Memorial University of Newfoundland
Engineering 9516
Similitude, Modelling, & Data Analysis

Term Project

Ice Hockey:
Factorial Analysis on the Goal Scoring Response

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Introduction

Since my earliest days playing ice hockey in Newfoundland and Labrador, coaches have encouraged players to shoot from certain places on the ice, to use a certain type of shot in certain situations and from varying distances. Shooters themselves also have natural tendencies to use certain types of shots when playing to increase their chances of scoring.

Some players love to wind up and take a slap shot when they have an opportunity. Other players stick to the lower velocity, yet quicker, wrist shot when they find themselves in the open. As well, some players try to take shots from angles to the net, while others choose to get to the middle of the ice for a better angle at the goalie.

It is my interest to statistically prove what the effect of these factors would be on the success rate of ice hockey players in trying to score goals.

The factors evaluated include: A – Shot Type, B – Distance, C – Angle

Experimental Design

The design of the experiment was conducted using four shooters (see Figure 1) who took up four positions on the ice surface at each shooting interval.

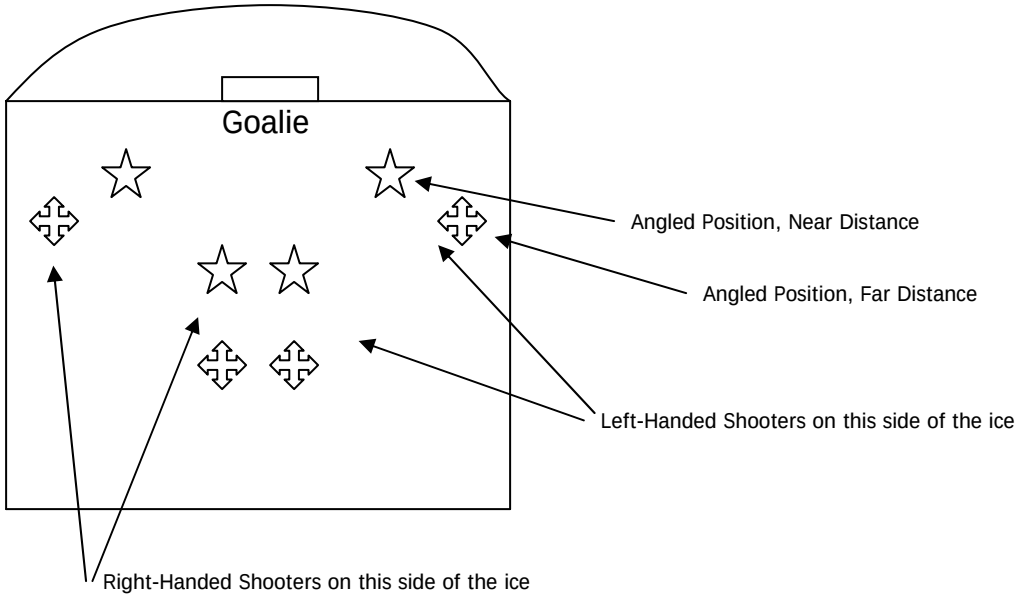


Figure 1 - Experimental Set-Up

First, the players took up the near distance position with each shooter at one of the four positions forming a semi-circle of sorts. The players would take 10 shots going from man to man around the circle, called rapid fire in hockey terms. The players would then move to the far distance, switch positions in the semi-circle, and take another type of shot. The two right-handed shooters would stay on their side of the ice, and the left-handed shooters on their side. The shooters would then move again to the near distance, switch positions and again take another type of shot. This stepping sequence would repeat 8 times until all runs were complete.

The four shooters each took 10 shots from 2^3 or 8 positions. The four shooter's scores at any one position were added up to give 40 in total. The response was then measured as number of goals scored out of 40.

The runs for the experiment were randomly set-up, with shooters switching from near distance to far, from wrist to slap shot, and from angle to center in random order. The only lack of randomness was the fact that the two left-handed players and the two right-handed players took turns from center to angled position at each switch. The data collection sheet is included in Appendix A.

Non-Studied Factors

This exercise definitely involved several non-studied factors that for good design of experiments, one must attempt to keep constant. In this experiment, the goalie was instructed to stay within the confines of his crease (a semi-circle in front of his net) and not to attack any player's shots by cutting down angles or through other standard goalie techniques. The goalie was told to play every shot exactly the same (as much as humanly possible). The players also took turns starting the rapid-fire sequences to ensure the goalie was not more focused on stopping that first shot from the same guy at each interval, and thereby creating an effect. In this way, the effect of goalie preparedness for those first shots was balanced. By choosing four players to shoot, any special player skills amongst particular players were balanced through the study. As well, two left shots were selected and two rights, to balance advantages by simple geometry. As well, two forwards and two defencemen were involved, to balance any differences from different types of players.

Statistical Analysis

The design was input into Design-Expert 6 by Stat-Ease. A 2^3 Full-Factorial Design was selected.

Std	Run	Block	Factor 1 A:Shot Type	Factor 2 B:Distance ft	Factor 3 C:Angle deg.	Response 1 Goals out of 40
1	8	Block 1	Wrist	-1.00	45	22
2	7	Block 1	Slap	-1.00	45	19
3	6	Block 1	Wrist	1.00	45	5
4	4	Block 1	Slap	1.00	45	8
5	1	Block 1	Wrist	-1.00	90	30
6	2	Block 1	Slap	-1.00	90	25
7	5	Block 1	Wrist	1.00	90	7
8	3	Block 1	Slap	1.00	90	12

Table 1 - Experimental Data

The model summary from Design-Expert is as follows:

Study Type	**Factorial, Experiments: 8**
Initial Design	**2-Level Factorial, Blocks: No Blocks**
Center Points	**0**
Design Model	**3FI**

Response	Name	Units	Obs	Minimum	Maximum	Trans	Model
Y1	Goals	out of 40	8	5.00	30.00	None	R2FI

Factor	Name	Units	Type	Low Actual	High Actual	Low Coded	High Coded
A	Shot Type		Categorical	Wrist	Slap	Levels:	2
B	Distance	ft	Numeric	-1.00	1.00	-1.000	1.000
C	Angle	deg.	Categorical	45	90	Levels:	2

A Half-Normal Plot, Figure 2, was used to identify significant effects: As shown, B, C, AB, BC were selected for the ANOVA.

'A' was also manually added because of the principle of hierarchy. If higher level interaction effects are significant, individual factors making up the interaction must also be included in the model.

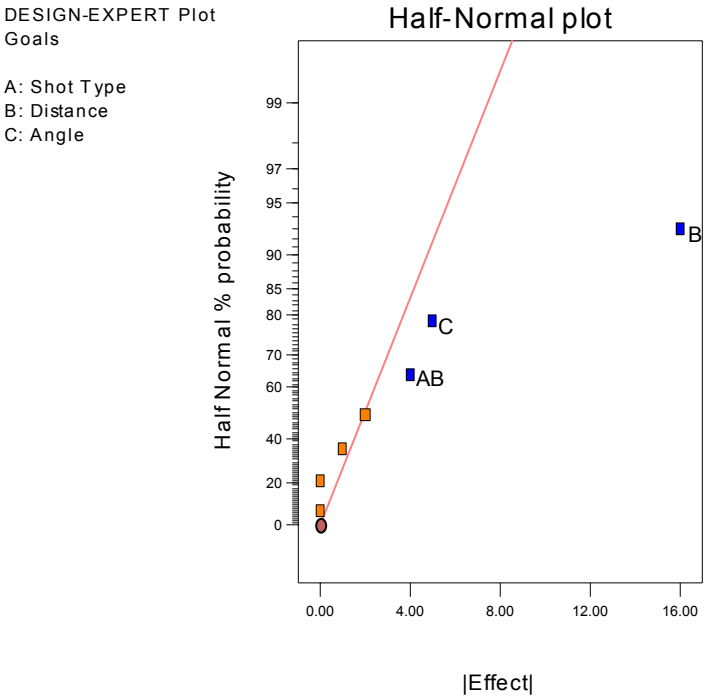


Figure 2 - Half-Normal Plot of Effects (No Transform)

Response: Goals

Hierarchical Terms Added after Manual Regression A

ANOVA for Selected Factorial Model

Analysis of variance table [Partial sum of squares]

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	594.00	4	148.50	44.55	0.0053	significant
A	*0.000*	*1*	*0.000*	*0.000*	*1.0000*	
B	*512.00*	*1*	*512.00*	*153.60*	*0.0011*	
C	*50.00*	*1*	*50.00*	*15.00*	*0.0305*	
AB	*32.00*	*1*	*32.00*	*9.60*	*0.0534*	
Residual	10.00	3	3.33			
Cor Total	604.00	7				

The Model F-value of 44.55 implies the model is significant. There is only a 0.53% chance that a "Model F-Value" this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case B, C are significant model terms.
Values greater than 0.1000 indicate the model terms are not significant.
If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Std. Dev.	1.83	R-Squared	0.9834
Mean	16.00	Adj R-Squared	0.9614
C.V.	11.41	Pred R-Squared	0.8823
PRESS	71.11	Adeq Precision	17.321

The "Pred R-Squared" of 0.8823 is in reasonable agreement with the "Adj R-Squared" of 0.9614.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 17.321 indicates an adequate signal. This model can be used to navigate the design space.

Coefficient Factor	Estimate	DF	Standard Error	95% CI Low	95% CI High	VIF
Intercept	16.00	1	0.65	13.95	18.05	
A-Shot Type	0.000	1	0.65	-2.05	2.05	1.00
B-Distance	-8.00	1	0.65	-10.05	-5.95	1.00
C-Angle	2.50	1	0.65	0.45	4.55	1.00
AB	2.00	1	0.65	-0.054	4.05	1.00

Diagnostic Plots

I will skip the analysis of the diagnostic plots, since the Box Cox recommended a Log Transform.

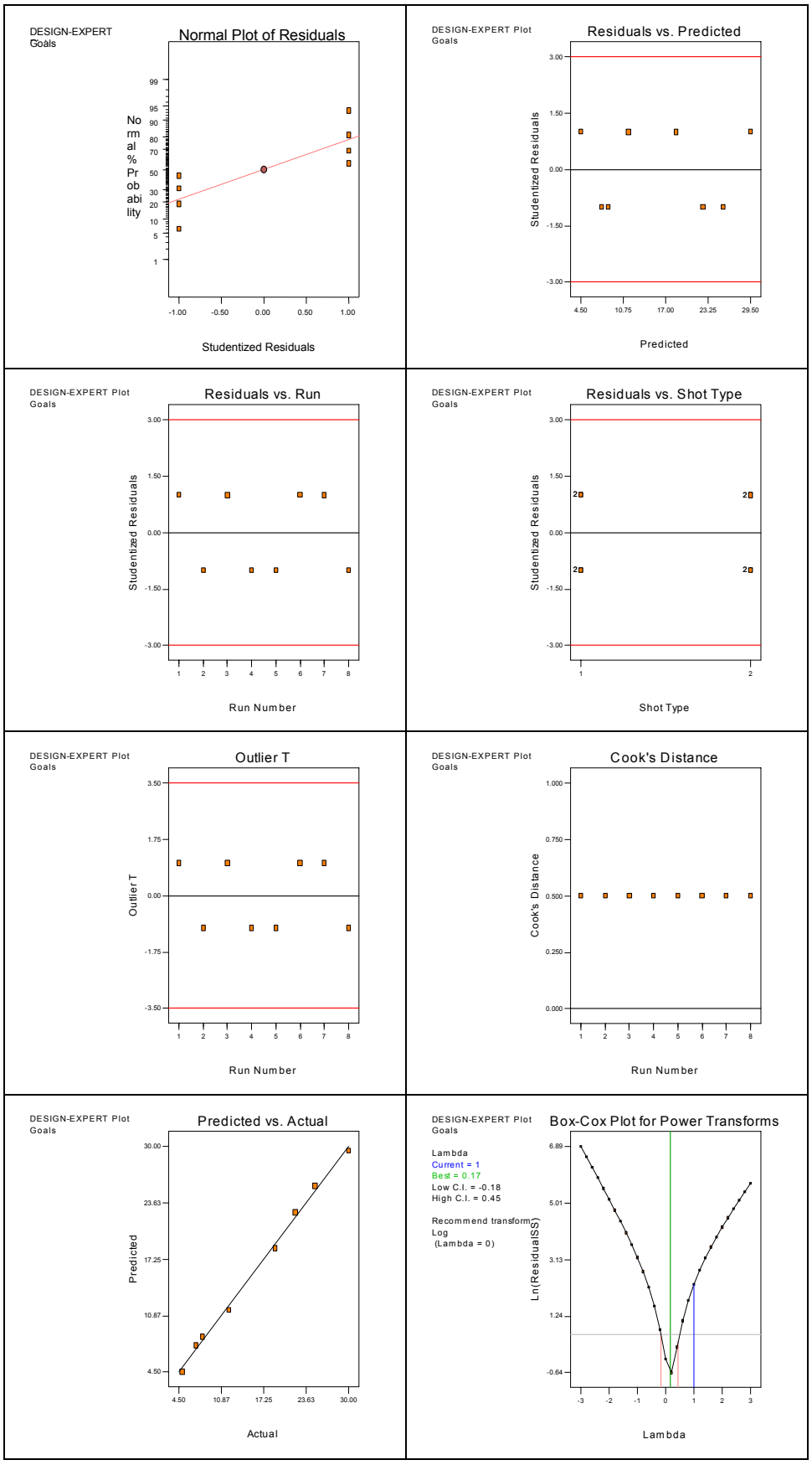


Table 2 - Diagnostic Plots (No Transform)

Log Transform

The data was log transformed and the Half-Normal Plot, Figure 3, of effects was prepared using Design-Expert.

The significant effects were selected for ANOVA as shown at right.

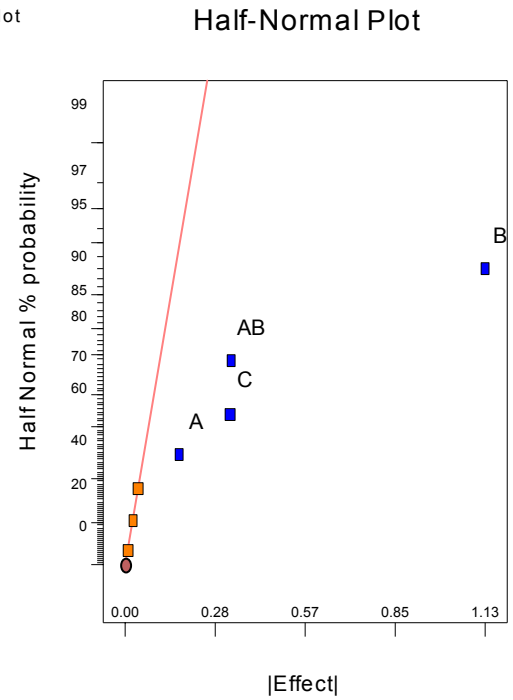


Figure 3 - Plot of Effects (Log Transform)

Response: Goals
Transform: Natural log
Constant: 0

ANOVA for Selected Factorial Model

Analysis of variance table [Partial sum of squares]

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	3.07	4	0.77	500.68	0.0001	significant
A	*0.058*	*1*	*0.058*	*37.67*	*0.0087*	
B	*2.57*	*1*	*2.57*	*1675.90*	*< 0.0001*	
C	*0.22*	*1*	*0.22*	*143.34*	*0.0013*	
AB	*0.22*	*1*	*0.22*	*145.81*	*0.0012*	
Residual	4.604E-003	3	1.535E-003			
Cor Total	3.08	7				

The Model F-value of 500.68 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case A, B, C, AB are significant model terms.
Values greater than 0.1000 indicate the model terms are not significant.
If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Std. Dev.	0.039	R-Squared	0.9985
Mean	2.60	Adj R-Squared	0.9965
C.V.	1.51	Pred R-Squared	0.9894
PRESS	0.033	Adeq Precision	58.125

The "Pred R-Squared" of 0.9894 is in very good agreement with the "Adj R-Squared" of 0.9965.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 58.125 indicates an adequate signal. This model can be used to navigate the design space.

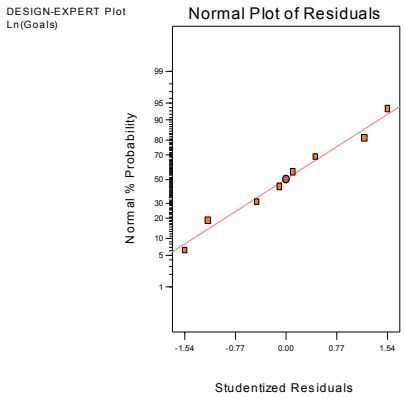
Coefficient Factor	Estimate	DF	Standard Error	95% CI Low	95% CI High	VIF
Intercept	2.60	1	0.014	2.55	2.64	
A-Shot Type	0.085	1	0.014	0.041	0.13	1.00
B-Distance	-0.57	1	0.014	-0.61	-0.52	1.00
C-Angle	0.17	1	0.014	0.12	0.21	1.00
AB	0.17	1	0.014	0.12	0.21	1.00

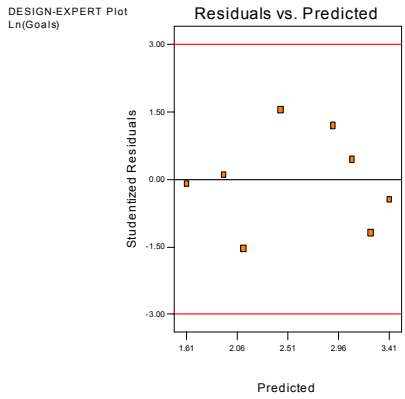
Diagnostic Plots for Log Transform

Analysis

Normal plot of Residuals
- Okay. Straight line is desired.

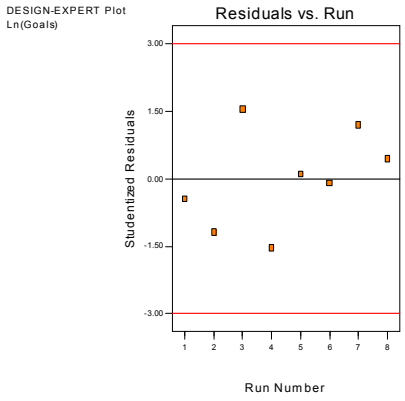
Residuals vs. Predicted
- Even scatter with no pattern evident.

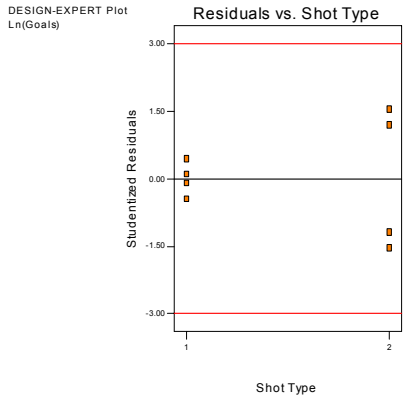




Residuals vs Run
- OK. Even scatter is desired, and this looks okay.

Residuals vs Factor Plots
- These look okay. Slight pattern in Residuals vs Shot Type, but not enough to cause concern.





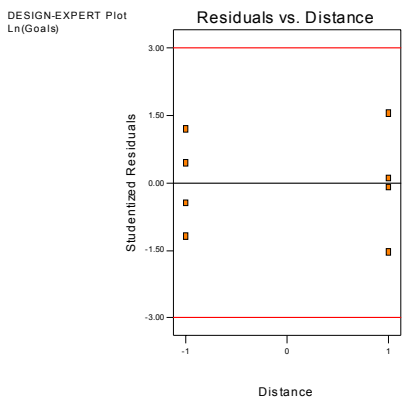
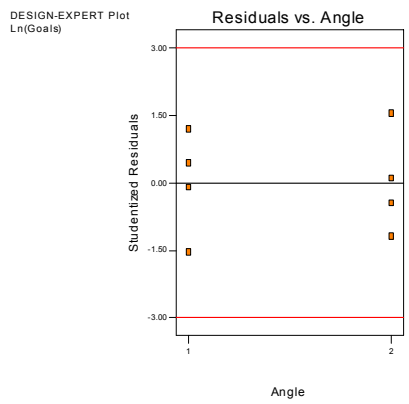
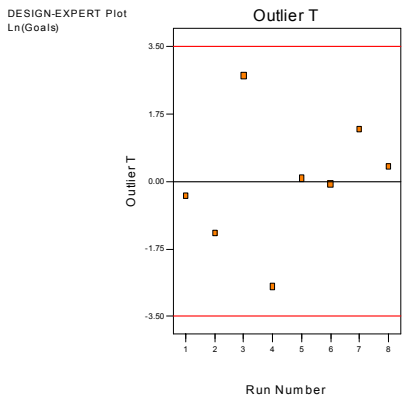
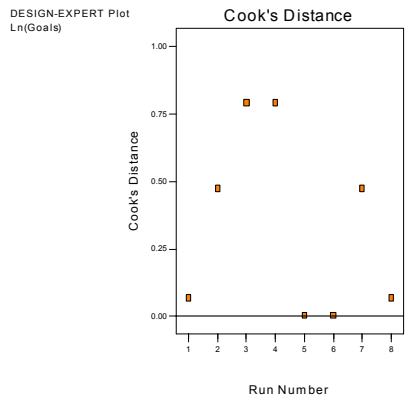
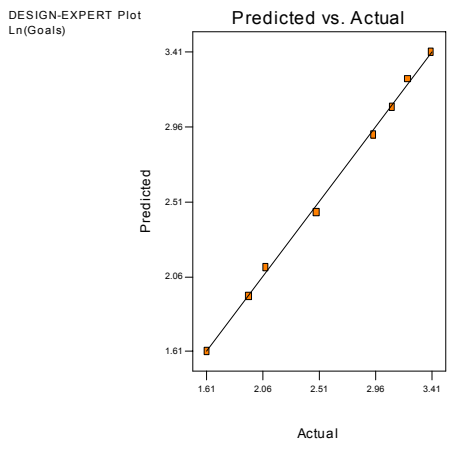
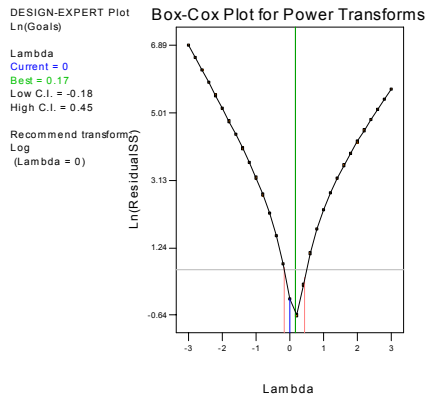
Residuals vs Factor Plots Cont'd... - These look okay. No pattern evident.		
Outlier Plots - Some data points seem to be more significant. I basically propose this is a consequence of the human nature and natural variations in the type of experiment I conducted.		
Predicted vs. Actual - The plot is a straight line, and our model matches the data very well. Box Cox - Okay.		

Table 3 - Diagnostic Plots (Log Transform)

Discussion

From the list of Effects at Right (Figure 4) we see that B (Distance), C (Angle), AB (Shot Type-Distance Interaction), and A (Shot Type) are the most significant Effects.

	Term	Stdized Effects	Sum of Squares	% Contribution
	Intercept			
M	A	0.17	0.058	1.88
M	B	-1.13	2.57	83.56
M	C	0.33	0.22	7.15
M	AB	0.33	0.22	7.27
e	AC	8.319E-003	1.384E-004	4.497E-003
e	BC	0.039	3.095E-003	0.10
e	ABC	0.026	1.371E-003	0.045
	Lenth's ME	0.59		
	Lenth's SME	1.41		

Figure 4 - List of Effects (Log Transform)

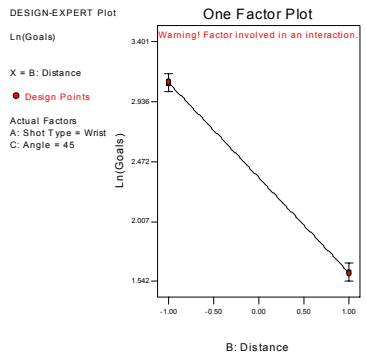
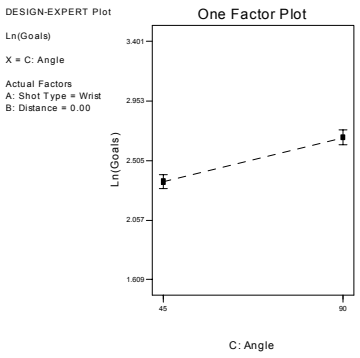
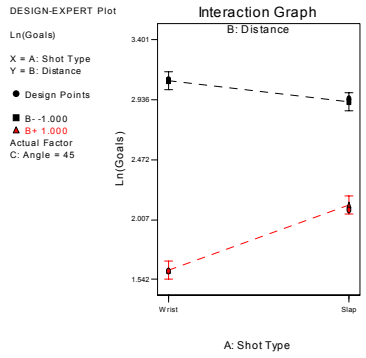
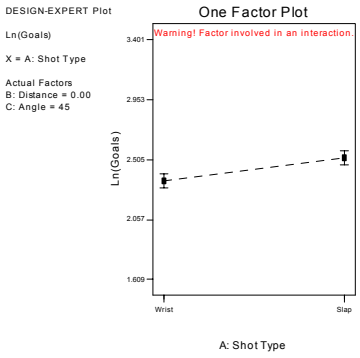
	
Distance is the most significant effect, and is shown in the plot above. A distance increases, goals decrease. Players should endeavour to get close to the net to score goals. (Anecdotally, we believe this to be true.)	Angle is the next most significant effect. Players should get to the middle of the ice, 90 deg., and shoot from there. (Again, anecdotally, we believe this to be true.)
	
This interaction plot is interesting. At high B, or distance, a slap shot is better than a wrister (wrist shot). At low B, a wrist shot is better than a slap. Intuitively this makes sense. At low distance, the increased accuracy and form of a wrister is better for goal scoring. At high distance, the increased speed of a slap shot is required to overtake the goalies reflexes.	The shot type factor is significant, but the least of all. Overall, a slap shot is more effective than a wrister. This sounds reasonable, because the slap shot is harder, and it is more effective at longer distances and at oblique angles to the net. Although less accurate overall, the slap shot simply does not miss often at the closer ranges.

Table 4 - Effect Plots (Log Transform)

Conclusions

This analysis was used to statistically prove how several basic factors affected an ice hockey player's ability to score goals. The factors evaluated include: A - Shot Type, B – Distance, C- Angle.

From a 2^3 Full-Factorial Analysis, it was concluded that B (Distance), C (Angle), AB (Shot Type-Distance Interaction), A (Shot Type) are the most significant effects on scoring goals.

If a hockey player wishes to score goals he or she should focus on the following:

- Distance is the most significant effect on goal scoring. Players should attempt to get as close to the net as possible to score goals.

- Angle is the next most significant effect on goal scoring. Players should get to the middle of the ice, what the analysis called 90 deg., and shoot from there.

- There is an interaction between distance and type of shot. At high distance, players should use a slap shot rather than a wrist shot or wrister. At low distance, players should attempt, what I consider to be more accurate, the wrist shot.

- Shot type on its own is also a significant effect, but the least significant compared to the others above. Overall, a slap shot is more effective than a wrister. This sounds reasonable, because the slap shot is harder, and it is more effective at longer distances and at 45 degree angles to the net. Although less accurate, the slap shot will not miss at close range.