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Drawing of Random Four-Digit Numbers from a Single Table of Random Two-Digit Numbers

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ABSTRACT: In the study, behind the content of this paper, an attempt has been made on searching for some method of drawing of random four digit numbers from a single table of random two-digit numbers. A method has been developed here for drawing of random four-digit numbers from a single table of random two-digit numbers as an alternative of the two methods, already developed, of drawing of random four-digit numbers namely (i) drawing of random four-digit numbers from a single table of random four-digit numbers and (ii) drawing of random four-digit numbers from two independent tables of random two-digit respectively. This paper describes the theoretical derivation of the method and numerical example in order to show the application of the method derived.

KEYWORDS: Table of random two-digit numbers, drawing of random four-digit numbers, method of drawing from single table.

I. INTRODUCTION

There had already been a number of studies on the construction of tables of random numbers. These tables have been constructed by *Tippett* (1927), *Mahalanobis* (1934), *Kendall* & *Smith* (1938 , 1939), *Fisher* & *Yates* (1938), *Hald* (1952), *Royo* & *Ferrer* (1954), *RAND Corporation* (1955), *Quenouille* (1959), *Moses* & *Oakford* (1963), *Rao*, *Mitra* & *Matthai* (1966), *Snedecor* and *Cochran* (1967), *Rohlf* & *Sokal* (1969), *Manfred* (1971), *Hill* & *Hill* (1977) and others. Among these tables, the following four tables are treated as suitable in drawing of simple random sample (with or without replacement) from a population (*Cochran*, 1940):

(1) Tippett's Random Numbers Table that consists of 10,400 four-digit numbers giving in all 41,600 single digits selected at random from the British Census report (*Tippett*, 1927).

(2) Fisher and Yates Random Numbers Table that comprises 15000 digits arranged in two's (*Fisher* & *Yates*, 1938).

(3) Kendall and Smith's Random Numbers that consists of 100,000 digits grouped into 25,000 sets of random four-digit numbers (*Kendall* & *Smith*, 1938).

(4) Random Numbers Table by Rand Corporation that contains of one million digits consisting of 200,000 random numbers of 5 digits each (*Rand Corporation*, 1955).

The proper randomness of these tables is yet to be tested. In a study made by *Chakrabarty* (2010) on the testing of randomness of the table due to *Fisher* and *Yates* (1938), it has been found that this table, consisting of the 7500 occurrences of the 100 two-digit numbers, is not properly random and deviates significantly from proper randomness. Due to this reason, one table consisting of 6000 random occurrences of the 100 two-digit numbers has been constructed as an alternative/competitor of this table (*Chakrabarty*, 2013*a*). Also, one table containing 5000 random occurrences of the 1000 two-digit numbers has been constructed by *Chakrabarty* (2013*b*) due to the unavailability of such table of two-digit numbers. Two more tables, one containing 20000 occurrences of random two-digit numbers and the other containing 20000 occurrences of random two-digit numbers, have also been constructed by the same author [*Chakrabarty*(2016*a* , 2016*b*)]. Recently, study has been made on testing the proper randomness of the random number tables due to Tippett (*Sarmah* & *Chakrabarty*, 2014), due to Kendall & Smith (*Sarmah* & *Chakrabarty*, 2014*b*), due to *Rand Corporation* (*Sarmah*, *Chakrabarty* & *Barman* (2015*b*). In the studies, each of the tables has been found to be suffered from proper randomness. This leads to think of constructing of table of random four-digit numbers. Moreover, there is or there may be necessity of drawing of random five-digit numbers, random four-digit numbers, random seven-digit numbers etc.. However, due to the increasing difficulties in the construction of tables of these types of random numbers by the method composed by *Chakrabarty* (2013*a*), it had been compelled to think of an alternative approach

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of drawing of these types of random numbers. As the first attempt on this approach, one method was developed for drawing of random five-digit numbers from a pair of two tables namely one table of random two-digit numbers and the other of random three-digit numbers (*Chakrabarty*, 2016*c*). Later on, in a study, one method was derived for drawing of random four-digit numbers from a pair of two independent tables of random two-digit numbers (*Chakrabarty*, 2016*d*). In this method of drawing of random four-digit numbers, two independent tables of random two-digit numbers are required. In this study, an attempt has been made on searching for some method of drawing of random four digit numbers from a single table of random two-digit numbers. A method has been developed here for drawing of random four-digit numbers from a single table of random two-digit numbers as an alternative of the two methods, already developed, of drawing of random four-digit numbers namely (i) drawing of random four-digit numbers from a single table of random four-digit numbers and (ii) drawing of random four-digit numbers from two independent tables of random two-digit respectively. This paper describes the theoretical derivation of the method and numerical example in order to show the application of the method derived.

II. METHOD OF DRAWING OF RANDOM TWO-DIGIT NUMBERS

The table of random Two-digit numbers constructed by Chakrabarty (2013*a* , 2016*a*) carries the following features:

Features of the Table of Random Two-digit numbers:

(1) In the table, each of the 100 two-digit numbers occurs n times out of $100n$ consecutive occurrences ($n = 1 , 2 ,$ …….) if we start counting from the observation at the $(1000k + 1)^{th}$ position ($k = 0 , 1 , 2 ,$ …….).

(2) In the table, the frequency of occurrence of each of the 100 two-digit numbers out of $100n$ consecutive trials ($n = 1 ,$ $2 ,$ …….) may be one more or less than n if we start counting from any position.

(3) The table can be treated as random as per the logic behind the two definitions of probability namely definition in theoretically ideal situation and definition in practically ideal situation (Chakrabarty, 2011).

(4) The table is random with respect to the occurrences of the numbers row-wise but not column-wise. Thus while drawing random numbers from the table, one requires moving row-wise either to the right or to the left starting from any position in the table. The starting position and the direction of movement are to be selected at random by suitable randomized trials in order to keep their randomness intact.

Method of Drawing of Random Two-digit numbers from the Table:

Each of the two tables, constructed here, can be used in drawing of random two-digit numbers

(1) which are distinct

and (2) which are not necessarily distinct.

A. Method of Drawing of Distinct Random Two-digit numbers

Suppose that we want to draw n random two-digit numbers from the table such that the drawn numbers are distinct. Since distinct two-digit numbers are to be drawn, one can draw a maximum of 1000 such numbers since the total number of such numbers is 100.

Feature no (2), mentioned above, implies that if n two-digit numbers occurred consecutively from the $(100k + 1)^{th}$ position ($k = 0 , 1 , 2 ,$ …….) in the table are drawn subject to the feature no (4) then the drawn n numbers will be distinct and random.

Also feature no (3), mentioned above, implies that if n two-digit numbers occurred consecutively in the table are drawn starting from any position then the drawn n numbers may not be distinct. Some of them may occur twice. Thus in order to draw distinct numbers, it is required to exclude the next occurrence of the same number and to draw the next consecutive number occurred in the table following feature no (4).

Thus the drawing of random two-digit numbers consists of the two basic tasks namely

(a) selection of the starting position at random

and (*b*) selection of the direction (right or left) of movement at random.

Accordingly, in order to obtain the n random two-digit numbers one is to proceed with the following steps:

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1. Select the position, from where to start, at random. Since the table contains 10000 random occurrences of the 100 two-
digit numbers, accordingly there are 10000 positions of the numbers namely

0000 , 0001 , 0002 , …… , 9999.

In selecting the starting position, one thus can apply some usual manual randomization technique of drawing one number from among the10000 numbers

0000 , 0001 , 0002 , …… , 9999

in the case of the table of random two-digit numbers due to Chakrabarty (2013 *b*)
and from among the 20000 numbers

00000 , 00001 , 00002 , …… , 19999

in the case of the table of random two-digit numbers due to Chakrabarty (2016 *b*).

One method of drawing of such number is as follows:

Take a set of 10 identical small balls marking them by the 10 digits

0 , 1 , 2 , 3 , 4 , 5 , 6 , 7 , 8 , 9

respectively and put them inside a opaque container C_1 .
Similarly, take another set of 4 identical small balls marking them by

L , R , M_1 & M_2

respectively and put them inside a different opaque container C_2 .
Now, draw one ball at random from the container C_1 containing the 10 balls and note down digit appeared on it.
Let the digit drawn be d_1.
Next, draw another ball at random from the container C_1 containing the same 10 balls and note down digit appeared on it.
Let the digit drawn at this stage be d_2.
Then, draw one ball at random from the container C_2 putting 2 balls marked with L & R inside it.
If the drawn ball is R, put the digit d_2 at the right position of $d_1$and if the drawn ball is L, put the digit d_2 at the left position of d_1.
Thus if the ball R appears, the selected two-digit number will be d_1d_2 and if the ball L appears, the selected two-digit number will be d_2d_1.
Let the selected two-digit number be d_2d_1.
Next, draw another ball at random from the container C_1 containing all the 10 balls and note down digit appeared on it.
Let the digit drawn here be d_3.
Then, draw one ball at random from the container C_2 putting 3 balls marked with

L , M_1 & M_2

inside it and put the digit d_3 at the

left position of d_2d_1 if the drawn ball is L ,
middle position of d_2d_1 if the drawn ball is M_1
& right position of d_2d_1 if the drawn ball is .

Thus the selected two-digit number will be $d_3d_2d_1$ or $d_2d_3d_1$ or $d_2d_1d_3$ in accordance with the selected ball is L or M_1 or R .
Let the selected two-digit number be $d_2d_3d_1$.
Finally, draw another ball at random from the container C_1 containing all the 10 balls and note down digit appeared on it. Let the digit drawn here be d_4.
Then, draw one ball at random from the container C_2 putting 4 balls marked with

L , M_1 , M_2 & R

inside it and put the digit d_4 at the

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left position of $d_2d_3d_1$ if the drawn ball is L ,
1st middle position (from left) of $d_2d_3d_1$ if the drawn ball is M_1 ,
2nd middle position (from left) of $d_2d_3d_1$ if the drawn ball is M_2
& right position of $d_2d_3d_1$ if the drawn ball is .

Thus the selected four-digit number will be $d_4d_3d_2d_1$ or $d_2d_4d_3d_1$ or $d_2d_1d_4d_3$ or $d_2d_1d_3d_4$ in accordance with the selected ball is L or M_1 or M_2 or R .

The position of the four-digit number selected here will be the required starting position f**or the table of random two-digit numbers due to Chakrabarty (2013 *a*)**

. Let the i^{th} (i is any of the four numbers $d_4d_3d_2d_1$, $d_2d_4d_3d_1$, $d_2d_1d_4d_3$, $d_2d_1d_3d_4$) position be selected in the earlier step.

In this step, draw the number that occurs at the i^{th} position in the table.

For the table of random two-digit numbers due to Chakrabarty (2013 *b*), one digit from the two digits 0 & 1 is to be selected by conducting a Bernoulli trial and is to be placed at the left position of the selected number as selected above. The number so obtained is the selected number of the starting position.

2. Let the i^{th} position be selected in the earlier step. Draw the number that occurs at the i^{th} position in the table.
3. Chose whether to move towards left or towards right. The choice can be made at random by a binary trial e.g. by tossing of an unbiased coin or by drawing a number from the container C_2 putting two identical balls, marked with L and R respectively, inside it.
4. If it is chosen to move towards right, draw the numbers occurred at the positions
$$i\ ,\ i+1\ ,\ i+2\ ,\ \ldots\ldots\ldots\ldots\ ,\ i+n-1$$
in the table to obtain the n random two-digit numbers.
5. If it is chosen to move towards left, draw the numbers occurred at the positions
$$i\ ,\ i-1\ ,\ i-2\ ,\ \ldots\ldots\ldots\ldots\ ,\ i-n+1$$
in the table to obtain the n random two-digit numbers.
6. It may occur that some number or numbers among those drawn may be occurred twice. In that situation, retain only One occurrence of them and draw additional numbers appeared at the consecutive positions in the table as per requirement.
If k additional numbers are required to draw, then draw the numbers occurred at the positions
$$i+n\ ,\ i+n+1\ ,\ ,\ i+n+2\ ,\ \ldots\ldots\ldots\ldots\ ,\ i+n+k-1$$
if it is chosen to move towards right and draw the numbers occurred at the positions
$$i-n\ ,\ i-n-1\ ,\ ,\ i-n-2\ ,\ \ldots\ldots\ldots\ldots\ ,\ i-n-k+1$$
if it is chosen to move towards left.

Note 2.1: Drawing of distinct random numbers corresponds to the drawing of simple random sample without replacement.

B. Method of Drawing of Random Two-digit numbers (Not Necessarily Distinct)

The features (1) and (2), mentioned in above, imply that if two-digit numbers are picked up at a gap of g positions ($101 \leq g \leq 199$), the picked up numbers will not necessarily be distinct.
Thus in order to to draw n random two-digit numbers which need not necessarily be distinct, one is to proceed with the following steps:

1. Select one position from where to start at random by the similar method as in the case of drawing of distinct random two-digit numbers mentioned above. Let the i^{th} position be selected.
2. Draw the number that occurs at the i^{th} position in the table.
3. Chose the length of jump that is to be 101 or more and 1999 or less at random. It can be chosen by some usual manual
randomization technique of drawing one number from among the numbers
$$101\ ,\ 102\ ,\ 103\ ,\ \ldots\ldots\ldots\ldots\ ,\ 198\ ,\ 199.$$
Let the selected length of jump be l.

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The random selection of the length of the jump can be done by similar method as done in the selection of the starting position.

4. Chose whether to jump towards left or towards right. The choice can be made by the same method as in the earlier case.
5. If it is chosen to jump towards right, draw the numbers occurred at the positions

$$i\ ,\ i+l\ ,\ i+2l\ ,\ \ldots\ldots\ldots\ldots\ ,\ i+(n-1)\,l$$

in the table to obtain the required *n* random thre-digit numbers.

6. If it is chosen to move towards left, draw the numbers occurred at the positions

$$i\ ,\ i-l\ ,\ i-2l\ ,\ \ldots\ldots\ldots\ldots\ ,\ i-(n-1)\,l$$

in the table to obtain the required *n* random two-digit numbers.

Note 2.2: Drawing of random numbers, not necessarily, distinct corresponds to the drawing of simple random sample with replacement.

III. METHOD OF DRAWING OF RANDOM FOUR-DIGIT NUMBERS

Let d_1d_2 be a random two-digit number drawn from a table of random two-digit numbers.
The possible values that d_1d_2 assumes are the 100 two-digit numbers

$$00\ ,\ 01\ ,\ 02\ ,\ \ldots\ldots\ldots\ldots\ ,\ 98\ ,\ 99$$

and the probability that d_1d_2 assumes any of them is equal which is 0.01.
Similarly, if d_3d_4 *is another two-digit number drawn independently from the same table then* the possible values that d_3d_4 assumes are also the 100 two-digit numbers

$$00\ ,\ 01\ ,\ 02\ ,\ \ldots\ldots\ldots\ldots\ ,\ 98\ ,\ 99$$

and the probability that that d_3d_4 assumes any of them is equal which is 0.01.
Now if the two two-digit numbers namely

$$d_1d_2 \quad \& \quad d_3d_4$$

are combined together to form the four-digit number $d_1d_2d_3d_4$
then the possible values that $d_1d_2d_3d_4$ assumes are the 10000 four-digit numbers

$$0000\ ,\ 0001\ ,\ 0002\ ,\ \ldots\ldots\ldots\ldots\ ,\ 9998\ ,\ 9999$$

and the probability that $d_1d_2d_3d_4$ assumes any one of them is equal which is 0.0001
(since the two numbers d_1d_2 & d_3d_4 have been drawn independently).
Thus the four-digit number $d_1d_2d_3d_4$ is a random one.
Similarly, the other four-digit number

$$d_3d_4d_1d_2$$

is also a random one.
If one of these two four-digit numbers is selected by performing a random binomial trial, the selected number will be a random four-digit number.
If the process is repeated once, one more random four-digit number can be obtained.
By further repetitions, one can obtain more random four-digit numbers.
Therefore in order to draw *n* random four-digit numbers from a single table of random two-digit numbers, it is required to draw two independent sets, each of *n* random two-digit numbers, from the table.

It is to be noted that any successive three digits of different four-digit numbers can be same. Conversely, with the same successive three digits there can be different four-digit numbers. Therefore, the random two-digit numbers in each of the two independent sets of random two-digit numbers, drawn in order to form random four-digit numbers, need not be distinct.

It is further to be noted that the random selection of which set's two-digit numbers will be placed at the left position, which set's two-digit number will be placed at the right position while combining them in the formation of random four-digit number can be made afresh for each random four-digit number to be drawn or can be made once, before

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drawing the two-digit numbers for the two sets, to be applied in the construction of all random four-digit numbers to be selected.

Thus, in order to draw *n* random four-digit numbers one can apply the following two methods:

First method of drawing

In order to draw *n* random four-digit numbers, in this method, one can proceed with the following steps:

(1) Make a choice at random which set's two-digit numbers will be placed at the left position and which set's two-digit number will be placed at the right position while combining them in the formation of random four-digit numbers. This can be done by a random binomial trial.
(2) Draw the 1st set of *n* random two-digit number from the table by the method discussed in Section II *b*.
(3) Draw the 2nd set of *n* random two-digit number from the table by the same method independently from the 1st set.
(4) Combine the random two-digit numbers of the 1st set with the corresponding random two-digit numbers of the 2nd set by the choice of the positions obtained in step (1) to obtain the *n* random four-digit numbers.

Second method of drawing

In order to draw *n* random four-digit numbers, in this method, one can proceed with the following steps:

(1) Draw two random two-digit numbers independently from the table of random two-digit numbers by the same method as discussed in Section II *b*.
(2) Make a choice at random which set's two-digit numbers will be placed at the left position and which set's two-digit number will be placed at the right position while combining them in the formation of random four-digit numbers. This can be done by a random binomial trial.
(3) Combine the two two-digit numbers, obtained in step (1), as per the selected choice of the positions to obtain one random four-digit number.
(4) Perform the above three steps more $(n-1)$ times to obtain more $(n-1)$ random four-digit numbers.
(5) The random four-digit numbers obtained in step (3) & Step (4) are the required *n* random four-digit numbers.

IV. NUMERICAL EXAMPLE

Example (4.1): Let it be wanted to draw 20 random four-digit numbers from the table of random two-digit numbers constructed by *Chakrabarty* (2016*a*).

First method of drawing

Let a trial namely the throwing of an unbiased coin be performed to make a choice which set's two-digit number will be placed at the left position and which set's two-digit number will be placed at the right position while combining them in the formation of random four-digit number.
Suppose, the selected choice is as follows:

Two-digit number belonging to the **1st Set** will be placed at the **Right** position,
& Two-digit number belonging to the **2nd Set** will be placed at the **Left** position.

Now let us draw the 1st set of 20 random two-digit numbers from the table by the method as described in Section II *b*. Let the numbers drawn be

64 , 47 , 55 , 83 , 37 , 90 , 50 , 28 , 54 , 36 , 51 , 09 , 90 , 27 , 42 , 13 , 46 , 59 , 27 , 77 .

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Next, let us draw the 2nd set of 20 random two-digit numbers from the table by the same method but independently of the 1st set.
Let the numbers drawn, in this case, be

09 , 96 , 39 , 94 , 52 , 07 , 80 , 66 , 42 , 27 , 99 , 02 , 89 , 28 , 50 , 52 , 36 , 81 , 53 , 34 .

Now, let us combine the corresponding numbers drawn from the two tables as per the selected choice of combination.
Thus, the selected 20 random four-digit numbers are

0964 , 9647 , 3955 , 9483 , 5237 , 0790 , 8050 , 6628 , 4254 , 2736 , 9951 , 0209 , 8990 , 2827 , 5042 , 5213 , 3646 , 8159 , 5327 , 3477 .

Second method of drawing

First, let us draw two random two-digit numbers independently to include in the two sets namely the 1st Set, & the 2nd Set respectively by the method described in Section II *b*.
Let the two numbers drawn be

32 & 77

respectively.
Next, let a random binomial trial namely tossing of an unbiased coin be performed to choice which set's two-digit number will be placed at the left position and which set's two-digit numbers will be placed at the right position while combining them in the formation of random four-digit numbers.
Suppose, the selected choice is as follows:

Two-digit number belonging to the 1st Set will be placed at the Left position,
& Two-digit number belonging to the 2nd Set will be placed at the Right position.

Thus, the 1st selected four-digit random number is **3277** .

In order to obtain the remaining 19 random four-digit numbers, the two steps are to be repeated 19 times.
Let the outcomes of all the 20 trials be as follows:

Table-4-1

Serial No of Trial	Two-digit number obtained in 1st Set	Two-digit number obtained in 2nd Set	Outcome of the Random Trial: Position of Two-digit number belonging to		Selected Random Four-digit number
			1st Set	2nd Set	
1	**32**	**77**	Left	Right	**3277**
2	**66**	**26**	Right	Left	**2666**
3	**45**	**03**	Left	Right	**4503**
4	**89**	**99**	Right	Left	**9989**
5	**27**	**52**	Right	Left	**5227**
6	**92**	**11**	Left	Right	**9211**
7	**18**	**80**	Right	Left	**8018**
8	**87**	**47**	Right	Right	**8747**
9	**42**	**50**	Left	Right	**4250**
10	**60**	**27**	Left	Right	**6027**
11	**45**	**99**	Right	Left	**9945**
12	**94**	**40**	Right	Left	**4094**
13	**08**	**89**	Left	Right	**0889**

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14	**77**	**28**	Left	Right	**7728**
15	**24**	**50**	Right	Left	**5024**
16	**36**	**18**	Left	Right	**3618**
17	**46**	**33**	Right	Left	**3346**
18	**59**	**81**	Right	Left	**8159**
19	**78**	**53**	Right	Left	**5378**
20	**04**	**35**	Left	Right	**0435**

Thus, the selected 20 random four-digit numbers to are

3277 , 2666 , 4503 , 9989 , 5227 , 9211 , 8018 , 8747 , 4250 , 6027 , 9945 , 4094 , 0889 , 7728 , 5024 , 3618 , 3346 , 8159 , 5378 , 0435 .

V. CONCLUSION

The method of drawing of random four-digit numbers, developed here, is an alternative way of drawing of random four-digit numbers in the absence of table of random four-digit numbers.

The method of drawing of random four-digit numbers from a single table of random two-digit numbers, developed here, is an alternative of the two methods, already developed, of drawing of random four-digit numbers namely (i) drawing of random four-digit numbers from a single table of random four-digit numbers and (ii) drawing of random four-digit numbers from two independent tables of random two-digit respectively.

Thus it has been now possible to draw random four-digit numbers from a single table of random two-digit numbers.

It is to be noted that among the two methods of drawing of random four-digit numbers, explained in Section III, the first one is simpler than the second one.

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