ARIZONA STATE UNIVERSITY

INDUSTRIAL ENGINEERING

IEE 572: Design Engineering Experiments

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ANALYSIS OF VARIOUS FACTORS ON THE PERFORMANCE OF A BATSMAN IN A CRICKET MATCH

Contributors:

Varun Agrawal

Sachin Kesarwani

Sunil Kumar Nandigam

Arvind Rajendran

Supervisor:

Dr. Douglas C. Montgomery

Arizona State University

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1. Introduction to Cricket

Cricket is a game which is played between two teams consisting of eleven players by using bat-and-ball. It is played at the center of a field on a 20-meter (22 yards) pitch with a wicket at each end, and wickets comprise two bails balanced on three wickets. The batting side score runs by striking the ball balled at the wicket with the bat, while the bowling or opponent side tries to prevent this and dismiss each player. When ten players of the batting side have been dismissed, the innings ends and the team swap roles. The game is judged by two umpires, aided by a third umpire and a match referee in international matches. To record the match's statistical information, the umpires communicate with two off-field scorers.

2. Pre-Experimental Planning

2.1 Recognition of and statement of the problem-

The purpose of the experiment is to analyze what important factors affect the performance of the batsman in the cricket. There are several design factors which must be considered to perform this analysis. This experiment will result in the effect of those factors so that effective conclusions can be made.

2.2 Selection of the Response variable-

The response variable is to analyze the maximum distance travelled by the ball on the ground after hitting by a batsman. The distance will be measured by using the measuring tape on the ground.

2.3 Choice of factors, levels, and range-

There are a lot of factors which can affect the response variables. The factors are separated according to their effect in the following way:

2.3.1 Held-Constant Factors-

- Batsman Form/Technique
- Type of pitch (grassy, dry, dusty)
- Umpire Decisions
- Ground Dimensions
- Type of batsman (like actual batsman or a bowler coming for a batting)
- Gear weight (safety equipment)
- Nature of outfield
- Support by the fans i.e., moral support
- Field placement by a bowler

2.3.2 Uncontrollable Factors-

- Batsman Confidence
- Batsman Anticipation to the ball
- Fielder's ability to stop the ball
- Batsman Temper on the field
- Batsman Aggression (attacking ability of a batsman)
- Extra runs by a bowler (it is an unpredictable factor)
- The cleverness of a batsman to find gaps.

2.3.3 Design Factors (with levels and range)

(i) Weight of the bat

According to the type of willow, the weight of the bat varies. So, we decided to take two weights in this factor:

- 2 lb
- 2.8 lb

(ii) Type of Bowler

Bowling action is generally of two types and we considered them as the levels:

- Pace
- Spin

(iii) Batting hand direction

There can be only two kinds of batting direction and that are-

- Right hand
- Left hand

The type of ball will be a Hard-Tennis ball which is used in regular County Cricket.

S. No.	Factors	Low Level	High Level
1	Weight of the bat	2 lb(-)	2.8 lb(+)
2	Type of bowler	Pace(-)	Spin(+)
3	Batting hand direction	Right (-)	Left (+)

Table 1 Chosen Factors and Levels

3. Experimental Design of the Experiment

The following concepts are applied to all the experiments-

Choice of Design: There are 3 main factors in which one is quantitative and two are qualitative. Each of the factors has two levels. So, we are going with $\mathbf{2^k}$ Full Factorial Design (k = number of factors = 3). Hence, we have to run a total of $\mathbf{2^3}$ (=8) runs per replicate with varying conditions.

Number of Replicates: We replicated the experiment 6 times.

Blocking: The entire experiment was performed on a total of six days with a gap of one day. And those six days are considered as six blocks. The reason for the blocking is because the playing capability of the player varies due to the different weather conditions on different days. Each replicate will be considered as one block for the blocking effect.

Hence, a total number of runs in the experiment will be 8*6 = 48 (8 combinations*6 replicates).

4. Performing the Experiment

The experiment was carried out on the SDFC (Sun Devil Fitness Center) ground of Arizona State University. The radius of the ground is 55 meters. The experiment was performed on 6 alternate days. A total of 8 players (subjects) participated in performing the experiment. A regular measuring tape was used to measure the distance of the ball. While performing the runs, there was only one batsman, one bowler, two for measuring the distance and rest all were fielders. As mentioned earlier, two bats with different weights were used by the batsman. A single hard-tennis ball was used by the pace-bowler and the spin-bowler. The same ball was used for the entire experiment. The experiment was carried out according to the randomized treatment combination based on the JMP output.

5. Sources of Nuisance Variation

- The playing time on all the six days was the same.
- The grounded ball when crossed the boundary line was considered to travel a distance of 55 meters (radius of the ground) because after touching the boundary rope, it can't travel the actual distance which it could have without touching the rope.
- The accuracy of measuring tape was considered to be significant up to one decimal digit.
- The batsman was not allowed to run on the pitch after hitting the ball.

6. Statistical Analysis of the Data

The maximum distance traveled by the ball after hitting by the batsman for every run is shown in the table below –

	Pattern	Block	Batting Hand Direction	Type Of Bowler	Weight Of Bat	Distance Of Ball
1	−++	1	Right	Spin	2.8	55
2	−−+	1	Right	Pace	2.8	74
3	+−−	1	Left	Pace	2	63
4	−+−	1	Right	Spin	2	55
5	−−−	1	Right	Pace	2	65
6	+−+	1	Left	Pace	2.8	70
7	++−	1	Left	Spin	2	34.8
8	+++	1	Left	Spin	2.8	55
9	+++	2	Left	Spin	2.8	40
10	−−+	2	Right	Pace	2.8	81
11	−−−	2	Right	Pace	2	69.3
12	+−+	2	Left	Pace	2.8	75
13	−+−	2	Right	Spin	2	71
14	+−−	2	Left	Pace	2	71
15	−++	2	Right	Spin	2.8	68
16	++−	2	Left	Spin	2	45.6
17	−−−	3	Right	Pace	2	72
18	+−+	3	Left	Pace	2.8	71
19	−++	3	Right	Spin	2.8	55
20	++−	3	Left	Spin	2	32.9
21	+−−	3	Left	Pace	2	67
22	−+−	3	Right	Spin	2	63
23	+++	3	Left	Spin	2.8	55
24	−−+	3	Right	Pace	2.8	77
25	−+−	4	Right	Spin	2	64
26	++−	4	Left	Spin	2	49.2
27	−++	4	Right	Spin	2.8	61
28	+−+	4	Left	Pace	2.8	70
29	+++	4	Left	Spin	2.8	48
30	−−−	4	Right	Pace	2	75
31	+−−	4	Left	Pace	2	60
32	−−+	4	Right	Pace	2.8	79
33	++−	5	Left	Spin	2	37.8
34	−++	5	Right	Spin	2.8	72
35	+−+	5	Left	Pace	2.8	73
36	−+−	5	Right	Spin	2	69
37	−−−	5	Right	Pace	2	60
38	−−+	5	Right	Pace	2.8	83
39	+++	5	Left	Spin	2.8	55

38	−−+	5	Right	Pace	2.8	83
39	+++	5	Left	Spin	2.8	55
40	+−−	5	Left	Pace	2	55
41	−++	6	Right	Spin	2.8	70
42	−−−	6	Right	Pace	2	80
43	+++	6	Left	Spin	2.8	55
44	+−+	6	Left	Pace	2.8	74
45	++−	6	Left	Spin	2	40
46	−−+	6	Right	Pace	2.8	85
47	+−−	6	Left	Pace	2	48
48	−+−	6	Right	Spin	2	68

Table 2 Design Table

For the analysis of the experiment, we have included all the main factors, 2-factor, and 3-factor interactions as well as 6 blocks in the model that fit the data.

The JMP output is as follows. With an R square as 0.835, the actual by predicted plot and the summary of fit are shown in figure 1 and table 3.

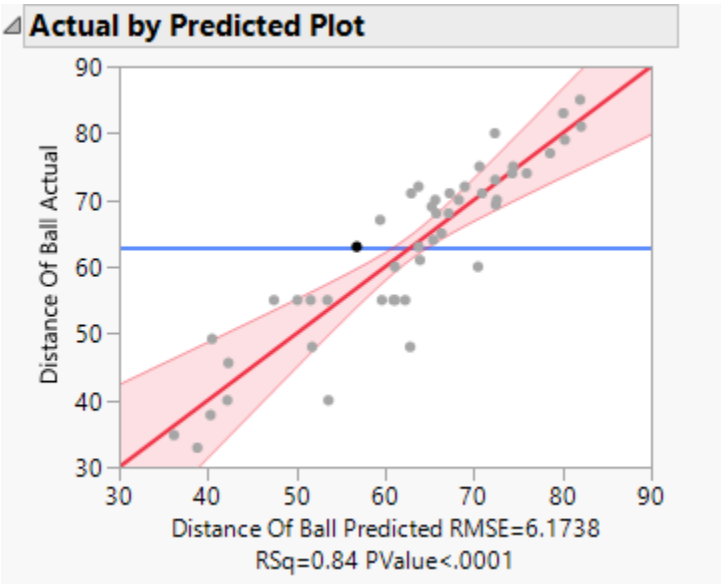

Figure 1 Actual v/s predicted plot

Summary of Fit	
RSquare	0.83524
RSquare Adj	0.778751
Root Mean Square Error	6.173827
Mean of Response	62.84583
Observations (or Sum Wgts)	48

Table 3 Summary of Fit

The ANOVA as given in table 4 conclude that all the three factors that we have considered are highly significant: batting hand direction, the weight of the bat and type of bowler. The interaction effect between batting hand direction and type of bowler is also significant. We considered days as a block but eventually, we found that block effects were insignificant. Blocks have a P value of nearly 0.3.

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	12	6762.9742	563.581	14.7859
Error	35	1334.0650	38.116	Prob > F
C. Total	47	8097.0392		<.0001*

Table 4 ANOVA

Press		
Press	Press RMSE	Press RSquare
2509.1312327	7.23004615	0.6901

Table 5 Press

Effect Summary			
Source	LogWorth		PValue
Type Of Bowler	9.712		0.00000
Batting Hand Direction	8.212		0.00000
Weight Of Bat(2,2.8)	3.930		0.00012
Batting Hand Direction*Type Of Bowler	2.074		0.00844
Batting Hand Direction*Weight Of Bat	1.326		0.04716
Type Of Bowler*Weight Of Bat	0.918		0.12088
Batting Hand Direction*Type Of Bowler*Weight Of Bat	0.869		0.13526
Block	0.431		0.37097

Table 6 Effect Summary

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Batting Hand Direction	1	1	2214.0833	58.0878	<.0001*
Type Of Bowler	1	1	2976.7500	78.0968	<.0001*
Batting Hand Direction*Type Of Bowler	1	1	297.0075	7.7922	0.0084*
Weight Of Bat(2,2.8)	1	1	716.1075	18.7875	0.0001*
Batting Hand Direction*Weight Of Bat	1	1	161.3333	4.2327	0.0472*
Type Of Bowler*Weight Of Bat	1	1	96.3333	2.5274	0.1209
Batting Hand Direction*Type Of Bowler*Weight Of Bat	1	1	89.1075	2.3378	0.1353
Block	5	5	212.2517	1.1137	0.3710

Table 7 Effect Tests

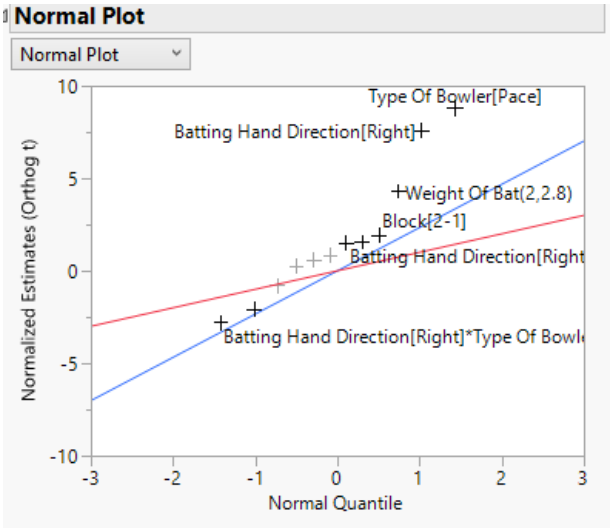

Figure 2 Normal Plot

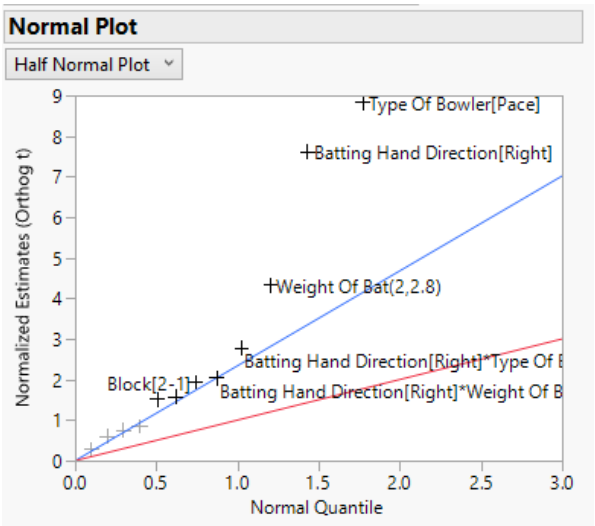

Figure 3 Half Normal Plot

The two-factor interaction plots are shown in figure 4 below.

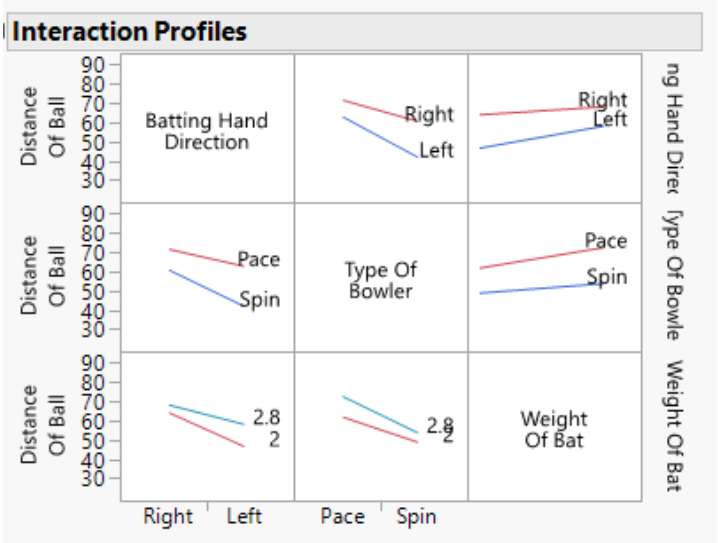

Figure 4 Interaction Profiles

On analyzing the prediction profiler we can see the tendency of the distance covered by the ball for all the factors.

The plot signifies that the right-hand batting direction, pace bowler and the heavy weight bat (2.8 pounds) lead to cover more distance by the ball hit by the batsman.

Figure 5 Prediction Profiler

Finally, the residual vs predicted was taken and analyzed to confirm that the assumptions we made in the ANOVA model are sufficiently validated. Figure 6 and 7 reveals that there is no specific pattern formed in the plot. Therefore it is evident that there is no abnormality in both the residuals plot.

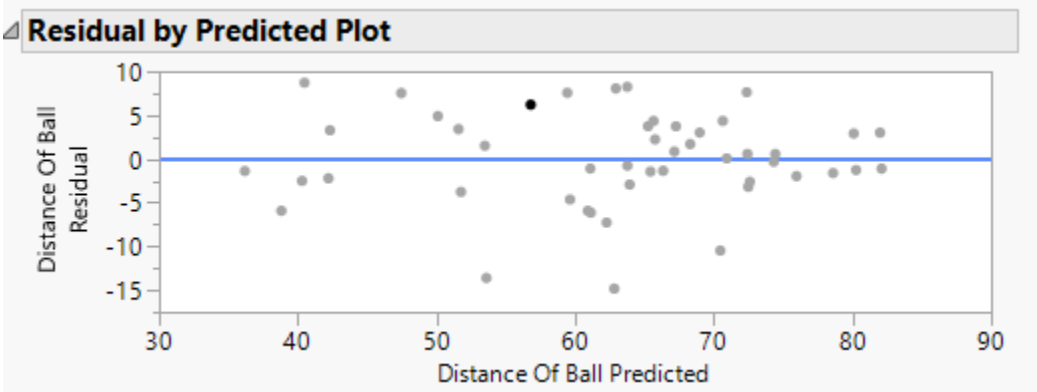

Figure 6 Residual by Predicted Plot

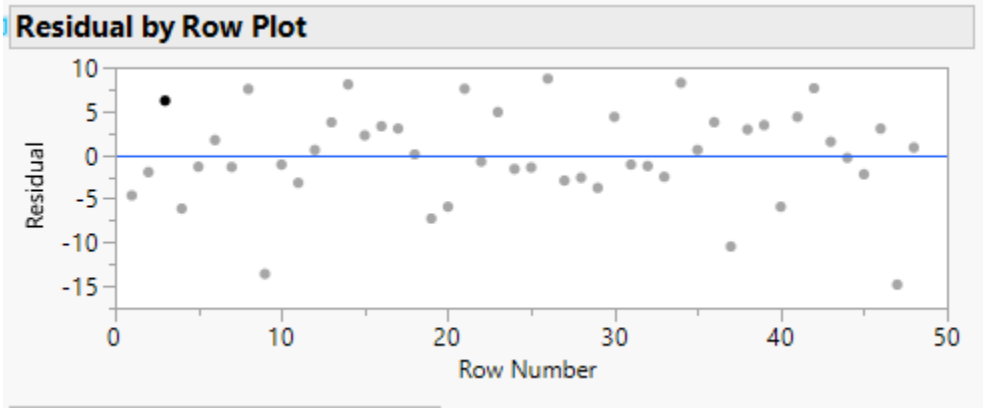

Figure 7 Residual by Row Plot

7. Analysis for Reduced Model

In this reduced model we removed all the insignificant two factor and three-factor interactions. So, we decided to run the model with four factors that are the type of bowler, batting hand direction, the weight of the bat, and batting hand direction-type of bowler interaction.

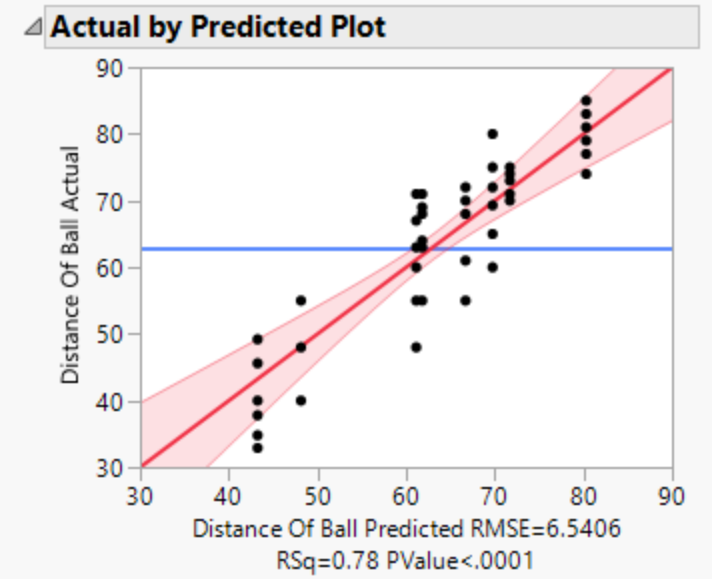

Figure 8 Actual by Predicted Plot for Reduced Model

Summary of Fit	
RSquare	0.7662
RSquare Adj	0.744451
Root Mean Square Error	6.635162
Mean of Response	62.84583
Observations (or Sum Wgts)	48

Table 8 Summary of Fit for Reduced Model

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	6203.9483	1550.99	35.2294
Error	43	1893.0908	44.03	Prob > F
C. Total	47	8097.0392		<.0001*

Table 9 ANOVA for Reduced Model

We can see that the F ratio of the reduced model has been increased approximately 2.5 times compared to the F ratio of the complete model. The value of R square adjusted decreased as compared to the R square adjusted value of the actual model which shows that the actual model is more significant. But, the reduction in the value of R square adjusted in the reduced model is less than 4% which is less than the value of alpha (say 0.05), so the reduced model is more significant in terms of data, a number of factors, and the analysis of the model.

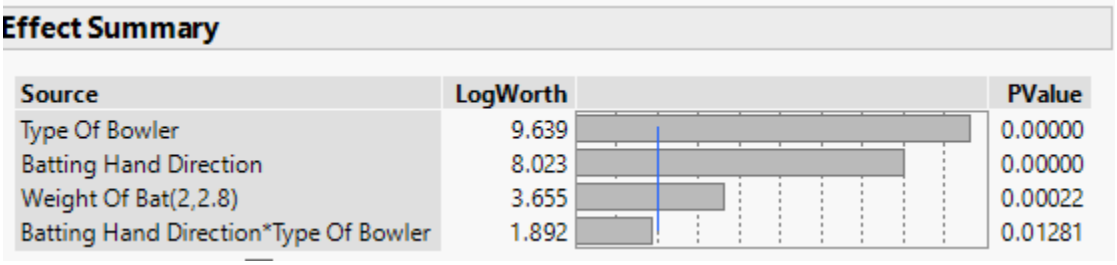

Figure 9 Effect Summary for Reduced Model

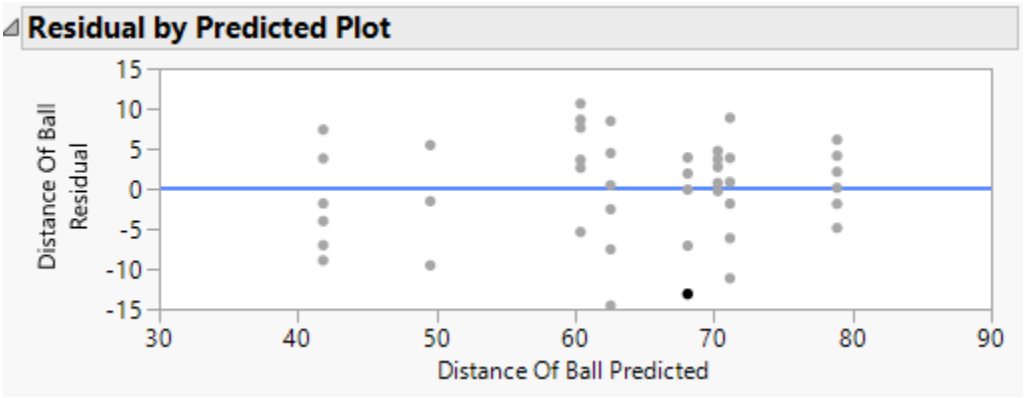

Figure 10 Residual by Predicted Plot for Reduced Model

8. Conclusion

Our experiment proved our assumptions of the factors to be important for hitting the ball to a larger distance in Cricket. We can easily conclude that all the factors (Batting hand direction, Bat Weight and bowler type) are highly significant, In order to hit the ball to longer distance a batsman should be a right-handed with the heavier bat (2.8 lbs) and the bowler should be a pacer.