**IEE 572**

**DESIGN OF ENGINEERING EXPERIMENTS**

**FALL 2022**

# OPTIMIZATION OF DISTANCE COVERED BY A FOOTBALL USING DESIGN OF EXPERIMENTS


*Project by;*

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## *I. Recognition of and statement of the problem:*

Football is one of the most popularly played sports in the United States. National Football League (NFL) is one of the largest football associations that consist of 32 teams and is a part of the billion-dollar football industry. One of the most significant aspects of the game is to kick the football the furthest you can to score a goal. Therefore, we designed an experiment to estimate the optimized length or distance covered by the football post-kicking. We identified a few factors directly affecting this response variable i.e., the distance covered. We decided to go ahead with the $2^k$ design since it provides the smallest number of runs with which k factors can be studied in a complete factorial design.

## *II. Selection of Response Variable:*

As discussed above, we selected the length or distance covered by the football as our response variable.

### Methodology

1) We use the two-way or $2^k$ design with 5 factors (k = 5) and 2 levels within each factor. We would make use of the JMP software to generate randomized combinations of factors which will then be used to perform our designed experiment.
2) We will be measuring the distance traveled by a football post-kicking based on factors like kicking style, kicking angle, type of shoe used for kicking, and the number of steps taken back before kicking the ball for 2 levels within each factor.
3) The goal of this project is to understand the effects of these varying factors on our response variable i.e., distance traveled by implementing the design of experiments principles.

## ***III. Choice of Factors, Levels & Ranges:***

- The 5 factors and their corresponding ranges or types are discussed in the table below:

| Factor No. | Factors considered | Range or Type of factors considered |
|---|---|---|
| 1 | Kicking Style | Ordinary Style, Soccer Style |
| 2 | Kicking Angle | 45°,90° |
| 3 | Type of Shoe | Football Studs, Running/Trainer's Shoe |
| 4 | Number of steps before kicking | 4,6 |
| 5 | Kicker | Rohit, Jason |

### Response Variables:

Our main **response variable** is the ***length or distance covered by the football*** that is kicked in different combinations of ways. We could also explore the effect of using different balls like a soccer ball and basketball by measuring the same response variable.

### Constant Factors:

Ground conditions, Kicker, and Type of football used for the experiment.

### Uncontrollable Factors:

Wind (wind speed, wind direction, etc.), Weather conditions (Temperature, Humidity, etc.).

## ***IV. Choice of Experimental Design:***

- We have chosen the $2^k$ design (where k is 4) or two-level design with randomized run order generated using JMP because it is simpler due to its orthogonality.

## ***V. Performing the Experiment:***

**[Step 1]** - We have generated 32 combinations of factor levels which will be measured through manual experimentation. A glimpse of this is attached below:

DOXFinalProject - JMP Pro

File Edit Tables Rows Cols DOE Analyze Graph Tools View Window Help SOS

DOXFinalProject
Design Custom Design
Criterion D Optimal
Model
Evaluate Design
DOE Dialog

Columns (6/0)
Kicking Style *
Kicking Angle *
Shoe Type *
No. of Steps *
Kicker *
Distance Kicked *

Rows
All rows 32
Selected 0
Excluded 0
Hidden 0
Labelled 0

| | Kicking Style | Kicking Angle | Shoe Type | No. of Steps | Kicker |
|---|---|---|---|---|---|
| 1 | 1 | 45 | 2 | 4 | 1 |
| 2 | 1 | 45 | 3 | 4 | 1 |
| 3 | 0 | 45 | 2 | 4 | 1 |
| 4 | 0 | 45 | 2 | 6 | 1 |
| 5 | 0 | 45 | 3 | 6 | 1 |
| 6 | 1 | 45 | 3 | 4 | 1 |
| 7 | 1 | 45 | 3 | 6 | 1 |
| 8 | 0 | 45 | 2 | 6 | 1 |
| 9 | 1 | 90 | 2 | 6 | 1 |
| 10 | 0 | 90 | 3 | 4 | 1 |
| 11 | 1 | 90 | 3 | 6 | 1 |
| 12 | 0 | 90 | 3 | 4 | 1 |
| 13 | 0 | 90 | 2 | 4 | 1 |
| 14 | 1 | 90 | 2 | 6 | 1 |
| 15 | 0 | 90 | 3 | 4 | 1 |
| 16 | 1 | 90 | 2 | 6 | 1 |
| 17 | 1 | 45 | 3 | 4 | 2 |
| 18 | 1 | 45 | 2 | 4 | 2 |
| 19 | 0 | 45 | 3 | 6 | 2 |
| 20 | 1 | 45 | 3 | 6 | 2 |
| 21 | 1 | 45 | 2 | 6 | 2 |
| 22 | 0 | 45 | 2 | 4 | 2 |
| 23 | 0 | 45 | 2 | 6 | 2 |
| 24 | 0 | 45 | 3 | 4 | 2 |
| 25 | 1 | 90 | 2 | 4 | 2 |

evaluations done

*Note:* Kicking Style is coded as "0" for ordinary and "1" for soccer. The type of shoe is coded as "2" for trainers or running shoes and "3" for studs or football shoes.

Fig: Trainer's Shoes


Fig: Studs or Football Shoes

Kicking Angles are maintained at 45 degrees and 90 degrees which are done either by hand or using external support as shown in the pictures below.

**[Step 2]** – The distance kicked by the kicker for each of the 32 factor-level combinations in our unreplicated design was measured manually using a measuring tape shown below.


The distances kicked are measured and shown in the below table:

| | Kicking Style | Kicking Angle | Shoe Type | No. of Steps | Kicker | Distance Kicked |
|---|---|---|---|---|---|---|
| 1 | 1 | 45 | 2 | 4 | 1 | 15 |
| 2 | 1 | 45 | 3 | 4 | 1 | 15.5 |
| 3 | 0 | 45 | 2 | 4 | 1 | 15.5 |
| 4 | 0 | 45 | 2 | 6 | 1 | 16.5 |
| 5 | 0 | 45 | 3 | 6 | 1 | 17 |
| 6 | 1 | 45 | 3 | 4 | 1 | 16 |
| 7 | 1 | 45 | 3 | 6 | 1 | 17 |
| 8 | 0 | 45 | 2 | 6 | 1 | 16.5 |
| 9 | 1 | 90 | 2 | 6 | 1 | 23 |
| 10 | 0 | 90 | 3 | 4 | 1 | 22 |
| 11 | 1 | 90 | 3 | 6 | 1 | 24 |
| 12 | 0 | 90 | 3 | 4 | 1 | 22 |
| 13 | 0 | 90 | 2 | 4 | 1 | 21 |
| 14 | 1 | 90 | 2 | 6 | 1 | 23 |
| 15 | 0 | 90 | 3 | 4 | 1 | 22 |
| 16 | 1 | 90 | 2 | 6 | 1 | 22.5 |
| 17 | 1 | 45 | 3 | 4 | 2 | 18 |
| 18 | 1 | 45 | 2 | 4 | 2 | 17 |
| 19 | 0 | 45 | 3 | 6 | 2 | 19 |
| 20 | 1 | 45 | 3 | 6 | 2 | 20 |
| 21 | 1 | 45 | 2 | 6 | 2 | 19.5 |
| 22 | 0 | 45 | 2 | 4 | 2 | 17.5 |
| 23 | 0 | 45 | 2 | 6 | 2 | 17 |
| 24 | 0 | 45 | 3 | 4 | 2 | 16 |
| 25 | 1 | 90 | 2 | 4 | 2 | 19 |
| 26 | 1 | 90 | 3 | 6 | 2 | 24 |
| 27 | 0 | 90 | 2 | 6 | 2 | 23 |
| 28 | 0 | 90 | 3 | 6 | 2 | 25 |
| 29 | 1 | 90 | 2 | 4 | 2 | 20 |
| 30 | 0 | 90 | 3 | 6 | 2 | 24 |
| 31 | 0 | 90 | 2 | 4 | 2 | 22 |
| 32 | 1 | 90 | 3 | 4 | 2 | 23 |

## ***VI. Statistical Analysis of the data:***

**[Step 3] –** JMP was used to analyze the 2k full factorial design with blocking (kicker) to obtain the actual vs predicted plot, effect summary, residual plots (residual vs predicted, residual vs run number), ANOVA – Parameter estimates, Effect Tests, Response Distance Kicked - Box-Cox Transformation, PRESS, Power for all factors, Prediction Profiler, half normal plot, contour profile (one of 10 possible contour profile is shown below) and Interaction profile.

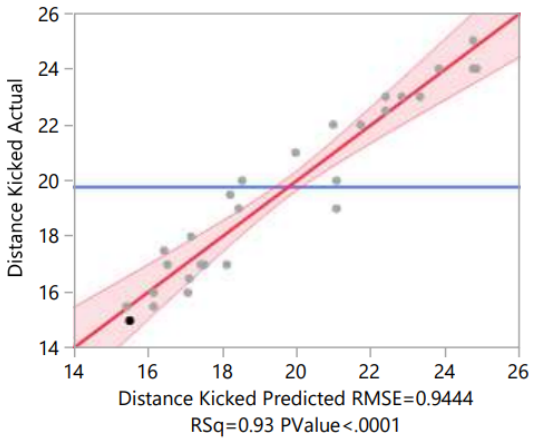
JMP analysis was run considering all factors and their interaction effects and saw that after observing the results, we determined that kicking style and the interaction terms were not significant and thus were removed to perform the reduced JMP model was analyzed as shown.

## JMP analysis of the full model with interaction effects:

**[Step 4]** – Interpretation and understanding of the statistical significance of our data based on the analysis JMP report.

**Response Distance Kicked**

**Actual by Predicted Plot**



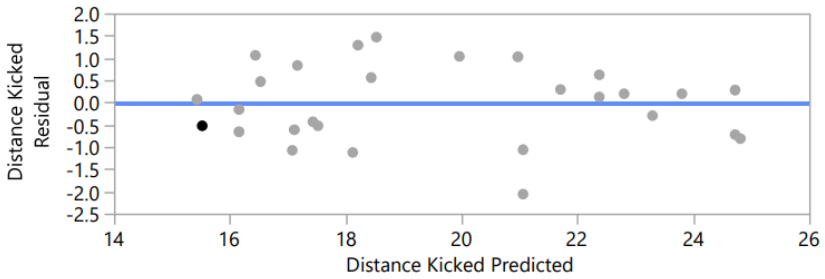

**Effect Summary**

| Source | LogWorth | PValue |
|---|---|---|
| Kicking Angle(45,90) | 13.340 | 0.00000 |
| No. of Steps(4,6) | 4.889 | 0.00001 |
| Shoe Type(2,3) | 2.285 | 0.00519 |
| Kicker | 2.117 | 0.00763 |
| Shoe Type*Kicking Angle | 0.911 | 0.12287 |
| No. of Steps*Kicking Angle | 0.441 | 0.36203 |
| No. of Steps*Shoe Type | 0.187 | 0.65045 |
| Kicking Style(0,1) | 0.094 | 0.80471 |

**Lack Of Fit**

| Source | DF | Sum of Squares | Mean Square | F Ratio |
|---|---|---|---|---|
| Lack Of Fit | 15 | 19.222321 | 1.28149 | 7.9370 |
| Pure Error | 8 | 1.291667 | 0.16146 | Prob > F |
| Total Error | 23 | 20.513988 | | 0.0030* |
| | | | | Max RSq |
| | | | | 0.9957 |

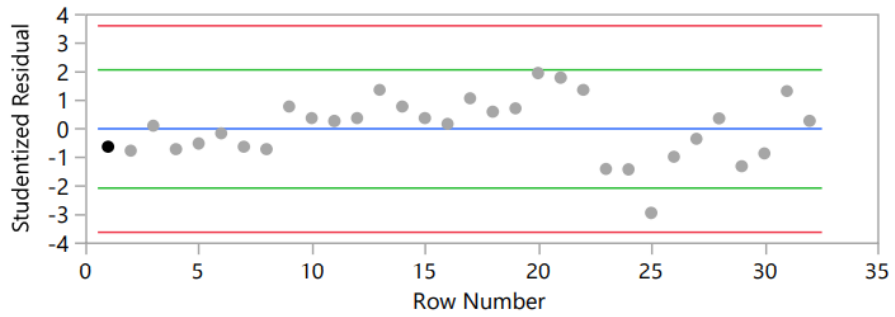
**Residual by Predicted Plot**




- As seen from the residual plot, we can see that the data is equally distributed on both sides which is good.

**Response Distance Kicked**

**Studentized Residuals**




Externally studentized residuals with 95% simultaneous limits (Bonferroni) in red, individual limits in green.

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio |
|---|---|---|---|---|
| Model | 8 | 280.47820 | 35.0598 | 39.3085 |
| Error | 23 | 20.51399 | 0.8919 | **Prob > F** |
| C. Total | 31 | 300.99219 | | <.0001* |

**Parameter Estimates**

| Term | Estimate | Std Error | t Ratio | Prob>\|t\| |
|---|---|---|---|---|
| Intercept | 19.765625 | 0.16695 | 118.39 | <.0001* |
| Kicking Style(0,1) | 0.0446429 | 0.178477 | 0.25 | 0.8047 |
| Kicking Angle(45,90) | 2.703125 | 0.16695 | 16.19 | <.0001* |
| Shoe Type(2,3) | 0.515625 | 0.16695 | 3.09 | 0.0052* |
| No. of Steps(4,6) | 0.921875 | 0.16695 | 5.52 | <.0001* |
| Kicker[1] | -0.504167 | 0.172425 | -2.92 | 0.0076* |
| Shoe Type*Kicking Angle | 0.2767857 | 0.17281 | 1.60 | 0.1229 |
| No. of Steps*Kicking Angle | 0.1607143 | 0.17281 | 0.93 | 0.3620 |
| No. of Steps*Shoe Type | -0.079167 | 0.172425 | -0.46 | 0.6504 |

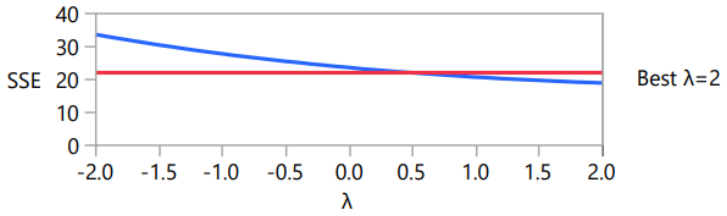
**Effect Tests**

| Source | Nparm | DF | Sum of Squares | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Kicking Style(0,1) | 1 | 1 | 0.05580 | 0.0626 | 0.8047 |
| Kicking Angle(45,90) | 1 | 1 | 233.82031 | 262.1561 | <.0001* |
| Shoe Type(2,3) | 1 | 1 | 8.50781 | 9.5388 | 0.0052* |
| No. of Steps(4,6) | 1 | 1 | 27.19531 | 30.4910 | <.0001* |
| Kicker | 1 | 1 | 7.62552 | 8.5496 | 0.0076* |
| Shoe Type*Kicking Angle | 1 | 1 | 2.28810 | 2.5654 | 0.1229 |
| No. of Steps*Kicking Angle | 1 | 1 | 0.77143 | 0.8649 | 0.3620 |
| No. of Steps*Shoe Type | 1 | 1 | 0.18802 | 0.2108 | 0.6504 |

- After performing ANOVA, we see that the Kicking angle, number of steps taken, and shoe type are important and in that order. Kicking style and iteration effects are not significant and thus were reduced to form the reduced model which is shown later.
- The small PRESS value indicates that the model is good. The very high value of power for the important factors is a good indicator.

## Response Distance Kicked

### Box-Cox Transformations




### Press

| Press | Press RMSE | Press RSquare |
|---|---|---|
| 40.37145126 | 1.12321318 | 0.8659 |

### Effect Details

#### Kicking Style(0,1)

##### Power Details

Test Kicking Style(0,1)

###### Power

| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 0.04176 | 32 | 0.0566 |

#### Kicking Angle(45,90)

##### Power Details

Test Kicking Angle(45,90)

###### Power

| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 2.703125 | 32 | 1.0000 |

#### Shoe Type(2,3)

##### Power Details

Test Shoe Type(2,3)

###### Power

| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 0.515625 | 32 | 0.8407 |

#### No. of Steps(4,6)

##### Power Details

Test No. of Steps(4,6)

###### Power

| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 0.921875 | 32 | 0.9995 |

#### Kicker

## Response Distance Kicked

### Effect Details

#### Kicker

##### Least Squares Means Table

| Level | Least Sq Mean | Std Error | Mean |
|---|---|---|---|
| 1 | 19.261458 | 0.24000559 | 19.2813 |
| 2 | 20.269792 | 0.24000559 | 20.2500 |

#### Power Details

Test Kicker

##### Power

| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 0.488157 | 32 | 0.7996 |

#### Shoe Type*Kicking Angle

##### Power Details

Test Shoe Type*Kicking Angle

##### Power

| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 0.2674 | 32 | 0.3357 |

#### No. of Steps*Kicking Angle

##### Power Details

Test No. of Steps*Kicking Angle

##### Power

| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 0.155265 | 32 | 0.1449 |

#### No. of Steps*Shoe Type

##### Power Details

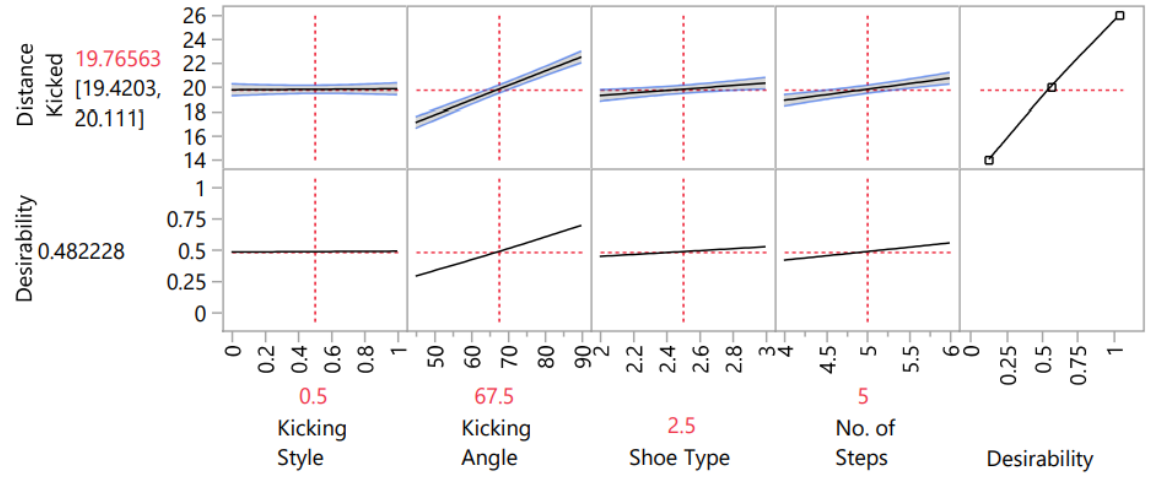
Test No. of Steps*Shoe Type

##### Power

| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 0.076653 | 32 | 0.0725 |

**Response Distance Kicked**

**Prediction Profiler**




**Effect Screening**

Using estimates standardized to have equal variances

Using estimates orthogonalized to be uncorrelated

| | Lenth PSE |
|---|---|
| t-Test Scale | 2.5010859 |
| Coded Scale | 0.417556 |

**Parameter Estimate Population**

| Term | Estimate | t Ratio | Orthog Coded | Orthog t-Ratio | Prob>\|t\| |
|---|---|---|---|---|---|
| Intercept | 19.7656 | 118.3926 | 19.7656 | 118.3926 | <.0001* |
| Kicking Style(0,1) | 0.0446 | 0.2501 | 0.0156 | 0.0936 | 0.9262 |
| Kicking Angle(45,90) | 2.7031 | 16.1912 | 2.7031 | 16.1912 | <.0001* |
| Shoe Type(2,3) | 0.5156 | 3.0885 | 0.5156 | 3.0885 | 0.0052* |
| No. of Steps(4,6) | 0.9219 | 5.5219 | 0.9219 | 5.5219 | <.0001* |
| Kicker[1] | -0.5042 | -2.9240 | -0.4844 | -2.9013 | 0.0080* |
| Shoe Type*Kicking Angle | 0.2768 | 1.6017 | 0.2784 | 1.6674 | 0.1090 |
| No. of Steps*Kicking Angle | 0.1607 | 0.9300 | 0.1553 | 0.9300 | 0.3620 |
| No. of Steps*Shoe Type | -0.0792 | -0.4591 | -0.0767 | -0.4591 | 0.6504 |

Each Orthog Estimate is conditioned on the effects before it

**Normal Plot**

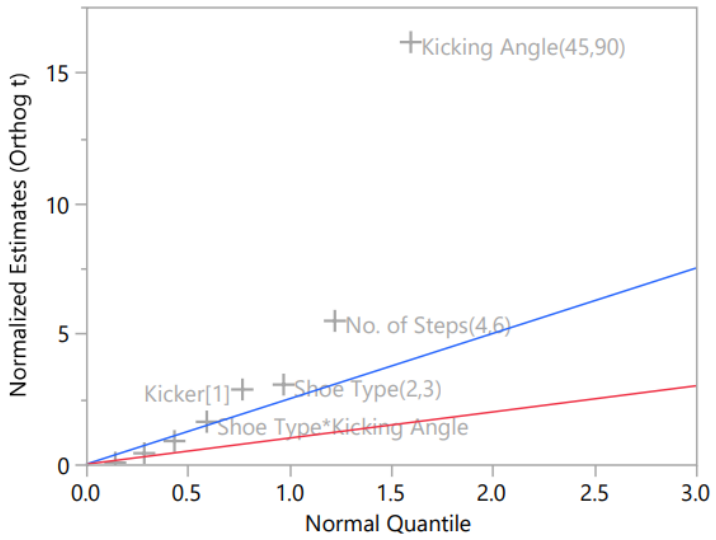
Half Normal Plot

- It can be inferred from the prediction profiler that the kicking angle is the most significant factor followed by the number of steps and then the shoe type which agrees with our conclusions made from ANOVA.
- It is also seen from the half-normal plot that these factors are indeed significant.

## Response Distance Kicked

### Effect Screening

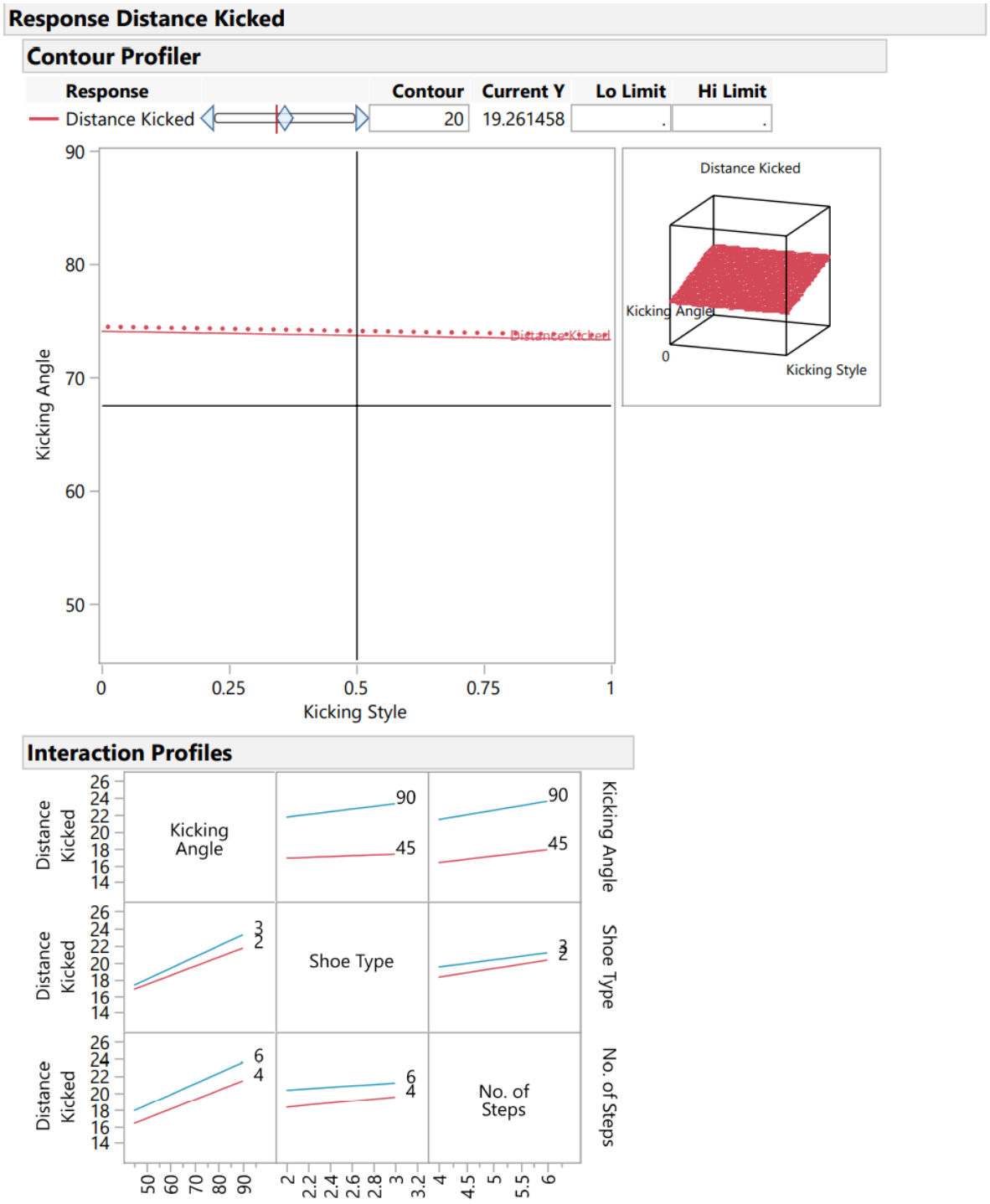
#### Normal Plot




Blue line has slope equal to Lenth's PSE.
Red line has slope 1.

### Contour Profiler

| Horiz | Vert | Factor | Current X |
|---|---|---|---|
| ◉ | ○ | Kicking Style | 0.5 |
| ○ | ◉ | Kicking Angle | 67.5 |
| ○ | ○ | Shoe Type | 2.5 |
| ○ | ○ | No. of Steps | 5 |
| ○ | ○ | Kicker | 0 1 |

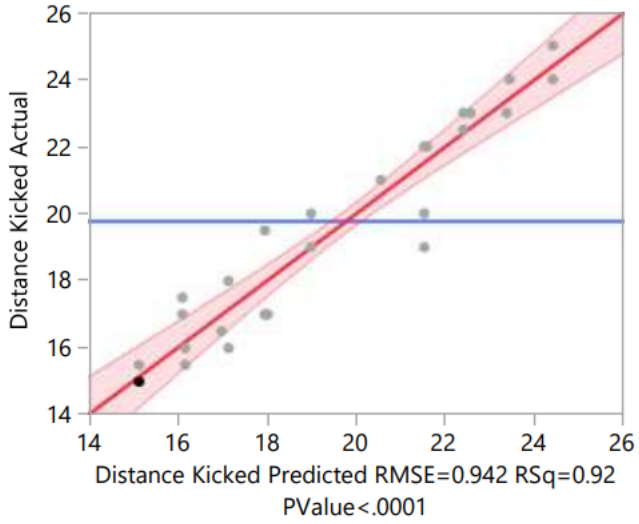



- From the contour profiles and the interaction profiles, one can observe that the interaction effects are not present as the contour profile has no curvature, and the lines in the interaction profiles are not intersecting which is a clear indication that there are no interaction effects. The reduced model contains only the significant factors to understand factor response relationships.

## Reduced Model JMP Results:

**Response Distance Kicked**

**Actual by Predicted Plot**



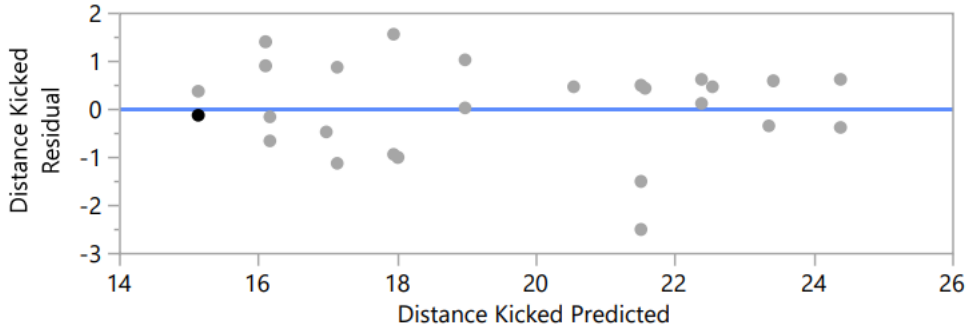

**Effect Summary**

| Source | LogWorth | PValue |
|---|---|---|
| Kicking Angle(45,90) | 14.727 | 0.00000 |
| No. of Steps(4,6) | 5.140 | 0.00001 |
| Shoe Type(2,3) | 2.344 | 0.00453 |
| Kicker | 2.144 | 0.00718 |

**Lack Of Fit**

| Source | DF | Sum of Squares | Mean Square | F Ratio |
|---|---|---|---|---|
| Lack Of Fit | 11 | 12.460937 | 1.13281 | 1.5761 |
| Pure Error | 16 | 11.500000 | 0.71875 | **Prob > F** |
| Total Error | 27 | 23.960938 | | 0.1981 |
| | | | | **Max RSq** |
| | | | | 0.9618 |

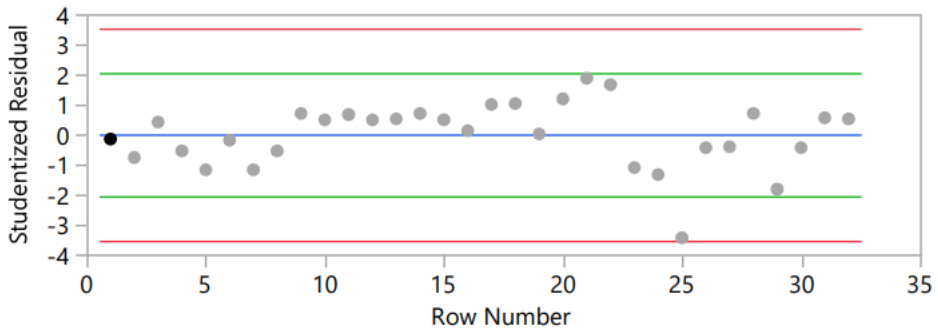
**Residual by Predicted Plot**




- The residual plots show an equal distribution which is a good indicator of the designed experiment is good and balanced. Results from ANOVA indicate all these factors are significant. It can be concluded that the kicking angle is the most significant factor followed by the number of steps and shoe type.

## Response Distance Kicked

### Studentized Residuals




Externally studentized residuals with 95% simultaneous limits (Bonferroni) in red, individual limits in green.

### Analysis of Variance

| Source | DF | Sum of Squares | Mean Square | F Ratio |
|---|---|---|---|---|
| Model | 4 | 277.03125 | 69.2578 | 78.0421 |
| Error | 27 | 23.96094 | 0.8874 | Prob > F |
| C. Total | 31 | 300.99219 | | <.0001* |

### Parameter Estimates

| Term | Estimate | Std Error | t Ratio | Prob>\|t\| |
|---|---|---|---|---|
| Intercept | 19.765625 | 0.166531 | 118.69 | <.0001* |
| Kicking Angle(45,90) | 2.703125 | 0.166531 | 16.23 | <.0001* |
| Shoe Type(2,3) | 0.515625 | 0.166531 | 3.10 | 0.0045* |
| No. of Steps(4,6) | 0.921875 | 0.166531 | 5.54 | <.0001* |
| Kicker[1] | -0.484375 | 0.166531 | -2.91 | 0.0072* |

### Effect Tests

| Source | Nparm | DF | Sum of Squares | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Kicking Angle(45,90) | 1 | 1 | 233.82031 | 263.4767 | <.0001* |
| Shoe Type(2,3) | 1 | 1 | 8.50781 | 9.5869 | 0.0045* |
| No. of Steps(4,6) | 1 | 1 | 27.19531 | 30.6446 | <.0001* |
| Kicker | 1 | 1 | 7.50781 | 8.4601 | 0.0072* |

### Press

| Press | Press RMSE | Press RSquare |
|---|---|---|
| 33.657064472 | 1.02556485 | 0.8882 |

### Effect Details

#### Kicking Angle(45,90)

##### Power Details

Test Kicking Angle(45,90)

###### Power

| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 0.04176 | 32 | 0.0567 |

- The value of $R^2_{PRESS}$ is good enough. The power values for the significant factors such as kicking angle and number of steps are as high as 99% which is a good indicator that the factor is significant.

**Summary of Fit**

| | |
|---|---|
| RSquare | 0.920393 |
| RSquare Adj | 0.9086 |
| Root Mean Square Error | 0.942041 |
| Mean of Response | 19.76563 |
| Observations (or Sum Wgts) | 32 |

- The $R^2$ and $R^2_{adj}$ values are above 90% which is a good indicator of the design. Although the value isn't very high (i.e., 95% or above), it is good enough for a $2^5$-factorial design with blocking. The value of PRESS is smaller than these two which is also good.

**Response Distance Kicked**

**Effect Details**

**Kicking Angle(45,90)**

**Power Details**

Test Kicking Angle(45,90)

**Power**

| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 2.703125 | 32 | 1.0000 |

**Power Details**

Test Kicking Angle(45,90)

**Power**

| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 0.515625 | 32 | 0.8454 |

**Power Details**

Test Kicking Angle(45,90)

**Power**

| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 0.921875 | 32 | 0.9996 |

**Response Distance Kicked**

**Effect Details**

**Shoe Type(2,3)**

**Power Details**

Test Shoe Type(2,3)

**Power**

| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 2.703125 | 32 | 1.0000 |

**Power Details**

Test Shoe Type(2,3)

**Power**

| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 0.515625 | 32 | 0.8454 |

**Power Details**

Test Shoe Type(2,3)

**Power**

| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 0.921875 | 32 | 0.9996 |

## Response Distance Kicked

### Effect Details

#### No. of Steps(4,6)

##### Power Details

Test No. of Steps(4,6)

###### Power

| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 2.703125 | 32 | 1.0000 |

##### Power Details

Test No. of Steps(4,6)

###### Power

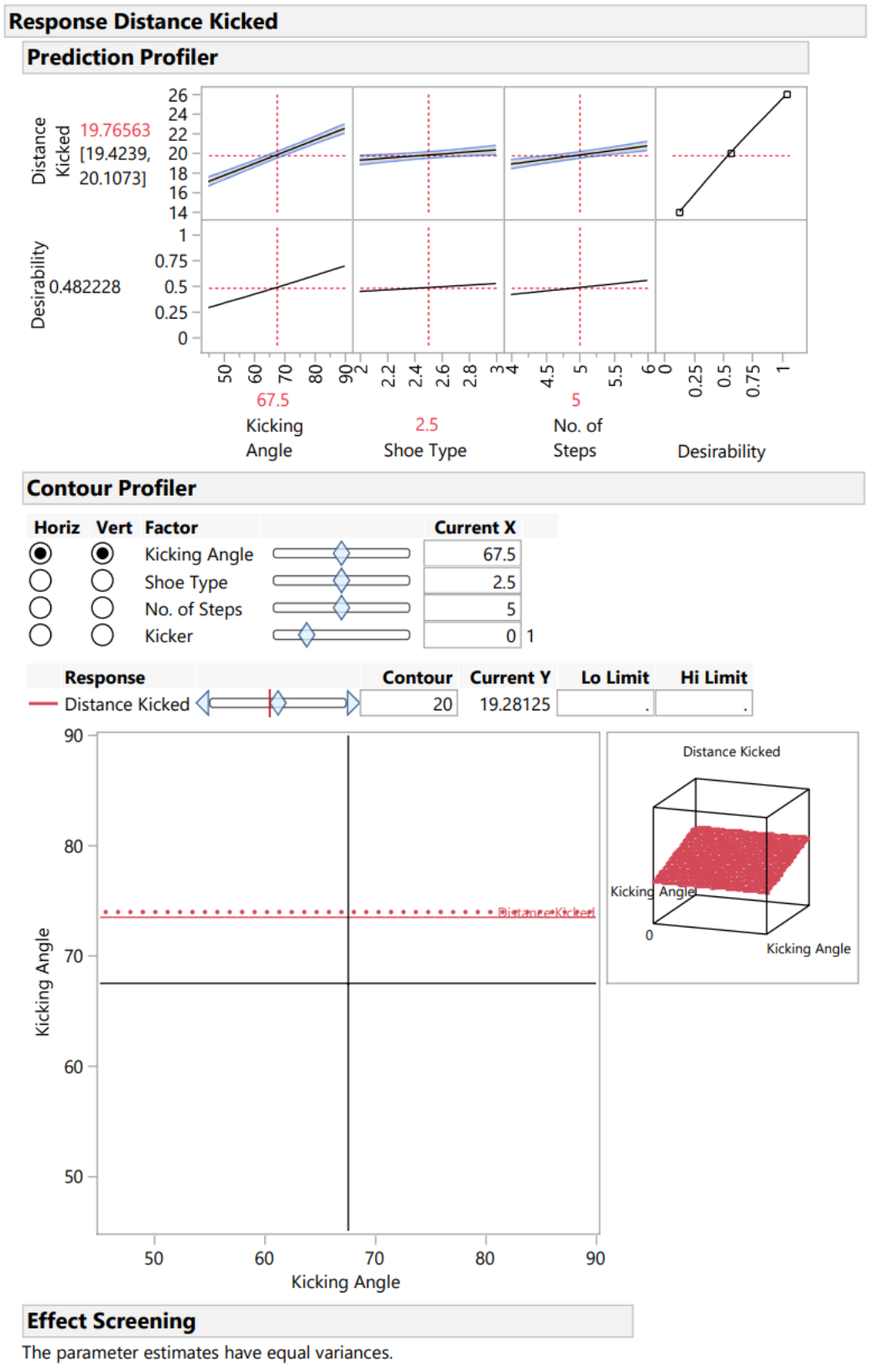
| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 0.515625 | 32 | 0.8454 |

##### Power Details

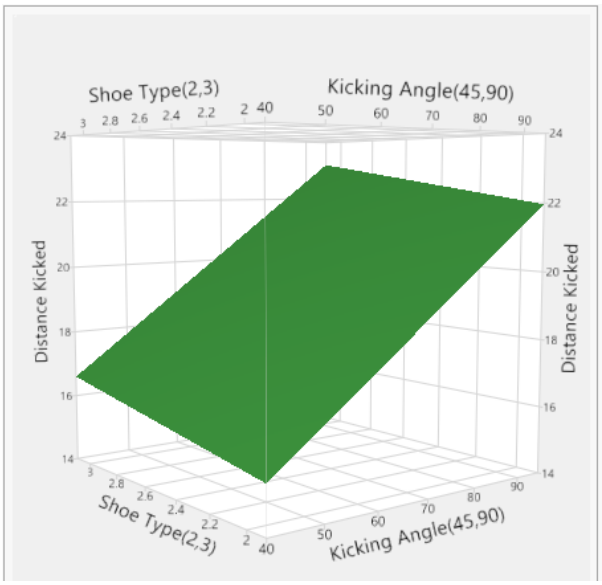
Test No. of Steps(4,6)

###### Power

| α | σ | δ | Number | Power |
|---|---|---|---|---|
| 0.0500 | 0.944411 | 0.921875 | 32 | 0.9996 |




- The prediction profile does agree with our conclusions made from the JMP analysis. It is observed that the kicking angle of 90 degrees, 6 number of steps and a football shoe provide the highest value for the distance kicked. The surface plot shows that there is no interaction effect as the surface is a plane.




## Response Distance Kicked

### Effect Screening

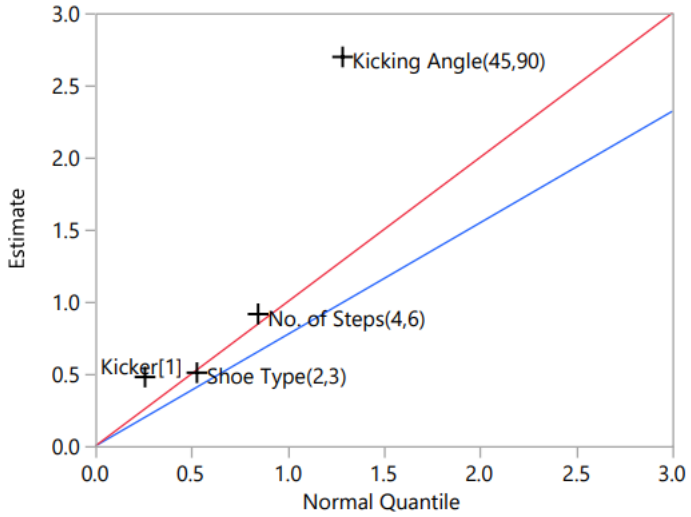
The parameter estimates are not correlated.

**Lenth PSE**

0.7734375

### Normal Plot

Half Normal Plot




Blue line has slope equal to Lenth's PSE.
Red line has slope 1.

The half-normal plot also agrees with our conclusion made above.

## ***VII. Conclusions and Recommendations:***

**[Step 5]** – Some of the conclusions and recommendations drawn based on results obtained from statistical analysis are mentioned below:

- The most significant factor in our design is the kicking angle with the 90-degree angle providing the maximum distance kicked by the footballer. This is also justified as it's easier to kick a ball at 90 degrees inclination in comparison to one at 45 degrees as results in lesser spin thus ensuring greater travel.
- The second most significant factor that helps in yielding the maximum distance kicked is the number of steps taken back before kicking the football. We notice that we get desirable results when we take 6 steps back as opposed to 4 before kicking.
- Another important factor in our design is the type of shoe that is worn by the footballer. The results obtained were better when studs were worn as opposed to training shoes. This makes sense because studs are shoes made specifically for the purpose of playing football.
- Finally, the decision to block kickers turned out to be appropriate and it also proved to be a significant factor indicating a considerable difference in distance kicked. Based on raw data, one can observe that there is a difference of about 5 yards between the distance kicked by the two different kickers.
- All these conclusions are also justified and agree with our prediction profiles, half-probability plots, and parameter estimates.
- Kicking style was not a significant factor as seen from the results. It also is understandable that it wouldn't as kicking style is more prominent in soccer than in football.
- The $R^2$ and $R^2_{adj}$ value are quite similar, and the PRESS value is lesser as compared to them which indicates that the model is good.
- The surface plots show no curvature, and the interaction profiles don't intersect which indicates that there are no interaction effects among the factors which indicate that they have no effect on our response variable. This makes sense as all these factors are independent of each other.
- The reduced model was then formed which omitted the kicking style and interaction effects.
- The significant factors have a high-power value indicating that although our design is un-replicated, it is still a good model.
- Our conclusion based on this study is that to get the maximum distance kicked for a football, the kicker must be wearing studs, the ball must be placed at 90 degrees, and the kicker must take 6 steps back before kicking.
- Our recommendation based on our designed experiment would be to analyze results obtained from a replicated design and compare them with our existing design. Although, it does get complicated to use a replicated design with 5 factors for a full factorial design considering the manual work and time required for each run.