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Four factors experiments for fixed models in completely randomized design Urip Tisngati1, Nely Indra Meifiani2, Dwi Cahyani Nur Apriyani 3 , Martini 4 STKIP PGRI Pacitan, 63511, East Java, Indonesia 1 uriptisngati@gmail.com 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] His work had profound influence on the use of statistics in agricultural and related life sciences [2]. 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 [2]. 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 [3], [4], [5]. 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 [6]. 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 [3].

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 [7].

Jaynes, Ding, Xu, Wong & Ho [8] sait ori iare y ?ci stng wo morfors. he ectofa act be 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 [9]. 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 ?? 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 [2].

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 unitsAccording 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 [6].

A design with four treatment is designated as a Completely Randomized Factorial (???? ??????) Design, where the letters CR identify the building block design, F indicates that it is a factorial design, and ?? , ?? , ?? and ?? 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 ?? × ?? × ?? × ?? treatment combinations; and (3) Random assignment of experimental units to treatment combinations. Each experimental unit must be assigned to only one combination. 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 [10].

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 ?? , the second factor is factor B with the level of ?? , the third factor is factor C with the level of ?? , and the fourth factor is factor D with the level of ?? .

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

Completely 4 factor randomized design layout 1111 ?? 1211 ... ?? 1 ?? 11 ?? 2111 ??

2211 … ?? 2 ?? 11 … ?? ?? 111 ?? ?? 211 … ?? 11 ?? 2 ?? 1112 ?? 1212 … ?? 1 ?? 12 ?? 2112 ?? 2212 … ?? 2 ?? 12 … ?? ?? 112 ?? ?? 212 … ?? 12 … … … … … … … … … … … … … … ?? ?? ?? 111 ?? ?? 121 ?? … ?? 1 ?? 1 ?? ?? 211 ?? ?? 221 ?? … ?? 2 ?? 1 ?? … ?? ?? 11 ?? ?? ?? 21 ?? … ?? 1121 ?? 1221 … ?? 1 ?? 21 ?? 2121 ?? 2221 … ?? 2 ?? 21 … ?? ?? 121 ?? ?? 221 … ?? 21 ?? 2 ?? 1122 ?? 1222 … ?? 1 ?? 22 ?? 2122 ?? 2222 … ?? 2 ?? 22 … ?? ?? 122 ?? ?? 222 … ?? 22 … … … … … … … … … … … … … … ?? ?? ?? 112 ?? ?? 122 ?? … ?? 1 ?? 2 ?? ?? 212 ?? ?? 222 ?? … ?? 2 ?? 2 ?? … ?? ?? 12 ?? ?? ?? 22 ?? … ?? 11 ?? 1 ?? 12 ?? 1 … ?? 1 ???? 1 ?? 21 ?? 1 ?? 22 ?? 1 … ?? 2 ???? 1 … ?? ?? 1 ?? 1 ?? ?? 2 ?? 1 … ?? ?????? 1 ?? 2 ?? 11 ?? 2 ?? 12 ?? 2 … ?? 1 ???? 2 ?? 21 ?? 2 ?? 22 ?? 2 … ?? 2 ???? 2 … ?? ?? 1 ?? 2 ?? ?? 2 ?? 2 … ?? ?????? 2 … … … … … … … … … … … … … … ?? ?? ?? 11 12 21 22 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 ^ ?? experiments will be needed [11]. There is another way to define the concept of main effects [8].

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 ^ 4 = 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 ?? / ???????? error.

A common regression model for studying main effects and interactions is: ?? ???????? = ?? + ?? ?? + ?? ?? + ?? ?? + ?? ?? + (????) ???? + (????) ???? + (????) ???? + ( ) ???? + ( ) ???? + (????) + (??????) ?????? + (??????) ?????? + (??????) ???? + (??????) ???? + (????????) ?????? + ?? ???????? Where: ?? = 1 , 2 , … ?? = 1 , 2 , … ?? = 1 , 2 , … ?? = 1 , 2 , … ?? = 1 , 2 , … ?? ???????? = observation on the experimental unit to ?? ???????? ?? ?? ?? ?? ?? = general average ?? ?? = influence of factor A on level ?? ?? ?? = influence of factor B on level ?? ?? ?? = influence of factor C on level ?? ?? ?? = influence of factor D on level ?? (= the effect of the interaction of factor A on the level of = the effect of the interaction of factor A on the level of i and factor C on the level of = the effect of the interaction of factor A on the level of ????) ???? = the effect of the interaction of factor B on the level of ?? ?? (????) ???? = the effect of the interaction of factor B on the level of ?? ?? (????) ???? = the effect of the interaction of factor C on the level of ?? ?? (??????) ?????? = the effect of the interaction of factor A on the level of ?? , factor B on the level of = the effect of the interaction of factor A on the level of , factor B on the level of ?????? = the effect of the interaction of factor B on the level of ?? ?? , and factor D on the level of = the effect of the interaction of factor A on the level of , factor C on the level of = the effect of the interaction of factor A on the level of i, factor B on the level of ?? and factor D on the level of = The effect of error that arises from a combination of experiments to 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: ? ?? ?? = 0 ; ?? = 1 ? ?? ?? = 0 ?? = 1 ; ? ?? ?? = 0 ?? = 1 ; ? ?? ?? = 0 ?? = 1 ; ? (????) ???? = ? (????) ???? ?? = 1 ; ? (????) ???? = ?? = 1 ?? = 1 ? (????) ???? ; ?? = 1 ? (????) ???? ?? = 1 = ? (????) ???? ?? = 1 ; ? ( ) ???? ?? = 1 = ? ( ) ???? ?? = 1 ; ? ( ) ???? ?? = 1 = ? ( ) ???? ?? = 1 ; ? (????) ?? = 1 = ? (????) ?? = 1 ; ? (??????) ?????? = ? (??????) ?????? ?? = 1 ?? = 1 = ? (??????) ?????? ?? = 1 ; ? (??????) ?????? = ?? = 1 ? (??????) ?????? ?? = 1 = ? (??????) ?????? ?? = 1 ; ? (??????) ???? ?? = 1 = ? (??????) ???? = ? (??????) ???? ?? = 1 ?? = 1 ; ? (??????) ???? = ?? = 1 ? (??????) ???? ?? = 1 = ? (??????) ???? ; ? (????????) ?????? ?? = 1 ?? = 1 = ? (????????) ?????? ?? = 1 = ? (?? ??????) ?????? = ?? = 1 ? (????????) ?????? ?? = 1 Based on the model used is a fixed model, EMS will be determined in advance as a step to determine the F-count Table 5.

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: ?? 0 : ?? 1 = ? = ?? ?? = 0 (factor A has no effect) ?? 1 : There is at least a pair ?? with ?? ?? ? 0 The main effect of factor B: ?? 0 : ?? 1 = ? = ?? ??

= 0 (factor B has no effect) ?? 1 : There is at least a pair ?? with ?? ?? ? 0 The main effect of factor C: ?? 0 : ?? 1 = ? = ?? ?? = 0 (factor C has no effect) ?? 1 : There is at least a pair ?? with ?? ?? ? 0 The main effect of factor D: ?? 0 : ?? 1 = ? = ?? ?? = 0 (factor D has no effect) ?? 1 : There is at least a pair ?? with ?? ?? ? 0 The simple effect (interaction) factor A to factor B: ?? 0 : ???? = ???? = ? = ???? = 0 (The interaction of factor A with B factor has no effect) ?? 1 : There is at least a pair (?? , ??) with ???? ???? ? 0 The simple effect (interaction) factor A to factor C: ?? 0 : ???? = ???? = ? = ???? = 0 (The interaction of factor A with C factor has no effect) ?? 1 : P There is at least a pair g (?? , ??) with ???? ???? ? 0 The simple effect (interaction) factor A to factor D: ?? 0 : ???? = ???? = ? = ???? = 0 (The interaction of factor A with D factor has no effect) ?? 1 : There is at least a pair (?? , ??) with ???? ???? ? 0 The simple effect (interaction) factor B to factor C: ?? 0 : = = ? = = 0 (The interaction of factor B with C factor has no effect) ?? 1 : There is at least a pair (?? , ??) with ???? ? 0 The simple effect (interaction) factor B to factor D: ?? 0 : = = ? = = 0 (The interaction of factor B with D factor has no effect) ?? 1 : There is at least a pair (?? , ??) with ???? ? 0 The simple effect (interaction) factor C to factor D: ?? 0 : ???? = ???? = ? = ???? = 0 (The interaction of factor C with D factor has no effect) ?? 1 : There is at least a pair (?? , ??) with ???? ? 0 The simple effect (interaction) factor A, factor B to factor C: ?? 0 : ?????? = ?????? = ? = ?????? ?????? = 0 (The interaction of factor A, factor B, with C factor has no effect) ?? 1 : There is at least a pair (?? , ?? , ??) with ???? ?? ?????? ? 0 The simple effect (interaction)) factor A, factor B to factor D: ?? 0 : ?????? = ?????? = ? = ?????? ?????? = 0 (The interaction of factor A, factor B, with D factor has no effect) ?? 1 : There is at least a pair (?? , ?? , ??) with ?????? ?????? ? 0 The simple effect (interaction) factor B, factor C to factor D: ?? 0 : ?????? = ?????? = ? = ?????? ?????? = 0 (The interaction of factor B, factor C, with D factor has no effect) ?? 1 : There is at least a pair (?? , ?? , ??) with ?????? ???? ? 0 The simple effect (interaction) factor A, factor C to factor D: ?? 0 : ?? ???? = ?? ???? = ? = ?? ???? ?????? = 0 (The interaction of factor A, factor C, with D factor has no effect) ?? 1 : There is at least a pair (?? , ?? , ??) with ?? ???? ???? ? 0 The simple effect (interaction) factor A, factor B, factor C to factor D: ?? 0 : ???????? 1 = ???????? = ? = ???????? ???????? = 0 (The interaction of factor A, factor B, factor C, with factor D has no effect) ?? 1 : There is at least a pair (?? , ?? , ?? , ??) with ???????? ?????? ? 0 Table 6.

ANOVA Table for CRF-2222 Design SV Degree of Freedom (Df) Sum of Square (SS) Mean Square (MS) F Ftabel ?? ?? - 1 MS C = MS D = MS AB = SAB (a - 1) (b - 1) ?? (MS AC = SAC (a - 1) (c - 1) ?? (MS AB = SAD (a - 1) (d - 1) ?? (???? (?? - 1) (?? - 1) ???? MS ????) = ???? ???? / ???? ?? ?? ; ????) ; ???? (?? - 1) (?? - 1) ???? MS BD = SBD (b - 1) (d - 1) ?? (????) = ?????? ???? / ???? ?? ?? ; ????) ; MS ????) ; (MS ABC = SABC (a - 1) (b - 1) (c - 1) ?? (??) = ???? ???? / ???? ?? ?? ;) MS ABD = SABD (a - 1) (b - 1) (d - 1) ?? (??) = ???????? ???? / ???? ?? ?? ; MS AC = SAC (a - 1) (c - 1) (d - 1) ?? (????) = ?????? ???? / ???? ?? ?? ; MS AC = SBC (b - 1) (c - 1) (d - 1) ?? (????) = ??????

???? / ???? ?? ?? ; ??????) ; MS ABD = SABC (a - 1) (b - 1) (c - 1) (d - 1) ?? (????) = ???????? ???? / ???? ?? ?? ; Based on the ???? found, the formula can be developed to complete this design.

Table 7. Completely ANOVA Table for CRF-2222 Design SS Df ???? (?? - 1) (?? - 1) ?????? - ? ?? ?? … . 2 ???? - ? ?? . . ?? . . 2 ?? + ?? … . . 2 ?????? ???? (?? - 1) (?? - 1) ???? (?? - 1) (?? - 1) ???? - ?? - ?? + 1 = ? ? ?? . ???? . . 2 ?? - ? ?? . ?? . . . 2 ?????? - ? ?? . . ?? . . 2 ?? + ?? … . . 2 ?????? ???? (?? - 1) (?? - 1) ???? - ?? - ?? + 1 = ? ? ?? . ?? . ?? . 2 ???? - ? ?? . ?? . . . 2 ?????? - ? ?? . . . ?? . 2 ???? + ?? … . .

2 ?????? ???? + ?? + ?? + ?? - 1 = ? ? ? ?? ???? . . 2 ???? + ?? + ?? + ?? - 1 = ? ? ? ?? ???? - ? ? ?? ?????? - ? ? ?? . ?? . ?? . 2 ?? + ? ?? ?? … . 2 ?????? + ? ?? . ?? . . . 2 ???? + ? ?? . . . ?? . 2 ?? - ?? … . . 2 ???? ???? . 2 ???? - ? ? ?? ?? . ?? . . 2 ???? - ? ? ?? ?? . . ?? . 2 ?????? - ? ? ?? . . ???? . 2 ?? + ? ?? ?? … . 2 ?????? + ? ?? . . ?? . . 2 ???? + ? ?? . . . ?? . 2 ?? - ?? … . . 2 ???? ???? - ???? - ???? . 2 ???? - ? ? ?? . ???? . 2 ?? + ? ?? .

?? . . . 2 ???? + ? ?? . . ?? . . 2 ???? + ? ?? . . . ?? . 2 ?? - ?? … . . 2 ???? ???? + ???? + ???? - ? ? ? ?? ?? . ???? . 2 ???? + ? ? ? ?? ?? . ???? . 2 ???? + ? ? ?? ?????? - ? ? ?? . ???? . 2 ?? - ? ?? ?? … . 2 ???? - ? ?? . ?? . . . 2 ?????? - ? ?? . . ?? . . 2 ?? - ? ?? . . . ?? . 2 ???? + ?? … . . 2 ?????? Total *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. 5. References [1] Steinberg D M & Hunter W G 1984 Experimental design: Review and comment Technometrics 26 71 97 [2] Pais M S, Peretta I S, Yamanaka K & Pinto E R 2014 Factorial design analysis applied to the performance of parallel ecolutionary algorithms Journal of The Brazilian Computer Society 20 1-17 [3] Mattjik A A & Sumertajaya I Made 2013 Perancangan percobaan dengan aplikasi SAS dan MINITAB, Bogor: IPB Press [4] Barka N, Abdennouri M, Boussaud A, Galadi A, Baalala M, Bensitel M, Dine A, Sahibed, Nohair K, Sadiq M 2014 Full factorial experimental design applied to oxalic acid photocatalytic degradation in tio2 aqueous suspension Arabian Journal of Chemistry 7 752-757 [5] Kumar L, Reddy M S, Managuli R S & Girish P 2015 Full factorial design for optimization, development and validation of hplc method to determine valsartan in nanoparticles Saudia Pharmaceuntal Journal 23 549-555 [6] Kirk R E 1995 Experimental design: Procedures for the behavioral sciences, USA: Brooks/ Cole Publishing Company [7] Zahran A R 2013 Two-level factorial design with circular response: Model and analysis Journal of Data Science 11 415-432 [8] Jaynes J, Ding X X H, Wong W K & Ho C M 2012 Application of fractional factorial design to study drug combinations, New York: Wiley Online Library (John Wiley & Sons, Ltd) [9] Wu C F J, Hamada M & Joseph V R 2009 Experiments: planning, analysis and parameter design

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