Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Four factors experiments for fixed models in completely randomized design

To cite this article: Urip Tisngati *et al* 2019 *J. Phys.: Conf. Ser.* **1175** 012152

Four factors experiments for fixed models in completely randomized design

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Abstract. This paper was written to find a table of Analysis of Variance (ANOVA) for four factors experiments for fixed models in completely randomized design. The things that must be determined are Source of Variance (SV), Degree of Freedom (df), Some of Square (SS), Mean Square (MS), Expected Values of Mean Square (EMS), F_0, and F tables. This four-factor experiment can be applied directly to experimental units with the experimental unit requirements used in the research in uniform relatively. The result of this research can found an ANOVA Table for Completely Randomized Factorial (CRF)-2222 Design for Fixed Model independently where consists of 16 of SV, 16 of df, 16 of SS, 16 of MS, 16 of EMS, 15 of F_0, and 15 of table F.

1. Introduction

Experiment design is one of the fields of science developed in statistics. Experimentation has been used in diverse areas of knowledge. Statistical design of experiments has the pioneering work of Sir R. A Fisher in the 1920s and early 1930s [1](Steinberg & Hunter, 1984). His work had profound influence on the use of statistics in agricultural and related life sciences (Pais, Peretta, Yamanaka, & Pinto, 2014). Experimental design has three principles: randomization, replication, and blocking. The order of the runs in the experimental design is randomly determined. Randomization helps in avoiding violations of independence caused by extraneous factors, and the assumption of independence should always be tested. Replication is an independent repeat of each combination of factors. It allows the experimenter to obtain an estimate of the experimental error. Blocking is used to account for the variability caused by controllable nuisance factors, to reduce and eliminate the effect of this factor on the estimation of the effects of interest. Blocking does not eliminate the variability; it only isolates its effects. A nuisance factor is a factor that may influence the experimental response but in which we are not interested.

In the application of the experimental design it is known that the response of individuals is a result of various factors simultaneously. This shows that a one-factor experiment will be very ineffective given the response that appears will be different if the conditions of other factors change. Therefore, many applied fields require experimental design that uses several factors as treatment at the same time (Mattjik & Sumertaya, 2013); [2]; [3]. In this study, an experiment will be discussed which involves four factors as a treatment combination that will be tested simultaneously. Which is usually better known as a four-factor factorial design.

According Kirk (1995), a factorial design is one in which all possible combinations of the levels of two or more treatments occur together in the design. Then the experimental design is a test or a series of tests, where is using the description statistics or inferential statistics, the aim is to convert the input variable into an output which is the response of the experiment (Mattjik & Sumertaya, 2013). Factorial designs are widely used in experiments involving several factors where it is necessary to investigate the joint effects of the factors on a response variable. These joint effects include either the sole effect of each factor (main) or any interaction between two or more factors. The analysis of factorial designs is well established for a response variable that is measured on the real line [4].

Factorial designs are very efficient for studying two or more factors [5]. The effect of a factor can be defined as the change in response produced by a change in the level of the factor. This is referred to as the main effect. In some experiments, it may be found that the difference in the response between levels of one factor is not the same at all levels of the other factors. This is referred to as an interaction effect between factors. Collectively, main effects and interaction effects are called the factorial effects (Wu, Hamada, & Joseph, 2009).

A factorial design is a strategy in which factors are simultaneously varied, instead of one at a time. It is recommended to use a 2^k factorial design when there are many factors to be investigated, and we want to find out which factors and which interactions between factors are the most influential on the response of the experiment [6]. The experimental design is a unity between treatment design, environmental design, and measurement design. The treatment design is a design related to how the treatment was formed. The composition of a treatment can be formed from 1 factor, 2 factors, 3 factors, 4 factors, and so on. Environmental design is a design that relates to how random treatments are placed in experimental units. With this randomization, complete random design, complete randomized group design, etc. can be formed. The measurement design is a design of how the experimental response is taken from the experimental units studied. Naming a design is a combination of treatment design and environmental design. For example in this study, treatment was formed from all combinations of four factor levels while the treatment was randomized to each unit of experiment, so the design was called a four-factor complete random design. In a four-factor complete randomized design, each treatment combination of the four factors was imposed on a number of different subjects or experimental units. According to Kirk (1995), the simplest factorial design, from the standpoint of data analysis and assignment of experimental units to treatment combination, is the completely randomized factorial design. A design with four treatment is designated as a Completely Randomized Factorial (CRF_{ijkl}) Design, where the letters CR identify the building block design, F indicates that it is a factorial design, and i, j, k and l denote the number of levels of treatments A, B, C, and D respectively. A completely randomized factorial design is appropriate for experiments that meet, in addition to the assumption of the completely randomized design described in the following conditions: (1) two or more treatments, with each treatment having two or more levels, (2) All levels of each treatments investigated in combination with all levels of every other treatment. If there are i levels of one treatment, j levels of a second treatment, k levels of a third treatment, and l levels of a fourt treatment, the experiment contains $i \times j \times k \times l$ treatment combinations; and (3) Random assignment of experimental units to treatment combinations. Each experimental unit must be assigned to only one combinatio.

2. Method

The method used in this study is literature study. Literature study is a type of research that answers problems by looking at and studying literature in accordance with the study of problems. Literature used is books, national journals and international journals. Literary research is the backbone of various research factors literary research including to find out all possible information is about a particular text or literature in published or unpublished matter in various forms such as manuscript, book etc to preserve them according to their forms with modem techniques (Nesari). To analyze them with study branches, revision & editing information to draw a concrete conclusion in accordance with present & future study. At this stage a theoretical study will be carried out which will become a critical analysis material in the efforts of researchers to answer existing problems. The study conducted was a study of factorial design or factorial experimental design for 2 and 3 factorials. Researchers have difficulty in finding literature in the form of books and journals that discuss the factorial design of 4 factors. Another difficulty is the search for previous research that uses experimental units in education. The main source of this research is the relevant book written by Mattjik. Next the researcher conducted a Focus Group Discussion (FGD) with a team of lecturers and a team of experts to produce research findings.

3. Result and Discussion

There are four treatment factors given to each experimental unit. Suppose the first factor is factor A with the level of i, the second factor is factor B with the level of j, the third factor is factor C with the level of k, and the fourth factor is factor D with the level of l. The combination of four treatments is given to n independent subjects in each treatment combination, then we will see the following combination of treatment, chart and layout.

Table 1. Treatment combination

1. A1B1C1D1	5. A1B2C1D1	9. A2B1C1D1	13. A2B2C1D1
2. A1B1C1D2	6. A1B2C1D2	10. A2B1C1D2	14. A2B2C1D2
3. A1B1C2D1	7. A1B2C2D1	11. A2B1C2D1	15. A2B2C2D1
4. A1B1C2D2	8. A1B2C2D1	12. A2B1C2D2	16. A2B2C2D2

The following experimental chart illustrates the randomization of treatment combinations in the study where the treatment combination was repeated three times.

Table 2. The experimental chart

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
A1B1C1D1	**A1B1C2D2**	**A1B1C1D2**	**A1B2C1D1**	**A1B2C2D1**	**A1B1C2D1**	**A2B1C1D1**	**A1B2C1D2**
9	10	11	12	13	14	15	16
A2B1C2D1	A2B2C1D1	A2B1C1D1	A2B2C2D1	A1B2C2D1	A2B2C1D1	A2B1C2D2	A2B2C1D2
17	18	19	20	21	22	23	24
A2B2C1D2	A1B1C2D1	A2B1C2D1	A1B1C1D1	A2B1C1D1	A2B2C2D1	A1B1C1D2	A2B2C2D1
25	26	27	28	29	30	31	32
A1B1C1D2	A2B1C1D2	A1B2C1D1	A1B2C1D2	A1B1C2D2	A1B2C2D1	A2B1C2D2	A2B1C1D2
33	34	35	36	37	38	39	40
A2B2C2D1	A1B2C1D2	A1B2C2D1	A1B1C2D1	A2B1C2D1	A2B2C2D1	A1B1C1D1	A2B2C1D1
41	42	43	44	45	46	47	48
A2B2C1D2	A2B1C2D2	A1B1C2D2	A1B2C2D1	A1B2C1D1	A2B2C2D1	A1B2C2D1	A2B1C1D2

Table 3. Completely 4 factor randomized design layout

		$\boldsymbol{A1}$				$\boldsymbol{A2}$				$\boldsymbol{\ldots}$	$\boldsymbol{A_i}$			
		$\boldsymbol{B1}$	$\boldsymbol{B2}$	$\boldsymbol{\ldots}$	$\boldsymbol{B_j}$	$\boldsymbol{B1}$	$\boldsymbol{B2}$	$\boldsymbol{\ldots}$	$\boldsymbol{B_j}$	$\boldsymbol{\ldots}$	$\boldsymbol{B1}$	$\boldsymbol{B2}$	$\boldsymbol{\ldots}$	$\boldsymbol{B_j}$
$\boldsymbol{C1}$	$D1$	Y_{1111}	Y_{1211}	$\cdots$	Y_{1j11}	Y_{2111}	Y_{2211}	$\cdots$	Y_{2j11}	$\cdots$	Y_{i111}	Y_{i211}	$\cdots$	Y_{ij11}
	$D2$	Y_{1112}	Y_{1212}	$\cdots$	Y_{1j12}	Y_{2112}	Y_{2212}	$\cdots$	Y_{2j12}	$\cdots$	Y_{i112}	Y_{i212}	$\cdots$	Y_{ij12}
	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
	D_l	Y_{111l}	Y_{121l}	$\cdots$	Y_{1j1l}	Y_{211l}	Y_{221l}	$\cdots$	Y_{2j1l}	$\cdots$	Y_{i11l}	Y_{i21l}	$\cdots$	Y_{ij1l}
$\boldsymbol{C2}$	$D1$	Y_{1121}	Y_{1221}	$\cdots$	Y_{1j21}	Y_{2121}	Y_{2221}	$\cdots$	Y_{2j21}	$\cdots$	Y_{i121}	Y_{i221}	$\cdots$	Y_{ij21}
	$D2$	Y_{1122}	Y_{1222}	$\cdots$	Y_{1j22}	Y_{2122}	Y_{2222}	$\cdots$	Y_{2j22}	$\cdots$	Y_{i122}	Y_{i222}	$\cdots$	Y_{ij22}
	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
	D_l	Y_{112l}	Y_{122l}	$\cdots$	Y_{1j2l}	Y_{212l}	Y_{222l}	$\cdots$	Y_{2j2l}	$\cdots$	Y_{i12l}	Y_{i22l}	$\cdots$	Y_{ij2l}
$\boldsymbol{\ldots}$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
$\boldsymbol{C_k}$	$D1$	Y_{11k1}	Y_{12k1}	$\cdots$	Y_{1jk1}	Y_{21k1}	Y_{22k1}	$\cdots$	Y_{2jk1}	$\cdots$	Y_{i1k1}	Y_{i2k1}	$\cdots$	Y_{ijk1}
	$D2$	Y_{11k2}	Y_{12k2}	$\cdots$	Y_{1jk2}	Y_{21k2}	Y_{22k2}	$\cdots$	Y_{2jk2}	$\cdots$	Y_{i1k2}	Y_{i2k2}	$\cdots$	Y_{ijk2}
	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
	D_l	Y_{11kl}	Y_{12kl}	$\cdots$	Y_{1jkl}	Y_{21kl}	Y_{22kl}	$\cdots$	Y_{2jkl}	$\cdots$	Y_{i1kl}	Y_{i2kl}	$\cdots$	Y_{ijkl}

The shape of the block diagram is actually very much. One application of the four-factors completely block randomized design with the same replication is as follows:

Table 4. Application of a completely block randomized design of the four-factors

		A1		A2	
		B1	B2	B1	B2
C1	D1	R1-R3	R4-R6	R7-R9	R10-R12
	D2	R13-R15	R16-R18	R19-R21	R22-R24
C2	D1	R25-R27	R28-R30	R31-R33	R34-R36
	D2	R37-R39	R40-R42	R43-R45	R46-R48

In the block diagram above, there are forty-eight experimental units placed on 2 levels of factor A, 2 levels of factor B, 2 levels of factor C, and 2 levels of factor D where there are three experimental units or subjects in each combination of treatments

If we call the number of variables to be tested, in order to measure the variables when each variable is tested at a high and a low level, $2 \wedge n$ experiments will be needed [7]. There is another way to define the concept of main effects [5]. Suppose we have a full factorial design studying the four factors: A, B, C, and D with two levels for each factor. There are $2 \wedge 4 = 16$ treatments or level combinations. The combination based on the block diagram above is the factor A, the factor B, the factor C, the factor D, the factor AB interaction, the AC factor interaction, the interaction of the factor AD, the interaction of the BC factor, the BD factor interaction, the CD factor interaction, the ABC factor interaction, ABD interaction factor ACD, BCD factor interaction, ABCD factor interaction, and $R / ABCD$ error. A common regression model for studying main effects and interactions is:

$$Y_{ijklm} = \mu + \alpha_i + \beta_j + \gamma_k + \delta_l + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\alpha\delta)_{il} + (\beta\gamma)_{jk} + (\beta\delta)_{jl} + (\gamma\delta)_{kl} + (\alpha\beta\gamma)_{ijk} + (\alpha\beta\delta)_{ijl} + (\beta\gamma\delta)_{jkl} + (\alpha\gamma\delta)_{ikl} + (\alpha\beta\gamma\delta)_{ijkl} + \varepsilon_{ijklm}$$

Where:
$i = 1,2, \ldots$
$j = 1,2, \ldots$
$k = 1,2, \ldots$
$l = 1,2, \ldots$
$m = 1,2, \ldots$

$\boldsymbol{Y_{ijklm}}$	=	observation on the experimental unit to $\boldsymbol{m}$ from the combination of $\boldsymbol{ijkl}$ treatment with factor A level to $\boldsymbol{i}$, factor B level to $\boldsymbol{j}$, factor C level to $\boldsymbol{k}$, and factor D level to $\boldsymbol{l}$
$\boldsymbol{\mu}$	=	general average
$\boldsymbol{\alpha_i}$	=	influence of factor A on level i
$\boldsymbol{\beta_j}$	=	influence of factor B on level j
$\boldsymbol{\gamma_k}$	=	influence of factor C on level k
$\boldsymbol{\delta_l}$	=	influence of factor D on level l
$\boldsymbol{(\alpha\beta)_{ij}}$	=	the effect of the interaction of factor A on the level of i and factor B on the level to j
$\boldsymbol{(\alpha\gamma)_{ik}}$	=	the effect of the interaction of factor A on the level of i and factor C on the level of k
$\boldsymbol{(\alpha\delta)_{il}}$	=	the effect of the interaction of factor A on the level of i and factor D on the level of l
$\boldsymbol{(\beta\gamma)_{jk}}$	=	the effect of the interaction of factor B on the level of j and factor C on the level of k
$\boldsymbol{(\beta\delta)_{jl}}$	=	the effect of the interaction of factor B on the level of j and factor D on the level of l
$\boldsymbol{(\gamma\delta)_{kl}}$	=	the effect of the interaction of factor C on the level of k and factor D on the level of l
$\boldsymbol{(\alpha\beta\gamma)_{ijk}}$	=	the effect of the interaction of factor A on the level of i, factor B on the level of j and factor C on the level of k
$\boldsymbol{(\alpha\beta\delta)_{ijl}}$	=	the effect of the interaction of factor A on the level of i, factor B on the level of j and factor D on the level of l
$\boldsymbol{(\beta\gamma\delta)_{jkl}}$	=	the effect of the interaction of factor B on the level of j, factor C on the level of k, and factor D on the level of l
$\boldsymbol{(\alpha\gamma\delta)_{ikl}}$	=	the effect of the interaction of factor A on the level of i, factor C on the level of k and factor D on the level of l
$\boldsymbol{(\alpha\beta\gamma\delta)_{ijkl}}$	=	the effect of the interaction of factor A on the level of i, factor B on the level of j, factor C on the level of k and factor D on the level of l

$\boldsymbol{\varepsilon_{ijklm}}$ = The effect of error that arises from a combination of experiments to m in factor A level to i, factor B on the level of j, factor C on the level of k, and factor D on the level of l

There are 16 combinations of models based on Random and Fixed factors for the factorial design 4 factors with the form of the block diagram above, namely:

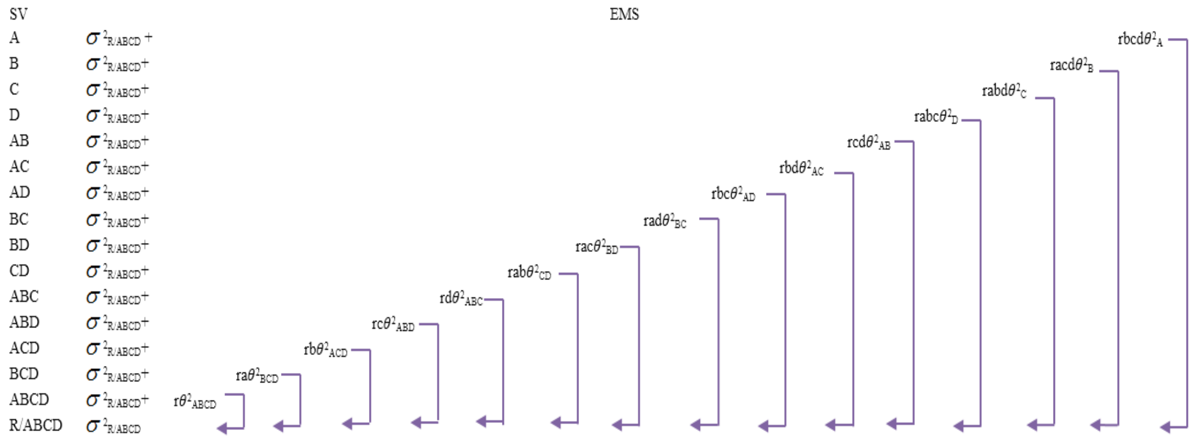
Table 5. A models based on random and fixed factors for the factorial design 4 factors

	Factor A	Factor B	Factor C	Factor D
1	T	T	T	T
2	A	A	A	A
3	T	A	A	A
4	A	T	A	A
5	A	A	T	A
6	A	A	A	T
7	T	T	A	A
8	T	A	T	A
9	T	A	A	T
10	A	T	T	A
11	A	T	A	T
12	A	A	T	T
13	T	T	T	A
14	T	T	A	T
15	T	A	T	T
16	A	T	T	T

Based on the model used is model number 1, which is a fixed model for all factors, then the assumption of the model above is as follows:
$\sum_{i=1}\alpha_i = 0$; $\sum_{j=1}\beta_j = 0$; $\sum_{k=1}\gamma_k = 0$; $\sum_{l=1}\delta_l = 0$; $\sum_{i=1}(\alpha\beta)_{ij} = \sum_{j=1}(\alpha\beta)_{ij}$; $\sum_{i=1}(\alpha\gamma)_{ik} = \sum_{k=1}(\alpha\gamma)_{ik}$; $\sum_{i=1}(\alpha\delta)_{il} = \sum_{l=1}(\alpha\delta)_{il}$; $\sum_{j=1}(\beta\gamma)_{jk} = \sum_{k=1}(\beta\gamma)_{jk}$; $\sum_{j=1}(\beta\delta)_{jl} = \sum_{l=1}(\beta\delta)_{jl}$; $\sum_{k=1}(\gamma\delta)_{kl} = \sum_{l=1}(\gamma\delta)_{kl}$; $\sum_{i=1}(\alpha\beta\gamma)_{ijk} = \sum_{j=1}(\alpha\beta\gamma)_{ijk} = \sum_{k=1}(\alpha\beta\gamma)_{ijk}$; $\sum_{i=1}(\alpha\beta\delta)_{ijl} = \sum_{j=1}(\alpha\beta\delta)_{ijl} = \sum_{l=1}(\alpha\beta\delta)_{ijl}$; $\sum_{j=1}(\beta\gamma\delta)_{jkl} = \sum_{k=1}(\beta\gamma\delta)_{jkl} = \sum_{l=1}(\beta\gamma\delta)_{jkl}$; $\sum_{i=1}(\alpha\gamma\delta)_{ikl} = \sum_{k=1}(\alpha\gamma\delta)_{ikl} = \sum_{l=1}(\alpha\gamma\delta)_{ikl}$; $\sum_{i=1}(\alpha\beta\gamma\delta)_{ijkl} = \sum_{j=1}(\alpha\beta\gamma\delta)_{ijkl} = \sum_{k=1}(\alpha\beta\gamma\delta)_{ijkl} = \sum_{l=1}(\alpha\beta\gamma\delta)_{ijkl}$

Based on the model used is a fixed model, EMS will be determined in advance as a step to determine the F-count

Table 6. EMS Table for CRF-2222 Design



Based on the EMS that has been found, F_0 can be determined based on the arrows depicted in the table. The arrow rule is to find the similarity of the formula that is owned by the factor or interaction of the factor with the error (by assuming there is no final formula). Based on the EMS table, there are 15 arrows found. This shows there are 15 F_0 formulas that appear at the same time explaining there are 15 hypotheses that are ready to be tested in the design. The form of the hypothesis tested in the design of the four factors in a completely randomized design is as follows:

The main effect of factors A:
$H_0: \alpha_1 = \cdots = \alpha_a = 0$ (factor A has no effect)
H_1: There is at least a pair i with $\alpha_i \neq 0$
The main effect of factor B:
$H_0: \alpha_1 = \cdots = \alpha_b = 0$ (factor **B** has no effect)
H_1: There is at least a pair j with $\alpha_j \neq 0$
The main effect of factor C:
$H_0: \alpha_1 = \cdots = \alpha_c = 0$ (factor C has no effect)
H_1: There is at least a pair k with $\alpha_i \neq 0$
The main effect of factor D:
$H_0: \alpha_1 = \cdots = \alpha_d = 0$ (factor D has no effect)
H_1: There is at least a pair l with $\alpha_i \neq 0$
The simple effect (interaction) factor A to factor B:
$H_0: \alpha\beta_{11} = \alpha\beta_{12} = \cdots = \alpha\beta_{ab} = 0$ (The interaction of factor A with B factor has no effect)
H_1: There is at least a pair (i, j) with $\alpha\beta_{ij} \neq 0$
The simple effect (interaction) factor A to factor C:
$H_0: \alpha\gamma_{11} = \alpha\gamma_{12} = \cdots = \alpha\gamma_{ac} = 0$ (The interaction of factor A with C factor has no effect)
H_1: P There is at least a pair g (i, k) with $\alpha\gamma_{ik} \neq 0$
The simple effect (interaction) factor A to factor D:
$H_0: \alpha\delta_{11} = \alpha\delta_{12} = \cdots = \alpha\delta = 0$ (The interaction of factor A with D factor has no effect)
H_1: There is at least a pair (i, l) with $\alpha\delta_{il} \neq 0$
The simple effect (interaction) factor B to factor C:
$H_0: \beta\gamma_{11} = \beta\gamma_{12} = \cdots = \beta\gamma_{ac} = 0$ (The interaction of factor B with C factor has no effect)
H_1: There is at least a pair (j, k) with $\beta\gamma_{jk} \neq 0$
The simple effect (interaction) factor B to factor D:
$H_0: \beta\delta_{11} = \beta\delta_{12} = \cdots = \beta\delta_{ac} = 0$ (The interaction of factor B with D factor has no effect)
H_1: There is at least a pair(j, l) with $\beta\delta_{jl} \neq 0$
The simple effect (interaction) factor C to factor D:
$H_0: \gamma\delta_{11} = \gamma\delta_{12} = \cdots = \gamma\delta_{ac} = 0$ (The interaction of factor C with D factor has no effect)
H_1: There is at least a pair (k, l) with $\gamma\delta_{kl} \neq 0$
The simple effect (interaction) factor A, factor B to factor C:
$H_0: \alpha\beta\gamma_{111} = \alpha\beta\gamma_{112} = \cdots = \alpha\beta\gamma_{abc} = 0$ (The interaction of factor A, factor B, with C factor has no effect)
H_1: There is at least a pair(i, j, k) with $\alpha\beta\gamma_{ijk} \neq 0$
The simple effect (interaction)) factor A, factor B to factor D:
$H_0: \alpha\beta\delta_{111} = \alpha\beta\delta_{112} = \cdots = \alpha\beta\delta_{abc} = 0$ (The interaction of factor A, factor B, with D factor has no effect)
H_1: There is at least a pair(i, j, l) with $\alpha\beta\delta_{ijl} \neq 0$
The simple effect (interaction) factor B, factor C to factor D:
$H_0: \beta\gamma\delta_{111} = \beta\gamma\delta_{112} = \cdots = \beta\gamma\delta_{abc} = 0$ (The interaction of factor B, factor C, with D factor has no effect)
H_1: There is at least a pair (j, k, l) with $\beta\gamma\delta_{jkl} \neq 0$
The simple effect (interaction) factor A, factor C to factor D:

$H_0: \alpha\gamma\delta_{111} = \alpha\gamma\delta_{112} = \cdots = \alpha\gamma\delta_{abc} = 0$ (The interaction of factor A, factor C, with D factor has no effect)

H_1: There is at least a pair(i, k, l) with $\alpha\gamma\delta_{ikl} \neq 0$

The simple effect (interaction) factor A, factor B, factor C to factor D:

$H_0: \alpha\beta\gamma\delta_{1111} = \alpha\beta\gamma\delta_{1112} = \cdots = \alpha\beta\gamma\delta_{abcd} = 0$ (The interaction of factor A, factor B, factor C, with factor D has no effect)

H_1: There is at least a pair (i, j, k, l) with $\alpha\beta\gamma\delta_{ijkl} \neq 0$

Table 7. ANOVA Table for CRF-2222 Design

SV	*Degree of Freedom (Df)*	*Sum of Square (SS)*	*Mean Square (MS)*	*F*	*F_{Table}*
A	$a-1$	SSA	$\mathrm{MSA} = \frac{\mathrm{SSA}}{\mathrm{a}-1}$	$F(A) = \frac{MSA}{MSR/ABCD}$	$F_{\alpha;db(A);db(R/ABCD)}$
B	$b-1$	SSB	$\mathrm{MSB} = \frac{\mathrm{SSB}}{\mathrm{b}-1}$	$F(B) = \frac{KTB}{MSR/ABCD}$	$F_{\alpha;db(B);db(R/ABCD)}$
C	$c-1$	SSC	$\mathrm{MSC} = \frac{\mathrm{SSC}}{\mathrm{c}-1}$	$F(C) = \frac{KTC}{MSR/ABCD}$	$F_{\alpha;db(C);db(R/ABCD)}$
D	$d-1$	SSD	$\mathrm{MSD} = \frac{\mathrm{SSD}}{\mathrm{d}-1}$	$F(D) = \frac{MSD}{MSR/ABCD}$	$F_{\alpha;db(D);db(R/ABCD)}$
AB	$(a-1)(b-1)$	$SSAB$	$\mathrm{MSAB} = \frac{\mathrm{SSAB}}{(\mathrm{a}-1)(\mathrm{b}-1)}$	$F(AB) = \frac{MSAB}{MSR/ABCD}$	$F_{\alpha;db(AB);db(R/ABCD)}$
AC	$(a-1)(c-1)$	$SSAC$	$\mathrm{MSAC} = \frac{\mathrm{SSAC}}{(\mathrm{a}-1)(\mathrm{c}-1)}$	$F(AC) = \frac{MSAC}{MSR/ABCD}$	$F_{\alpha;db(AC);db(R/ABCD)}$
AD	$(a-1)(d-1)$	$SSAD$	$\mathrm{MSAB} = \frac{\mathrm{SSAD}}{(\mathrm{a}-1)(\mathrm{d}-1)}$	$F(AD) = \frac{MSAD}{MSR/ABCD}$	$F_{\alpha;db(AD);db(R/ABCD)}$
BC	$(b-1)(c-1)$	$SSBC$	$\mathrm{MSBC} = \frac{\mathrm{SSBC}}{(\mathrm{b}-1)(\mathrm{c}-1)}$	$F(BC) = \frac{MSBC}{MSR/ABCD}$	$F_{\alpha;db(BC);db(R/ABCD)}$
BD	$(b-1)(d-1)$	$SSBD$	$\mathrm{MSBD} = \frac{\mathrm{SSBD}}{(\mathrm{b}-1)(\mathrm{d}-1)}$	$F(BD) = \frac{MSBD}{MSR/ABCD}$	$F_{\alpha;db(BD);db(R/ABCD)}$
CD	$(c-1)(d-1)$	$SSCD$	$\mathrm{MSCD} = \frac{\mathrm{SSCD}}{(\mathrm{c}-1)(\mathrm{d}-1)}$	$F(CD) = \frac{MSCD}{MSR/ABCD}$	$F_{\alpha;db(CD);db(R/ABCD)}$
ABC	$(a-1)(b-1)(c-1)$	$SSABC$	$\mathrm{MSABC} = \frac{\mathrm{SSABC}}{(\mathrm{a}-1)(\mathrm{b}-1)(\mathrm{c}-1)}$	$F(ABC) = \frac{MSABC}{MSR/ABCD}$	$F_{\alpha;db(ABC);db(R/ABCD)}$
ABD	$(a-1)(b-1)(d-1)$	$SSABD$	$\mathrm{MSABD} = \frac{\mathrm{SSABD}}{(\mathrm{a}-1)(\mathrm{b}-1)(\mathrm{d}-1)}$	$F(ABD) = \frac{MSABD}{MSR/ABCD}$	$F_{\alpha;db(ABD);db(R/ABCD)}$
ACD	$(a-1)(c-1)(d-1)$	$SSACD$	$\mathrm{MSACD} = \frac{\mathrm{SSACD}}{(\mathrm{a}-1)(\mathrm{c}-1)(\mathrm{d}-1)}$	$F(ACD) = \frac{MSACD}{MSR/ABCD}$	$F_{\alpha;db(ACD);db(R/ABCD)}$
BCD	$(b-1)(c-1)(d-1)$	$SSBCD$	$\mathrm{MSACD} = \frac{\mathrm{SSBCD}}{(\mathrm{b}-1)(\mathrm{c}-1)(\mathrm{d}-1)}$	$F(BCD) = \frac{MSBCD}{MSR/ABCD}$	$F_{\alpha;db(BCD);db(R/ABCD)}$
$ABCD$	$(a-1)(b-1)(c-1)(d-1)$	$SSABCD$	$\mathrm{MSABCD} = \frac{\mathrm{SSABCD}}{(\mathrm{a}-1)(\mathrm{b}-1)(\mathrm{c}-1)(\mathrm{d}-1)}$	$F(ABCD) = \frac{MSABCD}{MSR/ABCD}$	$F_{\alpha;db(ABCD);db(R/ABCD)}$
$R/ABCD$	$(r-1)abcd$	$SSR/ABCD$	$\mathrm{MSR/ABCD} = \frac{\mathrm{SSR/ABCD}}{(\mathrm{r}-1)\mathrm{abcd}}$		
$Total$	$abcdr-1$				

Based on the df found, the formula can be developed to complete this design.

Table 8. Completely ANOVA Table for CRF-2222 Design

SS	*Df*	
FK	1	$1 = \frac{Y_{.....}{}^2}{abcdr}$
SSA	$a-1$	$a-1 = \sum \frac{Y_{i....}{}^2}{bcdr} - \frac{Y_{.....}{}^2}{abcdr}$
SSB	$b-1$	$b-1 = \sum \frac{Y_{.j...}{}^2}{acdr} - \frac{Y_{.....}{}^2}{abcdr}$
SSC	$c-1$	$c-1 = \sum \frac{Y_{..k..}{}^2}{abdr} - \frac{Y_{.....}{}^2}{abcdr}$

SSD	$d-1$	$d-1=\sum\frac{Y_{..l..}{}^2}{abcr}-\frac{Y_{.....}{}^2}{abcdr}$
$SSAB$	$(a-1)(b-1)$	$ab-a-b+1=\sum\sum\frac{Y_{ij...}{}^2}{cdr}-\sum\frac{Y_{i....}{}^2}{bcdr}-\sum\frac{Y_{.j...}{}^2}{acdr}+\frac{Y_{.....}{}^2}{abcdr}$
$SSAC$	$(a-1)(c-1)$	$ac-a-c+1=\sum\sum\frac{Y_{i.k..}{}^2}{bdr}-\sum\frac{Y_{i....}{}^2}{bcdr}-\sum\frac{Y_{..k..}{}^2}{abdr}+\frac{Y_{.....}{}^2}{abcdr}$
$SSAD$	$(a-1)(d-1)$	$ad-a-d+1=\sum\sum\frac{Y_{i..l.}{}^2}{bcr}-\sum\frac{Y_{i....}{}^2}{bcdr}-\sum\frac{Y_{...l.}{}^2}{abcr}+\frac{Y_{.....}{}^2}{abcdr}$
$SSBC$	$(b-1)(c-1)$	$bc-b-c+1=\sum\sum\frac{Y_{.jk..}{}^2}{adr}-\sum\frac{Y_{.j...}{}^2}{acdr}-\sum\frac{Y_{..k..}{}^2}{abdr}+\frac{Y_{.....}{}^2}{abcdr}$
$SSBD$	$(b-1)(d-1)$	$bd-b-d+1=\sum\sum\frac{Y_{.j.l.}{}^2}{acr}-\sum\frac{Y_{.j...}{}^2}{acdr}-\sum\frac{Y_{...l.}{}^2}{abcr}+\frac{Y_{.....}{}^2}{abcdr}$
$SSCD$	$(c-1)(d-1)$	$cd-c-d+1=\sum\sum\frac{Y_{..kl.}{}^2}{abr}-\sum\frac{Y_{..k..}{}^2}{abdr}-\sum\frac{Y_{...l.}{}^2}{abcr}+\frac{Y_{.....}{}^2}{abcdr}$
$SSABC$	$(a-1)$ $(b-1)(c-1)$	$abc-ab-ac-bc+a+b+c-1=\sum\sum\sum\frac{Y_{ijk..}{}^2}{dr}-\sum\sum\frac{Y_{ij...}{}^2}{cdr}-\sum\sum\frac{Y_{i.k..}{}^2}{bdr}-\sum\sum\frac{Y_{.jk..}{}^2}{adr}+\sum\frac{Y_{i....}{}^2}{bcdr}+\sum\frac{Y_{.j...}{}^2}{acdr}+\sum\frac{Y_{..k..}{}^2}{abdr}-\frac{Y_{.....}{}^2}{abcdr}$
$SSABD$	$(a-1)$ $(b-1)(d-1)$	$abd-ab-ad-bd+a+b+d-1=\sum\sum\sum\frac{Y_{ij.l.}{}^2}{cr}-\sum\sum\frac{Y_{ij...}{}^2}{cdr}-\sum\sum\frac{Y_{i..l.}{}^2}{bcr}-\sum\sum\frac{Y_{.j.l.}{}^2}{acr}+\sum\frac{Y_{i....}{}^2}{bcdr}+\sum\frac{Y_{.j...}{}^2}{acdr}+\sum\frac{Y_{...l.}{}^2}{abcr}-\frac{Y_{.....}{}^2}{abcdr}$
$SSACD$	$(a-1)$ $(c-1)(d-1)$	$acd-ac-ad-cd+a+c+d-1=\sum\sum\sum\frac{Y_{i.kl.}{}^2}{br}-\sum\sum\frac{Y_{i.k..}{}^2}{bdr}-\sum\sum\frac{Y_{i..l.}{}^2}{bcr}-\sum\sum\frac{Y_{..kl.}{}^2}{abr}+\sum\frac{Y_{i....}{}^2}{bcdr}+\sum\frac{Y_{..k..}{}^2}{abdr}+\sum\frac{Y_{...l.}{}^2}{abcr}-\frac{Y_{.....}{}^2}{abcdr}$
$SSBCD$	$(b-1)$ $(c-1)(d-1)$	$bcd-bc-bd-cd+b+c+d-1=\sum\sum\sum\frac{Y_{i.kl.}{}^2}{br}-\sum\sum\frac{Y_{.jk..}{}^2}{adr}-\sum\sum\frac{Y_{.j.l.}{}^2}{acr}-\sum\sum\frac{Y_{..kl.}{}^2}{abr}+\sum\frac{Y_{.j...}{}^2}{acdr}+\sum\frac{Y_{..k..}{}^2}{abdr}+\sum\frac{Y_{...l.}{}^2}{abcr}-\frac{Y_{.....}{}^2}{abcdr}$
$SSABCD$	$(a-1)$ $(b-1)$ $(c-1)(d-1)$	$abcd-abc-abd-acd-bcd+ab+ac+ad+bc+bd+cd-a-b-c-d+1=\sum\sum\sum\sum\frac{Y_{ijkl.}{}^2}{r}-\sum\sum\sum\frac{Y_{ijk..}{}^2}{dr}-\sum\sum\sum\frac{Y_{ij.l.}{}^2}{cr}-\sum\sum\sum\frac{Y_{i.kl.}{}^2}{br}+\sum\sum\sum\frac{Y_{i.kl.}{}^2}{br}+\sum\sum\frac{Y_{ij...}{}^2}{cdr}-\sum\sum\frac{Y_{i.k..}{}^2}{bdr}-\sum\sum\frac{Y_{i..l.}{}^2}{bcr}-\sum\sum\frac{Y_{.jk..}{}^2}{adr}+\sum\sum\frac{Y_{.j.l.}{}^2}{acr}+\sum\sum\frac{Y_{..kl.}{}^2}{abr}-\sum\frac{Y_{i....}{}^2}{bcdr}-\sum\frac{Y_{.j...}{}^2}{acdr}-\sum\frac{Y_{..k..}{}^2}{abdr}-\sum\frac{Y_{...l.}{}^2}{abcr}+\frac{Y_{.....}{}^2}{abcdr}$
$SSR/ABCD$	$(r-1)abcd$	$\sum\sum\sum\sum\sum Y_{ijklm}{}^2-\sum\sum\sum\sum\frac{Y_{ijkl.}{}^2}{r}$
Total	$abcdr-1$	$\sum\sum\sum\sum\sum Y_{ijklm}{}^2-\frac{Y_{.....}{}^2}{abcdr}$

*where FK is Correction factor.

4. Conclusion

Based on the results of the study above can be found ANOVA Table for CRF-2222 Design for Fixed Model. Where consists of 16 of SV, 16 of df, 16 of SS, 16 of MS, 16 of EMS, 15 of F_0, and 15 of table F.

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Acknowledgments

We would like to acknowledge the special support by Ministry of Research, Technology and Higher Education of the Republic of Indonesia for funding this research. Also all cooperation done by our colleagues of STKIP PGRI Pacitan for motivation in this paper finishing.