Study & Analysis of Household WiFi Speed

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Questions of Interest

1

Obstacles

Do ***obstacles*** affect WiFi speed?

2

Distance

Does the ***distance*** between WiFi router and WiFi users affect the WiFi speed?

3

\# of WiFi Users

How does the ***number of WiFi users*** affect WiFi speed?

4

Interaction

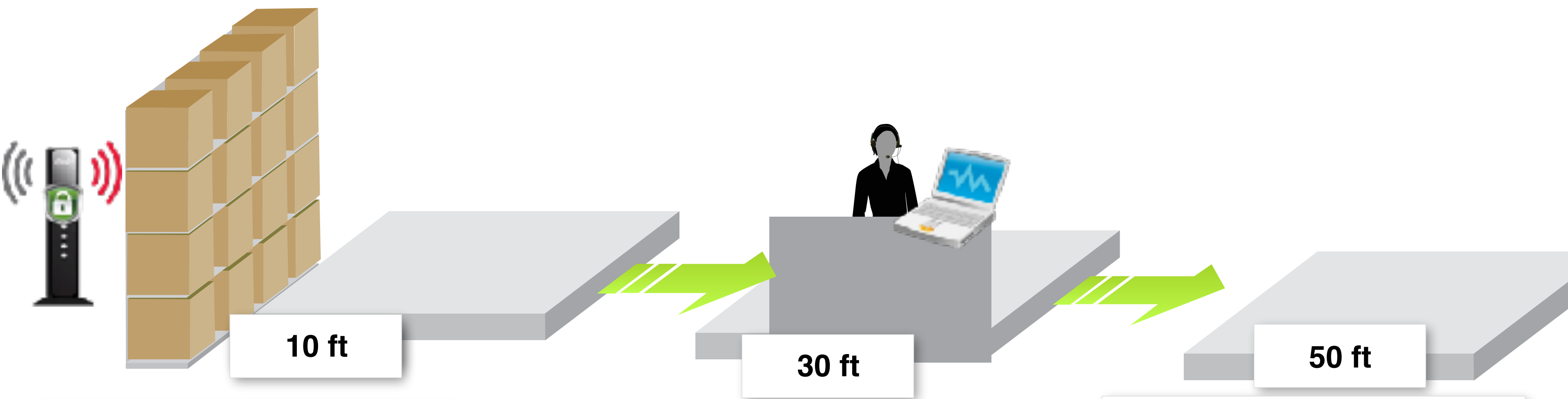
Is there any ***interaction*** among these three factors on WiFi speed?

Study Design— Three Factor Factorial CRD

Response: download speed;
Response unit: Mbps;
n=5, N=120.

Other issues:

1. Ran this experiment in the early morning .
2. Turned off Microwave and other devices.



Obstacle:

1. With or without.
2. Obstacle was simulated using a computer monitor and a board.
3. between WiFi router and WiFi users.

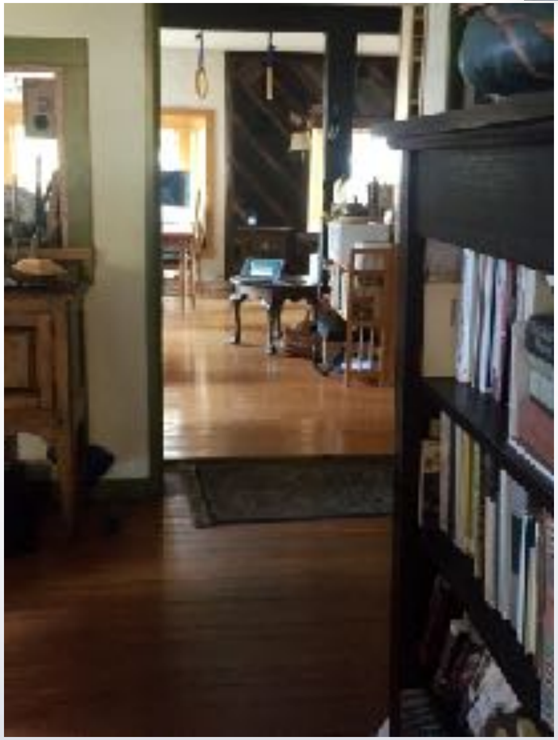
# of WiFi Users:

1. 1, 2, 3, 4
2. All Apple Devices.
3. All used Google Incognito to connect testmy.net
4. only allowed to download the same file (12 MB data) at the same time.

Distance:

1. 10, 30, 50 feet.
2. Was measured in a straight line free of obstacle.
3. Set a table between different distances.

Pics of the Experiment



Model

$$y_{ijkl} = \mu + \tau_i + \beta_j + \gamma_k + \tau\beta_{ij} + \tau\gamma_{ik} + \beta\gamma_{jk} + \tau\beta\gamma_{ijk} + \xi_{ijkl}$$

- y_{ijkl} is the WiFi speed for l^{th} observation from the $(i, j, k)^{th}$ treatment.
- μ is the baseline mean of WiFi speed.
- τ_i, β_j, γ_k are the main effect for the factors obstacle, distance, and number of users, respectively.
- $(\tau\beta)_{ij}$, $(\tau\gamma)_{ik}$, $(\beta\gamma)_{jk}$ are the two-factor interaction effects for the interaction *obstacle * distance*, *obstacle * number of users*, and *distance * number of users*.
- $(\tau\beta\gamma)_{ijk}$ is the three factor interaction effects for the *obstacle * distance * number of users* interaction.
- ξ_{ijkl} is the radom error of the l^{th} observation from the $(i, j, k)^{th}$ treatment, assumed that ξ_{ijkl} *sim* IID N$(0, \sigma^2)$

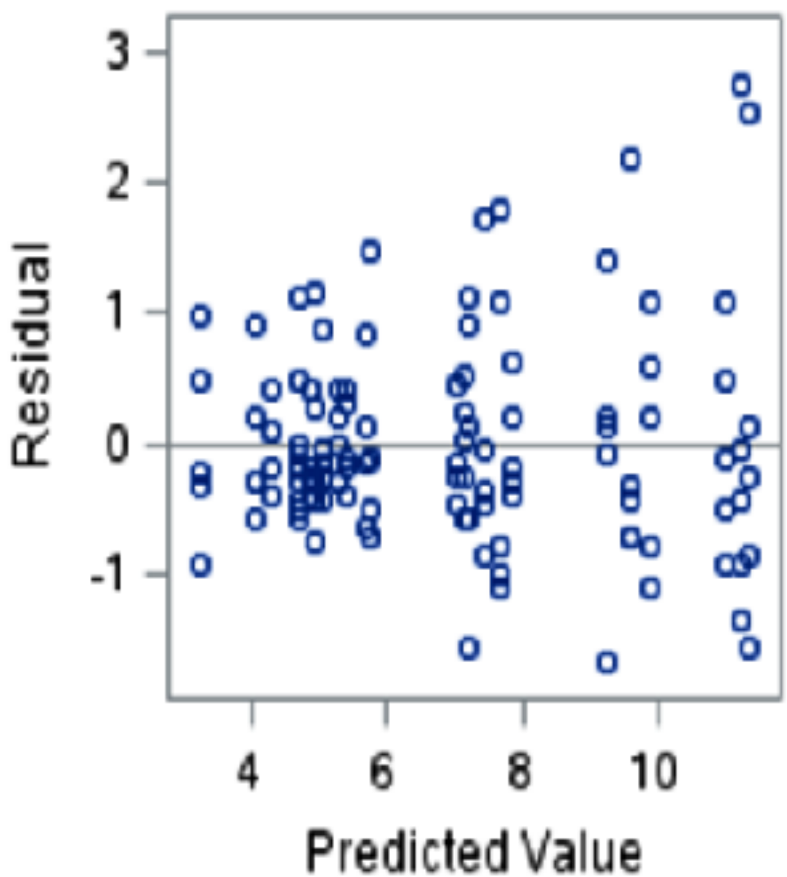
Model Descriptions

Hypotheses

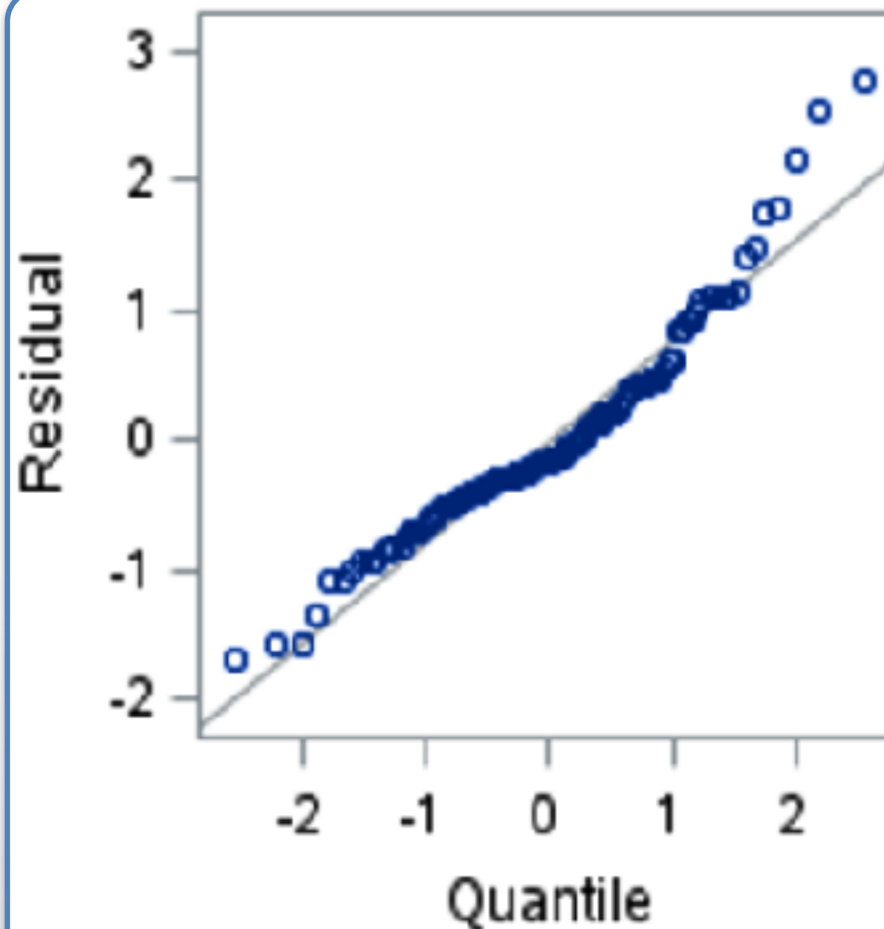
- H_0:τ_1=τ_2=0, H_a:$\exists\tau_i \neq 0$;
- H_0:β_1=β_2=β_3=0, H_a:$\exists$ $\beta_j \neq 0$;
- H_0:$\gamma_1 = \gamma_2 = \gamma_3 = 0$, H_a:$\exists$ $\gamma_k \neq 0$;
- H_0:$(\tau\beta)_{11}$=$(\tau\beta)_{12}$=...=$(\tau\beta)_{23}$=0, H_a: $\exists(\tau\beta)_{ij} \neq 0$
- H_0:$(\tau\gamma)_{11}$=$(\tau\gamma)_{12}$=...=$(\tau\gamma)_{24}$=0, H_a: $\exists(\tau\gamma)_{ik} \neq 0$
- H_0:$(\beta\gamma)_{11}$=$(\beta\gamma)_{12}$=...=$(\beta\gamma)_{34}$=0, H_a: $\exists(\beta\gamma)_{jk} \neq 0$
- H_0:$(\tau\beta\gamma)_{111}$=$(\tau\beta\gamma)_{12}$=...=$(\tau\beta\gamma)_{234}$=0, H_a: $\exists(\tau\beta\gamma)_{ijk} \neq 0$

Assumptions

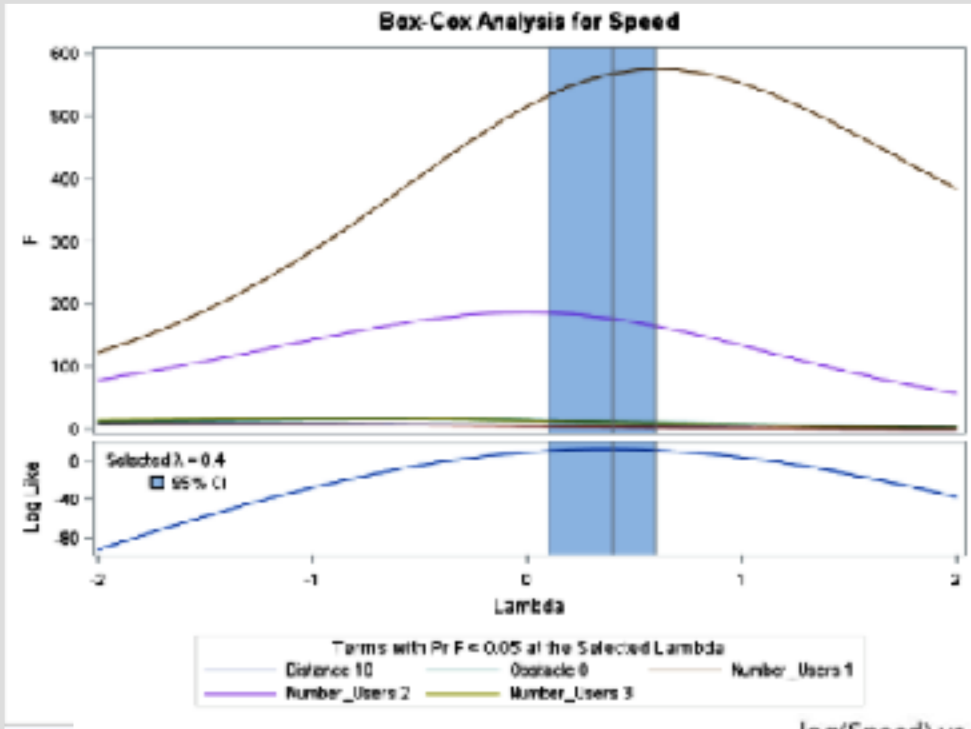
Homogeneity of Variance



Normality



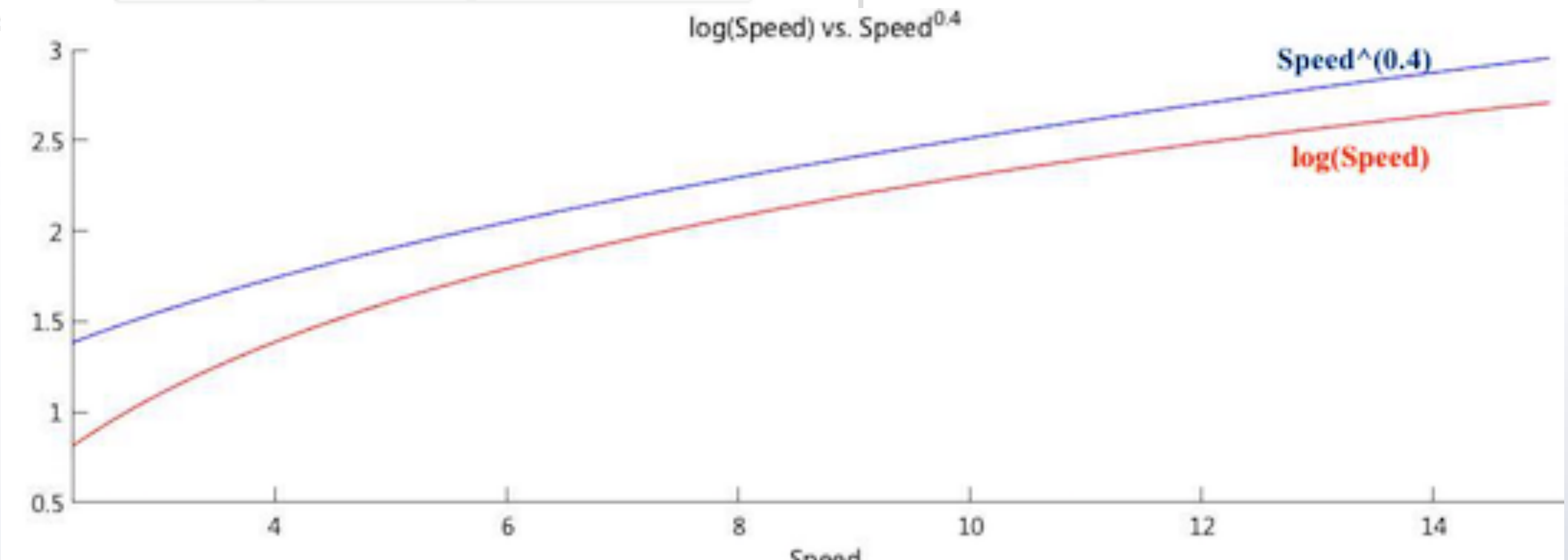
Box-Cox Transformation



The result suggests that λ=0.4, that is, the response *Speed* will be transformed to $Speed^{0.4}$ in order to maximize R^2.

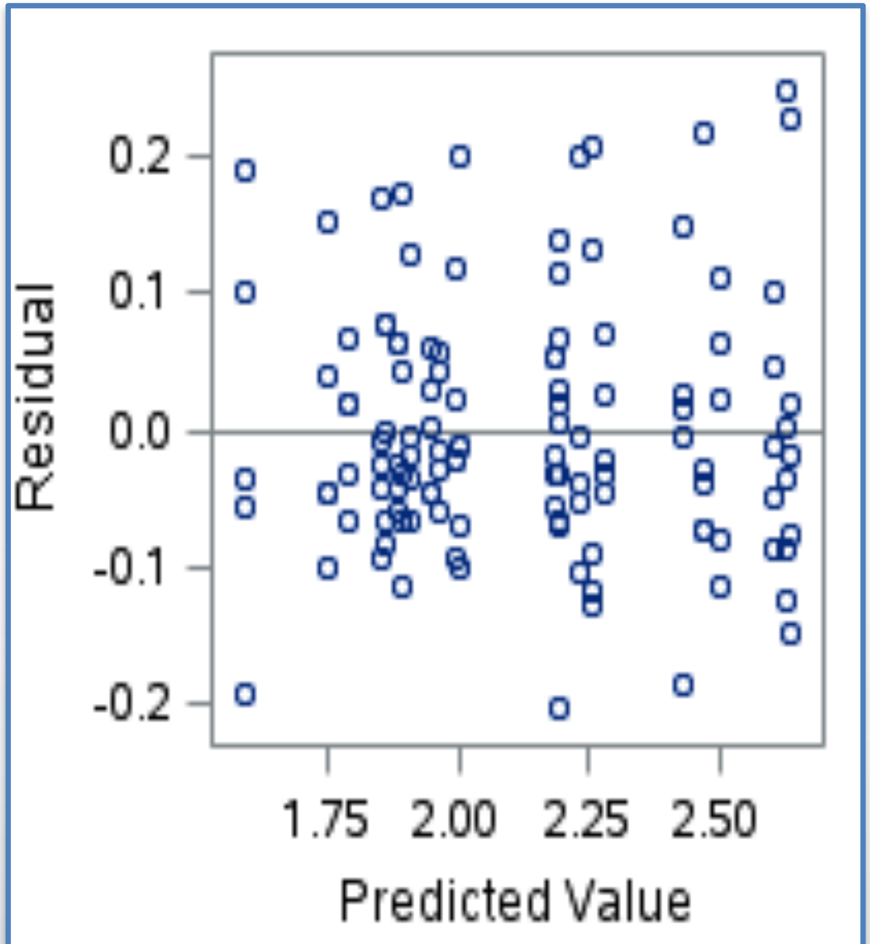
However, $Speed^{0.4}$ and *log(Speed)* are very close within the range of my WiFi speed (2-15), and R^2 for *log(Speed) is 0.9144, which is very close to the* R^2 for $Speed^{0.4}$ *(0.9149).*

It is easier to interpret the results when using log(Speed). So I transformed *speed* to *log(Speed).*

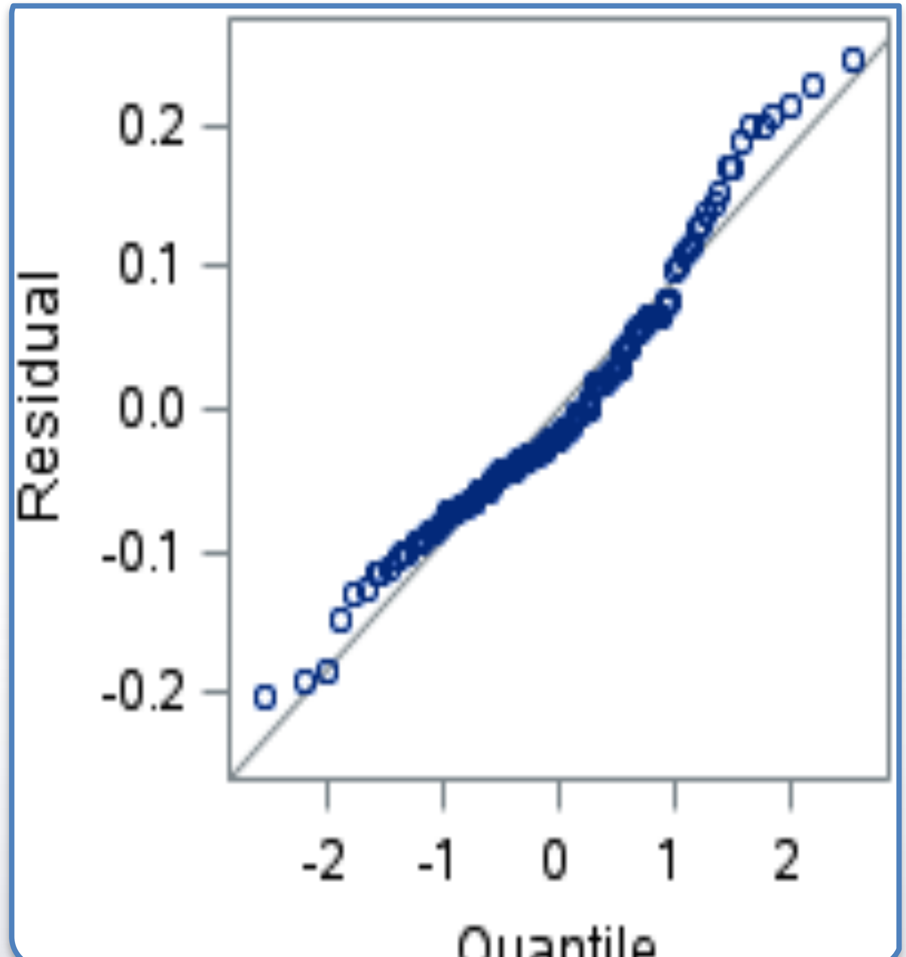


Diagnostics Plots for Transformed Data

Homogeneity of Variance



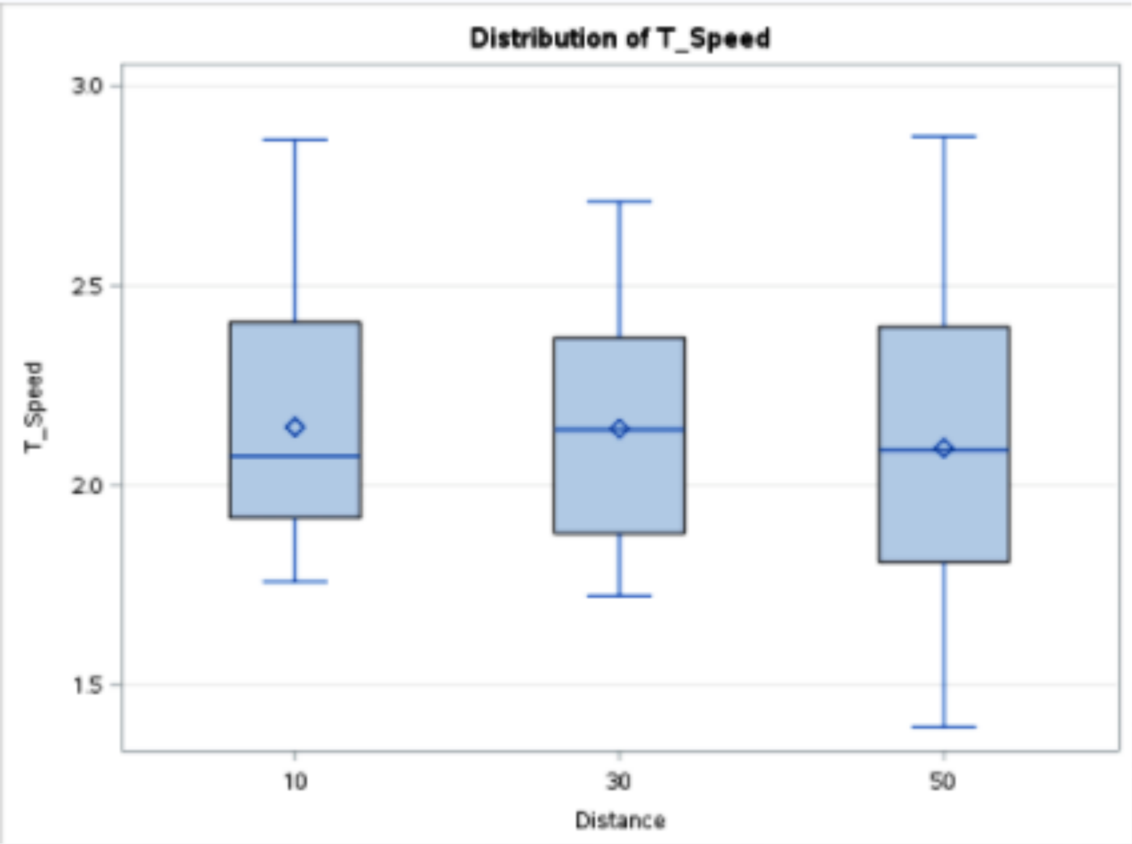
Normality



Results: Distance

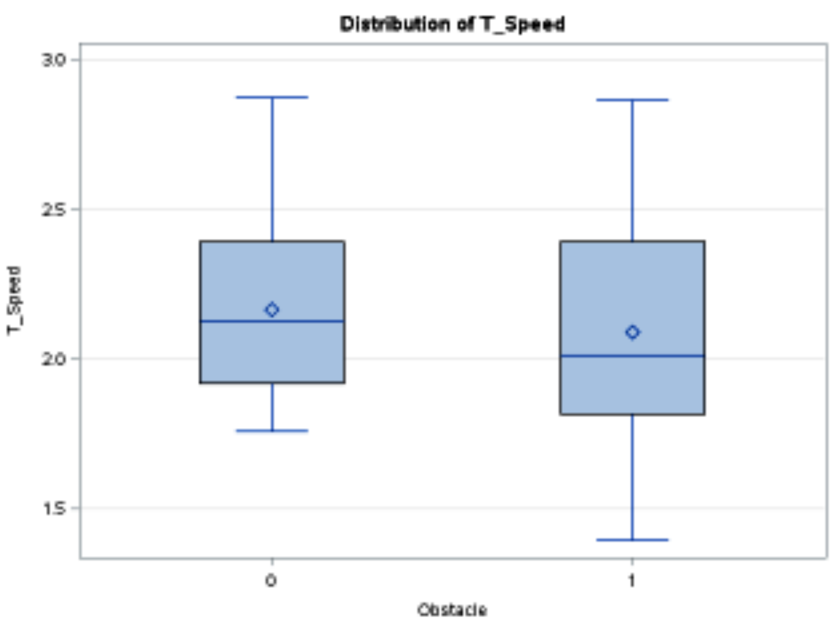
Model Summary

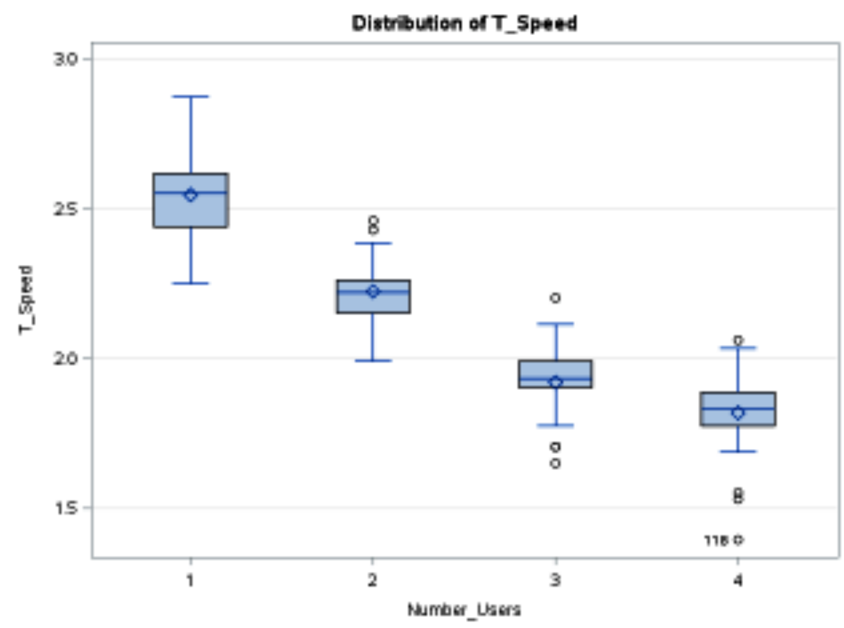
R Squared	**0.9144**
Model DF	23
Error DF	96
Root MSE	0.1189



Source	DF	Type III SS	Mean Square	F value	Pr>F
Distance	2	0.1438	0.0719	5.08	0.008

Results: Obstacle, Number_Users

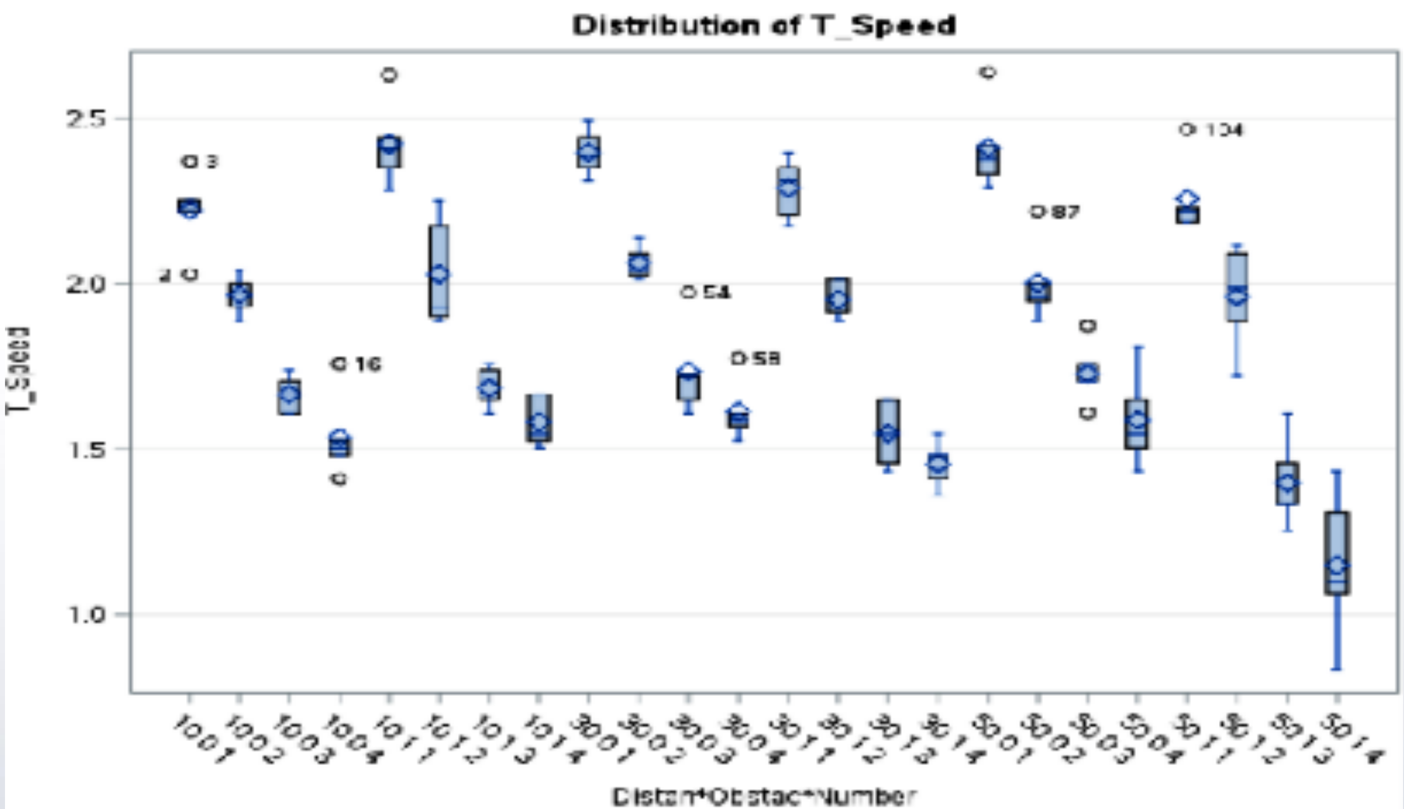




Source	DF	Type III SS	Mean Square	F value	Pr>F
Obstacle	1	0.3017	0.3017	21.32	<0.0001
Number_Users	3	13.0712	4.3572	307.93	<0.0001

Results: Interactions

Source	DF	Type III SS	Mean Square	F value	Pr>F
Obstacle*Distance*Number_Users	6	0.1288	0.0215	1.52	0.1807
Distance*Obstacle	2	0.5499	0.2749	19.43	<0.0001
Distance*Number_Users	6	0.1437	0.0239	1.69	0.1310
Obstacle*Number_Users	3	0.1706	0.0569	4.02	0.0097



Post-Hoc Power Analysis

Dependent Variable	log(Speed)
Alpha	0.05
Error Standard Deviation	0.1189
Test Sample Size	120
Error Degrees of Freedom	96

Source	Test DF	Power
Distance	2	0.477
Obstacle	1	0.929
Distance*Obstacle	2	0.997
Number_Users	3	>0.999
Distance*Number_Users	6	0.293
Obstacle*Number_Users	3	0.484
Distance*Obstacle*Number_Users	6	0.352

- This study has great power in finding effects of ***Obstacle*** (power = 0.929), ***Distance*Obstacle*** (power > 0.997), and ***Number_Users*** (power > 0.999) on the mean of log(Speed), if these effects actually exists.
- This study design has moderate power in detecting an effect of ***Distance*** (power = 0.477) and ***Obstacle*Number_Users*** (power = 0.484) on the mean of log(Speed), if these effects actually exists.
- Although the power for ***Distance*Number_Users*** (power = 0.293), ***Distance*Obstacle*Number_Users*** (power = 0.352) are relatively lower than other terms in the model, these two power are not extremely low.

Conclusions

Distance

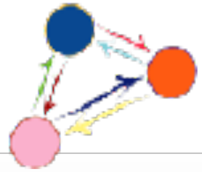
There is strong evidence that the distance between WiFi router and WiFi users has effects on the mean of log(Speed).(F(2, 96) = 5.08, p-value = 0.008)

Number of Users

There is very strong evidence against the null hypothesis that there is no effect of the number of WiFi users on the mean of log(Speed). (F(3,96) = 307.93, p-value < 0.0001)

Obstacle

There is very strong evidence that obstacle has effects on the mean of log(Speed) (F(1, 96) = 21.32, p-value < 0.0001).



Interactions

No evidence for interaction:

- Distance*Number_User (p-value=0.131);
- Distance*Obstacle*Number_User (p-value=0.1807).

Moderate evidence of interaction:

- Obstacle*Number_User (p-value=0.01)

Strong evidence of interaction:

- Distance*Obstacle (p-value<0.0001)

Lessons Learned

Design

- Use representative Apple laptops to record the data;
- Use a pilot study and preliminary power analysis to get sample size for desired power;
- Do a little bit more research about the normal file size for people to download.

Analysis

- If time allows, use practical significant difference while analyzing data;
- Interpret results using original scale;
- Use orthogonal contrast test to find the relationship between distance and WiFi speed.

Questions