# PROPOSING A SOLUTION FOR THE PROBLEM OF CHOOSING ORTHOGONAL CONTRASTS FOR EQUAL SAMPLE SIZES

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**Abstract**

Many scholars as it is stated in the literature faced the problem of finding a suitable solution for finding and selecting orthogonal contrasts with (k-1) number, in terms of having groups (samples, types and treatments) with (k) number, where (contrasts=treatments-1). These are based on independence and orthogonalization as two conditions for selecting significant differences between (averages) treatments, and for identifying which one is responsible for these differences. The researchers solve this problem by proposing a method for selecting orthogonal contrasts in terms of equal observations, where independence and orthogonalization exist simply ,to let the experimenter to test all averages with no need to test these two conditions if more averages are formulated or added.

**Keywords:** ANOVA, F-Test, Independence, p value, Stock Exchange, Orthogonal, Contrasts, Treatments, Trading, Rainfall, Annual.

**Contribution/Orginality**

The proposed method for simply selecting orthogonal contrasts in terms of equal observations where independence and othogonalization exist is important; especially it is concerned with (k) of averages and treatment. The application of this method is useful in experimental design since it is applied before experimenting, and consequently new results and conclusions may be revealed.

## 1 - INTRODUCTION

After ANOVA, and if a statistically-significant difference among the squares of treatments, and to identify how these averages are different, two methods are usually followed based on the time of these orthogonalities, namely before experimenting or after gathering data. One of the tests used before experimenting is orthogonal contrasts.

The literature is rich in studying orthogonal contrasts, especially after 1956. Recently, in 2004, Maria (4) examined these definitions and characteristics of these contrasts. In 2008, Al-Mashhadani & Abdulrazzaq (2) suggested new formulas for counting the values of orthogonal contrasts and the divided – on , and comparing these values with the common ones.

The researchers proposed a new method for solving the problem of selecting orthogonal contrasts with (k) of (averaged) treatments, where independence and orthogonalization as test's two conditions exist. This method works simply ad smoothly which in turn gives the experimental the possibility of using it without testing these two conditions.

## 2 - ORTHOGONAL CONTRASTS[(1)(3)(5)(6)]

If the decision taken is the selection of averages before experiments, it will be necessary for identifying the comparisons and for not preventing the existence of errors ($\propto$) which in turn represents the permitted error in ANOVA. This means the necessity of selecting contrasts carefully; it is also important to state that the number of contrasts is not exceeding the degree of freedom for averaged treatments. This method is called an orthogonal contrast.

Orthogonalization is defined as a linear combination for sums of treatments or averages, where this sum equals zero, and it is symbolized by C. Selecting orthogonal contrasts in terms of equal observations needs the existence of two conditions:

a- Independence, where the sum of parameters of treatments for a single orthogonality equals zero. That is:

$$\sum_{j=0}^{k} Cjm = 0 \ldots\ldots\ldots\ldots\ldots (1)$$

Where k is the number of treatments ( levels of a parameter), m the number of orthogonality (number of orthogonalities), and j=1,2,3,……..,k

b- Orthogonality , where the sum of multiplying the sums of corresponding parameters in each two contrasts equals zero. That is:

$$\sum_{j=1}^{k} Cjm\, Cjq = 0 \ldots\ldots\ldots\ldots (2)$$

The sum of each contrast can be counted as follows:

$$Cm = \sum_{j=1}^{k} Cjm\, T.j \ldots\ldots\ldots\ldots (3)$$

Where $T_{.j}$ is the sum of treatment j.

The sum of averages of each contrast can be counted as follows:

$$SSc = \frac{C_m^2}{n\sum_{j=1}^{k} C_{jm}^2} \ldots\ldots\ldots\ldots (4)$$

Where n is the number of observations for each treatment.

## 3 - THE PROPOSED METHOD

After doing ANOVA for experiments and using F-Test for testing null hypothesis, and if F-Test states the differences or variances among the averaged groups (samples, types or treatments) are statistically significant. But, it does not identify which one of these differences or variances is significant. Therefore, the experimenter will examine which one of the averages is causing these differences or variances. Among these tests are orthogonal contrasts.

Experimenting is a technique used to state these contrasts; this in turn needs an experienced statistician, plus time and efforts. Sometimes results will be misleading or unsuccessful, in both cases leading to wrong orthogonal contrasts or none. Consequently, experimenting before testing will be avoided.

The researchers in this paper propose a solution to this problem for all k of treatments or averages. It is simply, flexibly and smoothly-applicable. It is also possible to have a large number of groups or tables of orthogonal contrasts. It gives the possibility of testing all averages the experimenter wants to examine or use, of course with no prior need to hold independence and orthogonality in forming a new contrast. The procedure of this proposed method is as follows:

a- having a doubled table, with x-level for sums of treatments, and y-level for sequencing the contrasts, where (number of contrasts= number of treatments-1)

b- for identifying the parameters of the first contrast, we weigh one of the treatments of the first contrast (one of the cells of the first row) with (k-1), and the other treatments (or the rest of cells of the first row) with (-1)

c- for the parameters of the second contrast, we use (0) instead of (k-1). We weigh another cell in the second row with (k-2), of course not the one weighed before. Other cells will be weighed with (-1).

d- we weigh the treatment with (k-2) by (0) for other contrasts. A new treatment is weighed with (k-3) and put it in a cell in the third row, of course except the weighed ones. Other treatments will be with (0).

e- we keep on the same strategy for weighing the other contrasts till the last one where the values of parameters is (1) and (-1). Those weighed treatments will be (0). This can be summed up in the following tables:

Table(1): Select m of orthogonal contrasts in case of k treatments

| C.I.T. | $T_{.1}$ | $T_{.2}$ | $T_{.3}$ ……………………………….. | $T_{.k-1}$ | $T_{.k}$ |
|---|---|---|---|---|---|
| $C_1$ | k-1 | -1 | -1 | -1 | -1 |
| $C_2$ | 0 | k-2 | -1 | -1 | -1 |
| $C_3$ ↓ | 0 ↓ | 0 ↓ | k-3 ↓ | -1 ↓ | -1 ↓ |
| $C_m$ | 0 | 0 | 0 | k-m | -1 |

Or,

Table(2): Select m of orthogonal contrasts in case of k treatments

| C.I.T. | $T_{.1}$ | $T_{.2}$ | $T_{.3}$ ……………………………… | $T_{.k-1}$ | $T_{.k}$ |
|---|---|---|---|---|---|
| $C_1$ | -1 | -1 | k-1 | -1 | -1 |
| $C_2$ | -1 | -1 | 0 | -1 | k-2 |
| $C_3$ ↓ | k-3 ↓ | -1 ↓ | 0 ↓ | -1 ↓ | 0 ↓ |
| $C_m$ | 0 | -1 | 0 | k-m | 0 |

By the same procedure, it is possible to suggest many other tables including orthogonal contrasts with independence and orthogonalization for k of treatments or averages.

## 4 - Applications

The research included two applications. The first application if the number of treatments is small either the second application if the number of treatments is large.

### 4.1 - First Application

The application was based on real data taken from the annual reports of the Iraq Stock Exchange . The volume representing trading is sectorally divided for the Period ( 2008 – 2016 ). The researchers calculated the data ( see : table 1 , Appendix ) on the bases of annual reports. The volume of trading is the value of shares traded in the stock exchange. It equals the number of shares multiplied by the average price per share during a certain period . It is considered as one ofof the important indication of stock exchange in order to know of there are
significant differences among the sectors of the volume of trading and which average has contributed to these significant differences . ANOVA table was constituted and then we tested orthogonal contrasts in case ifThere are significant differences and as follows:

Table (3) : ANOVA table for volume of shares in the Iraqi Stock Exchange.

| S.O.V | d.f | SS | MS | F | P |
|---|---|---|---|---|---|
| Bet.Treat. | 6 | 8.556e+11 | 1.426e+11 | 19.951 | 0.00 |
| Error | 56 | 4.003e+11 | 7147535133 | | |
| Total | 62 | 1.256e+12 | | | |

Comparing calculated F with tabled F, we notice that the value of calculated F is grater in value than tabled F. this means that there are significant differences among the averages ( treatments ). Later , we have structured a table for orthogonal contrasts and as follows :

Table(4): Selection of orthogonal contrasts of volume of shares by sector

| T / C | $T_{.1}$ | $T_{.2}$ | $T_{.3}$ | $T_{.4}$ | $T_{.5}$ | $T_{.6}$ | $T_{.7}$ |
|---|---|---|---|---|---|---|---|
| $C_1$ | 6 | -1 | -1 | -1 | -1 | -1 | -1 |
| $C_2$ | 0 | 5 | -1 | -1 | -1 | -1 | -1 |
| $C_3$ | 0 | 0 | 4 | -1 | -1 | -1 | -1 |
| $C_4$ | 0 | 0 | 0 | 3 | -1 | -1 | -1 |
| $C_5$ | 0 | 0 | 0 | 0 | 2 | -1 | -1 |
| $C_6$ | 0 | 0 | 0 | 0 | 0 | 1 | -1 |

From the table above , we notice that all orthogonal contrasts have the two conditions of independence and orthogonalization. The value of these contrasts was calculated. They were as follows:

Table (5) : The values of the orthogonal contrasts for volume of shares in the Iraqi Stock Exchange.

| | | |
|---|---|---|
| $C_1$ = 17839721 | $C_3$ = - 782919 | $C_5$ = 592295 |
| $C_2$= -810349 | $C_4$ = - 306271 | $C_6$ = 137185 |

The following table explains ANOVA table for orthogonal contrasts. The value of calculated F of orthogonal contrasts which were calculated from the following formula:

$$FCm = \frac{MSCm}{MSE} \quad \dots\dots (5)$$

with the value of tabled F ( $F_{1,56,0.95}$ =4 ). The asterisk (*) means that the value of calculated F is greater than tabled F and that these is a significant difference among the averages at this contrast and according to its hypothesis.

Table(6) : ANOVA table for orthogonal contrasts for volume of shares in the Iraqi Stock Exchange.

| S.O.V | d.f | SS | MS | F |
|---|---|---|---|---|
| $C_1$ | 1 | 8.4194615e+11 | 8.4194615e+11 | 117.795* |
| $C_2$ | 1 | 2432094451 | 2432094451 | 0.340 |
| $C_3$ | 1 | 3405345336 | 3405345336 | 0.476 |
| $C_4$ | 1 | 868536346.6 | 868536346.6 | 0.122 |
| $C_5$ | 1 | 6496543833 | 6496543833 | 0.909 |
| $C_6$ | 1 | 1045540234 | 1045540234 | 0.146 |
| Error | 56 | 4.003e+11 | 7147535133 | |
| Total | 62 | | | |

We can structure many other groups of orthogonal contrasts which have the two conditions of independence and orthogonalization and as explained in the following tables.

Table(7): Selection of orthogonal contrasts of volume of shares by sector

| T \ C | $T_{.1}$ | $T_{.2}$ | $T_{.3}$ | $T_{.4}$ | $T_{.5}$ | $T_{.6}$ | $T_{.7}$ |
|---|---|---|---|---|---|---|---|
| $C_1$ | -1 | 6 | -1 | -1 | -1 | -1 | -1 |
| $C_2$ | -1 | 0 | -1 | -1 | -1 | -1 | 5 |
| $C_3$ | -1 | 0 | -1 | 4 | -1 | -1 | 0 |
| $C_4$ | 3 | 0 | -1 | 0 | -1 | -1 | 0 |
| $C_5$ | 0 | 0 | -1 | 0 | -1 | 2 | 0 |
| $C_6$ | 0 | 0 | 1 | 0 | -1 | 0 | 0 |

Or :

Table(8): Selection of orthogonal contrasts of volume of shares by sector

| T \ C | $T_{.1}$ | $T_{.2}$ | $T_{.3}$ | $T_{.4}$ | $T_{.5}$ | $T_{.6}$ | $T_{.7}$ |
|---|---|---|---|---|---|---|---|
| $C_1$ | -1 | -1 | -1 | -1 | 2 | -1 | -1 |
| $C_2$ | -1 | -1 | -1 | 6 | 0 | -1 | -1 |
| $C_3$ | 1 | -1 | -1 | 0 | 0 | -1 | -1 |
| $C_4$ | 0 | 4 | -1 | 0 | 0 | -1 | -1 |
| $C_5$ | 0 | 0 | -1 | 0 | 0 | 5 | -1 |
| $C_6$ | 0 | 0 | -1 | 0 | 0 | 0 | 3 |

And so on …..

**4.2 - Second Application**

We applied real data taken from the statistical annual giving by Iraqi Ministry of Planning – the central statistical body for the year 2016. These data represent the annual quantity of rain ( mm) as realized by the governorats from 2008 at 2011 . We would like to know if these are significant differences among the governorats in the annual quantity of rain and also which of these averages havecontributed to these significant difference. Later , we have to structure ANOVA table and then to test orthogonal contrasts in case there are significant difference and as follows:

Table (9) : ANOVA table for the total annual rainfall in Iraq.

| S.O.V | d.f | SS | MS | F | P |
|---|---|---|---|---|---|
| Bet.Treat. | 17 | 1061537.291 | 62443.370 | 36.980 | 0.00 |
| Error | 54 | 91183.615 | 1688.585 | | |
| Total | 71 | 1152720.906 | | | |

Comparing the value of calculated F with that of the tabled F, we notice that the value of calculated F is greater than tabled F. this only means that there are significant differences among the averages ( treatments ). Accordingly, we structure a table for orthogonal contrasts and as follows:

Table(10) : Selection of orthogonal contrasts for the total annual rainfall in Iraq by governorates

| | T.1 | T.2 | T.3 | T.4 | T.5 | T.6 | T.7 | T.8 | T.9 | T.10 | T.11 | T.12 | T.13 | T.14 | T.15 | T.16 | T.17 | T.18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $C_1$ | 17 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| $C_2$ | 0 | 16 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| $C_3$ | 0 | 0 | 15 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| $C_4$ | 0 | 0 | 0 | 14 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| $C_5$ | 0 | 0 | 0 | 0 | 13 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| $C_6$ | 0 | 0 | 0 | 0 | 0 | 12 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| $C_7$ | 0 | 0 | 0 | 0 | 0 | 0 | 11 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| $C_8$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| $C_9$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| $C_{10}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| $C_{11}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| $C_{12}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | -1 | -1 | -1 | -1 | -1 | -1 |
| $C_{13}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | -1 | -1 | -1 | -1 | -1 |
| $C_{14}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | -1 | -1 | -1 | -1 |
| $C_{15}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | -1 | -1 | -1 |
| $C_{16}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | -1 | -1 |
| $C_{17}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | -1 |

**Note:** we can structure other tables that have the tow conditions of Independence and orthogonalization. From the table above, we notice that all orthogonal contrasts have the two conditions of independence and rthgonalization. the values of these Contrasts are as follows:

Table(11) : The values of the orthogonal contrasts for the total annual rainfall in Iraq.

| | | |
|---|---|---|
| $C_1 = 17547.2$ | $C_7 = -260$ | $C_{13} = -170.6$ |
| $C_2 = 8580.5$ | $C_8 = -18$ | $C_{14} = -357.6$ |
| $C_3 = 21689.9$ | $C_9 = -451$ | $C_{15} = -375.2$ |
| $C_4 = 6209.9$ | $C_{10} = -289$ | $C_{16} = -229.4$ |
| $C_5 = 10722.1$ | $C_{11} = 1500.6$ | $C_{17} = 251.4$ |
| $C_6 = 5063.2$ | $C_{12} = 520.6$ | |

The following table explaining ANOVA table of orthogonal contrasts. Were the value calculated F is compared with that of tabled F.

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Table(12) : ANOVA table for orthogonal contrasts for the total annual rainfall in Iraq

| S.O.V | d.f | SS | MS | F |
|---|---|---|---|---|
| $C_1$ | 1 | 251555.75 | 251555.75 | 148.974* |
| $C_2$ | 1 | 67670.02 | 67670.02 | 40.075* |
| $C_3$ | 1 | 490053.92 | 490053.92 | 290.216* |
| $C_4$ | 1 | 45908.16 | 45908.16 | 27.187* |
| $C_5$ | 1 | 157916.80 | 157916.80 | 93.520* |
| $C_6$ | 1 | 41083.32 | 41083.32 | 24.330* |
| $C_7$ | 1 | 128.03 | 128.03 | 0.076 |
| $C_8$ | 1 | 0.7364 | 0.7364 | 0.00044 |
| $C_9$ | 1 | 565.003 | 565.003 | 0.335 |
| $C_{10}$ | 1 | 290.003 | 290.003 | 0.175 |
| $C_{11}$ | 1 | 10052.68 | 10052.68 | 5.953* |
| $C_{12}$ | 1 | 1613.24 | 1613.24 | 0.955 |
| $C_{13}$ | 1 | 242.54 | 242.54 | 0.144 |
| $C_{14}$ | 1 | 1598.47 | 1598.47 | 0.9466 |
| $C_{15}$ | 1 | 2932.81 | 2932.81 | 1.737 |
| $C_{16}$ | 1 | 2192.68 | 2192.68 | 1.299 |
| $C_{17}$ | 1 | 7900.245 | 7900.245 | 4.679* |
| Error | 54 | 91183.615 | 1688.585 | |
| Total | 71 | | | |

## 5 - **Conclusions**

a - The solution (the proposed method) is flexible, easy, simple and rapid . It is considered to be a successful and practical solution for a rather difficult problem that is almost possible for choosing orthogonal contrasts that have the two conditions of dependence and orthogonalization b - The proposed method could be considered as an important addition and a contribution in the field of statistics and experimental design

c - The simplicity for choosing and testing the orthogonal contrasts when sample Sizes are equal whether the number of treatments is small ( first application ) Or great ( second application ).

d - The other researchers can develop this method to cover the case of unequal sample sizes.

e - If we rely or the P value instead of the F value for testing the significant difference , we will find that the P value for the two applications is equal to zero. Because, it is less than the significant level 0.01 we reject the hypothesis of the null significant differences among the averages ( treatments ) and we accept the alternative hypothesis. Accordingly , the effect of the factor is to considered significant. In order to know which of these averages has caused this significant difference , we conduct the test of orthogonal contrasts.

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## Appendix

**Table (1) :** A table representing the volume of trading of shares by sectors in the Iraqi Stock Exchange for the period ( 2008 – 2016 ).

| years | Banks | Insurance | Investment | Services | Industry | Hot. & Tourism | Agriculture |
|---|---|---|---|---|---|---|---|
| 2008 | 91872 | 194 | 384 | 1902 | 17379 | 16035 | 179 |
| 2009 | 279696 | 373 | 1368 | 14550 | 61241 | 8968 | 613 |
| 2010 | 115988 | 523 | 2219 | 5968 | 18191 | 3305 | 697 |
| 2011 | 407175 | 203 | 1285 | 3360 | 9774 | 4949 | 618 |
| 2012 | 267156 | 503 | 6512 | 2683 | 16147 | 13667 | 540 |
| 2013 | 319235 | 1025 | 3461 | 14543 | 29934 | 42635 | 1093 |
| 2014 | 259411 | 2293 | 1141 | 20606 | 65530 | 50217 | 1158 |
| 2015 | 705455 | 7830 | 3149 | 48946 | 126222 | 42560 | 7033 |
| 2016 | 677332 | 2031 | 942 | 27065 | 94727 | 29254 | 62474 |

**Table (2) :** The total annual rainfall ( mm) in Iraq by governorates for the period (2008 – 2011)

| Governo. | 2008 | 2009 | 2010 | 2011 | Governo. | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| Dohouk | 370.1 | 487.2 | 293.4 | 434.0 | Wasit | 76 | 31.1 | 84.5 | 98.2 |
| Ninevah | 216.3 | 223.8 | 240.6 | 294.7 | Kerbala | 87.6 | 85.3 | 80.3 | 120.3 |
| Sulaimaniya | 381.2 | 607.9 | 385.2 | 507.4 | Salah Al-Deen | 158.8 | 111.7 | 138.2 | 104.8 |
| Kirkuk | 134.9 | 225.8 | 267.2 | 221.8 | Al- Najaf | 72.4 | 64.3 | 50.3 | 71.3 |
| Erbil | 297 | 311.6 | 261.8 | 301.6 | Al- Qadisiya | 44.2 | 46.2 | 49.1 | 81.4 |
| Diala | 197.9 | 164.7 | 206.9 | 167.2 | Al- Muthanna | 57.0 | 54.1 | 47.0 | 58.4 |
| Al- anbar | 72.9 | 23.3 | 109.0 | 87.9 | Thi Qar | 65.5 | 56.9 | 57.6 | 85.1 |
| Baghdad | 59.1 | 67.5 | 92.5 | 96.0 | Maysan | 90.6 | 175.9 | 128.3 | 110.7 |
| babylon | 51.8 | 52.4 | 87.3 | 80.3 | Basrah | 67.1 | 89.8 | 31.9 | 65.3 |