**Modern College of Arts, Science and Commerce, Pune-05**

**Department of Statistics**

**M.Sc. II (Semester IV)**

**Date: Submission date:**

**Practical No. – 03**

**Title:** **Balanced Incomplete Block Design.**

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Q1) An engineer is studying the mileage performance characteristics of five types of gasoline additives. In the road test he wishes to use cars as blocks; however, because of a time constraint, he must use an incomplete block design. He runs the balanced design with the five blocks that follow. Analyze the data from this experiment (use α= 0.05) and draw conclusions.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Additive | Car | | | | |
| 1 | 2 | 3 | 4 | 5 |
| 1 | 24 |  | 23 | 27 | 22 |
| 2 |  | 24 | 23 | 24 | 20 |
| 3 | 23 | 22 | 22 |  | 19 |
| 4 | 21 | 23 | 22 | 21 |  |
| 5 | 20 | 21 |  | 22 | 18 |

Q2) Seven different hardwood concentrations are being studied to determine their effect on the strength of the paper produced. However, the pilot plant can only produce three runs each day. As days may differ, the analyst uses the balanced incomplete block design that follows. Analyze the data from this experiment (use α= 0.05) and draw conclusions.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Hardwood Concentration (%) | Days | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 2 |  |  | 220 |  | 217 |  | 214 |
| 4 |  | 220 |  |  |  | 219 | 226 |
| 6 | 217 | 237 |  |  | 234 |  |  |
| 8 | 229 |  |  | 249 |  |  | 241 |
| 10 |  | 245 | 243 | 250 |  |  |  |
| 12 | 220 |  | 218 |  |  | 223 |  |
| 14 |  |  |  | 236 | 227 | 230 |  |

**Q1.]**

> v=5; r=4; b=5; k=4;lambda=3; N=20;

> d=matrix(c(24,0,23,27,22,0,2s4,23,24,20,23,22,22,0,19,21,23,22,21,0,20,21,0,22,18),nrow=5,ncol=5,byrow=TRUE)

> d

[,1] [,2] [,3] [,4] [,5]

[1,] 24 0 23 27 22

[2,] 0 24 23 24 20

[3,] 23 22 22 0 19

[4,] 21 23 22 21 0

[5,] 20 21 0 22 18

> n=matrix(nrow=5,ncol=5)

> for(i in 1:5)

+ {

+ for(j in 1:5)

+ {

+ n[i,j]=ifelse(d[i,j]==0,0,1)

+ }

+ }

> n

[,1] [,2] [,3] [,4] [,5]

[1,] 1 0 1 1 1

[2,] 0 1 1 1 1

[3,] 1 1 1 0 1

[4,] 1 1 1 1 0

[5,] 1 1 0 1 1

> Ti=rowSums(d);Ti

[1] 96 91 86 87 81

> Bj=colSums(d);Bj

[1] 88 90 90 94 79

> Ti\_sq=Ti^2;Ti\_sq

[1] 9216 8281 7396 7569 6561

> Bj\_sq=Bj^2;Bj\_sq

[1] 7744 8100 8100 8836 6241

> nijBj=n%\*%Bj;nijBj #%\*% is used for matrix multiplication

[,1]

[1,] 351

[2,] 353

[3,] 347

[4,] 362

[5,] 351

> Qi=Ti-(nijBj/k);Qi

[,1]

[1,] 8.25

[2,] 2.75

[3,] -0.75

[4,] -3.50

[5,] -6.75

> Qi^2

[,1]

[1,] 68.0625

[2,] 7.5625

[3,] 0.5625

[4,] 12.2500

[5,] 45.5625

> G=sum(Bj);G

[1] 441

> CF=(G^2)/N;CF

[1] 9724.05

> yij\_sq=d^2;yij\_sq

[,1] [,2] [,3] [,4] [,5]

[1,] 576 0 529 729 484

[2,] 0 576 529 576 400

[3,] 529 484 484 0 361

[4,] 441 529 484 441 0

[5,] 400 441 0 484 324

> TSS=(sum(yij\_sq))-CF;TSS

[1] 76.95

> BSS=((sum(Bj^2))/k)-CF;BSS

[1] 31.2

> r\_E=lambda\*v/k;r\_E

[1] 3.75

> TrmtSS=((sum(Qi^2))/r\_E);TrmtSS

[1] 35.73333

> ESS=TSS-TrmtSS-BSS;ESS

[1] 10.01667

> MStrmt=TrmtSS/(v-1);MStrmt

[1] 8.933333

> MBSS=BSS/(b-1);MBSS

[1] 7.8

> MESS=ESS/(b\*k-b-v+1);MESS

[1] 0.9106061

> F1=MBSS/MESS;F1

[1] 8.565724

> F2=MStrmt/MESS;F2

[1] 9.810316

**ANOVA:-**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Source of variation** | **d.f** | **Sum of squares** | **Mean sum of squares** | **F Ratio** |
| **Between Blocks**  **(unadjusted)** | **b-1=5-1=4** | **31.2** | **7.8** | **8.565724** |
| **Between Treatments (adjusted)** | **v-1=5-1=4** | **35.73333** | **8.933333** | **9.810316** |
| **Error** | **bk-b-v+1=5\*4-5-5+1=9** | **10.01667** | **0.9106061** |  |
| **Total** | **bk-1=5\*4-1=19** | **76.95** |  |  |

**Hypothesis:-**

**H0:- Block effect is not significant vs H1: Block effect is significant**

**H0:- Treatment effect is not significant vs H1: Treatment effect is significant**

**Conclusion:- Since F1 =8.565724 > F n1,n2,0.05 = F 4,9,0.05 = 3.63, thus we Reject H0**

**Since F2 =9.810316 > F n1,n2,0.05 = F 4,9,0.05 = 3.63, thus we Reject H0**

**Q2.]**

> v=7; r=3; b=7; k=3;lambda=1; N=21;

> d=matrix(c(0,0,220,0,217,0,214,0,220,0,0,0,219,226,217,237,0,0,234,0,0,229,0,0,249,0,0,241,0,245,243,250,0,0,0,220,0,218,0,0,223,0,0,0,0,236,227,230,0),nrow=7,ncol=7,byrow=TRUE)

> d

[,1] [,2] [,3] [,4] [,5] [,6] [,7]

[1,] 0 0 220 0 217 0 214

[2,] 0 220 0 0 0 219 226

[3,] 217 237 0 0 234 0 0

[4,] 229 0 0 249 0 0 241

[5,] 0 245 243 250 0 0 0

[6,] 220 0 218 0 0 223 0

[7,] 0 0 0 236 227 230 0

> n=matrix(nrow=7,ncol=7)

> for(i in 1:7)

+ {

+ for(j in 1:7)

+ {

+ n[i,j]=ifelse(d[i,j]==0,0,1)

+ }

+ }

> n

[,1] [,2] [,3] [,4] [,5] [,6] [,7]

[1,] 0 0 1 0 1 0 1

[2,] 0 1 0 0 0 1 1

[3,] 1 1 0 0 1 0 0

[4,] 1 0 0 1 0 0 1

[5,] 0 1 1 1 0 0 0

[6,] 1 0 1 0 0 1 0

[7,] 0 0 0 1 1 1 0

> Ti=rowSums(d);Ti

[1] 651 665 688 719 738 661 693

> Bj=colSums(d);Bj

[1] 666 702 681 735 678 672 681

> Ti\_sq=Ti^2;Ti\_sq

[1] 423801 442225 473344 516961 544644 436921 480249

> Bj\_sq=Bj^2;Bj\_sq

[1] 443556 492804 463761 540225 459684 451584 463761

> nijBj=n%\*%Bj;nijBj #%\*% is used for matrix multiplication

[,1]

[1,] 2040

[2,] 2055

[3,] 2046

[4,] 2082

[5,] 2118

[6,] 2019

[7,] 2085

> Qi=Ti-(nijBj/k);Qi

[,1]

[1,] -29

[2,] -20

[3,] 6

[4,] 25

[5,] 32

[6,] -12

[7,] -2

> Qi^2

[,1]

[1,] 841

[2,] 400

[3,] 36

[4,] 625

[5,] 1024

[6,] 144

[7,] 4

> G=sum(Bj);G

[1] 4815

> CF=(G^2)/N;CF

[1] 1104011

> yij\_sq=d^2;yij\_sq

[,1] [,2] [,3] [,4] [,5] [,6] [,7]

[1,] 0 0 48400 0 47089 0 45796

[2,] 0 48400 0 0 0 47961 51076

[3,] 47089 56169 0 0 54756 0 0

[4,] 52441 0 0 62001 0 0 58081

[5,] 0 60025 59049 62500 0 0 0

[6,] 48400 0 47524 0 0 49729 0

[7,] 0 0 0 55696 51529 52900 0

> TSS=(sum(yij\_sq))-CF;TSS

[1] 2600.286

> BSS=((sum(Bj^2))/k)-CF;BSS

[1] 1114.286

> r\_E=lambda\*v/k;r\_E

[1] 2.333333

> TrmtSS=((sum(Qi^2))/r\_E);TrmtSS

[1] 1317.429

> ESS=TSS-TrmtSS-BSS;ESS

[1] 168.5714

> MStrmt=TrmtSS/(v-1);MStrmt

[1] 219.5714

> MBSS=BSS/(b-1);MBSS

[1] 185.7143

> MESS=ESS/(b\*k-b-v+1);MESS

[1] 21.07143

> F1=MBSS/MESS;F1

[1] 8.813559

> F2=MStrmt/MESS;F2

[1] 10.42034

**ANOVA:-**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Source of variation** | **d.f** | **Sum of squares** | **Mean sum of squares** | **F Ratio** |
| **Between Blocks**  **(unadjusted)** | **b-1=7-1=6** | **1114.286** | **219.5714** | **8.813559** |
| **Between Treatments (adjusted)** | **v-1=7-1=6** | **1317.429** | **185.7143** | **10.42034** |
| **Error** | **bk-b-v+1=7\*3-7-7+1=8** | **168.5714** | **21.07143** |  |
| **Total** | **bk-1=7\*3-1=20** | **2600.286** |  |  |

**Hypothesis:-**

**H0:- Block effect is not significant vs H1: Block effect is significant**

**H0:- Treatment effect is not significant vs H1: Treatment effect is significant**

**Conclusion:- Since F1 =8.813559 > F n1,n2,0.05 = F 4,9,0.05 = 3.63, thus we Reject H0**

**Since F2 =10.42034 > F n1,n2,0.05 = F 4,9,0.05 = 3.63, thus we Reject H0**