

Bike Share System: Data Analysis & Incentive Program Proposal

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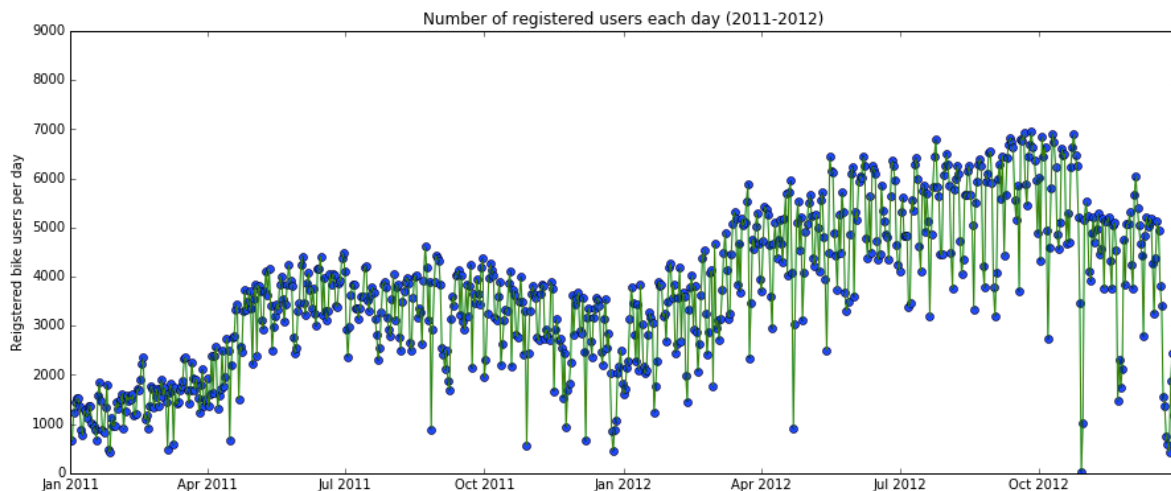
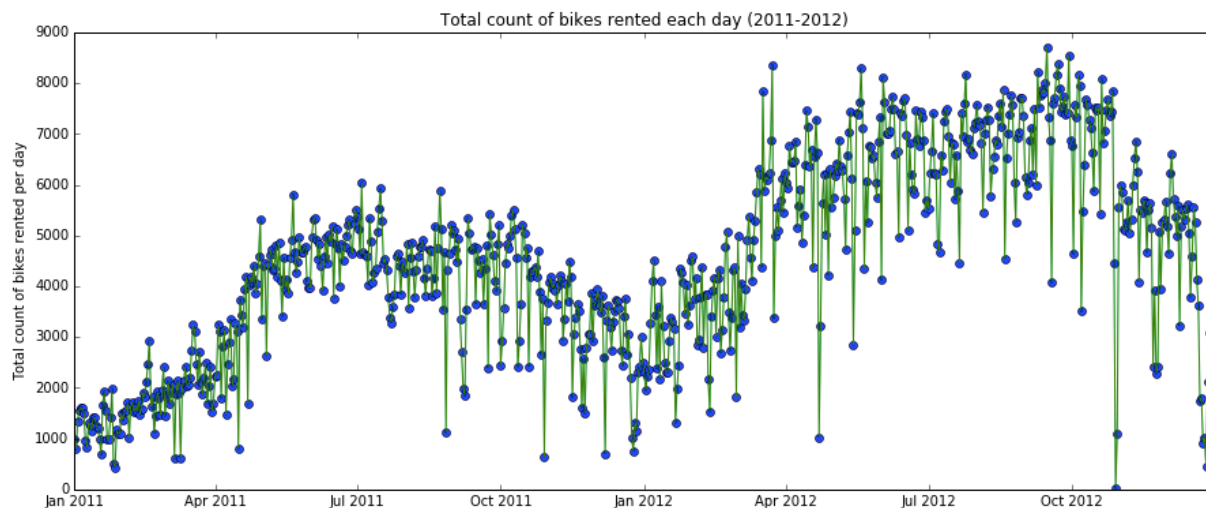
Overview: this report is organized into three parts: 1) data analysis, which includes visualizations, as well as discussions and incentive brainstorming, and 2) overview of incentive program. The graphs are created using numpy and the code is included in the file analysis.ipynb. At the end of the report, I include a section 3) future work, which outlines further tests/analyses I would conduct given more time.

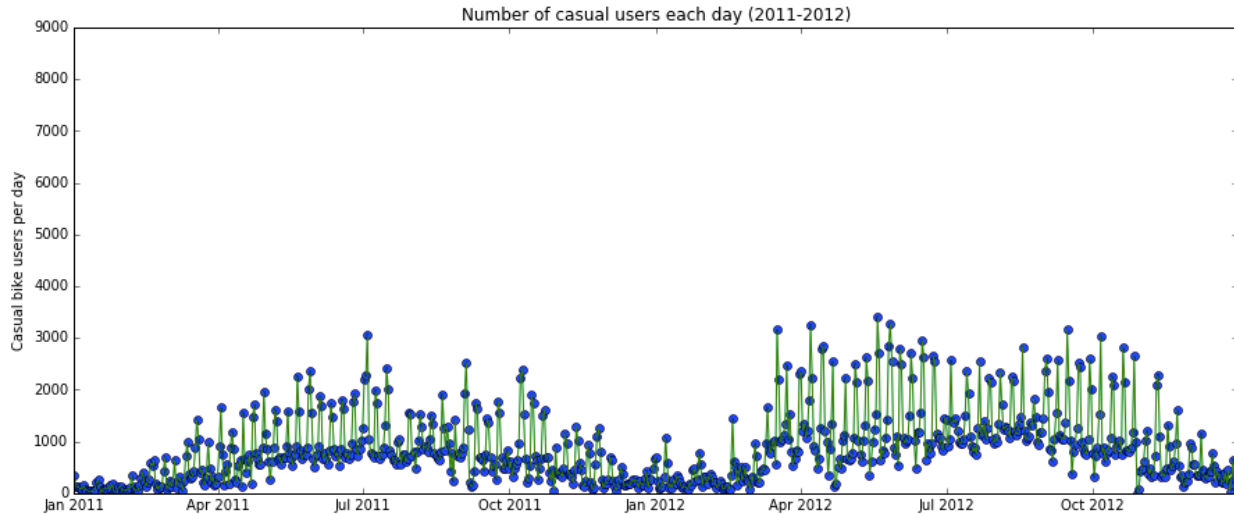
1. DATA ANALYSIS

a. Time Series Analysis

I created three time-series of:

- Total count
- Registered count
- Casual count
-





From these time-series, it is evident that total count of bike rentals has increased with time. Registered users make up the majority of bike share rentals. Growth in registered users is largely responsible for the overall growth of total rentals over time.

Casual usage has grown modestly, with variability in day-to-day usage being larger in 2012 than 2011. The larger extremes seen in 2012 may suggest that more people were willing to try a bike share on certain days in 2012 than in 2011.

Takeaways:

- Registered users account for the bulk of bike share rentals (they also typically pay a membership fee) so incentive programs may want to target acquisition of registered users.
- On the flip side, the small number of casual users may mean we should work on appealing better to casual users.

b. Multiple Regression Analysis

I conducted a multiple regression analysis to obtain an overview of which independent variables (season, holiday, weather, etc.) have a significant impact on the dependent variables (number of bikes rented).

I conducted three individual multiple regression analyses using ALL independent variables (except dteday). The three predictive, or dependent variables, are total count, registered count and casual count. I chose to conduct a multiple regression analysis because I wanted to account for relationships between variables and compare coefficients and std error between variables when combined in a single, global model. In conducting a multiple regression analysis, I am making the following assumption (which may or may not be valid):

- the dependent variable really is a linear function of the independent variables, with independent and identically normally distributed errors--the coefficient estimates are expected to be unbiased and their errors are normally distributed.

Because I am not certain this assumption is valid, a multiple regression analysis serves to indicate which variables will play a significant role in determining the predictive variable. But the results (coef, std err) cannot be assumed to be correct. Later, I will

narrow in on key variables of interest and supplement this multiple regression analysis with tests/analyses for individual variables.

The results for each analyses are summarized below:

TOTAL COUNT

-----Summary of Regression Analysis-----

Formula: Y ~ <season> + <yr> + <mnth> + <holiday> + <weekday> + <workingday>
+ <weathersit> + <temp> + <atemp> + <hum> + <windspeed> + <intercept>

Number of Observations: 731

Number of Degrees of Freedom: 12

R-squared: 0.8002

Adj R-squared: 0.7972

Rmse: 872.4164

F-stat (11, 719): 261.8539, p-value: 0.0000

Degrees of Freedom: model 11, resid 719

-----Summary of Estimated Coefficients-----

Variable	Coef	Std Err	t-stat	p-value	CI 2.5%	CI 97.5%
season	509.7752	54.7571	9.31	0.0000	402.4512	617.0992
yr	2040.7034	65.1853	31.31	0.0000	1912.9403	2168.4665
mnth	-38.9796	17.0791	-2.28	0.0228	-72.4545	-5.5046
holiday	-518.9919	201.0403	-2.58	0.0100	-913.0310	-124.9529
weekday	69.0622	16.2990	4.24	0.0000	37.1162	101.0082
workingday	120.3570	72.0073	1.67	0.0951	-20.7774	261.4914
weathersit	-610.9870	78.3633	-7.80	0.0000	-764.5791	-457.3949
temp	2028.9161	1403.6706	1.45	0.1488	-722.2782	4780.1104
atemp	3573.2743	1589.3886	2.25	0.0249	458.0726	6688.4760
hum	-1018.8616	313.9952	-3.24	0.0012	-1634.2921	-403.4311
windspeed	-2557.5691	456.2775	-5.61	0.0000	-3451.8731	-1663.2652
intercept	1469.0031	240.2182	6.12	0.0000	998.1755	1939.8306

-----End of Summary-----

REGISTERED COUNT

-----Summary of Regression Analysis-----

Formula: Y ~ <season> + <yr> + <mnth> + <holiday> + <weekday> + <workingday>
+ <weathersit> + <temp> + <atemp> + <hum> + <windspeed> + <intercept>

Number of Observations: 731

Number of Degrees of Freedom: 12

R-squared: 0.8163

Adj R-squared: 0.8135

Rmse: 673.8781

F-stat (11, 719): 290.3983, p-value: 0.0000

Degrees of Freedom: model 11, resid 719

-----Summary of Estimated Coefficients-----

Variable	Coef	Std Err	t-stat	p-value	CI 2.5%	CI 97.5%
season	447.9515	42.2959	10.59	0.0000	365.0515	530.8515
yr	1754.0185	50.3509	34.84	0.0000	1655.3308	1852.7062
mnth	-23.2353	13.1923	-1.76	0.0786	-49.0922	2.6217
holiday	-244.7780	155.2890	-1.58	0.1154	-549.1445	59.5884
weekday	42.6987	12.5898	3.39	0.0007	18.0227	67.3746
workingday	948.6076	55.6204	17.06	0.0000	839.5916	1057.6237
weathersit	-497.9377	60.5299	-8.23	0.0000	-616.5764	-379.2990
temp	834.0741	1084.2332	0.77	0.4420	-1291.0231	2959.1713
atemp	2678.4190	1227.6869	2.18	0.0295	272.1526	5084.6853
hum	-625.6313	242.5384	-2.58	0.0101	-1101.0066	-150.2561
windspeed	-1695.5151	352.4412	-4.81	0.0000	-2386.2998	-1004.7304
intercept	768.2098	185.5510	4.14	0.0000	404.5298	1131.8898

-----End of Summary-----

CASUAL COUNT

-----Summary of Regression Analysis-----

Formula: $Y \sim \text{<season> + <yr> + <mnth> + <holiday> + <weekday> + <workingday> + <weathersit> + <temp> + <atemp> + <hum> + <windspeed> + <intercept>}$

Number of Observations: 731

Number of Degrees of Freedom: 12

R-squared: 0.6883

Adj R-squared: 0.6835

Rmse: 386.2691

F-stat (11, 719): 144.3305, p-value: 0.0000

Degrees of Freedom: model 11, resid 719

-----Summary of Estimated Coefficients-----

Variable	Coef	Std Err	t-stat	p-value	CI 2.5%	CI 97.5%
season	61.8237	24.2441	2.55	0.0110	14.3051	109.3422
yr	286.6849	28.8613	9.93	0.0000	230.1168	343.2530
mnth	-15.7443	7.5619	-2.08	0.0377	-30.5656	-0.9230
holiday	-274.2139	89.0122	-3.08	0.0021	-448.6777	-99.7501
weekday	26.3635	7.2165	3.65	0.0003	12.2192	40.5079
workingday	-828.2507	31.8818	-25.98	0.0000	-890.7390	-765.7623
weathersit	-113.0493	34.6960	-3.26	0.0012	-181.0534	-45.0452
temp	1194.8420	621.4859	1.92	0.0549	-23.2705	2412.9544
atemp	894.8553	703.7140	1.27	0.2039	-484.4242	2274.1348
hum	-393.2302	139.0238	-2.83	0.0048	-665.7168	-120.7436
windspeed	-862.0540	202.0204	-4.27	0.0000	-1258.0140	-466.0941
intercept	700.7933	106.3584	6.59	0.0000	492.3308	909.2558

-----End of Summary-----

Takeaways:

For the purpose of time, I focus my analysis on the results from the 'total count' regression analysis:

- The rank of variables in terms of magnitude of coefficient (largest to small) is:

- 1) Feeling temp
- 2) Wind speed
- 3) Year
- 4) Temp
- 5) Humidity
- 6) Weather
- 7) Holiday
- 8) Season
- 9) Working day
- 10) Week day
- 11) Month

- Note: If I did this again, I would leave out 'month' from a multiple linear regression since it is not a linear variable but rather categorical.

Therefore, the low coefficient is misleading. In fact, month does have a

strong impact on total count, but it is not linear. More on this later in the analysis.

- The standard error for each variable is a measure of the precision of the measurement of the coefficient (similar to an inverse signal-to-noise ratio). It is important to take into account the precision because this indicates how much confidence we can have in our coefficient measurement. Below is the same list of variables ranked by coefficient magnitude, but those with notable std error are marked. We could proceed with caution when basing conclusions on the coefficient measurements with high standard error.

1) Feeling temp (high std err)

2) Windspeed (medium std err)

3) Year

4) Temp (high std err)

5) Humidity (medium std err)

6) Weather

7) Holiday (medium std err)

8) Season

9) Working day

10) Week day

11) Month *

- Despite the high std err for feeling temp, its 95% confidence interval is 458 to 6688, which, despite being a large range, still places it above most other coefficients.

Conclusions:

- Based on this multiple regression analysis, which again is conducted on uncertain assumptions, it appears that lean demand periods are determined largely by weather and natural conditions, including feeling temperature, wind speed, temperature, humidity and weather.
- This was against my own expectation that human-based factors, such as holiday, working day, week day would have the greatest impact. (always interesting to be proven wrong).
- Year also plays a large role according to this analysis, but we already knew that from the time series.
- Based on this knowledge, I would recommend an incentives program that encourages users to take up bike sharing during weather conditions, in which they typically refrain from bike sharing.

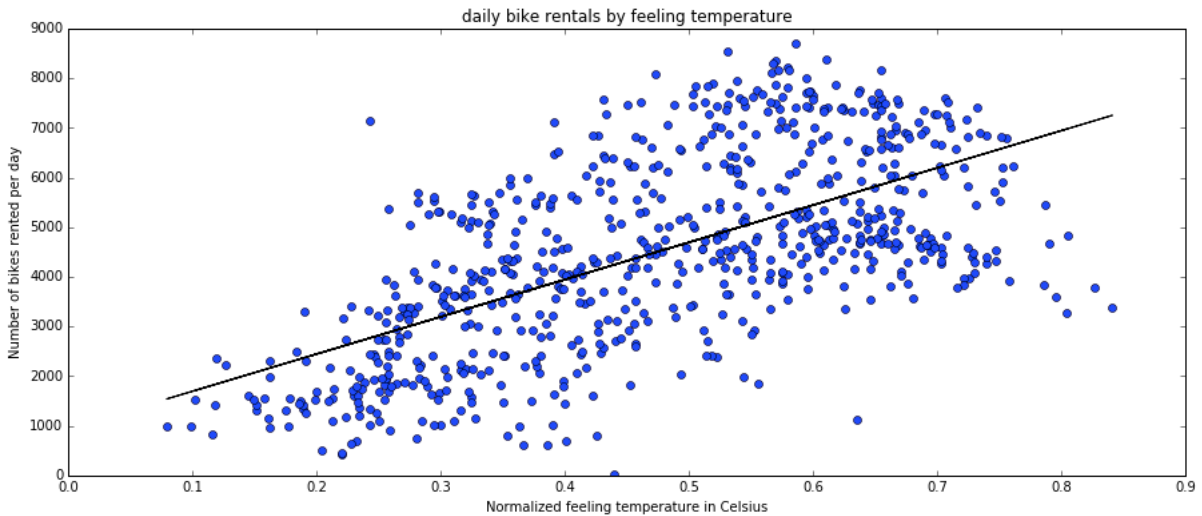
If I had more time, I would investigate the results for registered and casual users to better understand the factors that impact their behavior. For instance, for registered users it appears that rental rates are positively correlated with working day (more rentals on working days), whereas casual users are negatively correlated with working day (more casual rentals when it is not a working day).

I focused this analysis on total count since this is the most universal metric of bike share usage.

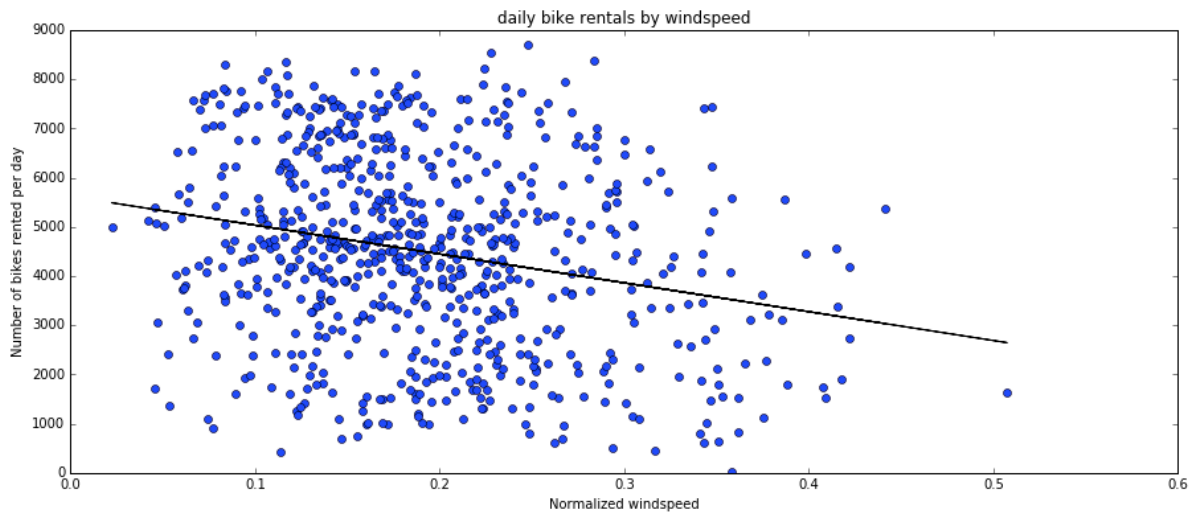
- c. **Investigation into individual, influential variables: feeling temperature, wind speed, temperature, humidity and weather**

These variables appear to be the most significant according to the multiple linear regression.

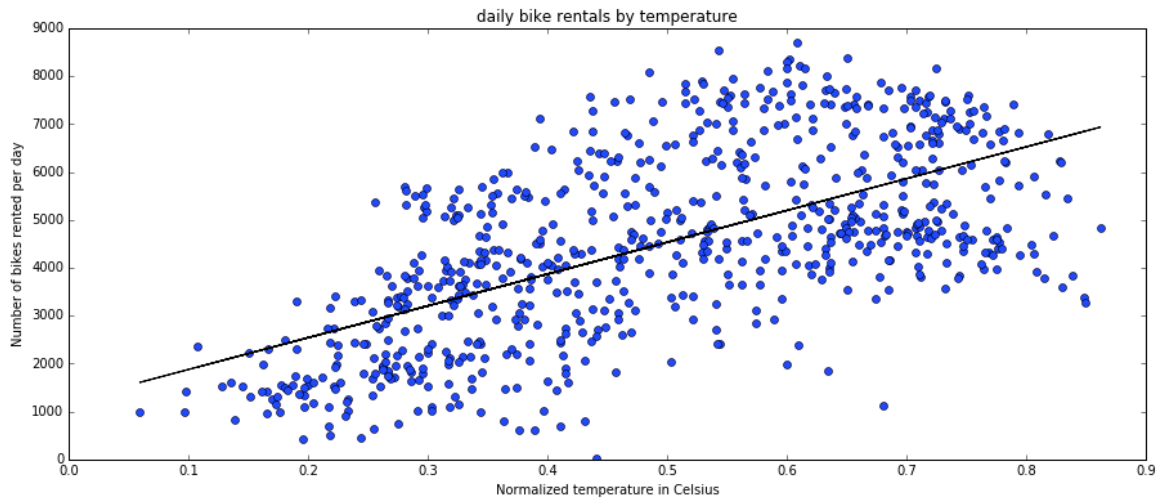
I conducted individual linear regressions for each variable.



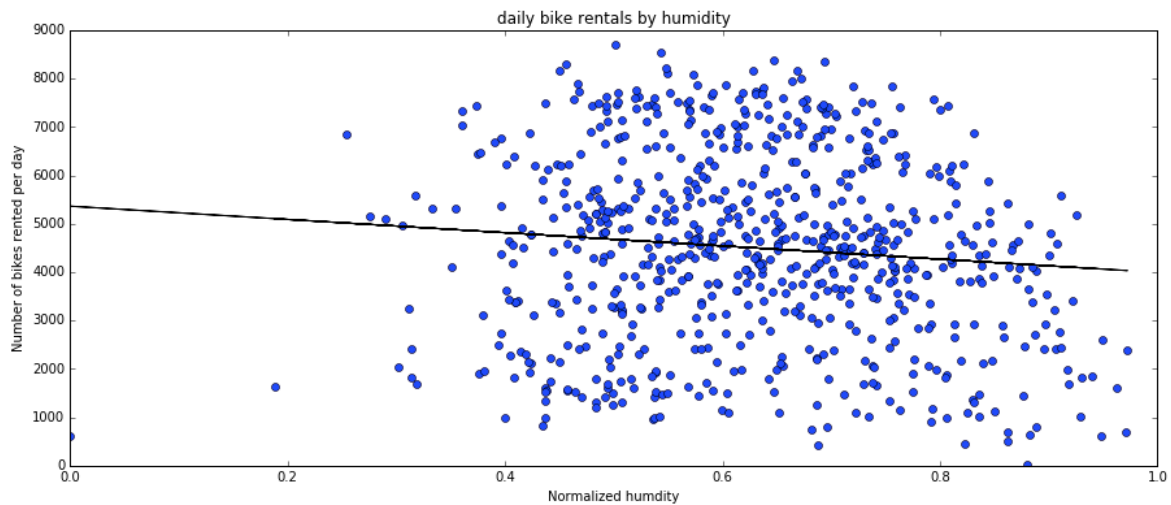
- Mostly linear, but drops off at high temperatures (convex)
- People seem more interested in bike during warmer weather. Cold weather has low rates for bike sharing.



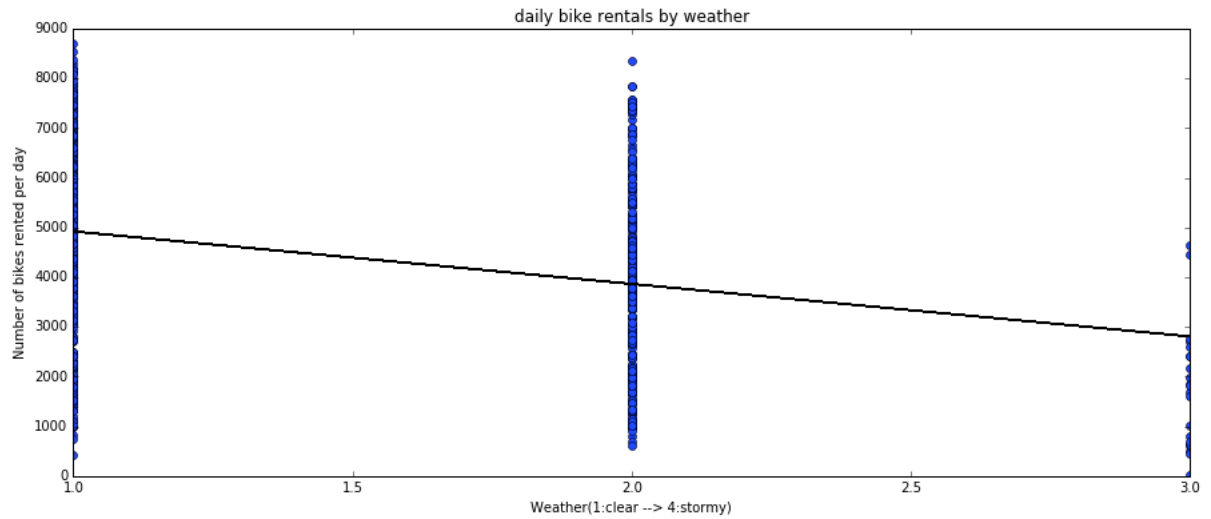
- Linear relationship: the higher the wind speed, fewer bike shares.



- Again convex relationship. Linear except at high temperatures (drops off)
- Warm weather sees higher bike share rates.



- Linear relationship, but not very strong. Lots of variability (std error). At high humidity, the bike share usage is slightly lower.



- Stormier weather is correlated with fewer bike share rentals.

Takeaways

- High bike share rates are correlated with warm (but not hot) temperature, warm (but not hot) feeling temperature, low wind speed, low humidity and clear sky weather.

Conclusions

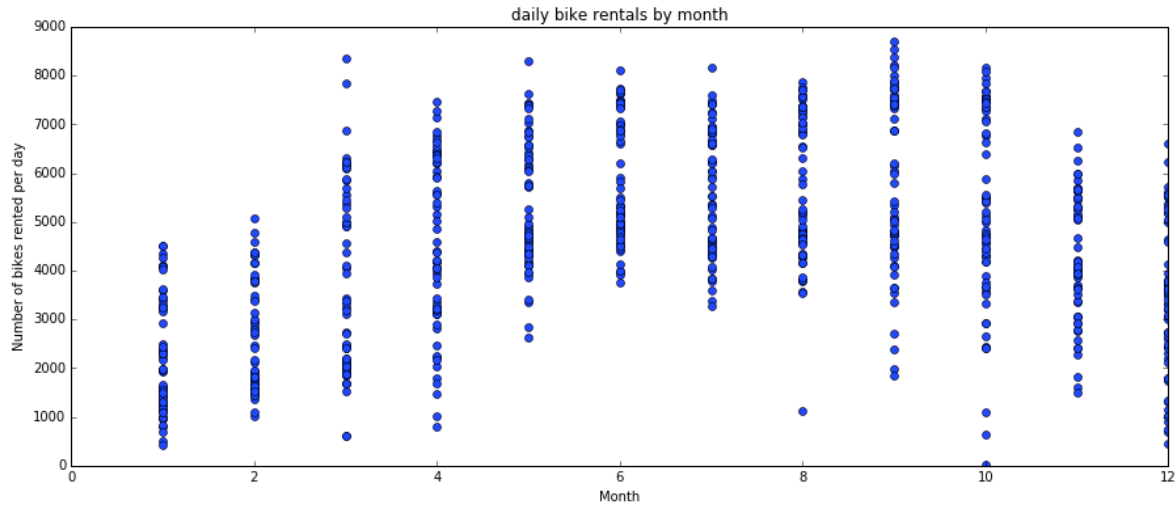
- I would create a program that incentivizes bike sharing during the conditions of low temperature, high wind speed, high humidity or stormy weather.

Analyses I would conduct if I had more time:

- Non-linear regressions for each variable, since many of them do not have linear behavior.
- A multiple (non-linear) regression using only feeling temperature, wind speed, temperature, humidity and weather as independent variables and test the strength of this model as compared to the global, linear model.
- Create several different models (using different variables for multiple regression). I would train the model on 80% of the data and use the other 20% of the data as a validation data set to measure the model's ability to predict new data points, as well as measure the model's error.

d. Effect of Month

Since the linear regression was an inappropriate way to assess the impact of month, I conduct an analysis here, creating a scatter plot of rental rates by month.

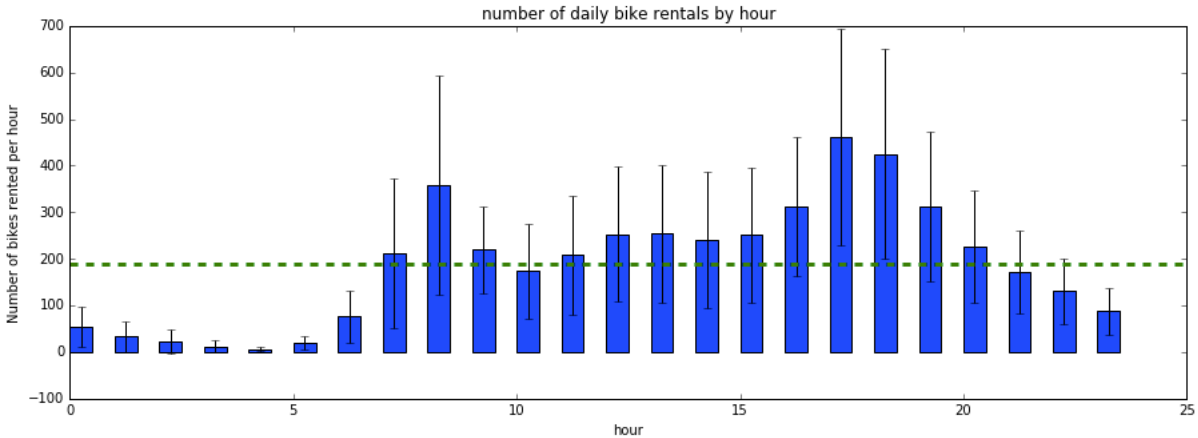


Here you can see that bike share rates are highest May-August. This corresponds with higher bike rates correlated with warm, clear weather as we might expect from the previous analysis (assuming this is a location in the Northern hemisphere). Based on this data, I would consider creating an incentive plan for the fall and winter months (Sep – April). Perhaps the membership has a 10% lower monthly cost in Sep-April than May-July to encourage more bikers in these under-utilized months. Additionally, the agency could sign up individuals for year-round memberships to encourage users to stay active biking all year. This could be incentivized by having a reduced yearly membership rate, as compared to the monthly rate, which the bike share program in DC currently offers. This may encourage members to continue using their membership throughout the year, even in the colder months.

Some non-monetary incentives could include free friend/guest passes during Sept-April. This means that members could take a friend on a bike trip with them for free, in order to expose more people to the bike share program, while taking advantage of under-utilized bikes in these months.

Other incentive ideas could include using games like Pokémon Go to encourage people to bike around a neighborhood and quickly catch Pokémon. Perhaps you could have a “gym” positioned at a bike station. Pokémon Go currently does this with business establishments to attract customers to business establishments.

e. Effect of time of day

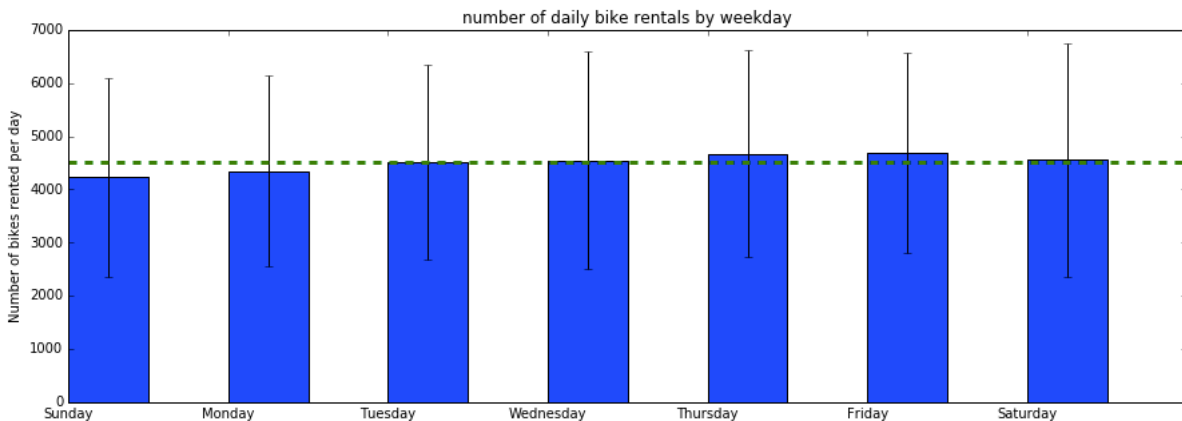


Note: dashed line signifies count averaged over all hours.

- Rentals are highest at 8am and 4pm – 7pm. This corresponds with regular work commute hours.
- Based on this data, an incentive could be established that reduces the cost of bike rental during non-peak hours:
 - 15% discount during low demand hours: 8pm – 6am and 10am.
 - 5% discount during mid demand hours: 9am – 3pm
 - 5% upcharge during high demand? 8am and 4pm – 7pm

f. Investigation into less influential variables: holiday, weekday, working day

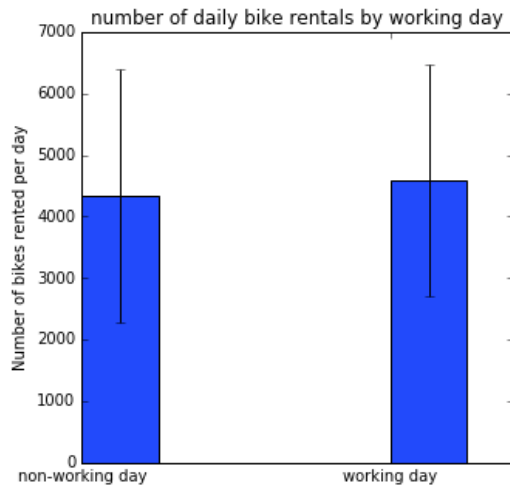
Surprisingly (to me), these variables had the smallest impact on bike share usage. Below is my analysis of bike rental rates by weekday and by working day.



Note: the error bars signify the standard deviation of the count for each weekday. Dashed line signifies count averaged over all weekdays.

It is evident from the graph that bike rentals do not vary significantly by day of the week.

- Sunday and Monday have lowest ridership
- Thursday and Friday show largest ridership
- Wednesday and Saturday have largest variability (std)
- The maximum variation between any two weekday averages (max - min / min) is 10.9%.



- Bike rentals are higher on working days. This may indicate that there are more regular, commute-oriented users than recreational users.

2. INCENTIVE PLAN OVERVIEW

Based on the data, it appears that the lean-demand periods are correlated most strongly with the following factors (not ranked in any particular order, since this has not been rigorously determined):

Cold or hot Feeling temp
 High Wind speed
 Cold or hot Temp
 High Humidity
 Stormy Weather

<----- bundled as "weather and natural conditions"

&

Month (sep. – april)
 Hour (8pm – 6am)

The incentive program outlined below aims to increase bike share usage during these lean demand periods.

First, I will state that the most responsive incentive plan would collect real-time rental data from bike stations and use the real-time demand to set prices (similar to Uber surge pricing). However, I would cap the surge prices for members. In the case that real-time rental data is unavailable, the following program(s) should incentivize bike usage during the conditions most correlated with lean-demand.

1) Financial incentives

- Apply discount during poor weather conditions (cold or hot temperature, high humidity, stormy weather, high wind speed). This requires bike stations with IoT capability to update prices. If stations had this capability, then they would likely just transmit real-time demand data to generate demand-based pricing. So, in essence, this scheme seems unlikely.
- Apply discount for low-demand months
 - May-July have highest rental rates

- ii. 10% discount on Sep. – April
- c. Apply discount for low-demand hours
 - i. 15% discount during low demand hours: 8pm – 6am and 10am.
 - ii. 5% discount during mid demand hours: 9am – 3pm
 - iii. 5% upcharge during high demand? 8am and 4pm – 7pm

2) Non-monetary incentives

- a. Run promotions during low-demand months
 - i. Free friend/guest passes to get people to introduce the service to more people
 - ii. Free month trial periods during low-demand months, the objective being to secure members for the rest of the year. A free trial during these months would have the least impact on other paying members, since bikes should be amply available at most bike stations and under-utilized.
 - iii. Free bike day all over a city—anyone can rent a bike for free on this day. The idea is to get people to download the bike share app and create an account so that they may use it later.
 - iv. Partner with a festival that occurs across a city.
- b. Incentives during poor weather conditions
 - i. The bike station could have a roof that keeps the bikes dry during rainy conditions
 - ii. Run competitions/challenges at businesses for employees to compete on who bikes to work the most days (even in rough weather conditions)
- c. Incentives during low-demand hours
 - i. The low demand hours are at night (8pm-6am) and midday (10am-3pm).
 - ii. I would incentive those individuals that use bikes for pleasure rather than for work commute. This could include:
 - 1. Placing bike stations in recreational areas (along a bike river path, along a nature trail area)
 - 2. Place bike stations in areas where individuals will use the bikes at non-commute times, such as universities, college dorms, gyms, parks, etc.

3) Actions/ improvements to the system that would increase demand during lean periods

- a. Create options that are more appealing during poor weather conditions.
 - i. Provide tricycles at bike rental stations. Many individuals (whether old, disabled or unexperienced on bike) feel safer on tricycles. In particular, during uncertain weather conditions (wet or ice-y roads) people feel safer on tricycles than two wheeled bikes. The slippage is lower and chance for accident is also reduced.
 - 1. Reclining bikes are more protected from wind and elements and warmer.
 - ii. Helmets with wind shield
 - iii. Mirrors on bike improves safety
- b. Partner with employers to incentivize employees to bike to work
 - i. One guess for the cause of low ridership during high humidity / hot temperature is that 1) its uncomfortable and 2) people don't want to come to work sweaty and seem unprofessional
 - ii. The agency could encourage employers to have a shower in their building or bike share stations at their office to encourage employees that it will be acceptable for them to arrive at work a bit sweaty in the morning.
 - iii. Employers should offer bike share memberships for their employees for free (the employer pays the cost)
- c. Partner with health insurance agencies to provide a discount for health insurance if a payer bikes regularly. It may encourage people to bike to work even when conditions are less than ideal (weather-wise).
- d. Partner with games like Pokémon Go.