IEE 572: Design of Engineering Experiments

ANALYSIS OF SIGNIFICANCE OF FACTORS INFLUENCING COMMUTE EFFICIENCY

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1. PROJECT SUMMARY

1.1 Problem Statement

A commute is an essential part of everybody's life. While a fortunate few have their home close to the office and they could just walk over to their workplace, many must endure a significant commute. We took this problem of commuting, specifically our commute from home to class as an approximation and have tried to find the best possible combinations of factors to make the commute more efficient. While calculating the efficiency of a walk vs car commute would be easy as it is obvious, few others seem a bit too close to compare. We have taken such two modes, skating and biking as our major differentiating factor to compare their effectiveness.

Many factors contribute to the efficiency of a commute. In our project, we consider some of the major factors like mode, ambient light & food which influence the best way to commute to reach the desired destination.

2. SETTING UP THE EXPERIMENT

2.1 Selection of Response Variable

We selected the Time in Minutes as the response variable. As our objective is to find the effect of various factors on the commute and to increase efficiency. This can be easily done by comparing the time taken to complete the commute in each of the combinations of the factors.

2.2 Selection of Factors

We considered three factors with two levels each. The mode of commute with Biking as a high level and Skateboarding as a low level. The mode could be one of the most significant differentiating factors as bike and skate as levels. The availability of natural light as Daytime as high and Nighttime as low. The appetite satisfaction of the subject with a full stomach as High and empty stomach as low.

Fig.-2.1 Factors of a model

S No	FACTORS	Low	High
1.	Mode	Skate	Bike
2.	Natural light	Low (Night)	High (Day)
3.	Food	Empty stomach	Full stomach

Table-2.1 Experimental factors and levels

Constant Factors:

- Route
- Commuter Gender
- Initial Heart rate
- Type of meal
- Type of Boke
- Type of Skateboard

Uncontrollable Factors:

- Weather
- Traffic
- Energy levels of the commuter
- Mechanical failure(Bike/Skate)

2.3 Selection of Blocking

As the subjects are individuals with varying physical capabilities and different skill levels, they could be a nuisance factor. We wanted to avoid the noise from this factor and created three blocks of one subject each and the runs are randomized within the blocks.

2.4 Design of experiment

The experiment is performed as a 2^3 factorial experiment with three subjects as blocks of 8 runs each.

3. PERFORMING THE EXPERIMENT

All 24 runs of the experiment were run in random order and along the same route shown below.

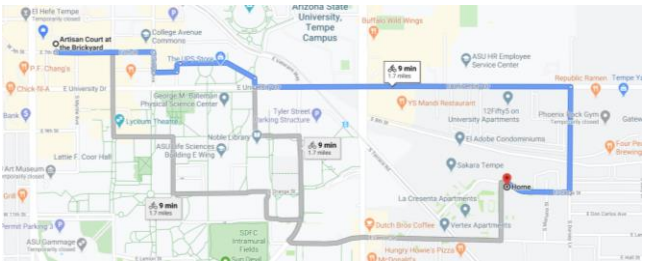


Fig.3.1 Distance

The experiment was conducted over a total duration of eight days. Each subject performed a random combination of factors over the eight days and we advised them to have similar kind of meals and use own bikes and skateboards of similar mechanical efficiency to avoid noise from the meal and machine. The readings are tabularized below

	Mode	Light	Food	Subject	Time	Run Order
1	Bike	Low	Full	1	18.65	7
2	Bike	Low	Empty	1	16.42	2
3	Bike	High	Full	1	17.17	1
4	Bike	High	Empty	1	13.3	4
5	Skate	Low	Full	1	19.71	3
6	Skate	Low	Empty	1	16.44	5
7	Skate	High	Full	1	19.62	6
8	Skate	High	Empty	1	16.35	8
9	Bike	Low	Full	2	19.7	16
10	Bike	Low	Empty	2	19.7	11
11	Bike	High	Full	2	20.6	14
12	Bike	High	Empty	2	15.96	13
13	Skate	Low	Full	2	21.68	12
14	Skate	Low	Empty	2	18.08	9
15	Skate	High	Full	2	21.58	15
16	Skate	High	Empty	2	17.99	10
17	Bike	Low	Full	3	24.99	24
18	Bike	Low	Empty	3	22	20
19	Bike	High	Full	3	23	18
20	Bike	High	Empty	3	17.82	21
21	Skate	Low	Full	3	24.24	23
22	Skate	Low	Empty	3	20.22	17
23	Skate	High	Full	3	24.13	19
24	Skate	High	Empty	3	20.11	22

Table-3.1 Design Table

4. ANALYSIS OF DATA

We have included all the 3 main factors, two-factor, and three-factor interactions as well as the three blocking factors in the model that will be fit to the data. This was set up using the Custom Design option in JMP

After conducting the runs in the order mentioned above, we proceeded to analyze and see how well the model fits the data. The JMP output is as follows, with the high R Square – 0.966 and R Square Adj – 0.945 values from Fig.-4.1 suggest that the model fits reasonably well.

Summary of Fit

RSquare	0.966696
RSquare Adj	0.945286
Root Mean Square Error	0.684205
Mean of Response	19.56083
Observations (or Sum Wgts)	24

Fig.-4.1: Summary of fit

The plot in Fig.-4.2 shows the relationship between actual and predicted response does not have any abnormality. The residual plot indicates that there is an equal distribution of variance.

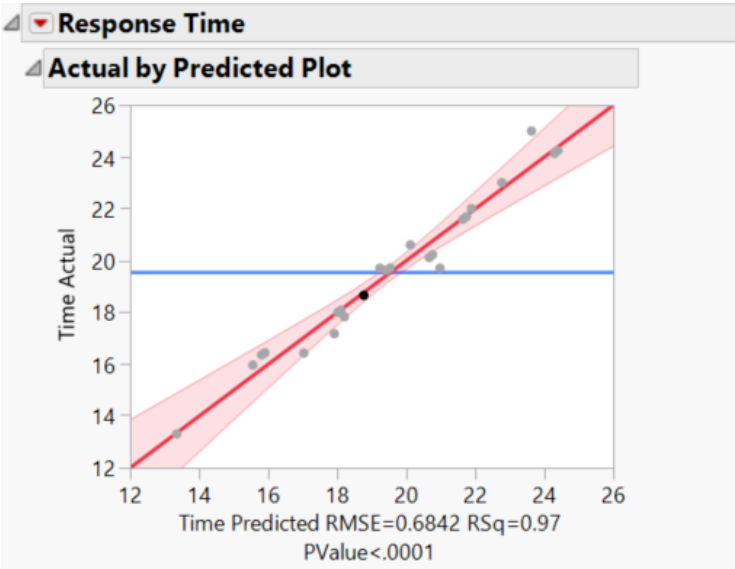
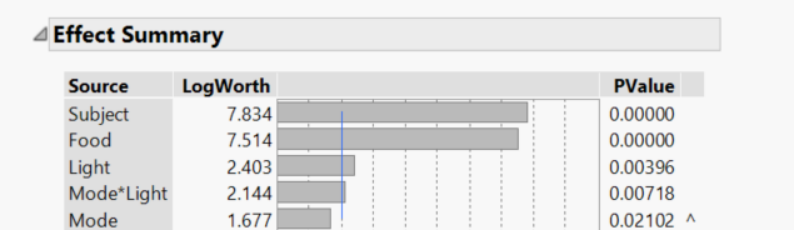


Fig.-4.2: Actual vs. Predicted plot



Effect Summary

Source	LogWorth	PValue
Subject	7.834	0.00000
Food	7.514	0.00000
Light	2.403	0.00396
Mode*Light	2.144	0.00718
Mode	1.677	0.02102 ^

Fig.-4.3: Effect Summary

From the Analysis of variance in table-4.1, we find that the f ratio is large. This rejects the null hypothesis and confirms that any one of the variables is significant.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	190.23407	21.1371	45.1516
Error	14	6.55391	0.4681	Prob > F
C. Total	23	196.78798		<.0001*

Table-4.1: ANOVA

From the table-(4.2 & 4.33), it is evident that the two-factor interactions between Bike and Full, Low and Full, and the three-factor interaction (Bike, Low, and Full) are insignificant. This is indicated by a low T ratio and a partial F ratio

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	19.560833	0.139663	140.06	<.0001*
Mode[Bike]	-0.451667	0.139663	-3.23	0.0060*
Light[Low]	0.5916667	0.139663	4.24	0.0008*
Food[Full]	1.695	0.139663	12.14	<.0001*
Subject[1]	-2.353333	0.197513	-11.91	<.0001*
Subject[2]	-0.149583	0.197513	-0.76	0.4614
Mode[Bike]*Light[Low]	0.5425	0.139663	3.88	0.0017*
Mode[Bike]*Food[Full]	-0.119167	0.139663	-0.85	0.4079
Light[Low]*Food[Full]	-0.3525	0.139663	-2.52	0.0243*
Mode[Bike]*Light[Low]*Food[Full]	-0.353333	0.139663	-2.53	0.0240*

Table-4.2: Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Mode	1	1	4.896067	10.4586	0.0060*
Light	1	1	8.401667	17.9471	0.0008*
Food	1	1	68.952600	147.2917	<.0001*
Subject	2	2	94.601158	101.0402	<.0001*
Mode*Light	1	1	7.063350	15.0882	0.0017*
Mode*Food	1	1	0.340817	0.7280	0.4079
Light*Food	1	1	2.982150	6.3703	0.0243*
Mode*Light*Food	1	1	2.996267	6.4004	0.0240*

Table-4.3: ANOVA breakdown

The residuals were analyzed to ensure that the assumptions made in the ANOVA model were sufficiently validated. Fig.-4.4 gives the JMP residuals vs. fitted values to verify the independence assumptions. Reviewing the residual by predicted plot the values show abnormality(equally and randomly spaced around the horizontal axis). So, the model assumptions have been validated and no data transformation is necessary. Hence, there is no violation of independence

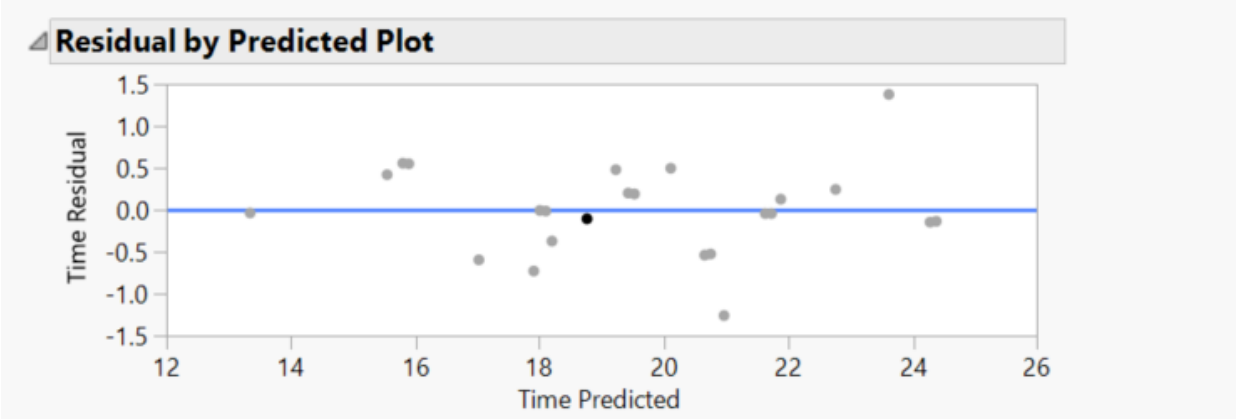


Fig.-4.4 Residual vs. Predicted values

Residual Analysis is plotted to predict the strong correlation between the residuals. In Fig.-4.5, the standard deviation for each residual is computed. It is found that there is no pattern or correlation among residuals to suspect any violation of independence or constant variance assumptions.

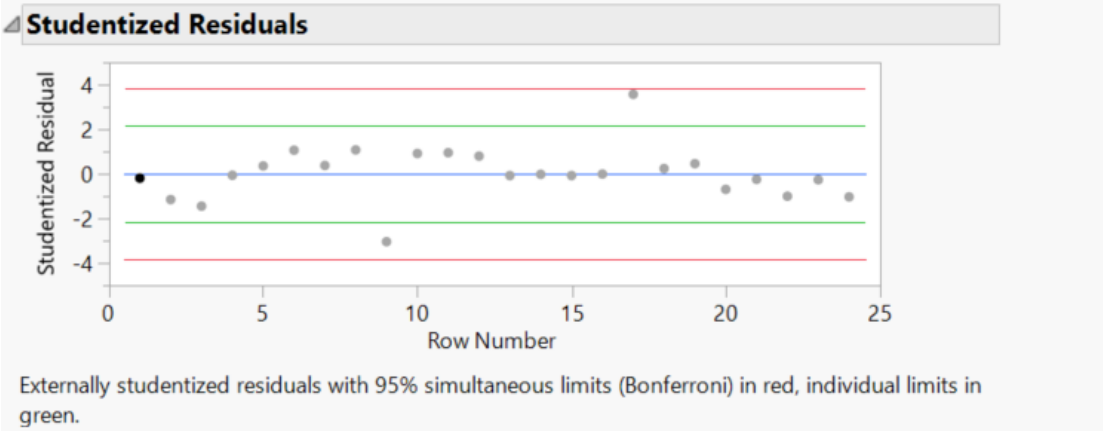


Fig.-4.5: Studentized Analysis

In Fig.-6 , shows the prediction profiler of the factors on the response variable. From the plot, it can be observed that the combination of biking in the daytime on an empty stomach leads to the best commute efficiency.

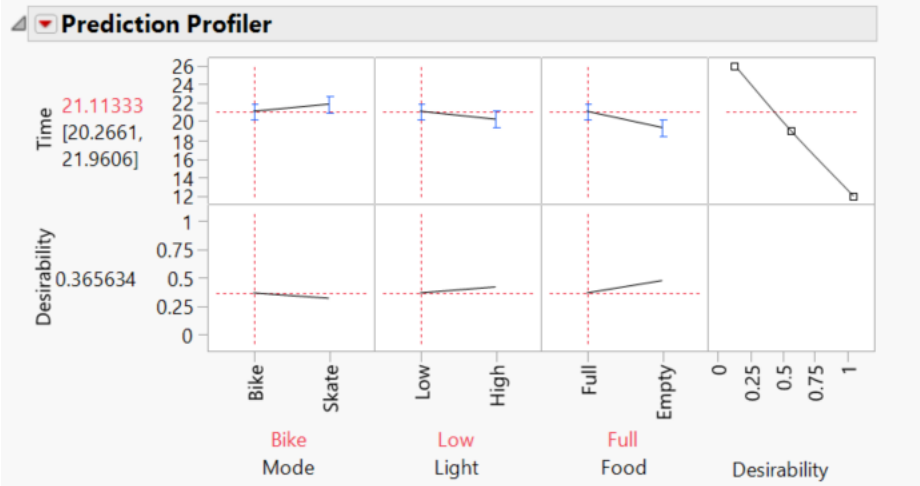


Fig.-4.6: Prediction Profiler

5. ANALYSIS FOR REDUCED MODEL

In the reduced model, after removing all the insignificant factors i.e. Bike and Full, Low and Full & Bike, Low and Full, in a model and made the model run and analyze with all significant factors. The summary of the result is as follows from (fig.-1 to fig.-4) and (table-1 to table-3)

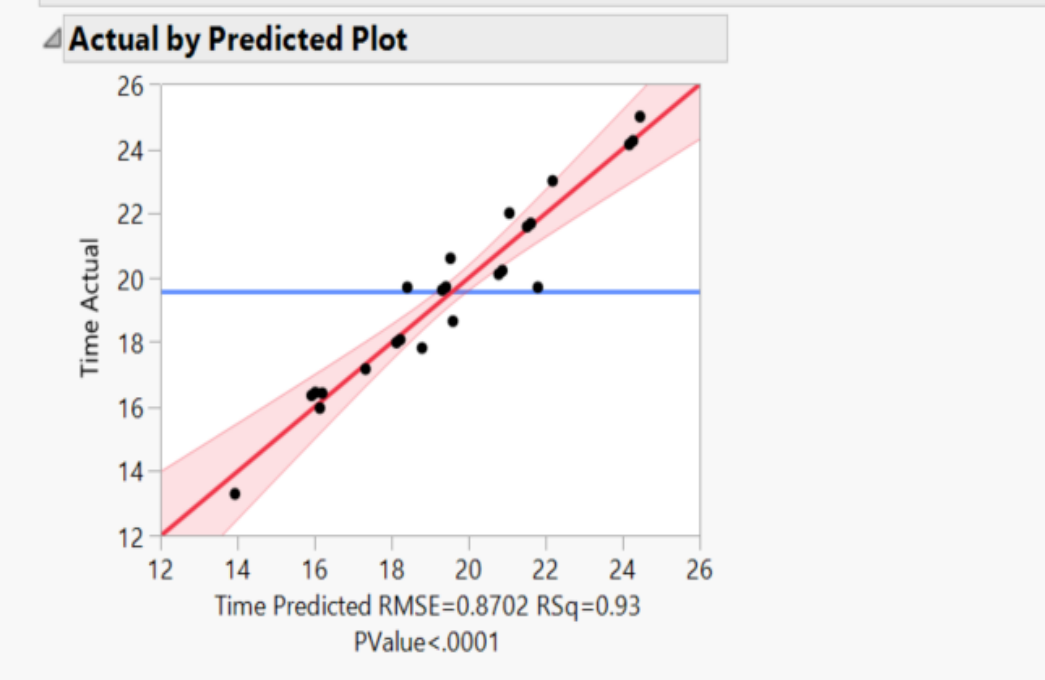


Fig.-5.1 Actual vs. Predicted plot for the reduced model

Summary of Fit

RSquare	0.934584
RSquare Adj	0.911496
Root Mean Square Error	0.870197
Mean of Response	19.56083
Observations (or Sum Wgts)	24

Fig.-5.2: Summary of fit for the reduced model

Effect Summary

Source	LogWorth	PValue
Subject	7.834	0.00000
Food	7.514	0.00000
Light	2.403	0.00396
Mode*Light	2.144	0.00718
Mode	1.677	0.02102 ^

Fig.-5.3: Effect Summary for the reduced model

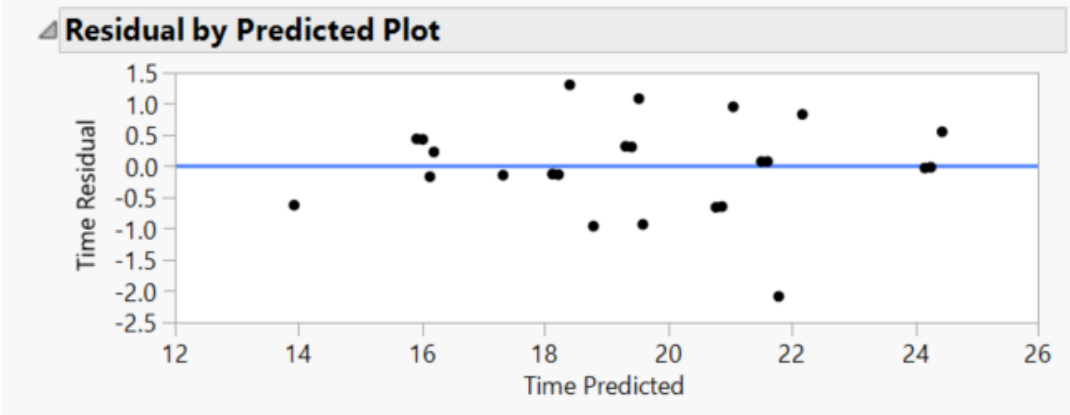


Fig.-5.4 Residual vs. Predicted values for the reduced model

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Mode	1	1	4.896067	6.4656	0.0210*
Light	1	1	8.401667	11.0951	0.0040*
Food	1	1	68.952600	91.0574	<.0001*
Subject	2	2	94.601158	62.4641	<.0001*
Mode*Light	1	1	7.063350	9.3277	0.0072*

Table-5.1: Effect Tests for the reduced model

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	183.91484	30.6525	40.4790
Error	17	12.87314	0.7572	Prob > F
C. Total	23	196.78798		<.0001*

Table-5.2: ANOVA for the reduced model

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	19.560833	0.177628	110.12	<.0001*
Mode[Bike]	-0.451667	0.177628	-2.54	0.0210*
Light[Low]	0.5916667	0.177628	3.33	0.0040*
Food[Full]	1.695	0.177628	9.54	<.0001*
Subject[1]	-2.353333	0.251204	-9.37	<.0001*
Subject[2]	-0.149583	0.251204	-0.60	0.5594
Mode[Bike]*Light[Low]	0.5425	0.177628	3.05	0.0072*

Table-5.3: Parameter Estimates for the reduced model

6. CONCLUSION

The results from the experiment make it clear that the ideal combination of bike, ample light, and empty stomach makes the commute more efficient. Though skating makes for a good hobby, the serious commute is to be made on the bikes due to higher mechanical efficiency than skates. Also, not every commute can be made in the daytime, the results can also be interpreted as the visibility of the road and other conditions. So, an artificial light attached to the bike and riding in well-lit streets accounts for both efficiency and safety. Also, an empty stomach though indicated ideal by the experiment, is not recommended. We would rather interpret the findings as not to bike right after a heavy meal. Instead of having a light meal and resting for a while before commuting should be ideal for both commute efficiency and attentiveness in class.