	83	65	—
27	AA,6AB,6BA,BB	14	86	50	50	39	—
28	7AB,7BA	14	100	—	—	—	—
29	3AA,4AB,4BA,3BB	14	57	100	100	79	—
30	4AA,3AB,3BA,4BB	14	43	100	100	79	—
31	AA, 2AB, 2AP, 2BA, BB, 2BP, 2PA, 2PB, PP	15	43	82	70	100*	100 [@]
32	AA, 2AB, 2AP, 2BA, BB, 2BP, 2PA, 2PB, PP	15	38	71	60	100*	100 [@]
33	3AA,5AB,5BA,3BB	16	63	94	94	86	—
34	2AA,6AB,6BA,2BB	16	75	75	75	69	—
35	AA,7AB,7BA,BB	16	87	44	44	40	—
36	8AB,8BA	16	100	—	—	—	—
37	4AA,4AB,4BA,4BB	16	50	100	100	92	—
38	4AA,5AB,5BA,4BB	18	56	100	100	80	—
39	3AA,6AB,6BA,3BB	18	67	90	90	72	—
40	2AA,7AB,7BA,2BB	18	78	70	70	56	—
41	9AB,9BA	18	100	—	—	—	—
42	2AA,2AB,2AP,2BA,2BB,2BP,2PA,2PB,2PP	18	33	77	68	87	67
43	3AB, 3AP, 3BA, 3BP, 3PA, 3PB	18	50	62	51	100*	100 [@]
44	5AA,5AB,5BA,5BB	20	50	100	100	80	—
45	4AA,6AB,6BA,4BB	20	60	96	96	77	—
46	3AA,7AB,7BA,3BB	20	70	84	84	67	—
47	2AA,8AB,8BA,2BB	20	80	64	64	51	—
48	10AB,10BA	20	100	—	—	—	—
49	3AA,2AB,2AP,2BA,3BB,2BP,2PA,2PB,3PP	21	30	77	69	82	67
50	AA, 3AB, 3AP, 3BA, BB, 3BP, 3PA, 3PB, PP	21	45	77	64	100*	100 [@]

Designs in bold denote new optimal and/or efficient COD to class having n number of subjects.

*New optimal COD under new defined model SSM.

@New optimal COD under SBM.

$cod(p)32\{AA, 2AB, 2AP, 2BA, BB, 2BP, 2PA, 2PB, PP\}$ is more useful in the class $COD(2 + 1, 16, 2)$, and, $cod(p)50$ is preferable in the class $COD(2 + 1, 22, 2)$.

4.3. Efficient CODs under NCM, TSM, TBM, SSM, and SBM

From studying Table 3, it is clear that increasing the number of replications of sequences AB, BA in a design increases the efficiency under NCM, but decreases under TSM, TBM, and SSM. In contrast, the replications of sequences AA, BB increases the efficiency under TSM, TBM, and SSM, and decreases under NCM. On the other hand, the replications of sequences in placebo, AP, PA, BP, PB,



and PP, increases efficiency under SSM and SBM, but decreases under NCM, TSM, and TBM. So, it is necessary to find combinations of sequences which can efficiently estimate treatment contrast under all the models. Almost all the optimality studies on CODs assume equal replications for their sequences. This will obviously prohibit designs in unequal replications of sequences to show up. Only a computer search algorithm can give assurance to search every possible CODs which are optimal and/or efficient under specified models. The results of the computer search algorithm (5M active algorithm) are shown in Table 3. Below we discuss some interesting cases for each class defined in terms of the crucial parameter of execution, the number of subjects. For the class $COD(2 + 1, 6, 2)$, the $cod(p)10\{AB, AP, BA, BP, PA, PB\}$ is efficient under NCM, TSM, and TBM, but optimal under the remaining two models. When nine subjects are available, generally a statistician would use replication of design $\{AA, AB, BA, BB\}$ as $cod(p)12\{2AA, 2AB, 2BA, 2BB\}$ in eight subjects but, $cod(p)15\{AA, AB, AP, BA, BB, BP, PA, PB, PP\}$ is efficient in the class $COD(2 + 1, 9, 2)$. However, if the experimenter is 100% sure about no possibility of self and mixed carryover model, then $cod(p)13\{AA, 3AB, 3BA, BB\}$ is useful. Interestingly, although not surprisingly enough, the same pattern continued to hold for further classes in increasing number of subjects. In the class $COD(2, 10, 2)$, $cod(p)17\{2AA, 3AB, 3BA, 2BB\}$ and $cod(p)18\{AA, 4AB, 4BA, BB\}$ perform efficient under NCM, TSM, TBM, and SSM. However, $cod(p)16\{AA, AB, AP, BA, BB, BP, PA, PB, PP\}$ is more suitable in presence of carryover, because it estimates treatment contrast under SBM also. Note that, this design uses nine subjects and hence it has less efficiency under NCM. Further, under all carryover models, $cod(p)16$ is also efficient than COD of Koch et al. (1989) (denoted as K) and Jones and Donev (1996) (denoted as $J1$ and $J2$), as shown in Table 4. Crossover design of Koch et al. (1989) is optimal under SSM and SBM, but it has poor efficiency under TBM. Note that, designs of both the authors are not balanced.

A general choice of design for the class $COD(2 + 1, 12, 2)$ is either six replications of COD $\{AB, BA\}$ or three replications of COD $\{AB, BA, AA, BB\}$. But $cod(p)21\{2AA, 4AB, 4BA, 2BB\}$, $cod(p)22\{AA, 5AB, 5BA, BB\}$, and $cod(p)25\{2AB, 2AP, 2BA, 2BP, 2PA, 2PB\}$ perform efficiently in this case. However, $cod(p)25$ is suitable in case of more possibility of self and mixed carryover. Useful design according to practical suitability in the class $COD(2 + 1, 15, 2)$ is $cod(p)31\{AA, 2AB, 2AP, 2BA, BB, 2BP, 2PA, 2PB, PP\}$, although it has poor efficiency under NCM. When 16 subjects are available, then COD in 15 subjects should be used, because $cod(p)32\{AA, 2AB, 2AP, 2BA, BB, 2BP, 2PA, 2PB, PP\}$ is able to estimate treatment contrast in all five models. In class $COD(2, 18, 2)$, $cod(p)43\{3AB, 3AP, 3BA, 3BP, 3PA, 3PB\}$ is optimal under SSM and SBM and efficient in other models. Design $cod(p)50\{AA, 3AB, 3AP, 3BA, BB, 3BP, 3PA, 3PB, PP\}$ is efficient under all the models for class $COD(2 + 1, 21, 2)$, although efficiency under NCM is poor.

In general, constructions of optimal and efficient two periods CODs under NCM, TSM, TBM, SSM, and SBM for the class $COD(t + 1, n, p)$ are when $n \equiv 0 \pmod{6}$, $n/6$ replications of $cod(p)10$ and, when $n \equiv 3 \pmod{6}$, $(n - 3)/6$ replications of $cod(p)10$ along with $\{AA, BB, PP\}$.

Table 4. Efficiency of Koch et al. (1989) and Jones and Donev (1996) COD comparable to our COD of Table 3 for class $COD(2 + 1, 10, 2)$.

Serial no.	Design	n	NCM	TSM	TBM	SSM	SBM
$cod(p)16$	AA,AB,AP,BA,BB,BP,PA,PB,PP	9	30	71	63	92	86
$cod(p)17$	2AA,3AB,3BA,2BB	10	60	100	100	92	–
$cod(p)18$	AA,4AB,4BA,BB	10	80	67	67	61	–
K	3AB,3BA,AP,PA,BP,PB	10	70	54	36	100	100
$J1$	3AB,3BA,2AP,PA,BP	10	67	20	19	37	53
$J2$	3AB,3BA,2AP,PP,BP	10	67	38	20	71	55



5. Two active treatments and one placebo CODs in three periods

A COD in two active treatments and one placebo having three periods is given by some of these 27 treatment sequences AAA, BAA, PAA, ABA, BBA, PBA, APA, BPA, PPA, AAB, BAB, PAB, ABB, BBB, PBB, APB, BPB, PPB, AAP, BAP, PAP, ABP, BBP, PBP, APP, BPP, and PPP. Due to increased options compared to two periods CODs, treatment contrasts are estimable under all models for all classes that is, according to desirable number of subjects. Also, now there are more choices for designs. Before defining such a COD, let us consider a practical situation reported by Tsoy et al. (1990) for a single center data from a multicenter trial, where such types of CODs are used.

Example 5.1 Values of forced expiratory volume in 1 s (FEV_1), obtained after an exercise challenge in a three periods three treatments double-blind crossover trial, comparing the protective effect of a single dose of an experimental treatment, formoterol solution aerosol (12 mg), to a single dose of a standard therapy, salbutamol suspension aerosol (100 mg), and placebo for patients suffering from exercise-induced asthma.

For the above crossover trial, any of the following three periods CODs would be useful according to the availability of subjects and choice of the carryover model. Naturally, an experimenter would prefer a design which is optimal under the most speculated carryover model and simultaneously efficient under the possible models. As per the following Table 5, a suitable design could be a two treatments design or a two treatments—one placebo design. Therefore, both types of designs are evaluated and tabulated as belonging to common classes. A class is determined by the number of subjects needed by an experiment. Note that, two treatments designs are in even number of subjects, and a two treatments—one placebo designs have subjects in multiples of three. Table 5 restricts classes of designs up to 20 but more classes can be developed using 5M active algorithm.

5.1. Optimal CODs under NCM, TSM, TBM, and SSM

Although CODs in two treatments are optimal under the four models, namely, NCM, TSM, TBM, and SSM but, they are not available in odd number of subjects like 3, 9, 15, and so on. In class $COD(2 + 1, 3, 3)$, the COD in two treatments $cod(p)53\{ABB, BAA\}$ has lesser variance of treatment contrasts under three models NCM, TSM, and TBM than the $cod(p)54\{APA, BAB, PBP\}$ having two treatments and one placebo. On the contrary, the $cod(p)54$ is optimal over $cod(p)53$ under SSM. In the class $COD(2 + 1, 9, 3)$, the COD of two treatments in eight subjects $cod(p)65\{4ABB, 4BAA\}$ is optimal under NCM, TSM, and TBM, whereas $cod(p)63\{AAB, 3ABB, 3BAA, BBA\}$ is optimal under SSM. Similarly, in case of 15 subjects, it is better to leave one unit and use $cod(p)86\{3AAB, 4ABB, 4BAA, 3BBA\}$ under NCM and SSM, whereas $cod(p)85\{3AAA, 4ABB, BAA, 3BAB, 3BBA\}$ under TSM and TBM.

5.2. Optimal CODs under SBM

We know that optimal design literature has shown that $\{\frac{n}{2}ABA, \frac{n}{2}BAB\}$, i.e., the design in which half of the subjects receive sequence ABA, and the other half receives BAB is optimal under SBM. However, this design is optimal only for the classes $COD(2, 2, 3)$ and $COD(2, 4, 3)$, and not in general for $COD(2, n, 3)$ for given n ($n \equiv 0 \pmod{2}$). These designs are recommended for bioequivalence studies in the FDA (2001). More optimal designs under SBM for number of subjects $n = 6, 8, 10, \dots, 20$ have been discussed by Gondaliya and Divecha (2018). Table 5 shows that when the class is expanded to include the designs having placebo, then the two treatments—one placebo designs become optimal over two treatments designs under SBM. For example, variance of treatment contrasts for $cod(p)57$ is 0.8889, while that for $cod(p)60$ is 0.4167 resulting in 53% gain. Also, CODs of approved type are not available in certain classes, in particular when number of subjects required are 9, 15, and so on. Also so far, no general



Table 5. Optimal and/or efficient balanced CODs for classes $COD(2 + 1, 3, 3)$ to $COD(2 + 1, 20, 3)$.

Serial no.	Design	n	NCM	TSM	TBM	SSM	SBM
51	ABA,BAB	2	100	25	25	78	100
52	AAB,BBA	2	100	75	75	–	–
53	ABB,BAA	2	100	100	100	–	–
54	APA,BAB,PBP	3	75	32	23	100*	92
55	AAB,ABA,ABB,BBA,BAB,BAA	6	100	81	81	78	45
56	AAB,2ABB,BBA,2BAA	6	100	99	99	96	25
57	2ABA,ABB,2BAB,BAA	6	100	67	67	62	47
58	ABA,2ABB,BAB,2BAA	6	100	92	92	100	28
59	3ABB,3BAA	6	100	100	100	–	–
60	ABP, BPA, PAB, APB, BAP, PBA	6	75	63	60	90	100 ^(*)
61	2AAB,2ABB,2BAA,2BBA	8	100	97	97	77	41
62	AAB,ABA,2ABB,2BAA,BAB,BBA	8	100	90	90	70	66
63	AAB,3ABB,3BAA,BBA	8	100	99	99	100	29
64	AAA,AAB,ABA,ABB,BAA,BAB,BBA,BBB	8	75	63	63	50	66
65	4ABB,4BAA	8	100	100	100	–	–
66	ABA,ABP,APB,BAP,BPA,BPB,PAB,PAP,PBA	9	75	55	52	64	100 ^(*)
67	2ABB,APB,2BAA,BPA,PAP,PBP,PPP	9	75	75	75	69	78
68	2ABB, APB, BAA, BAP, BPA, PAA, PBP, PPP	9	72	72	71	70	88
69	AAB, ABB, APB, BAA, BBA, BPA, PAP, PBP, PPP	9	75	73	73	70	84
70	ABB,ABP,APB,BAA,BAP,BPA,PAA,PBB,PPP	9	69	68	68	65	98
71	ABA,ABP,APB,BAP,BPA,BPB,PAB,PAP,PBA	9	60	44	42	65	100 ^(*)
72	2ABB,APB,2BAA,BPA,PAP,PBP,PPP	9	60	60	60	70	78
73	2ABB,APB,BAA,BAP,BPA,PAA,PBP,PPP	9	58	58	57	71	88
74	AAB,ABB,APB,BAA,BBA,BPA,PAP,PBP,PPP	9	60	59	58	71	84
75	ABB,ABP,APB,BAA,BAP,BPA,PAA,PBB,PPP	9	55	55	55	66	98
76	AAB,4ABB,4BAA,BBA	10	100	100	100	94	29
77	2AAB,3ABB,3BAA,2BBA	10	100	99	99	100	63
78	AAA,2ABA,2ABB,2BAA,2BAB,BBB	10	80	66	66	66	89
79	2AAB,ABA,3ABB,3BAA,BAB,2BBA	12	100	93	93	92	64
80	2AAB,4ABB,4BAA,2BBA	12	100	99	99	100	27
81	AAB,5ABB,5BAA,BBA	12	100	100	100	90	22
82	3AAB,3ABA,3BAB,3BBA	12	100	50	50	45	68
83	ABB,ABP,2APB,2BAA,BBA,BPA,PAB,PAP,PBP,PPP	12	69	67	66	81	68
84	2ABP, 2APB, 2BAP, 2BPA, 2PAB, 2PBA	12	75	63	60	94	100 ^(*)
85	3AAA,4ABB,BAA,3BAB,3BBA	14	94	100	100	76	34
86	3AAB,4ABB,4BAA,3BBA	14	100	93	93	100	45
87	2AAA,2AAB,2ABA,ABB,BAA,2BAB,2BBA,2BBB	14	71	51	51	76	56
88	ABB,2ABP,2APB,BAA,2BAP,2BPA,PAA,PAB,PBA,PBB,PPP	15	71	65	64	90	99
89	2ABB,ABP,2APB,2BAA,BAP,2BPA,PAB,PAP,PBA,PBP,PPP	15	75	69	68	93	90
90	2ABB, ABP, 2APB, BAA, 2BAP, 2BPA, PAA, PAB, PBA, PBP, PPP	15	73	67	66	94	94
91	ABA,2ABP,2APB,2BAP,2BPA,BPB,2PAB,PAP,2PBA	15	75	56	53	87	100 ^(*)
92	ABB,2ABP,2APB,BAA,2BAP,2BPA,PAA,PAB,PBA,PBB,PPP	15	63	59	59	57	99
93	2ABB,ABP,2APB,2BAA,BAP,2BPA,PAB,PAP,PBA,PBP,PPP	15	66	63	63	59	90
94	2ABB, ABP, 2APB, BAA, 2BAP, 2BPA, PAA, PAB, PBA, PBP, PPP	15	64	62	61	60	94
95	ABA,2ABP,2APB,2BAP,2BPA,BPB,2PAB,PAP,2PBA	15	66	51	49	56	100 ^(*)
96	2AAA,3ABA,3ABB,BAA,5BAB,2BBA	16	87	92	92	58	56
97	3AAB,5ABB,5BAA,3BBA	16	100	98	98	73	41
98	AAB,ABA,6ABB,6BAA,BAB,BBA	16	100	98	98	63	46
99	8ABB,8BAA	16	100	100	100	–	–
100	3AAA,ABA,4ABB,BAA,4BAB,3BBA	16	81	84	84	100	46
101	3AAA,3AAB,2ABB,3BBB,3BBA,2BAA	16	63	60	60	44	61
102	4AAB,ABA,4ABB,4BAA,BAB,4BBA	18	100	89	86	75	35
103	AAA,2AAB,5ABA,ABB,3BAA,3BAB,3BBB	18	78	100	58	46	34
104	3AAB,6ABA,3BAA,3BAB,3BBB	18	83	51	100	27	31
105	5AAA,4ABB,4BAB,4BBA,BBB	18	67	75	73	100	25
106	2AAA,3AAB,4ABB,4BAA,3BBA,2BBB	18	78	73	70	65	50
107	3ABP,3BPA,3PAB,3APB,3BAP,3PBA	18	75	60	55	76	100 ^(*)
108	2ABA,2ABP,2APB,2BAP,2BPA,2BPB,2PAB,2PAP,2PBA	18	67	47	43	59	77
109	4ABB,2APB,4BAA,2BPA,2PAP,2PBP,2PPP	18	67	64	61	63	60
110	4ABB,2APB,2BAA,2BAP,2BPA,2PAA,2PBP,2PPP	18	64	61	59	64	68
111	2AAB, 2ABB, 2APB, 2BAA, 2BBA, 2BPA, 2PAP, 2PBP, 2PPP	18	67	62	60	64	64
112	2ABB,2ABP,2APB,2BAA,2BAP,2BPA,2PAA,2PBB,2PPP	18	61	58	56	60	76

(Continued)



Table 5. (Continued).

Serial no.	Design	n	NCM	TSM	TBM	SSM	SBM
113	3ABP, 3BPA, 3PAB, 3APB, 3BAP, 3PBA	18	68	54	52	59	100 [@]
114	2ABA,2ABP,2APB,2BAP,2BPA,2BPP,2PAB,2PAP,2PBA	18	60	42	40	45	77
115	4ABB,2APB,4BAA,2BPA,2PAP,2PBP,2PPP	18	60	57	58	49	60
116	4ABB,2APB,2BAA,2BAP,2BPA,2PAA,2PBP,2PPP	18	58	54	55	50	68
117	2AAB,2ABB,2APB,2BAA,2BBA,2BPA,2PAP,2PBP,2PPP	18	60	55	56	49	64
118	2ABB,2ABP,2APB,2BAA,2BAP,2BPA,2PAA,2PBB,2PPP	18	55	52	53	46	76
119	AAA,4AAB,ABA,4ABB,4BAA,BAB,4BBA,BBB	20	90	79	81	86	35
120	3AAB,3ABA,4ABB,4BAA,3BAB,3BBA	20	100	81	82	59	46
121	3AAB,7ABB,7BAA,3BBA	20	100	94	96	69	36
122	8AAB,2ABA,2BAA,6BBA,2BBB	20	90	100	86	21	25
123	6AAB,3ABA,ABB,4BAA,3BBA,3BBB	20	85	70	100	33	30
124	4AAA,3AAB,3ABB,BAA,2BAB,5BBA,2BBB	20	70	59	60	100	31
125	9ABA,ABB,BAA,9BAB	20	100	37	38	29	89

Designs in bold denote new optimal and/or efficient COD to class having n number of subjects.

*New optimal COD under new defined model SSM.

@New optimal COD under SBM.

method of construction is known for varying number of subjects. As per 5M active algorithm construction, the class $COD(2 + 1, 6, 3)$ design replications constructs the classes $COD(2 + 1, 6r, 3)$. This means, multiple replications of the uniform $cod(p)60\{ABP, BPA, PAB, APB, BAP, PBA\}$ remain optimal under SBM. When the availability of subjects is 9 or 15, $cod(p)66\{ABA, ABP, APB, BAP, BPA, BPB, PAB, PAP, PBA\}$ and $cod(p)91\{ABA, 2ABP, 2APB, 2BAP, 2BPA, BPB, 2PAB, PAP, 2PBA\}$ are optimal under SBM, respectively in the classes $COD(2 + 1, 9, 3)$ and $COD(2 + 1, 15, 3)$. Most of the optimal two treatments CODs given for SBM, contains occurrences of self treatment sequences AAA and BBB. The above-mentioned $COD(2 + 1, n, 3)$ designs are suitable over $COD(2, n, 3)$, when self treatment sequences are unacceptable for some experiments. Optimal CODs of classes $COD(2 + 1, n, 3)$ are uniform when $n \equiv 0 \pmod{6}$ and approximately uniform when $n \equiv 3 \pmod{6}$. Notice that, the design introduced here does not exist for number of subjects as 10, 16, 20, and so on, due to lack of balance in periods. In these cases, designs having number of subjects 9, 15, 18, and so on; in general, CODs less by one or two subjects may be used without losing optimality. For example, $cod(p)71\{ABA, ABP, APB, BAP, BPA, BPB, PAB, PAP, PBA\}$ in nine subjects is optimal than $cod(p)78\{AAA, 2ABA, 2ABB, 2BAA, 2BAB, BBB\}$ in 10 subjects. Similarly, $cod(p)95\{ABA, 2ABP, 2APB, 2BAP, 2BPA, BPB, 2PAB, PAP, 2PBA\}$ in 15 subjects is optimal than $cod(p)101\{3AAA, 3AAB, 2ABB, 3BBB, 3BBA, 2BAA\}$ in 16 subjects, and $cod(p)113\{3ABP, 3BPA, 3PAB, 3APB, 3BAP, 3PBA\}$ in 18 subjects is optimal than $cod(p)125\{9ABA, ABB, BAA, 9BAB\}$ in 20 subjects. Further, $cod(p)71$ is optimal under SBM than COD of Koch et al. (1989) (denoted as K), as well as Jones and Donev (1996) (denoted as $J1$ and $J2$) as shown in Table 6. Crossover design $J1$ of Jones and Donev (1996) is optimal for the treatment contrast $\tau_A - \tau_B$ and $\tau_A - \tau_P$ but not for the treatment contrast $\tau_B - \tau_P$ as it has efficiency 90% whereas, $cod(p)71$ is optimal for all three treatment contrasts. Note that, designs of both the authors are not balanced.

Table 6. Efficiency of Koch et al. (1989) and Jones and Donev (1996) COD comparable to our COD of Table 3 for class $COD(2 + 1, 10, 3)$.

Serial no.	Design	n	NCM	TSM	TBM	SSM	SBM
$cod(p)71$	ABA,ABP,APB,BAP,BPA,BPB,PAB,PAP,PBA	9	60	44	42	65	100
$cod(p)72$	2ABB,APB,2BAA,BPA,PAP,BPB,PPP	9	60	60	60	70	78
$cod(p)73$	2ABB,APB,BAA,BAP,BPA,PAA,BPB,PPP	9	58	58	57	71	88
$cod(p)74$	AAB,ABB,APB,BAA,BBA,BPA,PAP,BPB,PPP	9	60	59	58	71	84
$cod(p)75$	ABB,ABP,APB,BAA,BAP,BPA,PAA,PBB,PPP	9	55	55	55	66	98
K	3ABB,3BAA,APP,PAA,BPP,PBB	10	70	70	70	42	46
$J1$	PAB,BAP,2PBA,3ABP,BPA,2BAB	10	80	49	46	72	100
$J2$	PAB,BAP,PBA,ABP,BAA,ABB,2ABA,2BAB	10	90	61	59	73	74



5.3. Efficient CODs under NCM, TSM, TBM, SSM, and SBM

Most of the CODs in two treatments have poor efficiency under SBM. Inclusion of a placebo as an additional treatment improves the efficiency of active treatment comparison considerably. Also, CODs in two active treatments and a placebo have an additional benefit in analysis (Divecha and Gondaliya (2019)). For example, $cod(p)60$ has least variance for treatment contrasts under SBM. This design is now optimal under SBM; incidentally, it is also efficient under the remaining four models. Hence, in class $COD(2 + 1, 6, 3)$, $cod(p)60$ is optimal and efficient than the COD $\{3ABA, 3BAB\}$ of FDA (2001), $\{ABB, ABA, AAB, BAA, BAB, BBA\}$ of Hedayat and Stufken (2003) and $\{2ABA, ABB, 2BAB, BAA\}$ of Gondaliya and Divecha (2018). In the class $COD(2 + 1, 9, 3)$, both $cod(p)68\{2ABB, APB, BAA, BAP, BPA, PAA, PBP, PPP\}$ and $cod(p)69\{AAB, ABB, APB, BAA, BBA, BPA, PAP, PBP, PPP\}$ are more efficient than $cod(p)66\{ABA, ABP, APB, BAP, BPA, BPB, PAB, PAP, PBA\}$, because both designs have more than 70% efficiency in all five models; while the latter is optimal under SBM, but has only 55% and 52% efficiency, respectively, under TSM and TBM. In the class of 12 subjects designs, $cod(p)79\{2AAB, ABA, 3ABB, 3BAA, BAB, 2BBA\}$ and $cod(p)84\{2ABP, 2APB, 2BAP, 2BPA, 2PAB, 2PBA\}$ are efficient under all five models, with the former design optimal under NCM and the next under SBM. In the class $COD(2 + 1, 15, 3)$, two designs perform well. Specifically speaking, when an experimenter has interest in estimations of TSM and TBM then he should use $cod(p)90\{2ABB, ABP, 2APB, BAA, 2BAP, 2BPA, PAA, PAB, PBA, PBP, PPP\}$ because it is more efficient than $cod(p)91$ and otherwise, should use $cod(p)91$ because it is optimal under SBM and efficient under the remaining models. In class $COD(2 + 1, 18, 3)$, although number of choices of designs are available as replication of smaller designs, the two designs $cod(p)107\{3ABP, 3BPA, 3PAB, 3APB, 3BAP, 3PBA\}$ and $cod(p)111\{2AAB, 2ABB, 2APB, 2BAA, 2BBA, 2BPA, 2PAP, 2PBP, 2PPP\}$ give efficient estimation of treatment contrast under all five models. $cod(p)107$ is optimal under SBM, whereas $cod(p)111$ has more than 60% efficiency in all five models. Note that, we can obtain more efficient designs in $COD(2 + 1, 18, 3)$ using 5M active algorithm because the designs listed in Table 5 are obtained by replication of smaller designs. This shows that new designs will certainly have more than 50% efficiency under TSM and TBM while being optimal under SBM.

6. Two active treatments and one placebo CODs in four periods

All possible combinations of three treatments in four periods have 81 treatment sequences. Here, we have restricted the number of subjects to be at most nine because, cases of such CODs with large number of subjects is often unlikely in practice. However, an interesting case of the said COD in 12 subjects is considered, because there is opportunity to generate CODs which are nearly uniform in subjects. Before construction, let us consider a motivational example, the phase IIa trial TD-4208, reported by Theravance, for the treatment of chronic obstructive pulmonary disease (COPD) (<https://www.centerwatch.com/clinical-trials/results/new-therapies/nmt-details.aspx?CatID=44>).

Example 6.1 The randomized, double-blind, four periods crossover study enrolled subjects with moderate to severe COPD. The subjects were randomized to receive TD-4208 (350 and 700 mcg), ipratropium bromide, and placebo, each administered as single doses via a nebulizer for four doses. The primary endpoint of the study was mean change from baseline in peak FEV1 compared to placebo.

In the above situation, one of the following four periods CODs is useful according to the availability of the subjects and possibility of the carryover model.



Table 7. Optimal and/or efficient balanced CODs for classes $COD(2 + 1, 3, 4)$ to $COD(2 + 1, 14, 4)$.

Serial no.	Design	n	NCM	TSM	TBM	SSM	SBM
126	AABA,BBAB	2	75	55	55	24	81
127	AABB,BBAA	2	100	91	91	24	81
128	ABAA,BABB	2	75	55	55	24	81
129	ABAB,BABA	2	100	18	18	26	88
130	ABBA,BAAB	2	100	91	91	24	81
131	ABBA,BPPB,PAAP	3	75	67	68	55	100 [@]
132	APPA,BAAB,PBBP	3	75	73	68	41	100
133	AABB, BPPA, PBAP	3	100	100*	100*	97	61
134	ABBP,BAPB,PPAA	3	80	80	76	100*	50
135	AAPP,BPAB,PBBA	3	80	75	72	87	72
136	AABB,2ABBA,2BAAB,BBAA	6	100	100	100	99	34
137	2AABB,ABBA,BAAA,BBAA,BBAB	6	92	92	92	100	34
138	AABB,ABAA,ABBA,BAAB,BABB,BBAA	6	92	90	90	92	35
139	ABBP,APPB,BAAP,BPPA,PABB,PBAA	6	63	63	63	90	76
140	AABB, APBP, BAPP, BBAA, PBPA, PPAB	6	67	67	67	87	76
141	ABPA,APBP,BABA,BPAB,PAPB,PBAP	6	65	55	52	96	97
142	ABAB,APBP,BABA,BPAP,PAPB,PBPA	6	67	54	54	95	100 [@]
143	2AABB,2ABBA,2BAAB,2BBAA	8	100	100	100	96	34
144	2AABA,2ABBA,2BAAB,2BBAB	8	88	73	73	73	35
145	AABB,ABBA,APBP,BAAB,BBAA,BPAP,PAPB,PBPA,PPPP	9	75	75	75	94	83
146	ABAB,APBP,APPB,BABA,BBAA,BPAP,PAPB,PAPB,PBPA	9	75	70	68	96	99
147	ABBA, ABPB, APBP, BAAP, BABA, BPAP, PAPB, PBPA, PPAB	9	73	67	66	100*	100 [@]
148	AABB, ABPP, APPB, 2BBAA, BPAP, PAPB, PPBA	9	75	75	75	89	81
149	AABB, ABBA, APBP, BAAB, BBAA, BPAP, PAPB, PBPA, PPPP	9	60	60	60	79	83
150	ABAB,APBP,APPB,BABA,BBAA,BPAP,PAPB,PAPB,PBPA	9	60	56	55	81	99
151	ABBA,APPB,APBP,BAAP,BABA,BPAP,PAPB,PBPA,PPAB	9	59	54	53	84	100 [@]
152	AABB, ABPP, APPB, 2BBAA, BPAP, PAPB, PPBA	9	60	60	60	75	81
153	3AABB,2ABBA,2BAAB,3BBAA	10	100	100	100	100	42
154	2AABB,3ABBA,3BAAB,2BBAA	10	100	100	100	100	42
155	3AABB,2ABBA,BAAA,BAAB,2BBAA,BBAB	10	95	95	95	100	42
156	2AABA,ABAB,2ABBA,2BAAB,BABA,2BBAB	10	90	67	67	72	44
157	3AABB,3ABBA,3BAAB,3BBAA	12	100	100	100	100	36
158	3ABAA,3ABBA,3BAAB,3BABBB	12	88	73	73	76	38
159	2ABPP, 2APBB, 2BAPP, 2BPAA, 2PABB, 2PBAA	12	63	63	63	74	80
160	2ABPB,2APBA,2BAPA,2BPAP,2PABP,2PBAB	12	63	53	50	89	100 [@]
161	AABP, ABBP, 2APPB, BAAP, BBAP, 2BPPA, 2PABB, 2PBAA	12	63	62	62	88	81
162	2ABPP,2APBB,2BAPP,2BPAA,2PABB,2PBAA	12	54	54	54	64	80
163	2ABPB,2APBA,2BAPA,2BPAP,2PABP,2PBAB	12	54	45	43	77	100 [@]
164	AABP, ABBP, 2APPB, BAAP, BBAP, 2BPPA, 2PABB, 2PBAA	12	54	54	54	76	81
165	3AABB,4ABBA,4BAAB,3BBAA	14	100	100	100	100	42
166	4AABB,3ABBA,BAAA,2BAAB,3BBAA,BBAB	14	96	97	97	100	42
167	AABA,2AABB,ABAA,3ABBA,3BAAB,BABB,2BBAA,BBAB	14	93	90	90	93	44

Designs in bold denote new optimal and/or efficient COD to class having n number of subjects.

*New optimal COD under new defined model SSM.

@New optimal COD under SBM.

*New optimal COD under TSM and TBM.

6.1. Optimal CODs under NCM, TSM, TBM, and SSM

In Gondaliya and Divecha (2018), optimal CODs under NCM, TSM, TBM, and SSM were obtained for various even number of subjects. Obviously, it could not include CODs having odd number of subjects such as 3, 9, 15, and so on. These designs exist for CODs in three treatments. Among these three treatments CODs, optimal CODs exist only for the class $COD(2 + 1, 3, 4)$; the $cod(p)133\{AABB, BPPA, PBAP\}$ is optimal under NCM, TSM, and TBM; and $cod(p)134\{ABBP, BAPB, PPAA\}$ is optimal under SSM. However, for the remaining two classes, two treatments CODs remain optimal because they carry more replications of treatments. Comparison of CODs in two active treatments with and without help of placebo shown in Table 7 clearly shows that it is better to forgo one unit and use optimal two treatments COD under NCM, TSM, TBM, and SSM for number of subjects 9, 15, and so on.



6.2. Optimal CODs under SBM

The CODs in two active treatments and a placebo have lesser variance of treatment contrasts under SBM, than those of two treatments CODs of Hedayat and Stufken (2003), Ozan and Stufken (2010), and Gondaliya and Divecha (2018). These designs are also optimal than the two treatments four periods CODs. Note that, in class $COD(2 + 1, 3, 4)$, two designs $cod(p)131\{ABBA, BPPB, PAAP\}$ and $cod(p)132\{APPA, BAAB, PBBP\}$ are optimal under SBM. This design also outperforms the COD $(2, 2, 4)$ in variance, making it the only efficient COD under SBM. In the same way, when a trial has six subjects, $cod(p)142\{ABAB, APBP, BABA, BPAP, PAPB, PBPA\}$ is optimal under SBM, and hence preferable over the previous optimal two treatments $cod(p)138\{AABB, ABAA, ABBA, BAAB, BABB, BBAA\}$ which has an efficiency of only 35% under SBM. Similarly, $cod(p)147\{ABBA, ABPB, APBP, BAAP, BABA, BPAP, PAPB, PBPA, PPAB\}$ is optimal under SBM in class $COD(2 + 1, 9, 4)$, with very low variance than the two treatments $cod(p)144\{2AABA, 2ABBA, 2BAAB, 2BBAB\}$, which has an efficiency of only 35%. The same discussion can go on for more than nine subjects, but we switch to an interesting case of CODs in 12 subjects. When $n = 12$, we consider only those sequences which are approximately uniform in subjects. That is, only those sequences which contain all three treatments at least once. In this class $COD(2 + 1, 12, 4)$, the $cod(p)160\{2ABPB, 2APBA, 2BAPA, 2BPAP, 2PABP, 2PBAB\}$ is optimal with substantial gain in efficiency, compared to the COD in two treatments, the $cod(p)158\{3ABAA, 3ABBA, 3BAAB, 3BABB\}$ having an efficiency 38%. Regarding trials in 10 subjects, the COD in two active treatments and a placebo, given by $cod(p)151\{ABBA, ABPB, APBP, BAAP, BABA, BPAP, PAPB, PBPA, PPAB\}$ in nine subjects, beats two treatments $cod(p)153\{3AABB, 2ABBA, 2BAAB, 3BBAA\}$, under SBM. Similarly, $cod(p)163$ is also optimal in class $COD(2 + 1, 14, 4)$. Hence, it is better to use $cod(p)163$ in 12 subjects for estimation of SBM, with savings of cost incurred on two subjects.

6.3. Efficient CODs under NCM, TSM, TBM, SSM, and SBM

For experimenters who want to switch from one to the other model, it is desirable that a COD is chosen such that, it is optimal in one model and efficient under rest of the models. Alternatively, a COD could be desirable which is highly efficient under all five models. The addition of placebo in comparing two active treatments reduces the variance of treatment contrast by 50% under SBM. However, the gain is lesser under rest of the four models. Therefore, it is necessary to find CODs which are efficient under all five models. In class $COD(2 + 1, 3, 4)$, $cod(p)133$ is optimal under NCM, TSM, and TBM, and, efficient under SSM and SBM with efficiencies 97% and 61%, respectively. When six subjects are available, then $cod(p)140\{AABB, APBP, BAPP, BBAA, PBPA, PPAB\}$ is useful because, this is the only design which has an efficiency of more than 65% in all five models. In class $COD(2 + 1, 9, 4)$, $cod(p)148\{AABB, ABPP, APPB, 2BBAA, BPAP, PABP, PAPB, PPBA\}$ has an efficiency of more than 74% for each of five models. Crossover designs $cod(p)153$ and $cod(p)154\{2AABB, 3ABBA, 3BAAB, 2BBAA\}$ in 10 subjects are optimal under NCM, TSM, TBM, and SSM but have very poor efficiency, which is only 42% under SBM. Since, $cod(p)149\{AABB, ABBA, APBP, BAAB, BBAA, BPAP, PAPB, PBPA, PPPP\}$ and $cod(p)152\{AABB, ABPP, APPB, 2BBAA, BPAP, PABP, PAPB, PPBA\}$ in nine subjects have efficiencies more than 60%, they are efficient in all five models. Similarly, in the class $COD(2 + 1, 12, 4)$, $cod(p)157\{3AABB, 3ABBA, 3BAAB, 3BBAA\}$ is optimal under all models except SBM, because, it has very poor efficiency of 36% under SBM. Hence, $cod(p)159\{2ABPP, 2APBB, 2BAPP, 2BPAA, 2PABB, 2PBAA\}$ and $cod(p)161\{AABP, ABBP, 2APPB, BAAP, BBAP, 2BPPA, 2PABB, 2PBAA\}$ having efficiencies more than 60% are better choices in such cases. Again as $cod(p)165$ in 14 subjects is optimal under all models except SBM, with only 42% efficiency under SBM, it is better to use an overall efficient design, $cod(p)164\{AABP, ABBP, 2APPB, BAAP, BBAP, 2BPPA, 2PABB, 2PBAA\}$ in 12 subjects, having an efficiency of more than 50% in all five models.



7. Conclusion

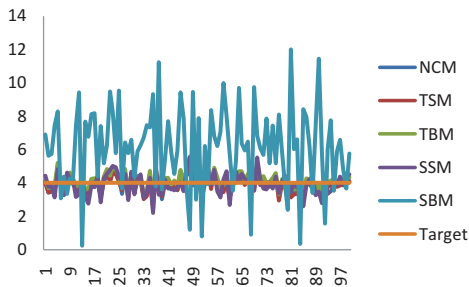
This article contributes several new three treatments crossover designs consisting of two active treatments and a placebo. Such a crossover design is characterized as an optimal and/or efficient for two to four periods having different number of subjects. Moreover, such crossover designs can be constructed by 5M active algorithm. Now the experimenter can use a crossover design in three more situations: first, when the carryover of both active treatments are not equal; second, to estimate treatment contrasts under self and mixed carryover model when measurement of subjects is possible up to two periods only; and third, when availability of subjects is in multiple of three. Also, experimenters now have more choices of optimal and/or efficient crossover designs for precise comparison of two active treatments in three and four periods. We recommend that an optimal design should be chosen when one is sure about the model. Otherwise, one should opt for a design which is efficient for all five models.

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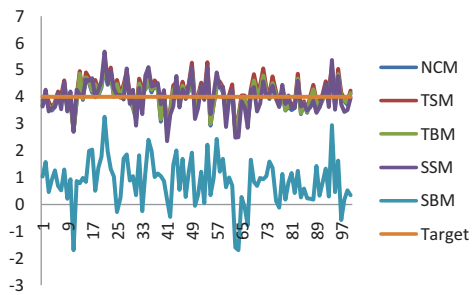
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Appendix

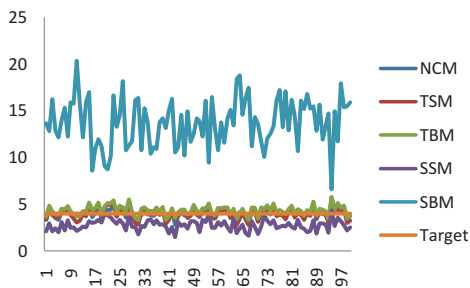
Simulation study of cod(p)1 (Table 1)



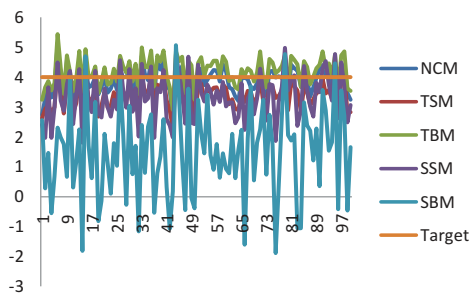
Simulation study of cod(p)2 (Table 1)



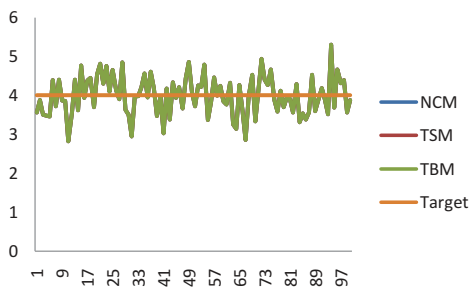
Simulation study of cod(p)3 (Table 1)



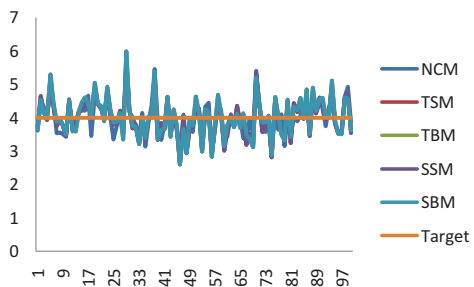
Simulation study of cod(p)4 (Table 1)



Simulation study of cod(p)5 (Table 1)



Simulation study of cod(p)6 (Table 1)





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Some new generators to obtain efficient circular weakly balanced repeated measurements designs

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ABSTRACT

Minimal balanced repeated measurements designs (RMDs) are not possible to construct in several experimental situations. In these situations, weakly balanced RMDs are preferred which demand less experimental subjects without loss of efficiency. In this article, several generators are developed to construct the minimal circular weakly balanced RMDs in periods of (i) equal sizes, (ii) two different sizes, and (iii) three different sizes. All these constructions possess high efficiency and save the cost of experiments due to less number of experimental subjects.

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Treatment effects; residual effects; method of cyclic shifts; traditional model; efficiency of separability

MATHEMATICS SUBJECT CLASSIFICATION

05B05; 62K10; 62K05

1. Introduction

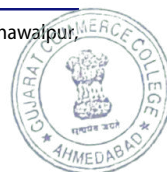
In repeated measurements designs (RMDs), more than one measurement is taken on each subject/experimental unit. RMDs are widely used in the fields of medicine, pharmacology, animal sciences, and psychology where residual effects may exist. Minimal balanced RMDs (BRMDs) balance out these residual effects at low budget constraints. The situations for which minimal BRMDs cannot be constructed, weakly balanced RMDs (WBRMDs) are preferred. Some important definitions related to this study are:

Residual Effect: The effect which a treatment has during its period of application (treatment effect) may persist into the following period(s). If the effect persists only into the immediately following period the effect is called first-order carry over/residual effect.

Balanced RMD: RMD is balanced with respect to the first-order residual effects if each treatment is immediately preceded λ' times by each other treatment (excluding itself). This design will be minimal if $\lambda' = 1$.

Strongly Balanced RMD: RMD is strongly balanced with respect to the first-order residual effects if each treatment is immediately preceded λ' times by each other treatment (including itself).

RMD for v (treatments) and p_i (period sizes) is weakly balanced with respect to the first-order residual effects if each treatment is immediately preceded λ'_1 or λ'_2 times by each other treatment (excluding itself) where $|\lambda'_2 - \lambda'_1| = 1$.



Williams (1949) initiated for RMDs. Cheng and Wu (1980) constructed circular balanced and strongly balanced RMDs. Afsarinejad (1994) constructed minimal balanced and strongly balanced RMDs in periods of unequal sizes. Using method of cyclic shifts, (a) Iqbal and Jones (1994) constructed efficient RMDs and strongly BRMDs with periods of equal and unequal sizes, (b) Iqbal and Tahir (2009) constructed circular strongly BRMDs for some classes, (c) Iqbal, Tahir, and Ghazali (2010) constructed some first-order and second-order circular balanced and strongly balanced RMDs, (d) Rajab et al. (2018) developed some generators to obtain the circular BRMDs in periods of equal sizes, (e) Rasheed et al. (2018) developed some generators to obtain minimal circular strongly BRMDs in periods of three different sizes, (f) Bashir et al. (2018) presented circular BRMDs for $p = 3$. Some more references of the designs constructed through method of cyclic shifts can be found in Ahmed et al. (2020).

Bailey et al. (2017) constructed universally optimal WBRMDs for $p = v$. Khan et al. (2019) developed some generators to obtain minimal CWBRMDs for $p \leq v$ in periods of equal sizes. Hussain et al. (2019) developed some generators to obtain minimal CWBRMDs in periods of two different sizes for (i) $v = 2mi + s + 2$, $p_1 = 2m$, and $p_2 = s$ (even), (ii) $v = 2mi + s$, $p_1 = 2m$, and $p_2 = s$ (even), (iii) $v = 2mi + s + 1$, $p_1 = 2m$, and $p_2 = s$ (even) > 2 , (iv) $v = 2mi + s + 1$, $p_1 = 2m$, and $p_2 = s$ (odd) > 3 , (v) $v = 2mi + s - 1$, $p_1 = 2m$, and $p_2 = s$ (even) > 2 , (vi) $v = 2mi + s$, $p_1 = 2m$, and $p_2 = s + 1$, s even. In this article, some new generators are developed to obtain minimal CWBRMDs in periods of (i) equal sizes, (ii) two different sizes, and (iii) three different sizes.

The paper is organized as follows: the model, estimation of treatment and residual effects, and, its efficiency calculation is presented in Section 2. In Section 3, method of cyclic shifts is explained to construct CWBRMDs. New generators are discussed for minimal CWBRMDs in periods of equal sizes, two different sizes, and three different sizes in Section 3, in Section 4, and in Section 5, respectively.

2. Model and efficiency for circular RMDs

The model repeatedly discussed for RMDs in the literature is traditional model given by,

$$y_{ijk} = \mu + \tau_{d(k,j)} + \gamma_{d(k-1,j)} + \pi_k + \xi_{ij} + \varepsilon_{ijk} \quad (1)$$

where y_{ijk} is the observation from subject j having sequence i in period k to which treatment $d(k, j)$ is given, μ is the general mean, $\tau_{d(k,j)}$ is the effect of treatment $d(k, j)$, $\gamma_{d(k-1,j)}$ is the residual effect of treatment $d(k-1, j)$ in the period k which was applied in the period $k-1$ to the same subject, π_k is the effect of period k , ξ_{ij} is the effect of subject j having sequence i , ε_{ijk} are independently normally distributed error term with mean 0 and variance σ^2 .

2.1. Efficiency for residual effects

The joint information matrix of the treatment and residual effects for the Circular RMD is given by



$$C_{(\tau, \gamma)} = \begin{pmatrix} C_{11} & C_{12} \\ C'_{12} & C_{22} \end{pmatrix}$$

where C_{11} , C_{12} , and C_{22} in periods of two different sizes are given by

$$\begin{aligned} C_{11} &= rI - \frac{1}{n_1 + n_2} M_1 M'_1 - \frac{1}{n_1} M_2 M'_2 - \frac{1}{p_1} N_1 N'_1 - \frac{1}{p_2} N_2 N'_2 + \frac{r^2}{n_1 p_1 + n_2 p_2} J \\ C_{12} &= Z - \frac{1}{n_1 + n_2} M_1 \bar{M}'_1 - \frac{1}{n_1} M_2 \bar{M}'_2 - \frac{1}{p_1} N_1 \bar{N}'_1 - \frac{1}{p_2} N_2 \bar{N}'_2 + \frac{r\bar{r}}{n_1 p_1 + n_2 p_2} J \\ C_{22} &= \bar{r}I - \frac{1}{n_1 + n_2} \bar{M}_1 \bar{M}'_1 - \frac{1}{n_1} \bar{M}_2 \bar{M}'_2 - \frac{1}{p_1} \bar{N}_1 \bar{N}'_1 - \frac{1}{p_2} \bar{N}_2 \bar{N}'_2 + \frac{\bar{r}^2}{n_1 p_1 + n_2 p_2} J \end{aligned}$$

Here, n_1 subjects repeatedly measures up to p_1 periods, n_2 subjects repeatedly measures up to p_2 periods; M_1 is the incidence matrix of treatments versus 1 to p_2 periods; M_2 the incidence matrix of treatments versus $p_2 + 1$ to p_1 periods; \bar{M}_1 the incidence matrix of residual versus 1 to p_2 periods; \bar{M}_2 the incidence matrix of residual versus $p_2 + 1$ to p_1 periods; N_1 the incidence matrix of treatments versus 1 to n_1 subjects; N_2 the incidence matrix of treatments versus $n_1 + 1$ to $n_1 + n_2$ subjects; \bar{N}_1 the incidence matrix of residual versus 1 to n_1 subjects; \bar{N}_2 the incidence matrix of residual versus $n_1 + 1$ to $n_1 + n_2$ subjects. Similarly, C_{11} , C_{12} , and C_{22} in periods of three different sizes are given by

$$\begin{aligned} C_{11} &= rI - \frac{1}{n_1 + n_2 + n_3} M_1 M'_1 - \frac{1}{n_1 + n_2} M_2 M'_2 - \frac{1}{n_1} M_3 M'_3 - \frac{1}{p_1} N_1 N'_1 \\ &\quad - \frac{1}{p_2} N_2 N'_2 - \frac{1}{p_3} N_3 N'_3 + \frac{r^2}{n_1 p_1 + n_2 p_2 + n_3 p_3} J \\ C_{12} &= Z - \frac{1}{n_1 + n_2 + n_3} M_1 \bar{M}'_1 - \frac{1}{n_1 + n_2} M_2 \bar{M}'_2 - \frac{1}{n_1} M_3 \bar{M}'_3 - \frac{1}{p_1} N_1 \bar{N}'_1 \\ &\quad - \frac{1}{p_2} N_2 \bar{N}'_2 - \frac{1}{p_3} N_3 \bar{N}'_3 + \frac{r\bar{r}}{n_1 p_1 + n_2 p_2 + n_3 p_3} J \\ C_{22} &= \bar{r}I - \frac{1}{n_1 + n_2 + n_3} \bar{M}_1 \bar{M}'_1 - \frac{1}{n_1 + n_2} \bar{M}_2 \bar{M}'_2 - \frac{1}{n_1} \bar{M}_3 \bar{M}'_3 - \frac{1}{p_1} \bar{N}_1 \bar{N}'_1 \\ &\quad - \frac{1}{p_2} \bar{N}_2 \bar{N}'_2 - \frac{1}{p_3} \bar{N}_3 \bar{N}'_3 + \frac{\bar{r}^2}{n_1 p_1 + n_2 p_2 + n_3 p_3} J \end{aligned}$$

Here, n_1 subjects repeatedly measures up to p_1 periods; n_2 subjects repeatedly measures up to p_2 periods; n_3 subjects repeatedly measures up to p_3 periods; M_1 is the incidence matrix of treatments versus 1 to p_3 periods; M_2 the incidence matrix of treatments versus $p_3 + 1$ to p_2 periods; M_3 the incidence matrix of treatments versus $p_2 + 1$ to p_1 periods; \bar{M}_1 the incidence matrix of residual versus 1 to p_3 periods; \bar{M}_2 the incidence matrix of residual versus $p_3 + 1$ to p_2 periods; \bar{M}_3 the incidence matrix of residual versus $p_2 + 1$ to p_1 periods; N_1 the incidence matrix of treatments versus 1 to n_1 subjects; N_2 the incidence matrix of treatments versus $n_1 + 1$ to $n_1 + n_2$ subjects; N_3 the incidence matrix of treatments versus $n_1 + n_2 + 1$ to $n_1 + n_2 + n_3$ subjects; \bar{N}_1 the incidence matrix of residual versus 1 to n_1 subjects; \bar{N}_2 the incidence matrix of residual versus $n_1 + 1$ to $n_1 + n_2$ subjects; \bar{N}_3 the incidence matrix of residual versus $n_1 + n_2 + 1$ to $n_1 + n_2 + n_3$ subjects.



1 to $n_1 + n_2 + n_3$ subjects. Also we have r as the replication of treatment; \bar{r} the replication of residual; J the matrix with all elements as one. Then the information matrix of the treatment and residual effects are $C_\tau = C_{11} - C_{12}C_{22}^{-1}C_{21}$ and $C_\gamma = C_{22} - C_{21}C_{11}^{-1}C_{12}$, respectively. Note that, the information matrix in case of Circular RMD in periods of equal sizes (p) is obtain by substituting $p_1 = p$, $n_1 = n$ and $p_2 = n_2 = M_1 = \bar{M}_1 = N_2 = \bar{N}_2 = 0$ in C_{11} , C_{12} , and C_{22} . for periods of two different sizes.

The efficiency factor for residual effect can be regarded as the harmonic mean of non zero Eigen values of their respective information matrix, see James and Wilkinson (1971) and Pearce, Caliński, and Marshall (1974). The high value of E_r shows that design is suitable for the estimation of residual effects. Our developed generators provide the designs with high values of E_r , therefore, these designs are suitable for the estimation of residual effects.

2.2. Efficiency of separability

Every RMDs must be characterized for its ability of separating the treatment effects from residual effects. Divecha and Gondaliya (2014) provided simple formula of efficiency of Separability (ES) for the balanced RMDs. We have modified this formula according to the constraints of RMDs constructed in this paper is given by,

$$ES = \left[1 - \left\{ \frac{(l_1 + 4l_2)v - (l_1 + 2l_2)^2}{(v-1)(l_1 + 2l_2)^2} \right\}^{\frac{1}{2}} \right] \times 100\% \quad (2)$$

where l_1 is the number of a treatment immediately preceded by other treatment single time; l_2 is the number of a treatment immediately preceded by other treatment two times.

3. Method of cyclic shifts

Method of cyclic shifts is introduced by Iqbal (1991). Let we discuss Rule I and Rule II of method of cyclic shifts for the construction of CBRMDs and CWBRMDs.

Rule I. Let $S_1 = [q_{11}, q_{12}, \dots, q_{p_1-1}]$, $S_2 = [q_{21}, q_{22}, \dots, q_{p_2-1}]$, and $S_3 = [q_{31}, q_{32}, \dots, q_{p_3-1}]$ be the sets of shifts, where $1 \leq q_{ij} \leq v-1$. If each element 1, 2, ..., $v-1$ appears an equal number of times, say λ' in S^* , where $S^* = [\{q_{11}, q_{12}, \dots, q_{p_1-1}, v-(q_{11} + q_{12} + \dots + q_{p_1-1}) \bmod v\}, \{q_{21}, q_{22}, \dots, q_{p_2-1}, v-(q_{21} + q_{22} + \dots + q_{p_2-1}) \bmod v\}, \{q_{31}, q_{32}, \dots, q_{p_3-1}, v-(q_{31} + q_{32} + \dots + q_{p_3-1}) \bmod v\}]$ then design from it will be CBRMD in periods of sizes p_1 , p_2 , and p_3 . If S^* contains all of 1, 2, ..., $v-1$ exactly λ'_1 times except a few of these which appear λ'_1-1 or λ'_1+1 times then it will be CWBRMD. Sum of any two, three, ..., $(p-1)$ consecutive elements of a set should not be 0 (mod v). If so, reorder the elements of the corresponding set.

Example 3.1. Minimal CWBRMD for $v=20$, $p_1=8$, $p_2=6$, and $p_3=4$ can be constructed through the following sets of shifts.

$$S_1 = [1, 2, 3, 4, 19, 18, 17] \quad S_2 = [5, 6, 7, 15, 14] \quad S_3 = [8, 9, 12]$$



Table 1. Array obtained from $S_1 = [1, 2, 3, 4, 19, 18, 17]$.

p	Subjects																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	0
3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	0	1	2
4	6	7	8	9	10	11	12	13	14	15	16	17	18	19	0	1	2	3	4	5
5	10	11	12	13	14	15	16	17	18	19	0	1	2	3	4	5	6	7	8	9
6	9	10	11	12	13	14	15	16	17	18	19	0	1	2	3	4	5	6	7	8
7	7	8	9	10	11	12	13	14	15	16	17	18	19	0	1	2	3	4	5	6
8	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	0	1	2	3

Table 2. Array obtained from $S_2 = [5, 6, 7, 15, 14]$.

p	Subjects																			
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
2	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	0	1	2	3	4
3	11	12	13	14	15	16	17	18	19	0	1	2	3	4	5	6	7	8	9	10
4	18	19	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
5	13	14	15	16	17	18	19	0	1	2	3	4	5	6	7	8	9	10	11	12
6	7	8	9	10	11	12	13	14	15	16	17	18	19	0	1	2	3	4	5	6

Table 3. Array obtained from $S_3 = [8, 9, 12]$.

p	Subjects																			
	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
2	8	9	10	11	12	13	14	15	16	17	18	19	0	1	2	3	4	5	6	7
3	17	18	19	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
4	9	10	11	12	13	14	15	16	17	18	19	0	1	2	3	4	5	6	7	8

Proof. $S_1^* = [1, 2, 3, 4, 19, 18, 17, 16]$, $S_2^* = [5, 6, 7, 15, 14, 13]$, $S_3^* = [8, 9, 12, 11]$.

Hence $S^* = [1, 2, 3, 4, 19, 18, 17, 16, 5, 6, 7, 15, 14, 13, 8, 9, 12, 11]$. Here each of 1, 2, ..., 19 appears exactly once except 10 which does not appear. Hence given sets of shifts provide minimal CWBRMD for $v = 20$, $p_1 = 8$, $p_2 = 6$, and $p_3 = 4$. Systematic procedure to construct this CWBRMD is given below.

Take v experimental subjects for one set of shifts $S_1 = [1, 2, 3, 4, 19, 18, 17]$. Assign 0, 1, ..., $v - 1$ to each subject in first period respectively. To get the elements of second period for each subject, add 1 (mod 20) to each element of first period for all subjects. Then add 2 (mod 20) to each element of second period for all subjects of third period. Similarly, add 3, 4, 19, 18, and 17 as shown in Table 1.

Take v more experimental subjects for second set of shifts $S_2 = [5, 6, 7, 15, 14]$. Assign 0, 1, ..., 19 to each subject in first period respectively. To get the elements of second period for each subject, add 5 (mod 20) to each element of first period for all subjects. Then add 6 (mod 20) to each element of second period for all subjects of third period. Similarly add 7, 15, and 14 as shown in Table 2.

Take v more experimental subjects for third set of shifts and get the array from $S_3 = [8, 9, 12]$ in a similar way as shown in Table 3.

Tables 1–3 together produce minimal CWBRMD for $v = 20$, $p_1 = 8$, $p_2 = 6$, and $p_3 = 4$. □



Table 4. Array obtained from $S_1 = [1, 2, 3, 4, 16, 15, 14]$.

p	Subjects																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	0
3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	0	1	2
4	6	7	8	9	10	11	12	13	14	15	16	0	1	2	3	4	5
5	10	11	12	13	14	15	16	0	1	2	3	4	5	6	7	8	9
6	9	10	11	12	13	14	15	16	0	1	2	3	4	5	6	7	8
7	7	8	9	10	11	12	13	14	15	16	0	1	2	3	4	5	6
8	4	5	6	7	8	9	10	11	12	13	14	15	16	0	1	2	3

Rule II. Let $S_a = [q_{a1}, q_{a2}, \dots, q_{a(p-1)}]$, $S_b = [q_{b1}, q_{b2}, \dots, q_{b(p-1)}]$, and $S_c = [q_{c1}, q_{c2}, \dots, q_{c(p-2)}]$ be the three sets of shifts, where $1 \leq q_i \leq v-2$. Then S^* will be $[q_{a1}, q_{a2}, \dots, q_{a(p-1)}, (v-1) - (q_{a1} + q_{a2} + \dots + q_{a(p-1)}) \bmod (v-1), q_{b1}, q_{b2}, \dots, q_{b(p-1)}, (v-1) - (q_{b1} + q_{b2} + \dots + q_{b(p-1)}) \bmod (v-1), q_{c1}, q_{c2}, \dots, q_{c(p-2)}]$. If each element $1, 2, \dots, v-2$ appears an equal number of times, say λ' in S^* then design from it will be CBRMD. If S^* contains all of $1, 2, \dots, v-2$ exactly λ'_1 time except a few of these which appear $\lambda'_1 - 1$ or $\lambda'_1 + 1$ times then it will be CWBRMD. Sum of any two, three, $\dots, (p-1)$ consecutive elements of a set should not be $0 \bmod (v-1)$. If so, reorder the elements of the corresponding set.

Example 3.2. Minimal CWBRMD for $v=18$, $p_1=8$, $p_2=6$, and $p_3=3$ can be constructed through the following sets of shifts.

$$S_1 = [1, 2, 3, 4, 16, 15, 14] S_2 = [5, 6, 7, 12, 11] S_3 = [8]t$$

Proof. $S_1^* = [1, 2, 3, 4, 16, 15, 14, 13]$, $S_2^* = [5, 6, 7, 12, 11, 10]$, $S_3^* = [8]$.

Hence $S^* = [1, 2, 3, 4, 16, 15, 14, 13, 5, 6, 7, 12, 11, 10, 8]$. Here each of $1, 2, \dots, 16$ appears exactly once except 9 which does not appear. Hence given sets of shifts provide minimal CWBRMD for $v=18$, $p_1=8$, $p_2=6$, and $p_3=3$. Systematic procedure to construct this CWBRMD is given below.

Take $v-1$ experimental subjects for first set of shifts $S_1 = [1, 2, 3, 4, 16, 15, 14]$. Assign $0, 1, \dots, v-2$ to each subject in first period, respectively. To get the elements of second period for each subject, add 1 (mod 17) to each element of first period for all subjects. Then add 2 (mod 17) to each element of second period for all subjects of third period. Similarly, add 3, 4, 16, 15, and 1 to complete the array as shown in Table 4.

Take more $v-1$ experimental subjects for second set of shifts $S_2 = [5, 6, 7, 12, 11]$. Assign $0, 1, \dots, v-2$ to each subject in first period, respectively. To get the elements of second period for each subject, add 5 (mod 17) to each element of first period for all subjects. Then add 6 (mod 17) to each element of second period for all subjects of third period. Similarly, add 7, 12, and 11 to complete the array as shown in Table 5.

Take more $v-1$ experimental subjects for third set of shifts $[8]t$. Assign $0, 1, \dots, v-2$ to each subject in first period respectively. To get the elements of second period for each subject, add 8 (mod 17) to each element of first period for all subjects. Then assign 17 to each element of third period for all subjects as shown in Table 6.

Tables 4–6 together produce minimal CWBRMD for $v=18$, $p_1=8$, $p_2=6$, and $p_3=3$. □



Table 5. Array obtained from $S_2 = [5, 6, 7, 12, 11]$.

p	Subjects																
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2	5	6	7	8	9	10	11	12	13	14	15	16	0	1	2	3	4
3	11	12	13	14	15	16	0	1	2	3	4	5	6	7	8	9	10
4	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	0
5	13	14	15	16	0	1	2	3	4	5	6	7	8	9	10	11	12
6	7	8	9	10	11	12	13	14	15	16	0	1	2	3	4	5	6

Table 6. Array obtained from $S_3 = [8]t$.

p	Subjects																
	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	41
1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2	8	9	10	11	12	13	14	15	16	0	1	2	3	4	5	6	7
3	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17

Table 7. CWBRMDs for $v = 2mi$, $p = 2m$, i integer.

v	p	Set(s) of shifts	E_r	E_s
16	8	$[1, 2, 3, 4, 15, 14, 13] + [6, 5, 7, 8, 11, 10, 9]$	0.93	0.91
20	10	$[1, 2, 3, 4, 5, 19, 18, 17, 16] + [6, 7, 8, 14, 9, 10, 13, 11, 12]$	0.945	0.93
24	12	$[1, 2, 4, 3, 6, 5, 23, 22, 21, 20, 19] + [7, 8, 10, 9, 11, 17, 12, 16, 15, 14, 13]$	0.955	0.94
28	14	$[1, 2, 6, 3, 4, 5, 27, 7, 26, 25, 24, 23, 22] + [8, 9, 13, 10, 11, 12, 14, 20, 19, 18, 17, 16, 15]$	0.96	0.95

4. Minimal CWBRMDs in periods of equal sizes

In this section, one generator is developed to generate minimal CWBRMDs in periods of equal sizes using method of cyclic shifts (Rule I).

Generator 4.1. Following i sets of shifts provide minimal CWBRMD for $v = 2mi$, $p = 2m$, i integer, and m (integer) > 2 . Here, ordered pairs $\{(0, v/2), (1, (v+2)/2), \dots, ((v-2)/2, v-1), (v/2, 0), ((v+2)/2, 1), \dots, (v-1, (v-2)/2)\}$ appear twice together as preceded values while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-(mj+1), v-(mj+2), \dots, v-(mj+m-1)]; j=0, 1, \dots, i-1$$

Examples are given in Table 7.

5. Minimal CWBRMDs in periods of two different sizes

5.1. Minimal CWBRMDs in periods of two different sizes using Rule I

In this section, generators are developed to generate minimal CWBRMDs in periods of two different sizes using method of cyclic shifts (Rule I). Here i sets are for p_1 and two for p_2 .

Generator 5.1.1. Following $(i+2)$ sets of shifts provide minimal CWBRMD for $v = 2mi + 4s + 2$, $p_1 = 2m$, and $p_2 = 2s$, i integer, and m (integer) > 2 . Here, ordered pairs $\{(0, v/2), (1, (v+2)/2), \dots, ((v-2)/2, v-1), (v/2, 0), ((v+2)/2, 1), \dots, (v-1, (v-2)/2)\}$ do not appear together while all other appear once.



Table 8. CWBRMDs for $v = 2mi + 2s + 2$, $p_1 = 2m$, and $p_2 = s$ (even), i integer.

v	p_1	p_2	Sets of shifts	E_r	E_s
28	10	8	[1,2,3,4,5,27,26,25,24] + [6,7,8,9,22,21,20] + [10,11,12,13,18,17,16]	0.91	0.95
38	10	8	[1,2,3,4,5,37,36,35,34] + [6,7,8,9,10,32,31,30,29] + [11,12,13,14,27,26,25] + [15,16,17,18,23,22,21]	0.91	0.94
30	12	8	[1,2,4,3,6,5,29,28,27,26,25] + [7,8,9,10,23,22,21] + [11,12,13,14,19,18,17]	0.92	0.95
42	12	8	[1,2,4,3,6,5,41,40,39,38,37] + [7,9,8,10,11,12,35,33,34,32,31] + [13,14,16,29,15,28,27] + [17,18,19,20,25,24,23]	0.92	0.94

Table 9. CWBRMDs for $v = 2mi + 2s$, $p_1 = 2m$, and $p_2 = s$ (even), i integer.

v	p_1	p_2	Sets of shifts	E_r	E_s
22	10	6	[1,2,3,4,5,21,20,19,18] + [6,7,8,16,15] + [9,10,11,13,12]	0.90	0.93
32	10	6	[1,2,3,4,5,31,30,29,28] + [6,7,8,9,10,26,25,24,23] + [11,12,13,21,20] + [14,15,16,18,17]	0.90	0.96
28	12	8	[1,2,4,3,6,5,27,26,25,24,23] + [7,8,9,10,21,20,19] + [12,11,13,14,17,16,15]	0.92	0.95
30	14	8	[1,2,3,4,5,6,7,29,28,27,26,25,24] + [9,8,10,11,21,22,20] + [13,12,14,15,18,17,16]	0.93	0.95

$$S_{j+1} = [mj + 1, mj + 2, \dots, mj + m, v - (mj + 1), v - (mj + 2), \dots, v - (mj + m - 1)]; j = 0, 1, \dots, i - 1$$

$$S_{i+1} = [mi + 1, mi + 2, \dots, mi + s, v - (mi + 1), v - (mi + 2), \dots, v - (mi + s - 1)]$$

$$S_{i+2} = [mi + s + 1, mi + s + 2, \dots, mi + 2s, v - (mi + s + 1), v - (mi + s + 2), \dots, v - (mi + 2s - 1)]$$

Examples are given in Table 8.

Generator 5.1.2. Following $(i + 2)$ sets of shifts provide minimal CWBRMD for $v = 2mi + 4s$, $p_1 = 2m$, and $p_2 = 2s$, i integer, and m (integer) > 2 . Here, ordered pairs $\{(0, v/2), (1, (v + 2)/2), \dots, ((v - 2)/2, v - 1), (v/2, 0), ((v + 2)/2, 1), \dots, (v - 1, (v - 2)/2)\}$ appear twice together while all other appear once.

$$S_{j+1} = [mj + 1, mj + 2, \dots, mj + m, v - (mj + 1), v - (mj + 2), \dots, v - (mj + m - 1)]; j = 0, 1, \dots, i - 1$$

$$S_{i+1} = [mi + 1, mi + 2, \dots, mi + s, v - (mi + 1), v - (mi + 2), \dots, v - (mi + s - 1)]$$

$$S_{i+2} = [mi + s + 1, mi + s + 2, \dots, mi + 2s, v - (mi + s + 1), v - (mi + s + 2), \dots, v - (mi + 2s - 1)]$$

Examples are given in Table 9.

5.2. Minimal CWBRMDs in periods of two different sizes using Rule II

In this section, some generators are developed to obtain minimal CWBRMDs in periods of two different sizes using method of cyclic shifts (Rule II). Here i sets are for p_1 and two for p_2 .

Generator 5.2.1. Following $(i + 2)$ sets of shifts provide minimal CWBRMD for $v = 2mi + 4s + 1$, $p_1 = 2m$, and $p_2 = 2s$, where i integer, m (integer) > 4 . Here, ordered pairs $\{(0, (v + 1)/2), (1, (v + 3)/2), \dots, ((v - 5)/2, v - 2), ((v - 3)/2, 0), ((v - 1)/2, 1), \dots, (v - 2, (v - 1)/2)\}$ do not appear together while all other appear once.

$$S_{j+1} = [mj + 1, mj + 2, \dots, mj + m, v - 1 - (mj + 1), v - 1 - (mj + 2), \dots, v - 1 - (mj + m - 1)]; j = 0, 1, \dots, i - 1$$



Table 10. CWBRMDs for $v = 2mi + 2s + 1$, $p_1 = 2m$, and $p_2 = s$, where i integer, s (even) > 2 .

v	p_1	p_2	Sets of shifts	E_r	E_s
21	8	6	$[1,2,3,4,19,18,17] + [5,6,7,15,14] + [8,9,10,12]t$	0.99	0.93
23	10	6	$[1,2,3,4,5,21,20,19,18] + [6,7,8,16,15] + [9,10,11,13]t$	0.99	0.93
29	12	8	$[1,2,3,4,5,6,27,26,25,24,23] + [7,8,9,10,21,20,19] + [11,12,13,14,17,16]t$	0.91	0.95
31	14	8	$[1,2,3,4,5,6,7,29,28,27,26,25,24] + [9,8,10,11,21,22,20] + [13,12,14,15,18,17]t$	0.99	0.95

Table 11. CWBRMDs for $v = 2mi + 2s - 1$, $p_1 = 2m$, and $p_2 = s$, where i integer, s (even) > 2 .

v	p_1	p_2	Sets of shifts	E_r	E_s
19	8	6	$[1,2,3,4,17,16,15] + [5,6,13,7,12] + [8,9,10,10]t$	0.99	0.92
25	10	8	$[1,2,3,4,5,23,22,21,20] + [7,6,8,9,17,18,16] + [10,11,12,13,14,13]t$	0.99	0.94
27	12	8	$[1,2,4,3,6,5,25,24,23,22,21] + [7,8,9,10,19,18,17] + [11,12,13,14,15,14]t$	0.99	0.95
33	14	10	$[1,2,3,4,5,6,7,31,30,29,28,27,26] + [8,9,10,11,12,24,23,22,21] + [13,14,15,16,17,19,18,17]t$	0.99	0.96

$$S_{i+1} = [mi + 1, mi + 2, \dots, mi + s, v - 1 - (mi + 1), v - 1 - (mi + 2), \dots, v - 1 - (mi + s - 1)]$$

$$S_{i+2} = [mi + s + 1, mi + s + 2, \dots, mi + 2s, v - 1 - (mi + s + 1), v - 1 - (mi + s + 2), \dots, v - 1 - (mi + 2s - 2)]t$$

Examples are given in Table 10.

Generator 5.2.2. Following $(i + 2)$ sets of shifts provide minimal CWBRMD for $v = 2mi + 4s - 1$, $p_1 = 2m$, and $p_2 = 2s$, where i integer, m (integer) > 4 . Here, ordered pairs $\{(0, (v + 1)/2), (1, (v + 3)/2), \dots, ((v - 5)/2, v - 2), ((v - 3)/2, 0), ((v - 1)/2, 1), \dots, (v - 2, (v - 1)/2)\}$ appear twice together while all other appear once.

$$S_{j+1} = [mj + 1, mj + 2, \dots, mj + m, v - 1 - (mj + 1), v - 1 - (mj + 2), \dots, v - 1 - (mj + m - 1)]; j = 0, 1, \dots, i - 1$$

$$S_{i+1} = [mi + 1, mi + 2, \dots, mi + s, v - 1 - (mi + 1), v - 1 - (mi + 2), \dots, v - 1 - (mi + s - 1)]$$

$$S_{i+2} = [mi + s + 1, mi + s + 2, \dots, mi + 2s, v - 1 - (mi + s + 1), v - 1 - (mi + s + 2), \dots, v - 1 - (mi + 2s - 2)]t$$

Examples are given in Table 11.

6. Minimal CWBRMDs in periods of three different sizes

6.1. Minimal CWBRMDs in periods of three different sizes using Rule I

In this section, some generators are developed to generate minimal CWBRMDs in periods of three different sizes using method of cyclic shifts (Rule I).

Generator 6.1.1. If $v = 2mi + 2s + 2u + 2$, $p_1 = 2m$, $m > 3$ integer, $p_2 = 2s$, $s > 2$, and $p_3 = 2u$, $u > 1$, where $u < s < m$ then minimal CWBRMD can be constructed through the following $i + 2$ sets of shifts. Here i sets are for p_1 , one for p_2 , and also one for p_3 . In these designs, ordered pairs $\{(0, v/2), (1, (v + 2)/2), \dots, ((v - 2)/2, v - 1), (v/2, 0), ((v + 2)/2, 1), \dots, (v - 1, (v - 2)/2)\}$ do not appear together as preceded value while all other appear once.

$$S_{j+1} = [mj + 1, mj + 2, \dots, mj + m, v - (mj + 1), v - (mj + 2), \dots, v - (mj + m - 1)]; j = 0, 1, \dots, i - 1$$

$$S_{i+1} = [mi + 1, mi + 2, \dots, mi + s, v - (mi + 1), v - (mi + 2), \dots, v - (mi + (s - 1))]$$



Table 12. CWBRMDs for $v=2mi+2s+2u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

v	p_1	p_2	p_3	Sets of shifts	E_r	E_s
26	12	8	4	$[1,2,4,3,6,5,25,24,23,22,21] + [7,8,9,10,19,18,17] + [11,12,15]$	0.92	0.94
38	12	8	4	$[1,2,4,3,6,5,37,36,35,34,33] + [8,7,9,10,11,12,30,31,29,28,27] + [13,14,15,16,25,24,23] + [17,18,21]$	0.91	0.96
38	14	12	10	$[1,2,3,4,5,6,7,37,36,35,34,33,32] + [10,8,9,12,11,30,13,29,28,27,26] + [14,15,16,17,18,24,23,22,21]$	0.94	0.96
52	14	12	10	$[1,2,3,4,5,6,7,51,50,49,48,47,46] + [9,8,11,10,13,12,14,43,44,42,41,40,39] + [15,16,17,18,19,20,37,36,35,34,33] + [21,22,23,24,25,31,30,29,28]$	0.94	0.97

Table 13. CWBRMDs for $v=2mi+4s+2u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

v	p_1	p_2	p_3	Sets of shifts	E_r	E_s
36	12	8	6	$[1,2,4,3,6,5,35,34,33,32,31] + [7,8,9,10,29,28,27] + [11,12,25,13,14,24,23] + [15,16,17,21,20]$	0.90	0.96
48	12	8	6	$[1,2,4,3,6,5,47,46,45,44,43] + [7,8,9,10,11,12,41,40,39,38,37] + [13,14,15,16,35,34,33] + [17,18,19,20,31,30,29] + [21,22,23,27,26]$	0.91	0.97
38	14	8	6	$[1,2,3,4,5,6,7,37,36,35,34,33,32] + [8,9,10,30,11,29,28] + [12,13,14,15,26,25,24] + [16,17,18,22,21]$	0.91	0.96
52	14	8	6	$[1,2,3,4,5,6,7,51,50,49,48,47,46] + [9,8,11,10,13,12,14,43,44,42,41,40,39] + [15,16,17,18,37,36,35] + [19,20,21,22,33,32,31] + [23,24,25,29,28]$	0.92	0.97

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+s+u, v-(mi+s+1), v-(mi+s+2), \dots, v-(mi+s+u-1)]$$

Examples are given in Table 12.

Generator 6.1.2. If $v=2mi+4s+2u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$, where $u<s<m$ then minimal CWBRMD can be constructed through the following $(i+3)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and one for p_3 . In these designs, ordered pairs $\{(0, v/2), (1, (v+2)/2), \dots, ((v-2)/2, v-1), (v/2, 0), ((v+2)/2, 1), \dots, (v-1, (v-2)/2)\}$ do not appear together as preceded value while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-(mj+1), v-(mj+2), \dots, v-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-(mi+1), v-(mi+2), \dots, v-(mi+(s-1))]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-(mi+s+1), v-(mi+s+2), \dots, v-(mi+(2s-1))]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-(mi+2s+1), v-(mi+2s+2), \dots, v-(mi+2s+u-1)]$$

Examples are given in Table 13.

Generator 6.1.3. If $v=2mi+4s+4u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$, where $u<s<m$ then minimal CWBRMD can be constructed through the following $(i+4)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and also two for p_3 . In these designs, ordered pairs $\{(0, v/2), (1, (v+2)/2), \dots, ((v-2)/2, v-1), (v/2, 0), ((v+2)/2, 1), \dots, (v-1, (v-2)/2)\}$ do not appear together as preceded value while all other appear once.



Table 14. CWBRMDs for $v=2mi+4s+4u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

v	p_1	p_2	p_3	Sets of shifts	E_r	E_s
32	10	6	4	[1,2,3,4,5,31,30,29,28] + [6,7,8,26,25] + [9,10,11,23,22] + [12,13,20] + [14,15,18]	0.86	0.95
40	10	8	6	[1,2,3,4,5,39,38,37,36] + [6,7,8,9,34,33,32] + [10,11,12,13,30,29,28] + [14,15,16,26,25] + [17,18,19,23,22]	0.88	0.96
42	12	8	6	[1,2,4,3,6,5,41,40,39,38,37] + [7,8,9,10,35,34,33] + [11,12,13,14,31,30,29] + [15,16,17,27,26] + [18,19,20,24,23]	0.89	0.97
50	12	10	8	[1,2,4,3,6,5,49,48,47,46,45] + [7,8,9,10,11,43,42,41,40] + [12,13,14,15,16,38,37,36,35] + [17,18,19,20,33,32,31] + [21,22,23,24,29,28,27]	0.91	0.97

Table 15. CWBRMDs for $v=2mi+2s+2u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

v	p_1	p_2	p_3	Sets of shifts	E_r	E_s
24	12	8	4	[1,2,4,3,6,5,23,22,21,20,19] + [7,8,17,9,10,16,15] + [11,12,13]	0.91	0.94
36	12	8	4	[1,2,4,3,6,5,35,34,33,32,31] + [7,8,9,10,11,12,29,28,27,26,25] + [13,14,15,16,23,22,21] + [17,18,19]	0.91	0.96
26	14	8	4	[4,1,3,2,6,5,7,25,24,23,22,21,20] + [8,9,10,11,18,17,16] + [12,13,14]	0.92	0.94
40	14	8	4	[1,2,3,4,5,6,7,39,38,37,36,35,34] + [8,9,11,10,13,12,14,32,31,30,29,28,27] + [15,16,17,18,25,24,23] + [19,20,21]	0.92	0.96

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-(mj+1), v-(mj+2), \dots, v-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-(mi+1), v-(mi+2), \dots, v-(mi+(s-1))]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-(mi+s+1), v-(mi+s+2), \dots, v-(mi+(2s-1))]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-(mi+2s+1), v-(mi+2s+2), \dots, v-(mi+2s+u-1)]$$

$$S_{i+4} = [mi+2s+u+1, mi+2s+u+2, \dots, mi+2s+2u, v-(mi+2s+u+1), v-(mi+2s+u+2), \dots, v-(mi+2s+2u-1)]$$

Examples are given in Table 14.

Generator 6.1.4. If $v=2mi+2s+2u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+2)$ sets of shifts. Here i sets are for p_1 , one for p_2 , and also one for p_3 . In these designs, ordered pairs $\{(0, v/2), (1, (v+2)/2), \dots, ((v-2)/2, v-1), (v/2, 0), ((v+2)/2, 1), \dots, (v-1, (v-2)/2)\}$ appear twice together as preceded values while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-(mj+1), v-(mj+2), \dots, v-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-(mi+1), v-(mi+2), \dots, v-(mi+(s-1))]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+s+u, v-(mi+s+1), v-(mi+s+2), \dots, v-(mi+s+u-1)], \text{ for } u>1$$

Examples are given in Table 15.

Generator 6.1.5. If $v=2mi+4s+2u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+3)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and one for p_3 . In these designs, ordered pairs



Table 16. CWBRMDs for $v=2mi+4s+2u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

v	p_1	p_2	p_3	Sets of shifts	E_r	E_s
38	12	10	6	$[1,2,4,3,6,5,37,36,35,34,33] + [9,7,8,10,11,30,31,29,28] + [12,13,14,16,15,26,25,24,23] + [17,18,19,21,20]$	0.92	0.96
50	12	10	6	$[1,2,4,3,6,5,49,48,47,46,45] + [8,7,9,10,11,12,42,43,41,40,39] + [13,14,15,16,17,37,36,35,34] + [18,19,20,21,32,22,31,30,29] + [23,24,25,27,26]$	0.92	0.97
40	12	10	8	$[1,2,4,3,6,5,39,38,37,36,35] + [7,8,9,10,11,33,32,31,30] + [12,13,14,15,16,28,27,26,25] + [18,17,19,20,23,22,21]$	0.92	0.96
52	12	10	8	$[1,2,4,3,6,5,51,50,49,48,47] + [7,8,9,10,11,12,45,44,43,42,41] + [13,14,15,16,17,39,38,37,36] + [18,19,20,21,22,34,33,32,31] + [24,23,25,26,29,28,27]$	0.92	0.97

$\{(0, v/2), (1, (v+2)/2), \dots, ((v-2)/2, v-1), (v/2, 0), ((v+2)/2, 1), \dots, (v-1, (v-2)/2)\}$ appear twice together as preceded values while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-(mj+1), v-(mj+2), \dots, v-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-(mi+1), v-(mi+2), \dots, v-(mi+(s-1))]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-(mi+s+1), v-(mi+s+2), \dots, v-(mi+(2s-1))]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-(mi+2s+1), v-(mi+2s+2), \dots, v-(mi+2s+u-1)]$$

Examples are given in Table 16.

Generator 6.1.6. If $v=2mi+4s+4u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+4)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and also two for p_3 . In these designs, ordered pairs $\{(0, v/2), (1, (v+2)/2), \dots, ((v-2)/2, v-1), (v/2, 0), ((v+2)/2, 1), \dots, (v-1, (v-2)/2)\}$ appear twice together as preceded values while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-(mj+1), v-(mj+2), \dots, v-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-(mi+1), v-(mi+2), \dots, v-(mi+(s-1))]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-(mi+s+1), v-(mi+s+2), \dots, v-(mi+(2s-1))]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-(mi+2s+1), v-(mi+2s+2), \dots, v-(mi+2s+u-1)]$$

$$S_{i+4} = [mi+2s+u+1, mi+2s+u+2, \dots, mi+2s+2u, v-(mi+2s+u+1), v-(mi+2s+u+2), \dots, v-(mi+2s+2u-1)]$$

Examples are given in Table 17.

6.2. Minimal CWBRMDs in periods of three different sizes using Rule II

In this section, generators are developed to obtain minimal CWBRMDs in periods of three different sizes using method of cyclic shifts (Rule II).

Generator 6.2.1. If $v=2mi+2s+2u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u+1$, u integer then minimal CWBRMD can be constructed through the following



Table 17. CWBRMDs for $v=2mi+4s+4u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

v	p_1	p_2	p_3	Sets of shifts	E_r	E_s
40	12	8	6	$[1,2,4,3,6,5,39,38,37,36,35] + [7,8,9,10,33,32,31] + [11,12,13,14,29,28,27] + [15,16,17,25,24] + [18,19,20,22,21]$	0.89	0.96
52	12	8	6	$[1,2,4,3,6,5,51,50,49,48,47] + [7,8,9,10,11,12,45,44,43,42,41] + [13,14,15,16,39,38,37] + [17,18,19,20,35,34,33] + [21,22,23,31,30] + [24,25,26,28,27]$	0.91	0.97
50	14	10	8	$[1,2,3,4,5,6,7,49,48,47,46,45,44] + [8,9,10,11,42,12,41,40,39] + [13,14,15,16,17,37,36,35,34] + [18,19,20,21,32,31,30] + [23,22,24,25,28,27,26]$	0.92	0.97
64	14	10	8	$[1,2,3,4,5,6,7,63,62,61,60,59,58] + [8,9,11,10,13,12,14,56,55,54,53,52,51] + [15,16,17,18,19,49,48,47,46] + [20,21,22,23,24,44,43,42,41] + [25,26,27,28,39,38,37] + [30,29,31,32,35,34,33]$	0.92	0.98

Table 18. CWBRMDs for $v=2mi+2s+2u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u+1$.

v	p_1	p_2	p_3	Sets of shifts	E_r	E_s
19	8	6	3	$[1,2,3,4,17,16,15] + [5,6,13,7,12] + [8]t$	1.0	0.90
21	8	6	5	$[1,2,3,4,19,18,17] + [5,6,7,15,14] + [8,9,12]t$	1.0	0.91
25	10	8	5	$[1,2,3,4,5,23,22,21,20] + [7,6,8,9,17,18,16] + [10,11,14]t$	1.0	0.93
29	12	10	5	$[1,2,4,3,6,5,27,26,25,24,23] + [7,8,9,10,11,21,20,19,18] + [12,13,16]t$	1.0	0.94

$(i+2)$ sets of shifts. Here i sets are for p_1 , one for p_2 , and also one for p_3 . In these designs some ordered pairs do not appear together while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+s+u, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+s+u-1)]t$$

Examples are given in Table 18.

Generator 6.2.2. If $v=2mi+4s+2u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u+1$, u integer then minimal CWBRMD can be constructed through the following $(i+3)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and one for p_3 . In these designs some ordered pairs do not appear together while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+2s-1)]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-1-(mi+2s+1), v-1-(mi+2s+2), \dots, v-1-(mi+2s+u-1)]t$$

Examples are given in Table 19.

Generator 6.2.3. If $v=2mi+2s+2u+1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+2)$ sets of shifts. Here i sets are for p_1 , one for p_2 , and also one for p_3 . In these designs some ordered pairs do not appear together while all other appear once.



Table 19. CWBRMDs for $v=2mi+4s+2u+2$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u+1$.

V	p_1	p_2	p_3	Sets of shifts	E_r	E_s
24	8	6	3	$[1,2,3,4,22,21,20] + [5,6,7,18,17] + [8,9,10,15,14] + [11]t$	0.99	0.94
26	8	6	5	$[1,2,3,4,24,23,22] + [5,6,7,20,19] + [8,9,10,17,16] + [11,12,14]t$	0.99	0.94
32	10	8	5	$[1,2,3,4,5,30,29,28,27] + [6,7,8,9,25,24,23] + [10,11,12,13,21,20,19] + [14,15,17]t$	0.99	0.95
38	12	10	5	$[1,2,4,3,6,5,36,35,34,33,32] + [7,8,9,10,11,30,29,28,27] + [12,13,14,15,16,25,24,23,22] + [17,18,20]t$	0.99	0.96

Table 20. CWBRMDs for $v=2mi+2s+2u+1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

V	p_1	p_2	p_3	Sets of shifts	E_r	E_s
23	10	8	4	$[1,2,3,4,5,21,20,19,18] + [6,7,8,9,16,15,14] + [10,11]t$	1.00	0.93
25	10	8	6	$[1,2,3,4,5,23,22,21,20] + [7,6,8,9,17,18,16] + [10,11,12,14]t$	1.00	0.94
31	12	10	8	$[1,2,4,3,6,5,29,28,27,26,25] + [7,8,9,10,23,11,21,22,20] + [12,13,14,15,18,17]t$	0.95	0.95
37	14	12	10	$[1,2,3,4,5,6,7,35,34,33,32,31,30] + [8,9,10,11,12,28,13,27,25,26,24] + [14,15,16,17,18,22,21,20]t$	1.00	0.96

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)];$$

$$j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+s+u, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+s+u-2)]t$$

Examples are given in Table 20.

Generator 6.2.4. If $v=2mi+4s+2u+1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+3)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and one for p_3 . In these designs some ordered pairs do not appear together while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)];$$

$$j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+2s-1)]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-1-(mi+2s+1), v-1-(mi+2s+2), \dots, v-1-(mi+2s+u-2)]t$$

Examples are given in Table 21.

Generator 6.2.5. If $v=2mi+4s+4u+1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+4)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and also two for p_3 . In these designs some ordered pairs do not appear together while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)];$$

$$j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+2s-1)]$$



Table 21. CWBRMDs for $v=2mi+4s+2u+1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

V	p_1	p_2	p_3	Sets of shifts	E_t	E_s
31	10	8	4	$[1,2,3,4,5,29,28,27,26] + [6,7,8,24,9,23,22] + [10,11,12,13,20,19,18] + [14,15]t$	0.99	0.95
33	10	8	6	$[1,2,3,4,5,31,30,29,28] + [6,7,8,9,26,25,24] + [10,11,12,13,22,21,20] + [14,15,16,18]t$	0.99	0.96
41	12	10	8	$[1,2,4,3,6,5,39,38,37,36,35] + [7,8,9,10,11,33,32,31,30] + [12,13,14,15,16,28,27,26,25] + [17,18,19,20,23,22]t$	0.94	0.96
49	14	12	10	$[1,2,3,4,5,6,7,47,46,45,44,43,42] + [8,9,10,11,12,13,40,39,38,37,36] + [15,14,16,17,18,19,33,34,32,31,30] + [20,21,22,23,24,28,27,26]t$	0.99	0.97

Table 22. CWBRMDs for $v=2mi+4s+4u+1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

V	p_1	p_2	p_3	Sets of shifts	E_t	E_s
35	10	8	4	$[1,2,3,4,5,33,32,31,30] + [6,7,8,9,28,27,26] + [10,11,12,13,24,23,22] + [14,15,20] + [16,17]t$	0.96	0.96
39	10	8	6	$[1,2,3,4,5,37,36,35,34] + [6,7,8,9,32,31,30] + [10,11,12,13,28,27,26] + [14,15,16,24,23] + [17,18,19,21]t$	0.97	0.96
48	12	10	8	$[2,1,4,3,46,5,6,45,44,42,43] + [7,8,9,10,11,41,40,39,38] + [13,12,14,15,16,36,33,35,34] + [17,18,19,20,31,30,29] + [21,22,23,24,27,26]t$	0.84	0.94
59	14	12	10	$[1,2,3,4,5,6,7,57,56,55,54,53,52] + [8,9,10,11,12,13,50,49,48,47,46] + [14,15,16,17,18,19,44,43,42,41,40] + [20,21,22,23,24,38,37,36,35] + [25,26,27,28,29,33,32,31]t$	0.98	0.97

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-1-(mi+2s+1), v-1-(mi+2s+2), \dots, v-1-(mi+2s+u-1)]$$

$$S_{i+4} = [mi+2s+u+1, mi+2s+u+2, \dots, mi+2s+2u, v-1-(mi+2s+u+1), v-1-(mi+2s+u+2), \dots, v-1-(mi+2s+2u-2)]t$$

Examples are given in Table 22.

Generator 6.2.6. If $v=2mi+2s+2u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u+1$, u integer then minimal CWBRMD can be constructed through the following $(i+2)$ sets of shifts. Here i sets are for p_1 , one for p_2 , and also one for p_3 . In these designs some ordered pairs appear twice together while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+s+u, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+s+u-1)]t$$

Examples are given in Table 23.

Generator 6.2.7. If $v=2mi+4s+2u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u+1$, u integer then minimal CWBRMD can be constructed through the following $(i+3)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and one for p_3 . In these designs some ordered pairs appear twice together while all other appear once.



Table 23. CWBRMDs for $v=2mi+2s+2u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u+1$.

V	p_1	p_2	p_3	Sets of shifts	E_r	E_s
16	8	6	3	$[1,2,3,4,14,13,12] + [5,6,7,10,9] + [8]t$	1.00	0.91
18	8	6	5	$[1,2,3,4,16,15,14] + [5,6,7,12,11] + [8,9,9]t$	0.92	0.92
22	10	8	5	$[1,2,3,4,5,20,19,18,17] + [6,7,9,15,8,14,13] + [10,11,11]t$	0.94	0.94
26	12	10	5	$[1,2,4,3,6,5,24,23,22,21,20] + [7,8,9,10,11,18,17,16,15] + [12,13,13]t$	0.94	0.95

Table 24. CWBRMDs for $v=2mi+4s+2u$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u+1$.

V	p_1	p_2	p_3	Sets of shifts	E_r	E_s
22	8	6	3	$[1,2,3,4,20,19,18] + [5,6,7,16,15] + [8,9,10,13,12] + [11]t$	0.99	0.94
24	8	6	5	$[1,2,3,4,22,21,20] + [5,6,7,18,17] + [8,9,10,15,14] + [11,12,12]t$	0.90	0.94
30	10	8	5	$[1,2,3,4,5,28,27,26,25] + [6,7,8,9,23,22,21] + [10,11,12,13,19,18,17] + [14,15,15]t$	0.92	0.95
36	12	10	5	$[1,2,4,3,6,5,34,33,32,31,30] + [7,8,9,10,11,28,27,26,25] + [12,13,14,15,23,16,22,21,20] + [17,18,18]t$	0.93	0.96

Table 25. CWBRMDs for $v=2mi+2s+2u-1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

V	p_1	p_2	p_3	Sets of shifts	E_r	E_s
19	10	6	4	$[1,2,3,4,5,17,16,15,14] + [6,7,8,12,11] + [9,10]t$	1.0	0.93
23	10	8	6	$[1,2,3,4,5,21,20,19,18] + [6,7,8,9,16,15,14] + [10,11,12,12]t$	1.0	0.94
27	12	10	6	$[1,2,4,3,6,5,25,24,23,22,21] + [7,8,9,10,11,19,18,17,16] + [12,13,14,14]t$	1.0	0.95
29	12	10	8	$[1,2,4,3,6,5,27,26,25,24,23] + [7,8,9,10,11,21,20,19,18] + [12,13,14,15,16,15]t$	1.0	0.95

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+2s-1)]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-1-(mi+2s+1), v-1-(mi+2s+2), \dots, v-1-(mi+2s+u-1)]t$$

Examples are given in Table 24.

Generator 6.2.8. If $v=2mi+2s+2u-1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+2)$ sets of shifts. Here i sets are for p_1 , one for p_2 , and also one for p_3 . In these designs some ordered pairs appear twice together while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+s+u, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+s+u-2)]t$$

Examples are given in Table 25.

Generator 6.2.9. If $v=2mi+4s+2u-1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+3)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and one for p_3 . In these designs some ordered pairs appear twice together while all other appear once.



Table 26. CWBRMDs for $v=2mi+4s+2u-1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

V	p_1	p_2	p_3	Sets of shifts	E_r	E_s
29	10	8	4	$[1,2,3,4,5,27,26,25,24] + [6,7,8,9,22,21,20] + [10,11,12,13,18,17,16] + [14,15]t$	0.99	0.95
31	10	8	6	$[1,2,3,4,5,29,28,27,26] + [6,7,8,24,9,23,22] + [10,11,12,13,20,19,18] + [14,15,16,16]t$	0.99	0.95
39	12	10	8	$[1,2,4,3,6,5,37,36,35,34,33] + [8,7,9,10,11,30,31,29,28] + [12,13,14,16,15,26,25,24,23] + [17,18,19,20,21,20]t$	0.99	0.96
41	14	10	8	$[1,2,3,4,5,6,7,39,38,37,36,35,34] + [8,9,10,11,12,32,31,30,29] + [13,14,15,16,17,27,26,25,24] + [18,19,20,21,22,21]t$	0.99	0.97

Table 27. CWBRMDs for $v=2mi+4s+4u-1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, and $p_3=2u$, $u>1$.

V	p_1	p_2	p_3	Sets of shifts	E_r	E_s
33	10	8	4	$[1,2,3,4,5,31,30,29,28] + [6,7,8,9,26,25,24] + [10,11,12,13,22,21,20] + [14,15,18] + [16,17]t$	0.96	0.96
37	10	8	6	$[1,2,3,4,5,35,34,33,32] + [6,7,8,9,30,29,28] + [10,11,12,26,25,13,24] + [14,15,16,22,21] + [17,18,19,19]t$	0.97	0.96
43	12	10	6	$[1,2,4,3,6,5,41,40,39,38,37] + [7,8,9,10,11,35,34,33,32] + [13,12,14,15,16,29,30,28,27] + [17,18,19,25,24] + [20,21,22,22]t$	0.97	0.97
47	12	10	8	$[1,2,4,3,6,5,45,44,43,42,41] + [7,8,9,10,11,39,38,37,36] + [13,12,14,15,16,34,33,32,31] + [17,18,19,20,29,28,27] + [21,22,23,24,25,24]t$	0.98	0.97

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+2s-1)]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-1-(mi+2s+1), v-1-(mi+2s+2), \dots, v-1-(mi+2s+u-2)]t$$

Examples are given in Table 26.

Generator 6.2.10. If $v=2mi+4s+4u-1$, $p_1=2m$, $m>3$ integer, $p_2=2s$, $s>2$, and $p_3=2u$, $u>1$ then minimal CWBRMD can be constructed through the following $(i+4)$ sets of shifts. Here i sets are for p_1 , two for p_2 , and also two for p_3 . In these designs some ordered pairs appear twice together while all other appear once.

$$S_{j+1} = [mj+1, mj+2, \dots, mj+m, v-1-(mj+1), v-1-(mj+2), \dots, v-1-(mj+m-1)]; j=0, 1, \dots, i-1$$

$$S_{i+1} = [mi+1, mi+2, \dots, mi+s, v-1-(mi+1), v-1-(mi+2), \dots, v-1-(mi+s-1)]$$

$$S_{i+2} = [mi+s+1, mi+s+2, \dots, mi+2s, v-1-(mi+s+1), v-1-(mi+s+2), \dots, v-1-(mi+2s-1)]$$

$$S_{i+3} = [mi+2s+1, mi+2s+2, \dots, mi+2s+u, v-1-(mi+2s+1), v-1-(mi+2s+2), \dots, v-1-(mi+2s+u-1)]$$

$$S_{i+4} = [mi+2s+u+1, mi+2s+u+2, \dots, mi+2s+2u, v-1-(mi+2s+u+1), v-1-(mi+2s+u+2), \dots, v-1-(mi+2s+2u-2)]t$$

Examples are given in Table 27.



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Optimal minimal balanced crossover designs in first and second carryover effects

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ABSTRACT

Crossover designs balanced in first and second order carryover effects discussed in literature often require large number of experimental units. In practice experiments demand fewer experimental units where minimal balanced crossover designs are desirable. In this paper, a simple method of construction of minimal balanced crossover designs through a new form of terrace is presented. A new form of terrace constructs one series of crossover designs having less number of periods than the number of treatments and two series of crossover designs having more periods than the treatments. Crossover designs possess good efficiency of separability and optimal for the estimation of treatment effects.

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Crossover; treatment effect; minimal; terrace; second order carryover effect

1. Introduction

A crossover design is an arrangement of experiment in which experimental units are used repeatedly by exposing them according to a sequence of treatments over a span of time. Apparently each unit is influenced by the effect of current treatment and carryover effects of the previously applied treatments. The main advantage of a crossover design is that the treatments are compared within experimental units and such studies allow a more precise comparison of treatments. Some real life applications of the crossover designs are discussed by Taka and Armitage (1983) and Matthews (1989). Literature review of the applications of the three types of crossover designs shows that each of them has specific applications. The crossover designs with number of periods less than the treatments are suitable in clinical trials and pharmaceutical studies. The crossover designs with number of periods equal to the number of treatments so that each unit receives every treatment once are employed in agriculture and for the sensory evaluation of food and products. The crossover designs having periods more than the number of treatments are useful in animal nutrition and educational experiments (e.g., Gill 1978).

Crossover designs suitable for estimation of model with first order carryover effects have been discussed by many authors. However, the experimental studies like Thorough QT studies (ICH Guidance 2005; Ring et al. 2010, etc.), diet study, asthma study (Brusasco et al. 2002) etc. in which multi period crossover design is profitably used, it is



possible that carryover effects do not die unexpectedly after one period as commented by Jones and Quenouille (1977, 198). Only four authors discussed crossover designs suitable for such experiments which require balanced crossover design in first and second carryover. Patterson (1952) gave the conditions for carryover treatment effects designs balanced for first and second order carryover effects. Sharma (1977) presented a method of construction of crossover designs with complete balance for first and second order carryover effects. Collombier and Mercherme (1993) studied optimal crossover experimental designs for higher order carryover effects. Bose and Mukherjee (2000) constructed multi period crossover designs suitable for such studies. Their designs are optimal for estimation of treatment effects under non additive, higher order carryover model with correlated errors (Bose and Mukherjee 2003) for a specific correlation structure that, every two observations from a unit are identically correlated. Aggarwal, Deng, and Jha (2006) constructed balanced carryover treatment effects designs of first and second order using balanced incomplete block designs (BIBDs), balanced ternary designs and mutually orthogonal Latin squares (MOLS).

Bailey (1984) defined the term “terrace” and constructed Quasi-complete Latin squares. Morgan (1988) generalized the idea of terrace to m-terrace and constructed balanced polycross designs. Divecha and Gondaliya (2014) given modified forms of terrace called complementary pair of terraces and complementary trio of terraces and provided four series of minimal balanced crossover designs suitable for first order carryover model. Gondaliya (2019) provided a computer program that meet the practical need of experimenters/users through variety of terraces and crossover designs for the same class. The present paper introduces modified form of terrace called $terrace(t, g_1, g_2)$ and provides a simple method for the construction of three new series of minimal balanced crossover designs suitable for the optimal estimation of treatment effects. The $terrace(t, g_1, g_2)$ constructs two series of crossover designs for the case of more number of periods than the number of treatments while one series of crossover designs for the case of less number of periods than the number of treatments. All the designs are minimal balanced in first and second carryover and possess good efficiency of separability. Section 2 presents the model and characterization of crossover designs. Construction of three new series of crossover designs through $terrace(t, g_1, g_2)$ is discussed and illustrated by examples in Section 3. Newly constructed designs are compared with literature through efficiency.

2. Characterization and model

2.1. Characterization of crossover design

A crossover design for t treatments in n experimental units repeatedly measured for p periods is denoted by $COD(t, n, p)$.

Definition 2.1. A $COD(t, n, p)$ is said to be *balanced* with respect to the set of treatment, first and second order carryover effects if (i) in each period, each treatment is given to λ_1 units (ii) in two successive periods, each ordered pair of distinct treatments is given to λ_2 units, while, each pair of treatments with itself is given to λ_3 units, and



(iii) in two periods at distance of two position, each ordered pair of distinct treatments is given to λ_4 units, where integer $\lambda_1, \lambda_2, \lambda_4$ are positive and λ_3 is non negative.

Consequently, a balanced crossover design satisfies the following parametric relations,

$$n = \lambda_1 t \quad (1)$$

$$n(p-1) = (\lambda_2(t-1) + \lambda_3)t \quad (2)$$

$$n(p-2) = t(t-1)\lambda_4 \quad (3)$$

A minimal balanced crossover design is a design in which the number of experimental units that receive each treatment in each period (λ_1) is as small as possible. From (1), (2) and (3), Definition 2.2 follows.

Definition 2.2. A balanced $COD(t, n, p)$ is said to be *minimal* balanced crossover design if λ_1 is the smallest integer such that

$$(\lambda_1(p-1) - \lambda_3) \equiv 0(\text{modulo}(t-1)) \quad (4)$$

$$(\lambda_1(p-2)) \equiv 0(\text{modulo}(t-1)) \quad (5)$$

In addition of the characteristic minimal balanced, a crossover design must be characterized for its ability of separating the treatment effects from first and second order carryover effects. A measure called efficiency of separability (ES) is calculated on the basis of observed frequencies of treatment with first and second order carryover and the expected frequencies from an independent model. Following Hanford (2005), a measure of ES of treatment from first and second order carryover effects for balanced crossover designs is calculated by

$$ES = \left[1 - \left\{ \frac{(t-1)\lambda_4(\lambda_3 - \lambda_2)^2 + \lambda_4^2(\lambda_3 + (t-1)\lambda_2)}{(\lambda_3 + (t-1)\lambda_2)(t-1)\lambda_4(\lambda_1 + \lambda_3 + (t-1)\lambda_2 + (t-1)\lambda_4)} \right\}^{\frac{1}{2}} \right] \times 100\% \quad (6)$$

For example, the ES of the $COD\{AAB, BBA\}$ calculated by substituting $\lambda_1 = 1, \lambda_2 = 1, \lambda_3 = 1$ and $\lambda_4 = 1$ in the Equation (6) is 50%. The low ES indicates unsuitability while the high ES indicates suitability of crossover design for the estimation of treatment, first and second order carryover effects under model 7.

2.2. Model

The model with an addition of second order carryover effects to the simple carryover model is known as second order carryover model given by,

$$y_{ijk} = \mu + \pi_k + \xi_{ij} + \tau_{d(k,j)} + \gamma_{1d(k-1,j)} + \gamma_{2d(k-2,j)} + \epsilon_{ijk} \quad (7)$$

where, y_{ijk} is the observation from sequence i having experimental unit j in period k in which treatment $d(k, j)$ was given, μ is the general mean effect, π_k is the effect due to period k , ξ_{ij} is the effect due to experimental unit j having sequence i , $\tau_{d(k,j)}$ is the effect of treatment $d(k, j)$ in the period in which it is applied, $\gamma_{1d(k-1,j)}$ is the first order carryover effect of treatment $d(k-1, j)$ in the period k which was applied



in the period $k - 1$ to the same unit, $\gamma_{2d(k-1,j)}$ is the second order carryover effect of treatment $d(k-2,j)$ in the period k which was applied in the period $k - 2$ to the same unit and the ϵ_{ijk} are independently normally distributed error term with mean 0 and variance σ^2 . It is obvious that there is no first order carryover effect in the first period and second order carryover effect in first and second period, that is, $\gamma_{1d(0,j)} = \gamma_{2d(-1,j)} = \gamma_{2d(0,j)} = 0$.

The joint information matrix of the treatment effects and first and second order carryover effects for the balanced crossover design d is given by

$$C_{d(\tau, \gamma_1, \gamma_2)} = \begin{pmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{pmatrix}$$

where,

$$\begin{aligned} C_{11} &= R - \frac{1}{n}L_1L_1' - \frac{1}{p}L_2L_2' + \frac{r^2}{np}J, C_{12} = M_1 - \frac{1}{n}L_1E_1' - \frac{1}{p}L_2N_1' + \frac{rr_1}{np}J, \\ C_{13} &= M_2 - \frac{1}{n}L_1E_2' - \frac{1}{p}L_2N_2' + \frac{rr_2}{np}J, C_{22} = R_1 - \frac{1}{n}E_1E_1' - \frac{1}{p}N_1N_1' + \frac{r_1^2}{np}J, \\ C_{23} &= M_3 - \frac{1}{n}E_1E_2' - \frac{1}{p}N_1N_2' + \frac{r_1r_2}{np}J, C_{33} = R_2 - \frac{1}{n}E_2E_2' - \frac{1}{p}N_2N_2' + \frac{r_2^2}{np}J, \\ C_{21} &= C_{12}', C_{31} = C_{13}', C_{32} = C_{23}' \end{aligned}$$

Here, R is incidence matrix of observations vs treatments; R_1 incidence matrix of observations vs first order carryover; R_2 incidence matrix of observations vs second order carryover; M_1 is the incidence matrix of treatments vs first order carryover; M_2 the incidence matrix of treatments vs second order carryover; M_3 the incidence matrix of first order carryover vs second order carryover; L_1 the incidence matrix of treatments vs periods; L_2 the incidence matrix of treatments vs units; E_1 the incidence matrix of first order carryover vs periods; E_2 the incidence matrix of second order carryover vs periods; N_1 the incidence matrix of first order carryover vs units; N_2 the incidence matrix of second order carryover vs units. Also we have r is the replication of treatment; r_1 the replication of first order carryover; r_2 the replication of second order carryover; J the matrix with all elements unity.

3. Construction of crossover designs

Construction of crossover design balanced in first and second order carryover effects through only two simple steps is discussed in this section. Define a *terrace* (t, g_1, g_2) in form of $p \times s$ matrix and add all the numbers $0, 1, \dots, t - 1$ to it.

Step 1: Define terrace (t, g_1, g_2)

Let X be a $p \times s$ matrix for some positive integer $s = \frac{n}{t}$ having numbers from $Z_t = \{0, 1, \dots, t - 1\}$ in which repeats and non occurrences of the numbers are accepted during arrangement of numbers. Let $X^{(1)}$ and $X^{(2)}$ be the $(p - 1) \times s$ and $(p - 2) \times s$ matrices respectively contain difference of the numbers in following manner,



$$X^{(1)} = \begin{pmatrix} x_{21} - x_{11} & x_{22} - x_{12} & \dots & x_{2s} - x_{1s} \\ x_{31} - x_{21} & x_{32} - x_{22} & \dots & x_{3s} - x_{2s} \\ \vdots & \vdots & \vdots & \vdots \\ x_{p1} - x_{(p-1)1} & x_{p2} - x_{(p-1)2} & \dots & x_{ps} - x_{(p-1)s} \end{pmatrix} \text{ modulo } t$$

$$X^{(2)} = \begin{pmatrix} x_{31} - x_{11} & x_{32} - x_{12} & \dots & x_{3s} - x_{1s} \\ x_{41} - x_{21} & x_{42} - x_{22} & \dots & x_{4s} - x_{2s} \\ \vdots & \vdots & \vdots & \vdots \\ x_{p1} - x_{(p-2)1} & x_{p2} - x_{(p-2)2} & \dots & x_{ps} - x_{(p-2)s} \end{pmatrix} \text{ modulo } t$$

Definition 3.1. A $p \times s$ matrix X from Z_t is said to be a *terrace* (t, g_1, g_2) for some positive integer g_1 and non negative integer g_2 if $X^{(1)}$ contains each non zero numbers of Z_t exactly g_1 times, zero exactly g_2 times and $X^{(2)}$ contains each non zero number of Z_t exactly g_1 times.

Step 2: Write crossover design by adding all the numbers $0, 1, \dots, t-1$ to *terrace* (t, g_1, g_2)

A $p \times n$ matrix where $n = ts$ is obtained by adding all the numbers of Z_t to each elements of X modulo t in following way produces the specified crossover design.

$$\left(\begin{array}{cccc|cccc} x_{11} + 0 & x_{12} + 0 & \dots & x_{1s} + 0 & \dots & x_{11} + (t-1) & x_{12} + (t-1) & \dots & x_{1s} + (t-1) \\ x_{21} + 0 & x_{22} + 0 & \dots & x_{2s} + 0 & \dots & x_{21} + (t-1) & x_{22} + (t-1) & \dots & x_{2s} + (t-1) \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{p1} + 0 & x_{p2} + 0 & \dots & x_{ps} + 0 & \dots & x_{p1} + (t-1) & x_{p2} + (t-1) & \dots & x_{ps} + (t-1) \end{array} \right) \text{ modulo } t$$

Here, rows of the matrix are periods and columns are experimental units. From the definition of *terrace* (t, g_1, g_2) , it is clear that $\lambda_3 = g_2$ because occurrence of same number in two successive positions in same column of X contribute zero in $X^{(1)}$. Now, from the Equations (1)–(3), $\lambda_1 = \frac{n}{t}$, $\lambda_2 = \frac{n(p-1)-g_2t}{t(t-1)}$ and $\lambda_4 = \frac{n(p-2)}{t(t-1)}$.

Case 3.1. For $s = 2$, $p = \frac{t+3}{2}$ for odd t (> 3), $g_1 = 1$ and $g_2 = 2$, a *terrace* $(t, 1, 2)$ in $p \times 2$ matrix produces a series of minimal balanced $COD(t, 2t, \frac{t+3}{2})$ by adding all the numbers of Z_t to each elements of X reduced modulo t .

Here, $\lambda_3 = g_2 = 2$ and hence from the Equations (1)–(3), $\lambda_1 = 2$, $\lambda_2 = 1$ and $\lambda_4 = 1$. Now, substituting $\lambda_1 = 1$ in Equation (4), $(\lambda_1(p-1) - \lambda_3) = \frac{t-3}{2}$, which is not divisible by $t-1$. However, substituting $\lambda_1 = 2$ in Equations (4) and (5) respectively, $(\lambda_1(p-1) - \lambda_3) = t-1$ and $\lambda_1(p-2) = t-1$, which is divisible by $t-1$. Hence, $COD(t, 2t, \frac{t+3}{2})$ is minimal balanced, because, $\lambda_1 = 2$ is the smallest integer which satisfies both the conditions of minimal balanced. Let l_{ij} be occurrence of the number i in column j of matrix $X_{p \times s}$; n_{ij} occurrence of the number i in column j of matrix $X_{(p-2) \times s}$, then, following theorem must hold.

Theorem 3.1. If *terrace* $(t, 1, 2)$ have minimum value of $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2$ and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2$ among all possible *terrace* $(t, 1, 2)$, then design d^* with $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2 = t+7$ and



$\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2 = t-1$ from $\text{terrace}(t, 1, 2)$ is universal optimal for treatment effects over $\text{COD}(t, 2t, \frac{t+3}{2})$.

Proof 3.1. After considerable algebra using properties of matrices, it may be shown that under model 7, for any balanced crossover design d in $\text{COD}(t, 2t, \frac{t+3}{2})$, the coefficient matrix C_d of the reduced normal equations for τ is given by

$$\begin{aligned} C_d &= C_{11} - [C_{12} \ C_{13}] \begin{bmatrix} C_{22} & C_{23} \\ C_{32} & C_{33} \end{bmatrix}^{-1} \begin{bmatrix} C_{21} \\ C_{31} \end{bmatrix} \\ &= \left(\frac{rp - \sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2 + p}{p} I + \frac{r^2 - np - \lambda_1^2 p^2}{np} J \right) - \left(-\lambda_4 I + \frac{rr_2 + \lambda_4 np - \lambda_1^2 p(p-2) - np}{np} J \right) \\ &\quad \left(\frac{p}{r_2 p - \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2} I + \frac{-rp(r_2^2 - \lambda_1^2 p(p-2))}{n(r_2 p - \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2)(pr_2^2 - \lambda_1^2 p^2(p-2) + rr_2 p - r \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2)} J \right) \\ &\quad \left(-\lambda_4 I + \frac{rr_2 + \lambda_4 np - \lambda_1^2 p(p-2) - np}{np} J \right) \\ &= \left(\frac{rp - \sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2 + p}{p} - \frac{p}{r_2 p - \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2} \right) I + \\ &\quad \left(\frac{r^2 - np - \lambda_1^2 p^2}{np} + \frac{rp(r_2^2 - \lambda_1^2 p(p-2))}{n(r_2 p - \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2)(pr_2^2 - \lambda_1^2 p^2(p-2) + rr_2 p - r \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2)} \right) J \end{aligned}$$

Hence, C_d is completely symmetric. Now, the trace of C_d is maximum if and only if the $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2$ and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2$ are minimum. Minimization of $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2$ and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2$ subject to $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij} = 2p$ and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij} = 2(p-2)$ respectively leads to,

$$\begin{aligned} \text{tr} C_d &= t \left(\frac{rp - \sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2 + p}{p} - \frac{p}{r_2 p - \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2} \right) \\ &\quad + t \left(\frac{r^2 - np - \lambda_1^2 p^2}{np} + \frac{rp(r_2^2 - \lambda_1^2 p(p-2))}{n(r_2 p - \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2)(pr_2^2 - \lambda_1^2 p^2(p-2) + rr_2 p - r \sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2)} \right) \\ &\leq \frac{t(rp - p - 4)}{p} - \frac{tp}{r_2 p - 2p + 4} + \frac{t(r^2 - np - 4p^2)}{np} \\ &\quad + \frac{trp(r_2^2 - 4p(p-2))}{n(r_2 p - 2p + 4)(pr_2^2 - 4p^2(p-2) + rr_2 p - 2rp + 4r)} \\ &= \text{tr} C_{d^*} \end{aligned}$$

Hence, d^* satisfies the sufficient conditions for universal optimality as given by Kiefer (1975) and the theorem is proved.

Example 3.1. For $t=5$ in the series $\text{COD}(t, 2t, \frac{t+3}{2})$, arranging eight numbers from the group $Z_5 = \{0, 1, 2, 3, 4\}$ in 4×2 matrix as,



$$X = \begin{pmatrix} 0 & 1 \\ 4 & 2 \\ 1 & 0 \\ 1 & 0 \end{pmatrix}$$

gives terrace(1, 2, 5) because $X^{(1)}$ contains each non zero numbers of Z_5 exactly one time, zero exactly two times and $X^{(2)}$ contains each non zero number of Z_5 exactly one time as shown below.

$$X^{(1)} = \begin{pmatrix} 4 & 1 \\ 2 & 3 \\ 0 & 0 \end{pmatrix} \quad \text{and} \quad X^{(2)} = \begin{pmatrix} 1 & 4 \\ 2 & 3 \end{pmatrix}.$$

Note that, $1 \equiv -4$ (modulo 5), $2 \equiv -3$ (modulo 5), $3 \equiv -2$ (modulo 5) and $4 \equiv -1$ (modulo 5). Adding each number 0, 1, 2, 3 and 4 of Z_5 to the matrix X reduced modulo 5 constructs the minimal balanced $COD(5, 10, 4)$ given by

		<i>Experimental units</i>									
		<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>10</i>
<i>Periods</i>	<i>1</i>	<i>0</i>	<i>1</i>	<i>1</i>	<i>2</i>	<i>2</i>	<i>3</i>	<i>3</i>	<i>4</i>	<i>4</i>	<i>0</i>
	<i>2</i>	<i>4</i>	<i>2</i>	<i>0</i>	<i>3</i>	<i>1</i>	<i>4</i>	<i>2</i>	<i>0</i>	<i>3</i>	<i>1</i>
	<i>3</i>	<i>1</i>	<i>0</i>	<i>2</i>	<i>1</i>	<i>3</i>	<i>2</i>	<i>4</i>	<i>3</i>	<i>0</i>	<i>4</i>
	<i>4</i>	<i>1</i>	<i>0</i>	<i>2</i>	<i>1</i>	<i>3</i>	<i>2</i>	<i>4</i>	<i>3</i>	<i>0</i>	<i>4</i>

Note that, $\lambda_1 = 2, \lambda_2 = 1, \lambda_3 = 2, \lambda_4 = 1$ and $ES = 81\%$. Also, $(\sum_{i=0}^{t-1} l_{i1}^2 + \sum_{i=0}^{t-1} l_{i2}^2) = 12$ and $(\sum_{i=0}^{t-1} n_{i1}^2 + \sum_{i=0}^{t-1} n_{i2}^2) = 4$, hence design is optimal.

Example 3.2. For $t=7$ in the series $COD(t, 2t, \frac{t+3}{2})$, arranging ten numbers from the group $Z_7 = \{0, 1, 2, 3, 4, 5, 6\}$ in 5×2 matrix X gives terrace(1, 2, 7) because $X^{(1)}$ contains each non zero numbers of Z_7 exactly one time, zero exactly two times and $X^{(2)}$ contains each non zero number of Z_7 exactly one time as shown below.

$$X = \begin{pmatrix} 0 & 0 \\ 1 & 6 \\ 4 & 3 \\ 2 & 5 \\ 2 & 5 \end{pmatrix} \quad X^{(1)} = \begin{pmatrix} 1 & 6 \\ 3 & 4 \\ 5 & 2 \\ 0 & 0 \end{pmatrix} \quad \text{and} \quad X^{(2)} = \begin{pmatrix} 4 & 3 \\ 1 & 6 \\ 5 & 2 \end{pmatrix}.$$

Adding each number of Z_7 to the matrix X reduced modulo 7 constructs the minimal balanced $COD(7, 14, 5)$ given by

	<i>Experimental units</i>														
	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>10</i>	<i>11</i>	<i>12</i>	<i>13</i>	<i>14</i>	
<i>Periods</i>	<i>1</i>	0	0	1	1	2	2	3	3	4	4	5	5	6	6
	<i>2</i>	1	6	2	0	3	1	4	2	5	3	6	4	0	5
	<i>3</i>	4	3	5	4	6	5	0	6	1	0	2	1	3	2
	<i>4</i>	2	5	3	6	4	0	5	1	6	2	0	3	1	4
	<i>5</i>	2	5	3	6	4	0	5	1	6	2	0	3	1	4



Note that, $\lambda_1 = 2, \lambda_2 = 1, \lambda_3 = 2, \lambda_4 = 1$ and $ES = 86\%$. Also, $(\sum_{i=0}^{t-1} l_{i1}^2 + \sum_{i=0}^{t-1} l_{i2}^2) = 14$ and $(\sum_{i=0}^{t-1} n_{i1}^2 + \sum_{i=0}^{t-1} n_{i2}^2) = 6$, hence design is optimal.

Case 3.2. For $s = 1, p = t + 1, g_1 = 1$ and $g_2 = 1$, a $terrace(t, 1, 1)$ in $p \times 1$ matrix produces a series of minimal balanced $COD(t, t, t + 1)$ by adding all the numbers of Z_t to each elements of X reduced modulo t .

Here, $\lambda_3 = g_2 = 1$ and hence from the Equations (1)–(3), $\lambda_1 = 1, \lambda_2 = 1$ and $\lambda_4 = 1$. Now, substituting $\lambda_1 = 1$ in Equations (4) and (5) respectively, $(\lambda_1(p - 1) - \lambda_3) = t - 1$ and $\lambda_1(p - 2) = t - 1$, which is divisible by $t - 1$. Hence, $COD(t, t, t + 1)$ is minimal balanced, because, $\lambda_1 = 1$ is the smallest integer which satisfies both the conditions of minimal balanced.

Theorem 3.2 . If $terrace(t, 1, 1)$ have minimum value of $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2$ and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2$ among all possible $terrace(t, 1, 1)$, then design d^* with $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2 = t + 7$ for odd t , $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2 = t + 5$ for even t and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2 = t + 1$ from $terrace(t, 1, 1)$ is universal optimal for treatment effects over $COD(t, t, t + 1)$.

Proof 3.2. Under model 7, for any balanced crossover design d in $COD(t, t, t + 1)$, the coefficient matrix C_d of the reduced normal equations for τ is same as shown in Theorem 3.1. Hence, C_d is completely symmetric. Now, the trace of C_d is maximum if and only if the $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2$ and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2$ are minimum. Minimization of $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij}^2$ and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij}^2$ subject to $\sum_{i=0}^{t-1} \sum_{j=1}^s l_{ij} = t + 1$ and $\sum_{i=0}^{t-1} \sum_{j=1}^s n_{ij} = t - 1$ respectively leads to, for odd t ,

$$\begin{aligned} trC_d &\leq t \left(\frac{rp - (t + 7) + p}{p} - \frac{p}{r_2p - (t + 1)} \right) \\ &\quad + t \left(\frac{r^2 - np - p^2}{np} + \frac{rp(r_2^2 - p(p - 2))}{n(r_2p - (t + 1))(pr_2^2 - p^2(p - 2) + rr_2p - r(t + 1))} \right) \\ &= trC_{d^*} \end{aligned}$$

for even t ,

$$\begin{aligned} trC_d &\leq t \left(\frac{rp - (t + 5) + p}{p} - \frac{p}{r_2p - (t + 1)} \right) + \\ &\quad t \left(\frac{r^2 - np - p^2}{np} + \frac{rp(r_2^2 - p(p - 2))}{n(r_2p - (t + 1))(pr_2^2 - p^2(p - 2) + rr_2p - r(t + 1))} \right) \\ &= trC_{d^*} \end{aligned}$$

Hence, d^* satisfies the sufficient conditions for universal optimality as given by Kiefer (1975) and the theorem is proved.

Example 3.3. For $t = 6$ in the series $COD(t, t, t + 1)$, arranging seven numbers from the group $Z_6 = \{0, 1, 2, 3, 4, 5\}$ in 7×1 matrix $X = (0 \ 1 \ 5 \ 5 \ 2 \ 1 \ 3)'$ gives $terrace(1, 6)$ because $X^{(1)}$ contains each non zero numbers of Z_6 exactly one time, zero exactly one time and $X^{(2)}$



A Study of Optimum Timing of Laparoscopic Cholecystectomy in Patients Presenting with Acute Cholecystitis

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ABSTRACT

BACKGROUND

Laparoscopic cholecystectomy is difficult in acute cholecystitis because the gall bladder is usually thick walled and tensely distended. If the inflammation of the gall bladder extends to the porta hepatis the dissection becomes difficult. The normally thin minimally adherent tissue that invest the cystic duct and artery is markedly thickened and oedematous and may not readily separate from these structures with the usual blunt dissection technique. The duct wall also may be oedematous, thus making its external diameter similar to gall bladder neck and common bile duct. Moreover, operative difficulty substantially increases with time. It is believed that laparoscopic cholecystectomy in acute cholecystitis is having more operative time, more conversion rate and more chance of injury.

METHODS

We did an observational study to determine the safety, benefits and drawbacks of laparoscopic cholecystectomy within 72 hours of symptoms (and beyond that).

RESULTS

Total 325 patients underwent laparoscopic cholecystectomy in acute cholecystitis. Among them 110 patients were operated within 72 hours of appearance of symptoms while 215 patients were operated upon after 72 hours of appearance of symptoms. The mean duration of surgery was significantly ($p < 0.001$) less in early surgery group. There was no conversion. There was no serious intra operative complication (injury) in early group. There was no statistically significant post-operative complication in either group. Post-operative stay was significantly less ($p < 0.004$) in early laparoscopic cholecystectomy group. Period of return to work was also significantly less ($p < 0.001$) in early group.

CONCLUSIONS

Early (within 72 hours of appearance of symptoms) laparoscopic cholecystectomy can be safely advocated in patients of acute cholecystitis. It does not result in increased conversion rate or increased intra operative complication. Moreover it offers benefits shorter post-operative hospital stay and early return to work than laparoscopic cholecystectomy after 72 hours of appearance of symptoms.

KEY WORDS

Cholecystectomy, Laparoscopic, Cholecystitis, Acute

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BACKGROUND

The advent of laparoscopic cholecystectomy has been a significant milestone not only in the treatment of gallstone disease, but also in the evolution of surgical treatment by minimal access. Anecdotal reports of laparoscopic procedure related death and bile duct related injury necessitate viewing laparoscopic cholecystectomy with cautious enthusiasm.⁽¹⁾ With growing experience overcoming the learning curve, selection criteria for this surgery has become more liberal. Most of previous contraindications such as morbid obesity, previous upper abdominal surgery and acute cholecystitis are no longer absolute contraindications. Studies involving open cholecystectomy have suggested that performing surgery within the first 3 days of onset of symptoms reduced the length of hospital stay and recovery time without increasing complications.⁽²⁾ The appropriate timing for cholecystectomy in the treatment of acute cholecystitis still remains controversial. Reports suggested that early laparoscopic surgery for acute cholecystitis was associated with increased complication rates, prolonged operation times and increased conversion rates.⁽³⁾ As a consequence, initial conservative management with subsequent elective laparoscopic cholecystectomy became the accepted practice.⁽⁴⁾ Delayed cholecystectomy potentially increases the chances of further gallstone related complications and thus farther hospital admission.⁽⁵⁾

How early cholecystectomy is 'early' is not clear in the literature, as this parameter has not been effectively tested in controlled randomized trials. Optimal timing of laparoscopic cholecystectomy for acute cholecystitis still remains under debate.⁽⁶⁾ The aim of this study is to evaluate the results of laparoscopic cholecystectomy for acute cholecystitis when laparoscopy is carried out early (within 72 hours from the onset of the symptoms) and late (after 72 hours from the onset of the symptoms). The objective of this study is to determine optimal timing of surgery with regard to patient safety in cases of acute cholecystitis.

The degree of operative difficulty increases substantially over time in acute cholecystitis and surgeons have typically used 72 hours as an arbitrary cut off in degree of difficulty of dissection. Generally, in the first 48 to 72 hours of symptoms the tissue planes are oedematous, but structures are identifiable, and the tissue planes separate without much difficulty. After 72 hours, the tissues become more friable and separate less well, the important structures are less likely to be seen well and there is often more obscure bleeding. For these reasons it is important to consider operating early in acute cholecystitis. Often patients present late after many days of symptoms or the gallbladder appears extremely oedematous and thick walled on ultrasound. Generally, all of these patients should be considered for laparoscopic cholecystectomy unless they are extremely ill or significant comorbidities exist. If the patient goes to the operating room, an attempt at exposure of the Calot's triangle and a trial dissection should be undertaken. If it is determined that safe laparoscopic cholecystectomy cannot be performed, two potential options exist: 1. Conversion to open surgery or 2. Cholecystostomy tube placement. An open operation might not offer much additional benefit to a very experienced laparoscopic surgeon and many recently trained surgeons

today do not have a great deal of experience performing open cholecystectomy, so that conversion may not be that beneficial to the surgeon or the patient.

METHODS

The study was conducted at department of surgery, SMIMER hospital from September 2013 to December 2015 on patients presented and hospitalised with acute cholecystitis, of all age groups and gender. Thus, patients taken under this study are based on consecutive sampling and purposive sampling (With purpose of patients having acute cholecystitis). Diagnosis of acute cholecystitis was established on following parameters: 1) clinical presentation which included; a) pain in abdomen. b) Tenderness in right hypochondrium. c) Contraction of the abdominal wall in right upper quadrant. d) With or without fever. e) With or without nausea and vomiting. 2) Contributory laboratory findings. 3) Abdominal ultrasonographic confirmation of the diagnosis by presence of gallstones, gallbladder wall oedema, pericholecystic fluid collection. 4) Intra-operative findings 5) histopathologic examination. All cases undergone laparoscopic cholecystectomy, were studied under two categories: Group A: laparoscopic cholecystectomy performed within 72 hours of onset of symptoms of acute cholecystitis. Group B: laparoscopic cholecystectomy performed after 72 hours of onset of symptoms of acute cholecystitis. The following parameters were analysed: 1) demographic information, laboratory tests and ultrasonographic features. 2) Duration of surgery. 3) Duration of postoperative hospital stay. 4) Incidence of major biliary injury and injury to other organs. 5) Conversion of laparoscopic surgery to open surgery.

Laparoscopic cholecystectomy was performed using standard technique under general anaesthesia. It is an observational study with consecutive and purposive sampling. All patients registered from September 2013 to December 2015 who were hospitalised with acute cholecystitis, of all age groups and gender are considered as sample of study. So, the sample size is 325 patients. Amongst them 110 patients were operated within 72 hours of diagnosis and 215 patients were operated after 72 hours of diagnosis. So, study is based on two non-randomized groups. (Group A: 110 patients, group B: 215 patients).

Statistical Analysis

Descriptive and Inferential statistics have been carried out in the study. Using descriptive statistics, results on quantitative data are presented in mean (+/-) standard deviation and results on qualitative data are presented in percentage (%). Using inferential Statistics, significance is assessed at 95% level of significance. Student t test (two tailed, independent) has been used to find the significance of study parameters on continuous scale between two groups on metric parameters. Chi-square test, Fisher exact test and Yate's correction has been used to find the significance of study parameters on categorical scale between two groups. Data analysis is done using open EPI software. Microsoft Word and Microsoft Excel used to generate graphs, tables etc.

RESULTS

33.84% patients were operated upon within 72 hours of onset of symptoms and included in group A. 66.16% patients were operated upon after 72 hours of onset of symptoms and included in group B. Mean age (Mean±SD) for group A is 37.94±12.82 years and for group B it is 40.13±13.92 years. Group A included 18.19% males and 81.81% females; Group B included 24.65% males and 75.35% females. Most common presenting complaint was pain in abdomen which was seen in all patients. 46.36% of patients in group A and 43.25% of patients in group B were febrile at the time of presentation. One third of the patients (35.6%) presented within 24 hours of onset of complaints. Eleven percent of patients were found to have raised temperature (>100°F). Only 2.5% of patients had pulse rate more than 100 per minute. All patients presented with tenderness in right hypochondrium. Guarding was present in 71.81% of group A and 78.60% of patients of group B. Lump was palpable in 12.30% cases (13.63% in group A and 11.62% in group B).

Total WBC count between 11000-15000/cmm was noted in 45.45% of patients in group A and 55.34% of patients in group B. Total 18 (5.54%) patients had serum bilirubin levels more than 2 mg/dl (2.73% patients in group A and 6.98% in group B). Serum AST, serum ALT and serum ALP levels were found to be elevated only in 13.3%, 17.5% and 11.4 % patients respectively (In 11.82%, 16.37% and 8.19% patients respectively in group A, while in 13.96%, 18.14% and 13.03% respectively in group B). Majority of patients (72%) had multiple gallbladder calculi (71.81% in group A and 72.09% in group B) while pericholecystic fluid was present in 1.5% of cases (0.9% in group A and 1.86% in group B). Wall thickening was present in 72% of patients (58.18% in group A and 79.06% in group B). Common bile duct was normal in 98.5% of patients (99.09% in group A and 98.14% in group B).

Particulars	Group A	Group B	Particulars	Group A	Group B
N	110	215	WBC (11000-15000/cmm) (in %)	45.45	55.34
Percentage	34.92	68.25	Serum bilirubin levels (>2 mg/dl) (in %)	2.73	6.98
Mean	37.94	40.13	Serum AST (in %)	11.82	13.96
S.D.	12.82	13.92	Serum ALT (in %)	16.37	18.14
Male (%)	18.19	24.65	Serum ALP (in %)	8.19	13.03
Female (%)	81.81	75.35	Multiple gallbladder calculi (in %)	71.81	72.09
Febrile at the time of presentation (%)	46.36	43.25	Presence of pericholecystic fluid (in %)	0.9	1.86
Guarding (%)	71.81	78.6	Wall thickening (in %)	58.18	79.06
Lump	13.63	11.62	Normal Common bile duct (in %)	99.09	98.14
Mean Duration of Surgery	75.55	94.16	Standard Deviation of Duration of Surgery	10.47	13.47

Table 1. Descriptive Analysis (Pre Operation)

	N	Mean	S.D.	t-test	p-Value	Conclusion
Group A	110	75.55	10.47	12.281	0.000	Mean duration of surgery of group A is significantly less than group B.
Group B	215	94.16	13.47			

Table 2. Comparison of Mean Duration of Surgery Using Independent t Test

No patient in group A needed to be converted from laparoscopic to open procedure. In group B, laparoscopic surgery had to be converted in open surgery in 3 patients, due to intra-operative bleeding in 1 patient, due to difficult anatomy in 1 patient and due to adhesions in 1

patient. Duration of surgery was 75.55 +/- 10.87 minutes in group A, while it was 94.16 +/- 13.87 minutes in group B. The P value is less than 0.001. It shows that mean duration of surgery in patients operated under group A was significantly less than those operated under group B.

Most patients (95.38 %) had oedematous gallbladder (96.36% in group A and 95.38% in group B). Adhesions were present in 90.70% cases (90% in group A and 90.47% in group B) while cystic duct was normal in 96.92% cases (98.19% in group A and 96.28% in group B). Intraoperative bleeding was noted in 1.81% of cases in group A and 7.44% of cases in group B. Gallbladder perforation was noted in 1.81 % patients in group A and 7.44% patients in group B. Gallbladder aspiration was done in 2 cases. Bile duct injury occurred in 2 cases of group B. Stone spillage occurred in 0.9% of cases in group A and 4.18 % of cases in group B.

	Group A		Group B		p	Total Patients	% of Total
	No.	%	No.	%			
Bile Leak - Yes	-	-	1	00.46	1	1	00.40
Bile Leak - No	110	100	214	99.54		324	99.60
Icterus - Yes	-	-	3	01.39	0.5763	3	00.92
Icterus - No	110	100	212	98.61		322	90.08
Uncontrolled BP	-	-	3	01.39	0.5763	3	00.92
Uncontrolled Sugar	1	0.90	4	01.86	0.8547	5	01.53
Wound infection	1	0.90	9	4.18	0.2011	10	03.08

Table 3. Post-Operative Complications

	N	Mean	S.D.	t-test	p	Conclusion
Group A	110	4.46	3.73	2.884	0.004	Mean duration of postoperative stay of group A is significantly less than group B.
Group B	215	5.92	5.26			

Table 4: Comparison of Mean Duration of Postoperative Stay Using Independent T Test

Bile leak found postoperatively in one patient of group B. Icterus observed in 3 cases of group B. Surgical site infection occurred in 0.9% cases in group A and 3.08% of group B cases. P value is > 0.05 for all parameters including bile leak, icterus, uncontrolled blood pressure, uncontrolled blood sugar and wound infection. It means there is no statistically significant difference in occurrence of postoperative complications between group A and group B.

Most of the patients (50.15 %) were discharged within 3 days after surgery (60% in group A and 45.16 % in group B) while 24.92 % patients were discharged between 4 to 7 days after surgery. 55.15% of patients (60 % from group A and 45.16 % from group B) were discharged within 3 days of surgery. 20.9 % of patients from group A and 26.97 % of patients from group B (Total 24.92 %) were discharged within 4-7 days. 19.08% (17.27% from group A and 20% from group B) of patients were discharged in second week. Total of 19 (5.85%) patients (2 in group A and 17 in group B) were discharged after 2 weeks. Three of them had uncontrolled hypertension, four had uncontrolled sugar and nine of them had surgical site infection. Mean post-operative stay is 4.46 +/- 3.73 days in group A and 5.92 +/- 5.26 days in group B. The P value is p< 0.004. It shows that mean duration of postoperative stay in group A was significantly less than that in group B. Return to work was calculated from the day of surgery.

97.27% of patients in group A while 69.76% of patients in group B returned to work in first week of surgery. Of remaining patients of group B, 25.58 % returned to work in second week and 4.64 % in third week of surgery. P value is

$p < 0.001$. It shows that period for return to work is significantly less for patients in group A than for those in group B. About two third of the patients, 217 patients (66.80%) were found to have acute on chronic cholecystitis on histopathology report (91.81 % in group A and 53.95% in group B).

DISCUSSION

Several authors have reported performing laparoscopic cholecystectomy in the face of acute inflammation with success but with a higher conversion rate than for elective laparoscopic cholecystectomy.^(7,8,9,10) Lo et al in their prospective study reported that despite longer operative times and postoperative stays for early laparoscopic cholecystectomy (treatment within 5 days) versus delayed laparoscopic cholecystectomy (initial conservative treatment followed by laparoscopic cholecystectomy 3 to 4 months later), the advantage of early laparoscopic cholecystectomy was the reduction in the total hospital stay, from 15 to 7 days.⁽¹¹⁾ Another prospective study of 105 patients randomized to early laparoscopic cholecystectomy (within 24 hours of diagnosis of acute cholecystitis) versus delayed laparoscopic cholecystectomy (6 to 8 weeks later), reported no significant difference in conversion rate (Early 21% vs. delayed 24%), postoperative analgesic requirement or number of postoperative complications. The early group did have a longer operative time (123 min vs 107 min, $p = 0.04$); but total hospitalization was shorter (8 days v/s 12 days; $p = 0.001$).⁽¹²⁾

Rattner et al attempted laparoscopic cholecystectomy for acute cholecystitis and examined factors that were predictive of a successful procedure.⁽¹³⁾ Seven of the 20 patients (35%) required conversion to open cholecystectomy. The interval from admission to cholecystectomy in the successful cases was 0.6 days versus 5 days in the cases requiring conversion to open cholecystectomy. Chahin et al examined the relationship between the success rates for laparoscopic surgery and the time from onset of acute cholecystitis symptoms to surgery. The success rate has dropped significantly after the first 4 days.⁽¹⁴⁾ These results have been confirmed in more recent studies. In the study by Shamim disturbed anatomy at Calot's triangle accounted for more than one half of conversions (54.32%); The reasons of obscured anatomy were acute inflammation (52.27%), chronic cholecystitis (36.36%) and aberrant anatomy (11.36%).⁽¹⁰⁾ In 6.17% patients, dense adhesions were found between gallbladder and bowel. (3 with the stomach and 2 with the transverse colon). They were difficult to separate laparoscopically, so conversion to open surgery was made. With increasing laparoscopic experience, an inverse trend in conversion rates is seen.

CONCLUSIONS

Cholecystectomy for acute cholecystitis can be safely advocated in patients presenting within 72 hours of onset symptoms. This does not result in increased major

complication rates and conversion rates. Early laparoscopic cholecystectomy is not associated with more conversion to open procedures. Decreased conversion rates result in shorter post-operative hospital stay. Early cholecystectomy is beneficial as patients tend to return to work earlier.

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Angiolymphoid Hyperplasia with Eosinophilia Treated with Isotretinoin.

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Sunil N. Petkar¹, Venkatesh Giri², Pranit Farande³, Jigar Patel⁴, Asha Kushwaha⁵
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Garima Shah1, Rajni Soni2, Manjula Mehta3

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Role of Multi Detector Computed Tomography in the Evaluation of Glenoid Track in Patients with Anterior Instability and Its Correlation with Arthroscopy.

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Prabhu Radhan1, Yoshitha Siripurapu2, Prakash Ayyadurai3, Bhaskar Raj4, Arumugam Sivaraman5, Rajoo Ramachandran6

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Incidence and Clinical Outcome of Acute Kidney Injury in Patients with Sepsis Admitted in Multi-Disciplinary Unit in a Tertiary Care Center.

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Hussain Khan Tharappel Jalal1, Teju Parankimamootil Thomas2, Sreedas Gopalakrishnan3, Hamdan Mohammed4

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Faiza Hafiz1, Akhtar Un Nisa Salaria2, Kuldeep K. Koul3

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Suresh Kumar K.1, Anu Asokan2

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Correlation of Serum Fetuin A and Matrix Metalloproteinase-7 Levels in Periodontitis and the Outcome of Initial Periodontal Therapy on Their Levels - A Preliminary Report.

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Reena Lobo¹, M. L. V. Prabhuji², Karthikeyan B. V.³, Greeshma C.⁴

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Durga Prasada Rao Pothula¹

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Aarthi Rajamanickam¹, Manjula T. Rajendran², Sumangala Basavarajaiah³, Prathibha Shiveshi⁴

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Sudhakaran Selvaraj¹, Senthil Kumar Sivalingam²

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Date : 30-12-2019

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Compare and Correlate the Presence of Bacterial Pathogen Concentrations and Glycaemic Status in Type 2 Diabetic and Non-Diabetic Patients with Chronic Periodontitis Following Phase 1 Therapy.

Date : 30-12-2019

Amit Lakhani¹, Ena Sharma², Surinder Sachdeva³, Supreet Thind⁴, Karun Chaudhary⁵, Savita Kapila⁶

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Date : 30-12-2019

Sukumar Mitra¹, Seema Das²

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CORPORATE GOVERNANCE DISCLOSURE PRACTICES AND ITS IMPACT ON FINANCIAL PERFORMANCE: A CASE STUDY ON PHARMA SECTOR IN INDIA

ABSTRACT:

India is a strong emerging force on the global map. Corporate Governance is an integral part of the broader governance of the country. The CG Disclosure is important because reporting is widely viewed as the most effective tool to encourage better Corporate Governance Practices. India enjoys an important position in the global pharmaceuticals sector. This study is basically an analytical in nature. Period of the Study is 2012-13 to 2016-17. Ten Companies belonging to pharma sector are considered for the study. In present study using Panel data regression analysis, appropriate model is fitted for Tobin's Q, MVBV and Market Capitalisation using CG Score as an independent variable and ROA, ROE, D/E Ratio, DPR, Sales Growth, NPM, NAV and Firm Size as controlled variables. It is concluded that CG score has positive impact on firm performance.

Key words: Corporate Governance, Tobin's Q, Market Capitalisation, MV/BV Ratio, D/ E Ratio, Disclosure Score

INTRODUCTION:

India is a strong emerging force on the global map. The growth is enabled by the development of public and private sector enterprises across all the sectors of economy. The regulatory and legal framework of the governance is the way for the India to become a global leader. Corporate Governance is an integral part of the broader governance of the country.

Corporate Governance is the set of processes, customs, policies, laws and institutions affecting the way a corporation is directed, administered and controlled. The Prime objective of corporate governance is to contribute in the growth and development of organization by healthy practices and self sustainance in a competitive business environment, resolving conflicts and infusing confidence in the minds of shareholders and stakeholders. As good governance is the demand of the Information efficient market, corporate governance practices need a remarkable improvement in India. The CG Disclosure is important because reporting is widely viewed as the most effective tool to encourage better Corporate Governance Practices.

Grounds for Selecting Pharmaceutical Sector

India is the largest provider of generic drugs globally. Indian pharmaceutical industry supplies over 50% of global demand for various vaccines, 40% of generic demand in the US and 25% of all medicine in UK. India enjoys an important position in the global pharmaceuticals sector. The India's pharmaceutical industry is expected to expand at a CAGR of 22.4% over 2015-2020 to reach US\$ 55 billion. By 2020, India is likely to be among the top three pharmaceutical markets by incremental growth and 6th largest market globally in absolute size. Because of such explosive opportunities, the pharmaceutical market is alluring for a deeper study; hence selected for the study.

REVIEW OF LITERATURE:

Gugler, Mueller, & Yurtoglu (2003) attempted to shed a light on three conundrums of investment literature. They concluded that managers in countries of strong corporate governance preferred to rely on internal cash flow whereas managers in weak corporate governance countries were free to use the equity market as a source of finance. Moreover, managers with very attractive investment opportunities would favor equity over debt. It was also observed that weak corporate governance practices in developing countries provided less check on managers who wished to issue



equity to finance low return investments. They also conferred that weak corporate governance system led to slow economic growth and vice versa. Stronger accounting standards and better enforcement had a significant impact on firm performance so it had been suggested as a modest reform.

Inessa (2011) has tried to establish relationship between corporate governance and firm performance as measured by valuation ratio, operating performance or stock return. Most of the research till date suggested a positive correlation between CG score and firm performance. However, it suffered from endogeneity problems and that was difficult to resolve. The emerging conclusion indicated that corporate governance was likely to develop endogenously which depended on firm specific characteristic.

Vinitila & Stefan (2012) examined the relationship between corporate governance ratings and firm performance using the cross-sectional multiple linear regression model for 155 US companies listed on New York Stock Exchange. Negative relationship had been shown between corporate governance global rating and firm performance as well as between corporate governance sub-indices and firm performance. Hence, it was suggested that investors and shareholders should not rely entirely on commercial corporate governance ratings to make investment decisions.

Mittal & Zaidi (2015) have conducted study on 16 major industries covered under NSE CNX 100. It was concluded that healthcare, chemical, pesticides and fertilizers industries have built a strong relation with the shareholders by adopting maximum disclosure requirements whereas media and advertising companies have adopted only mandatory norms and were silent on voluntary norms. As a result, SEBI has made best standards on Corporate Governance practices for non-mandatory norms also.

Varshney, Kaul, & Vasal (2015) have used Economic Value Added as a value based performance measure as the primary metrics to measure the firm performance. To evaluate the linkage between corporate governance and firm performance, along with Economic Value Added other financial parameters used were Return on Net Worth, Return on Capital Employed and Tobin's Q. Sample size is CNX Nifty (Nifty) and CNX Nifty Junior (Nifty Junior) consisting 50 stocks (June 2011) have been considered. The analysis stated significantly positive correlation between the corporate governance index and Economic Value Added. Thus it was concluded that positive relationship existed between corporate governance and firm performance when Economic Value Added was considered as dependent variable. The relationship could not be validated for the traditional performance tools like return on net worth, return on capital employed and Tobin's Q.

RESEARCH METHODOLOGY:

This study is basically an analytical in nature to examine the Corporate Governance Disclosure Practices followed by the selected companies. The researcher has relied on the Corporate Governance Report for nonfinancial parameters and Annual reports of companies for financial parameters to critically analyse the performance of the selected listed companies. Period of the Study is 2012-13 to 2016-17. Ten Companies belonging to pharma sector considered for the study are enumerated as under:

Table No. 1 : Selected Pharmaceutical Companies	
Sr. No.	Name of Pharmaceutical Company
1	AurobindoPharma Ltd.
2	Biocon Ltd.
3	Cadila Healthcare Ltd.
4	Cipla Ltd.
5	Divis Laboratories Ltd.
6	DrReddys Laboratories Ltd.
7	Glen Mark Pharmaceuticals Ltd.
8	Lupin Ltd.
9	Sun Pharmaceutical Industries Ltd.



It is attempted to evaluate the whole mechanism of the corporate governance adopted by considered companies in pharma sector. The Disclosure score is calculated by assigning a weight to each of the parameter. Companies are scored out of 100 for their corporate governance practices and disclosures. Financial parameters apart from nonfinancial parameters used are Return on Assets, Return on Equity, Debt Equity Ratio, Dividend Payout Ratio, Market Value to Book Value Ratio, Tobin's Q, Sales Growth, Net profit Margin, Net Assets Value and Market Capitalisation.

Tools and Techniques used:

For the purpose of analysis of data, the Statistical techniques used were Shapiro Wilk Test and Panel Data Regression Analysis. Statistical tools like SPSS 21(trialversion) and EViews 10 Student Version Lite were used.

Correlation Analysis of CG Score with Parameters of Financial Performance:

In the present study it is examined whether Corporate Governance Score and other financial variable significantly affect MV/BV Ratio, Tobin's Q as well as

Market Capitalisation or not.

To verify the assumption of normality, Shapiro Wilk test statistic is applied as data is less than 100

Table No. 2 : Test of Normality			
Shapiro-Wilk Test			
	Statistic	Df	Sig.
CGSCORE	.937	50	.010
ROA	.978	50	.475
ROE	.978	50	.472
DERATIO	.866	50	.000
TOBINQ	.895	50	.000
DPR	.802	50	.000
SALES GROWTH	.547	50	.000
NPM	.943	50	.018
MARKETCAP	.693	50	.000
NAV	.939	50	.012
MVBVRATIO	.873	50	.000

It can be seen that p value of Shapiro – Wilk test statistic is less than 0.05 for all considered variables except ROA and ROE. So the considered variables do not follow normal distribution. So to test the significant correlation coefficient between any two parameters of financial indicators, Kendal Tau test (nonparametric test) is used.



Table No. 3: Correlation Coefficient : Pharma Sector

		CG SCOR E	ROA	ROE	D/E RATI O	TO BIN Q	DPR	SALES GROW TH	NPM	MARK ET CAP	NAV	MV/ BV RAT IO
CG SCORE	r	1.000										
	p value											
ROA	r	.050	1.000									
	p value	.614										
ROE	r	.082	.788	1.000								
	p value	.410	.000									
D/E RATIO	r	.188	-.111	.077	1.000							
	p value	.063	.261	.440								
TOBIN Q	r	.108	.037	.038	-.050	1.000						
	p value	.279	.707	.694	.615							
DPR	r	-.066	.081	.076	-.115	-.084	1.000					
	p value	.512	.407	.436	.247	.389						
SALES GROW TH	r	-.106	.369	.422	.071	-.072	-.115	1.000				
	p value	.293	.000	.000	.475	.461	.244					
NPM	r	.024	.649	.543	-.231	.068	.216	.222	1.000			
	p value	.814	.000	.000	.020	.487	.028	.024				
MARK ET CAP	r	.251	-.171	-.209	-.028	.468	-.286	-.245	-.133	1.000		
	p value	.012	.080	.033	.776	.000	.003	.013	.173			
NAV	r	.254	-.163	-.187	.045	.118	-.281	-.227	-.274	.549	1.000	
	p value	.011	.096	.055	.651	.225	.004	.021	.005	.000		
MV/B V RATIO	r	.153	.038	.075	.089	.795	.015	-.075	.088	.408	.056	1.000
	p value	.126	.700	.441	.370	.000	.880	.446	.366	.000	.569	

It can be observed that MV/BV Ratio and Tobin's Q have no significant correlation with CG Score whereas Market Capitalisation has significant correlation with CG Score for Pharma Sector. MV/BV Ratio has positive correlation with Tobin's Q and Market Capitalisation at 1% significance level. Tobin's Q has positive correlation with Market Capitalisation and MV/BV Ratio at 1% significance level. Market Capitalisation has positive correlation with CGRS Score, Tobin Q, NAV and MV/BV Ratio as well as negative correlation with ROA, ROE, DPR and sales growth at 10% significance level for Pharma Sector.



Panel Data Regression Analysis:

Panel data (also known as longitudinal or cross-sectional time-series data) is a dataset in which the behavior of companies is observed across time. Panel data considers individual heterogeneity which leads to efficient estimates. The regression model of panel data is known as panel data regression model.

In present study one way Fixed Effect Regression Model or one way Random Effect Regression Model is used for Tobin's Q, MVBV and Market Capitalisation using CG Score as an independent variable and ROA, ROE, D/ERatio, DPR, Sales Growth, NPM, NAV and Firm Size as controlled variables.

Panel Data Regression Model For Tobin's Q :

For Pharma Sector, it was observed through Hausman test that Random Effect Model is appropriate. From Table No. 4, it can be observed that p value (0.0037) of the F statistic (4.52) is less than 0.05. So model is statistically significant.

Table No. 4: Random Effect Model of Tobin's Q for Pharma Sector				
Dependent Variable: TOBINQ				
Method: Panel EGLS (Cross-section random effects)				
Periods included: 5				
Cross-sections included: 10				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	11.83219	3.641730	3.249057	0.0022
CGSCORE	0.111271	0.035891	3.100287	0.0033
ROE	-0.008526	0.024637	-0.346047	0.7309
D/ERATIO	-2.747510	1.339357	-2.051366	0.0461
FIRMSIZE	-2.066846	0.549187	-3.763464	0.0005
R-squared	0.286765	F-statistic		4.523207
S.E. of regression	1.141636	Prob(F-statistic)		0.003715

$$\text{Tobin's } \hat{Q}_{it} = 11.83 + 0.11\text{CGScore}_{it} - 0.008\text{ROE}_{it} - 2.75\text{D/ERatio}_{it} - 2.07\text{FirmSize}_{it}$$

H_0 : Random Effect Model is appropriate.

H_1 : Fixed Effect Model is appropriate.

Table No. 5 : Hausman Test – Tobin's Q for Pharma Sector			
Correlated Random Effects - Hausman Test			
Equation: Untitled			
Test cross-section random effects			
Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	9.397009	4	0.0519

From the above Table No 5, it can be observed that p value of Hausman chi square test is 0.0519 i.e. greater than 0.05. So, H_0 cannot be rejected. So, the fitted Random Effect Model of Tobin's Q for Pharma Sector is appropriate. CGScore affects positively to Tobin's Q at 1% level of significance and D/E Ratio as well as firm size affect negatively to Tobin's Q at 5% and 1% level of significance respectively. The variation in Tobin's Q is explained 28.68% by the all explanatory and control Variables together. Assuming control variables as constant, if CGScore increases by one unit across time and between companies then Tobin's Q goes up on an average by 0.11 percent. Same way, assuming independent and other control variables as constant, if D/E Ratio increases by one time across time and between companies then Tobin's Q goes down on an average by 2.75 percent. Assuming independent and other control variables as constant, if Firm size increases by one percent (in terms of natural log of NAV) across time and between companies then Tobin's Q goes down on an average by 2.07 percent. ROE does not impact significantly on Tobin's Q as p value is greater than 0.05. If all control variables and independent variable are zero then average common value of intercept is 11.83.

Panel Data Regression Model for Market Capitalisation:

It was observed through Hausman test that Fixed Effect Model is appropriate. This can be seen from the following Table No.6 of Random Effect Regression Model and Table No. 7 of Hausman Test.

Table No. 6 : Random Effect Model of Market Cap for Pharma Sector				
Dependent Variable: MARKETCAP				
Method: Panel EGLS (Cross-section random effects)				
Periods included: 5				
Cross-sections included: 10				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-92956.29	34452.78	-2.698078	0.0099
CGSCORE	1559.626	420.8761	3.705664	0.0006
DPR	-227.5988	149.1745	-1.525721	0.1344
SALESGROWTH	135.0389	64.63475	2.089262	0.0426
NPM	-546.9532	509.8239	-1.072828	0.2893
NETASSETSVALUE	10.48555	3.825689	2.740828	0.0089
DERATIO	-2853.662	17894.15	-0.159475	0.8740
R-squared	0.625345	F-statistic		11.96206
S.E. of regression	13156.94	Prob(F-statistic)		0.000000

From the above Table No.6, it can be said that model is appropriate and CG Score, Sales Growth and NAV have statistically significant impact on Market Capitalisation but DPR, NPM and DE Ratio have no significant impact on Market Capitalisation. But Hausman test revealed that Random Effect Model is not appropriate.

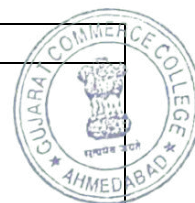
H_0 : Random Effect Model is appropriate.

H_1 : Fixed Effect Model is appropriate.

Table No. 7: Hausman Test – Market Cap for Pharma Sector			
Correlated Random Effects - Hausman Test			
Equation: Untitled			
Test cross-section random effects			
Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	13.001765	6	0.0430

From the above Table No. 7, it can be observed that p value of Hausman chi square test is 0.043 i.e. less than 0.05. So, H_0 can be rejected. So, the fitted Random Effect Model of Market Capitalisation for Pharma Sector is not appropriate. So, Fixed Effect Model is fitted as below.

Table No. 8 : Fixed Effect Model of Market Cap for Pharma Sector				
Dependent Variable: MARKETCAP				
Method: Panel Least Squares				
Periods included: 5				
Cross-sections included: 10				
MARKETCAP=C(1)+C(2)*CGSCORE+C(3)*DPR+C(4)*SALESGROWTH+C(5)*NPM+C(6)*NETASSETSVALUE+C(7)*D/ERATIO+C(8)*D2+C(9)*D3+C(10)*D4+C(11)*D5+C(12)*D6+C(13)*D7+C(14)*D8+C(15)*D9+C(16)*D10				
	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-144167.3	39163.44	-3.681170	0.0008
C(2)-CGScore	1692.838	433.0552	3.909059	0.0004
C(3)-DPR	-259.1807	151.5771	-1.709894	0.0964
C(4)-SalesGrowth	121.1031	64.78850	1.869207	0.0702
C(5)-NPM	-92.16429	539.3037	-0.170895	0.8653
C(6)-NAV	9.987178	4.074411	2.451195	0.0195
C(7)-D/ERatio	9516.592	19791.64	0.480839	0.6337



C(8)-D2	18280.94	16065.61	1.137892	0.2631
C(9)-D3	22823.52	9091.799	2.510341	0.0170
C(10)-D4	23422.90	15271.23	1.533793	0.1343
C(11)-D5	24532.29	14041.75	1.747096	0.0896
C(12)-D6	9679.027	10956.02	0.883443	0.3832
C(13)-D7	13887.26	13502.60	1.028488	0.3110
C(14)-D8	43757.40	13244.07	3.303923	0.0023
C(15)-D9	142412.5	14966.96	9.515121	0.0000
C(16)-D10	10929.65	9212.789	1.186357	0.2437
R-squared	0.948243	F-statistic	41.52781	
S.E. of regression	12201.02	Prob(F-statistic)	0.000000	

From Table No. 8, it can be observed that p value (0.000) of the F statistic (41.53) is less than 0.05. So model is statistically significant. CG Score affects positively to Market Capitalisation at 1% level of significance. NAV affects positively to Market Capitalisation at 5% level of significance. Sales Growth affects positively to Market Capitalisation at 10% level of significance. DPR affects negatively to Market Capitalisation at 10% level of significance. The variation in Market Capitalisation is explained 94.82% by the all explanatory and control Variables together. Assuming control variables as constant, if CG Score increases by one unit across time and between companies then Market Capitalisation goes up on an average by 1692.84 crore rupees. Same way, assuming independent and other control variables as constant, if NAV increases by one crore rupees across time and between companies then Market Capitalisation goes up on an average by 9.99 crore rupees. Same way, assuming independent and other control variables as constant, if DPR increases by one percent across time and between companies then Market Capitalisation goes down on an average by 259.18 crore rupees. Same way, assuming independent and other control variables as constant, if sales growth increases by one percent across time and between companies then Market Capitalisation goes up on an average by 121.10 crore rupees. NPM and D/E Ratio do not impact significantly to Market Capitalisation as p value is greater than 0.10. The intercept value for Aurobindo Pharma Ltd. is -144167.3, for Biocon Ltd. is -125886.36, for Cadila Healthcare Ltd. is -121343.78 and so on. The intercept value for each company is different may be due to unique feature of the company and the difference is statistically significant for some companies and the difference is statistically not significant for some companies. So, again it is tried to check whether Fixed Effect Model is appropriate or not. If Fixed Effect Model is not appropriate then Pooled Regression Model can be considered as appropriate.

$$\hat{MarketCap}_{it} = -144167.3 + 18280.94D_{2i} + 22823.52D_{3i} + 23422.90D_{4i} + 24532.29D_{5i} + 9679.03D_{6i} + 13887.26D_{7i} + 43757.4D_{8i} + 142412.5D_{9i} + 10929.65D_{10i} + 1692.84CGScore_{it} - 259.18DPR_{it} + 121.10SalesGrowth_{it} - 92.16NPM_{it} + 9.99NAV_{it} + 9516.59D/ERatio_{it}$$

H_0 : Pooled OLS Regression Model is appropriate (All dummy variables equal zero)

H_1 : Fixed Effect Model is appropriate (All dummy variables does not equal zero)

Table No. 9: Wald Test – Market Cap for Pharma Sector			
Wald Test:			
Equation: Untitled			
Test Statistic	Value	df	Probability
F-statistic	31.62192	(9, 34)	0.0000
Chi-square	284.5973	9	0.0000

From the above Table No. 9, it can be observed that p value of Wald test is 0.0000 i.e. less than 0.05. So, H_0 can be rejected. So, the fitted Fixed Effect Model of Market Capitalisation for Pharma Sector is appropriate.

Panel Data Regression Model for MV/BV Ratio:

For Pharma Sector, it was observed from the Table No.10 that p value (0.78) of F – statistic (0.36) is greater than 0.05 i.e. the model is not significant. In other words, Random Effect Model of



MV/BV Ratio is not appropriate. So, Fixed Effect Model of MV/BV Ratio is fitted and represented in Table No. 11.

Table No. 10 : Random Effect Model of MV/BV Ratio for Pharma Sector				
Dependent Variable: MVBV				
Method: Panel EGLS (Cross-section random effects)				
Periods included: 5				
Cross-sections included: 10				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.151410	3.852531	0.558441	0.5793
CGSCORE	0.042115	0.045876	0.918027	0.3634
ROE	-0.003843	0.035659	-0.107761	0.9147
SALESGROWTH	-0.005228	0.008941	-0.584671	0.5616
R-squared	0.023177	F-statistic		0.363819
Adjusted R-squared	-0.040528	Prob(F-statistic)		0.779415
S.E. of regression	1.730106			

The Table No.11 represents Fixed Effect Model of MV/BV Ratio for Pharma Sector. From Table No. 11, it can be observed that p value (0.000) of the F statistic (6.06) is less than 0.05. So model is statistically significant. It can be seen that CG Score affect positively to MV/BV Ratio but effect is not statistically significant. 66.29% of the variation in MV/BV Ratio is explained by the all explanatory and control Variables together. Assuming control variables as constant, if CG Score increases by one unit across time and between companies then MV/BV Ratio goes up on an average by 0.061 times. Same way, assuming independent and other control variables as constant, if ROE increases by one percent across time and between companies then MV/BV Ratio goes up on an average by 0.026 times. But independent variable as well as control variables do not have statistically significant impact on MV/BV Ratio. The intercept value for Aurobindo Pharma Ltd. is -1.07, for Biocon Ltd. is -2.05, for Cadila Healthcare Ltd. is 0.826 and so on. The intercept value for each company is different may be due to unique feature of the company and the difference is statistically significant for one company and the difference is statistically not significant for other companies. So, again it is tried to check whether Fixed Effect Model is appropriate or not. If Fixed Effect Model is not appropriate then Pooled Regression Model can be considered as appropriate.

Table No. 11: Fixed Effect Model of MV/BV Ratio for Pharma Sector				
Dependent Variable: MVBV				
Method: Panel Least Squares				
Periods included: 5				
Cross-sections included: 10				
Total panel (balanced) observations: 50				
MVBV=C(1)+C(2)*CGSCORE+C(3)*ROE+C(4)*SALESGROWTH+C(5)*D2+C(6)*D3+C(7)*D4+C(8)*D5+C(9)*D6+C(10)*D7+C(11)*D8+C(12)*D9+C(13)*D10				
	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-1.074703	4.337305	-0.247781	0.8057
C(2)-CGSCORE	0.060680	0.047560	1.275876	0.2100
C(3)-ROE	0.025753	0.041994	0.613246	0.5435
C(4)-SALESGROWTH	-0.009770	0.009214	-1.060277	0.2959
C(5)-D2	-0.984858	1.260654	-0.781228	0.4396
C(6)-D3	1.896387	1.096778	1.729053	0.0921
C(7)-D4	0.044027	1.306148	0.033708	0.9733
C(8)-D5	1.121667	1.105376	1.014739	0.3168
C(9)-D6	-0.111678	1.159927	-0.096280	0.9238
C(10)-D7	0.035194	1.152516	0.030537	0.9758



C(11)-D8	1.933381	1.091428	1.771424	0.0847
C(12)-D9	7.401563	1.649609	4.486859	0.0001
C(13)-D10	0.696324	1.131157	0.615586	0.5419
R-squared	0.662877	F-statistic	6.062674	
S.E. of regression	1.701922	Prob(F-statistic)	0.000010	

$$\begin{aligned} MV / \hat{BVRatio}_{it} = & -1.07 - 0.98D_{2i} + 1.896D_{3i} + 0.044D_{4i} + 1.12D_{5i} \\ & - 0.112D_{6i} + 0.035D_{7i} + 1.933D_{8i} + 7.40D_{9i} + 0.696D_{10i} \\ & + 0.061CGScore_{it} + 0.026ROE_{it} - 0.0098SalesGrowth_{it} \end{aligned}$$

H_0 : Pooled OLS Regression Model is appropriate (All dummy variables equal zero)

H_1 : Fixed Effect Model is appropriate (All dummy variables does not equal zero)

Table No. 12: Wald Test - MV/BV Ratio for Pharma Sector

Wald Test: Equation: Untitled			
Test Statistic	Value	df	Probability
F-statistic	7.477518	(9, 37)	0.0000
Chi-square	67.29766	9	0.0000



From the above Table No.12 , it can be observed that p value of Wald test is 0.0000 i.e. less than 0.05. So, H_0 can be rejected. So, the fitted Fixed Effect Model of MV/BV Ratio for Pharma Sector is appropriate.

Conclusion:

- MV/BV Ratio and Tobin's Q have no significant correlation with CG Score in Pharma Sector. CG Score does not affect the firm performance in terms of MV/BV Ratio and Tobin's Q in Pharma Sector. Market Capitalisation has significant positive correlation with CG Score in Pharma Sector. CG Score affects the firm performance in terms of Market Capitalisation in Pharma Sector.
- From Random Effect Model, it is revealed that CG Score has significant positive impact whereas D/E Ratio as well as Firm Size have significant negative impact on Tobin's Q in Pharma Sector.
- From Fixed Effect Model, it is revealed that CG Score, Sales Growth and NAV have significant positive impact on Market Capitalisation whereas DPR has significant negative impact on Market Capitalisation in Pharma Sector.
- From Fixed Effect Model, it is revealed that CG Score has little significant positive impact on MV/BV Ratio in Pharma Sector.

Pharmaceutical Sector plays an important role as it is concerned with life of the human being. Transparency in Disclosure Practices is directly related with the health of the citizens as the drugs are available for the sale in the market on the basis of clinical trials. Higher disclosure increases the faith and reliability. It is observed that CG score has positive impact on firm performance.

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A Comparative Trend Analysis of Liquidity Performance Of Selected Indian Pharmaceutical Companies

ABSTRACT

The developing economies like India, Pakistan, Sri Lanka are facing the problems of inadequate financial resources. Capital is the blood vein for any business. In business, money is required for the smooth functioning. The financial system is one of the most important inventions of the modern society. Some company with have surplus funds and some firm with have deficit. Liquidity Management is an intermediary between surplus funds and deficit and facilitates the flow of funds from the areas of surplus to the areas of deficit. The Indian pharmaceuticals market is the third largest in terms of volume and thirteenth largest in terms of value, as per a report by Equity Master. Hence, the Pharmaceutical sector is one among the leading sector in India and therefore this sector will be chosen for further study with regard to its liquidity. Researcher used trend analysis through different liquidity ratios to evaluate the liquidity position of selected Indian pharmaceutical companies.

Key words: *Liquidity Position, Trend analysis, Pharmaceutical companies*

INTRODUCTION:

According to (Bhalaa, 2014) the term Liquidity shows the relationship of current assets and current liabilities. Liquidity has three basic components time, amount and cost. An essential component of liquidity is the time an asset takes to be converted into cash or the time it takes to pay a current liability. So time stated as the ability of the firm to pay its liabilities on time. Liquidity may also be viewed as the ability of the firm to argument its future cash flows to cover any unforeseen needs or to take advantage of any unforeseen opportunities. This concept of liquidity has been referred to as financial flexibility. This viewpoint is much broader and would consider such things as the firm's stability of earnings, its relative debt/equity position and the availability of credit lines. Traditional method of analysis financial position such as ratio analysis is considered a weak tool for monitoring liquidity, but rather that ratios have yet to be developed that effectively measure the liquidity aspect of a business operation. According to (Jethmalani, 2017) goods and service tax applied in India in 1st July, 2017. It is a key challenge that small and medium enterprises are faced with in the goods and service tax era is the need for increased working capital. Ambiguous GST filling process have caused temporary disruption for SMES (small and medium enterprises) as their clients are delaying payments seeking clarity on invoice matching process, resulting in stretched working capital requirements. According to (Kishore, 2009) the quantitative liquidity concept includes the quantum, structure and utilization of liquid assets. The qualitative liquidity concept shows that it is the ability to meet all present and potential demands on cash in a manner that maximize cost and maximizes the value of the firm. The corporate liquidity is a vital factor in business. Excess liquidity though a guarantor of solvency would reflect lower profitability deterioration in managerial efficiency increased speculation and unjustified expansion, extension of too liberal credit and dividend policies. Too little liquidity then may lead to frustration in business operations, reduced rate of return, missed business opportunity and weakening of moral. Lack of liquidity implies lack of freedom of choice as well as constraints of management's freedom of management. If sufficient liquidity is not maintaining the enterprise is technically insolvent and faces the financial embracement of renegotiating its obligations to creditors. Thus the management of liquidity requires active management of working

