Understanding the Effects of Spatial Components: Towards better Trip Generation Estimators.

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Abstract

With the rapid growth of Bikeshare systems in major Urban centers', and their relatively high Demand sensitivity to conditions; there is a growing need for more accurate predictors for Bikeshare Trip Demand. In this study, we work towards constructing estimators incorporating various Spatial components and characteristics using historical data from Capital Bikeshare. We develop multinomial OLS regression models using crowd sourced data from OpenstreetMap, and spatial characteristics from the Smart Location Database provided by EPA.

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1. Introduction

With the adoption of modern technologies, a growing resurgence of Bikeshare programs for Urban centers has been observed across the globe [1]. About 855 cities in had a functional Bikeshare program with an estimated combined fleet of about 946 000 bicycles in 2014 as compared to about only 13 bikeshare programs in 2004 [2]. This sudden growth in demand has been attributed largely to the success of the the 3rd and 4th generation bikeshare technologies.

With an increased global focus towards creating a more sustainable and greener Smart Cities, bikeshare programs increasingly are being used as tools to attain the goals by organizations across [3]. With the revenues from Casual riders contributing upto 50% of share [4], a better understanding of demand generation can attribute greatly to the success and adoption of these programs.

Bikeshare trips, typically found to have about 16 to 22 min duration [5], exhibit a high sensitivity to both spatial and enviornmental conditions [6]. In addition, studies have shown a significant variance introduced attributed to trip purpose as well [7, 8]. Numerous studies have been undertaken in an effort to understand the Temporal Variations exhibited by the Bikeshare demand and trip charecteristics [6, 9]. Trips are longer and higher in demand during the summer months. During the weekdays, usage peaks between 7am-9am and 4pm-6pm, while a higher usage is observed in the middle of the day om weekends [10]. Owing to the availability of accurate data, many studies have been undertaken to understand the Spatial factors affecting bikeshare and understand benefit effects of bikeshare [9, 11, 12, 13]. Bikeshare demand is stronger amidst high-income urban population[7], and hence many systems can be criticized for their equity in overall accessibility for populous [14]. The combined effects of demographics and spatial charecteristics have been shown affect to the trip purpose and demand distribution[8]. Comprehensive surveys about the literature can be found by Fishman et al. [15, 16].
In this study, we seek to examine and establish the effects of these parameters on individual time-periods, as opposed to the coarser resolutions which ignore traffic distribution across time. We include variables derived from publicly available crowd-sourced data, with the assumption that similar information availability as on ground, will lead to more realistic demand predictors.

2. Datasets

2.1. Cabi Trip Dataset

Capital Bikeshare provides trip logs on its website. Each record in the log comprises of the Origin and Destination Bikeshare stations, start and end times, bikeid for the cycle used for the trip, and Member Type. Based upon observations and suggestion from n[10], we obtain trip origin and destination counts for each of the time-period in

1. 12:00am to 7:00am
2. 7:00am to 11:00am
3. 11:00am to 4:00pm
4. 4:00pm to 8:00pm
5. 8:00pm to 11:59pm

In addition, we estimate for each of these time-periods for both weekdays and weekends seperately. Thus we compute Trips starting/ending from each station for each of the time periods.
We ignore trips outside [5%,95%] quantiles from our analysis. ie: Trips shorter than 185secs and Trips greater than 3044secs.
The dataset contains trip-logs for 344 stations from the CaBi system. We ignore stations from the logs, whose location information is no longer available from the CaBi datafeed.

2.2. Data from OpenStreetMap

We obtain critical Points of Interests in a walking radius in a for each station assuming Rectilinear Space using OpenStreetMap's API and group similar POI's. The classification is enumerated in Table 1.
newline We make an assumption that the access to information about locations leads trip generation, and publicly available Open data can work as good model for the information accessible by an individual.
We also assume that the share of Trip demand for POI assigned to a particular Bike node is inversely proportional to it's distance from the POI. ie: Bike Nodes at equal distance from a POI will lead to an equal split of demand generated from the POI.
For a given node, we also ignore the demands generated from POI's that are outside Walk Accessibility of the node.

Points of Interest	Category
amenity, cafe, bar, pub, biergarten, restaurant	pubs
college, library, school, university	education
bus station, parking	bus
theatre, community center, social center, gym, townhall	leisure
hotel, stadium, hospital	building
points of tourist interests	tourism
shops	shops

Table 1: Point fo Interest Classification

We also assume that a POI will contribute equally to both Trip Attractions and Trip Destinations.
Accounting for the above, a Score is generated for each Bike Station based upon its spatial characteristic in each of the category.

POI	Number of Observations
bus	33
education	561
leisure	64
pubs	1845
shop	1720
tourism	640
Total	4863

Table 2: Point fo Interest Classification

2.3. Smart Land Database

The Environmental Protection Agency (EPA) maintains 'Smart Land Database' to enable understand the relation of the built environment and travel-behaviorsr. It summarizes several demographic, employment, and built environment variables at the Census block group level. We employ the following variable:

1. Residential Density : D1B (people/acre)
2. Employment Density : D1C (jobs/acre)
3. Percentage of Jobs within 0.5 miles of guided transit : D4050
4. Accessible Jobs within 45mins of Transit : D5br

5. Working Age Population within 45min of Transit : D5be
6. Percentage of Households having 0 cars : PctA00
7. Percentage of Households having 1 cars : PctA01
8. Percentage of Households having 2+ cars : PctA02P

For each station, averages across all of its Walk-accesible blocks or Maximum value in case of counts are used.

3. Analysis

We employ Ordinary Least Square (OLS) regression models to estimate the effect of independent variables upon bikeshare production and attraction rates. Multiple permutations of variables were tested to maximize the capturing of various Bikeshare characteristics and as well as maintaining mutlicollinearity and heteroskedacity of the model. A detailed result for regression can be found attached the appendix of this report.
We hypothesize that various parameters will affect trip demand in varying degrees across different time periods of the day. Hence we fit a model for each time period, for each demand type (Origin and Destination). Literature also suggests that Bikeshare usage patterns significantly during weekends and weekdays. Thus we treat each of the data seperately. Since for the given time period we have more samples for Weekdaysas compared to Weekends , hence, we consider the former to be more robust.

3.1. Analysis for Weekday Production

Coefficients indicated in Fig.1
It can be found that Pubs remain significant across the time periods. However, the co-efficients spike during the morning and evening commute hours.
Tourism also remains significant through out except for early morning hours, which can be logically explained. During evening commute, the variable,'D5br', indicating Accessibility to Jobs; and during the later period even 'D5be', Accessibility Working Population, become significant. This could very well explain the evening commute and leisure behaviorr.

3.2. Analysis for Weekend Production

Coefficients indicated in Fig.2
Tourism remains significant across time-periods.% Share of households having

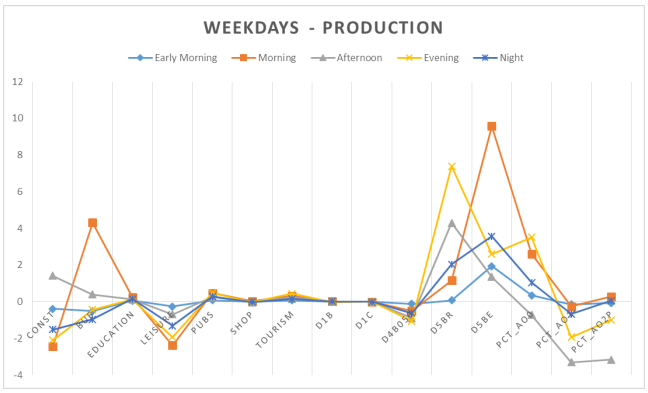

Figure 1: Co-efficients for Variables

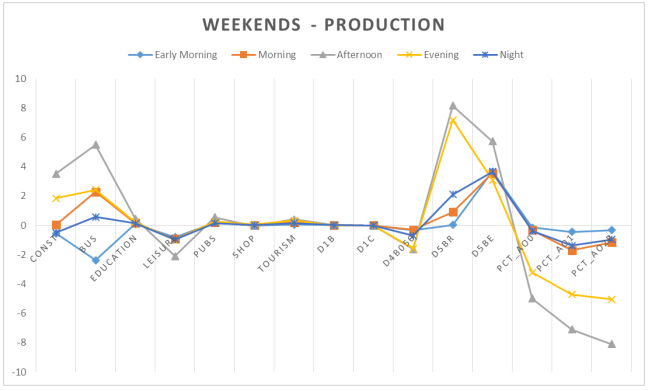

Figure 2: Co-efficients for Variables

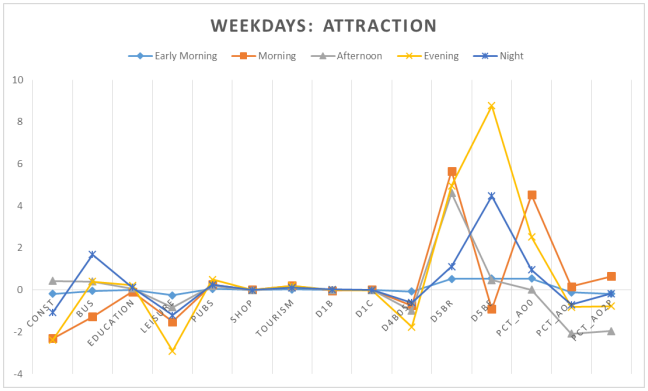

Figure 3: Co-efficients for Variables

0 or 1 car however become significant in the afternoon onwards with negative co-efficient, indicating their negative effect on bike demand. Also noteworthy is the significance of the effect Job density, which has a negative co-efficient.

3.3. Analysis for Weekday Attraction

Coefficients indicated in Fig.3

As with Prodiction scenarios, Tourism and Pubs continue to remain significant throughout. Afternoon onwards, Percentage Jobs accessible via transit becomes significant with negative co-efficients, thus representing the lack of attraction. During the evening hours, this effect gets more pronounced. Also during evening variables 'D5be' adn 'D1B' indicating Households accessible via transit and Residential density become significant with positive co-efficients, indicating the the evening commute attractions.

3.4. Analysis for Weekend Attraction

Coefficients indicated in Fig.4

Pubs continue to remain significant across the time-periods. During the morning commute period, D5br,ie: variable repesenting %age jobs accessible within 0.5 miles of guided transit becomes significant with positive co-efficient, indicating the morning commute pattern. The variable continues to remain significant, however with negative co-efficients, in lack of attraction at Workzone locations during the afternoon. During the later halves of the day, variables indicating access to Jobs and Working Population, 'D5br', 'D5be';

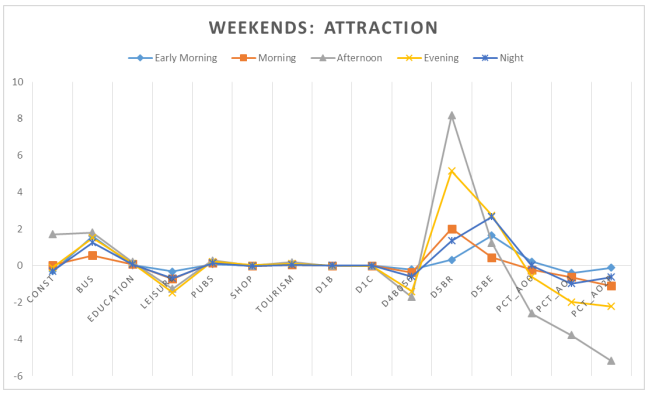

Figure 4: Co-efficients for Variables

become significant with positive co-efficient, indicating the evening commute pattern.

4. Conclusion

While the effects of Tourism and Restaurants were captured effectively into the model, generating accurate models using crowd sourced data continues to remain a challenging task. Particularly, the problem of effectively quantifying relative spatial properties needs to be addressed. The estimators currently generated do not model the effects of Biking conditions. ie: Weather, Street traffic. While incorporating weather is a simpler extension to the model, representing network conditions into these models remains an issue. Having mentioned this, we are able to observe the different factors affecting the Trip Generations effectively using the models thus generated. These results can be formulated as Trip Generation Rates for the system, and can be used as as heuristic measures in planning by themselves, or be integrated into other models.

5. References

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6. Appendix

6.1. Regression Results

Attraction: Weekend

For Time Period : 0

OLS Regression Results

Dep. Variable:	('bike_number', 0)	R-squared:	0.366
Model:	OLS	Adj. R-squared:	0.337
Method:	Least Squares	F-statistic:	12.54
Date:	Sat, 21 May 2016	Prob (F-statistic):	4.04e-23
Time:	17:34:44	Log-Likelihood:	-341.45
No. Observations:	319	AIC:	712.9
Df Residuals:	304	BIC:	769.4
Df Model:	14		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[95.0% Conf.	Int.]
const	-0.2956	0.315	-0.939	0.349	-0.915	0.324
bus	1.6187	1.544	1.049	0.295	-1.419	4.656
education	0.0371	0.034	1.100	0.272	-0.029	0.104
leisure	-0.3233	0.240	-1.347	0.179	-0.796	0.149
pubs	0.0743	0.022	3.449	0.001	0.032	0.117
shop	0.0023	0.017	0.136	0.892	-0.031	0.035
tourism	0.0290	0.031	0.948	0.344	-0.031	0.089
D1B	0.0065	0.002	3.006	0.003	0.002	0.011
D1C	-0.0023	0.001	-4.158	0.000	-0.003	-0.001
D4b050	-0.2134	0.135	-1.581	0.115	-0.479	0.052
D5br	0.3144	0.243	1.294	0.197	-0.164	0.792
D5be	1.6477	0.414	3.976	0.000	0.832	2.463
PCT_AO0	0.2240	0.301	0.743	0.458	-0.369	0.817
PCT_AO1	-0.4046	0.305	-1.324	0.186	-1.006	0.197
PCT_AO2P	-0.1144	0.399	-0.287	0.774	-0.899	0.670

Omnibus:	130.279	Durbin-Watson:	1.483
Prob(Omnibus):	0.000	Jarque-Bera (JB):	508.160
Skew:	1.759	Prob(JB):	4.51e-111
Kurtosis:	8.085	Cond. No.	5.22e+03

For Time Period : 1

OLS Regression Results

Dep. Variable:	('bike_number', 1)	R-squared:	0.294
Model:	OLS	Adj. R-squared:	0.262
Method:	Least Squares	F-statistic:	9.270
Date:	Sat, 21 May 2016	Prob (F-statistic):	4.41e-17
Time:	17:34:44	Log-Likelihood:	-625.91
No. Observations:	327	AIC:	1282.
Df Residuals:	312	BIC:	1339.
Df Model:	14		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[95.0% Conf. Int.]	
const	0.0402	0.726	0.055	0.956	-1.388	1.468
bus	0.5664	3.584	0.158	0.875	-6.486	7.619
education	0.0808	0.078	1.038	0.300	-0.072	0.234
leisure	-0.7111	0.557	-1.277	0.202	-1.806	0.384
pubs	0.1562	0.049	3.160	0.002	0.059	0.254
shop	-0.0203	0.038	-0.532	0.595	-0.095	0.055
tourism	0.0435	0.071	0.613	0.540	-0.096	0.183
D1B	-0.0039	0.005	-0.772	0.441	-0.014	0.006
D1C	-0.0032	0.001	-2.452	0.015	-0.006	-0.001
D4b050	-0.3708	0.311	-1.194	0.233	-0.982	0.240
D5br	2.0043	0.561	3.571	0.000	0.900	3.109
D5be	0.4424	0.962	0.460	0.646	-1.450	2.334
PCT_A00	-0.2281	0.698	-0.327	0.744	-1.602	1.146

PCT_AO1	-0.6267	0.705	-0.889	0.375	-2.014	0.761
PCT_AO2P	-1.0918	0.911	-1.198	0.232	-2.885	0.701

Omnibus:	357.654	Durbin-Watson:	1.887
Prob(Omnibus):	0.000	Jarque-Bera (JB):	20562.278
Skew:	4.646	Prob(JB):	0.00
Kurtosis:	40.720	Cond. No.	5.22e+03

For Time Period : 2

OLS Regression Results

Dep. Variable:	('bike_number', 2)	R-squared:	0.375
Model:	OLS	Adj. R-squared:	0.347
Method:	Least Squares	F-statistic:	13.36
Date:	Sat, 21 May 2016	Prob (F-statistic):	1.03e-24
Time:	17:34:44	Log-Likelihood:	-977.42
No. Observations:	327	AIC:	1985.
Df Residuals:	312	BIC:	2042.
Df Model:	14		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[95.0% Conf. Int.]	
const	1.7047	2.126	0.802	0.423	-2.479	5.889
bus	1.7974	10.502	0.171	0.864	-18.866	22.461
education	0.2115	0.228	0.927	0.354	-0.237	0.660
leisure	-1.2577	1.631	-0.771	0.441	-4.467	1.952
pubs	0.2936	0.145	2.027	0.044	0.009	0.579
shop	0.0075	0.112	0.067	0.946	-0.212	0.227
tourism	0.1985	0.208	0.955	0.341	-0.211	0.608
D1B	-0.0114	0.015	-0.780	0.436	-0.040	0.017
D1C	-0.0118	0.004	-3.105	0.002	-0.019	-0.004
D4b050	-1.7104	0.910	-1.880	0.061	-3.500	0.080

D5br	8.1815	1.644	4.976	0.000	4.946	11.417
D5be	1.2409	2.817	0.440	0.660	-4.302	6.784
PCT_AO0	-2.6005	2.046	-1.271	0.205	-6.627	1.426
PCT_AO1	-3.7790	2.066	-1.829	0.068	-7.844	0.286
PCT_AO2P	-5.1736	2.670	-1.938	0.054	-10.426	0.079

Omnibus:	212.063	Durbin-Watson:	1.871
Prob(Omnibus):	0.000	Jarque-Bera (JB):	2652.340
Skew:	2.493	Prob(JB):	0.00
Kurtosis:	16.031	Cond. No.	5.22e+03

For Time Period : 3

OLS Regression Results

Dep. Variable:	('bike_number', 3)	R-squared:	0.380
Model:	OLS	Adj. R-squared:	0.352
Method:	Least Squares	F-statistic:	13.64
Date:	Sat, 21 May 2016	Prob (F-statistic):	3.20e-25
Time:	17:34:44	Log-Likelihood:	-844.68
No. Observations:	327	AIC:	1719.
Df Residuals:	312	BIC:	1776.
Df Model:	14		
Covariance Type:	nonrobust		

coef	std err	t	P>|t|	[95.0% Conf. Int.]	
const	-0.0924	1.417	-0.065	0.948	-2.880	2.696
bus	1.5216	6.998	0.217	0.828	-12.248	15.291
education	0.1347	0.152	0.886	0.376	-0.164	0.434
leisure	-1.4690	1.087	-1.352	0.177	-3.607	0.669
pubs	0.2283	0.097	2.365	0.019	0.038	0.418
shop	0.0294	0.074	0.394	0.694	-0.117	0.176
tourism	0.1198	0.139	0.865	0.388	-0.153	0.392

D1B	0.0038	0.010	0.394	0.694	-0.015	0.023
D1C	-0.0086	0.003	-3.409	0.001	-0.014	-0.004
D4b050	-1.4048	0.606	-2.317	0.021	-2.598	-0.212
D5br	5.1524	1.096	4.703	0.000	2.997	7.308
D5be	2.7372	1.877	1.458	0.146	-0.957	6.431
PCT_AO0	-0.5894	1.364	-0.432	0.666	-3.273	2.094
PCT_AO1	-1.9690	1.377	-1.430	0.154	-4.678	0.740
PCT_AO2P	-2.2071	1.779	-1.241	0.216	-5.707	1.293

Omnibus:	166.285	Durbin-Watson:	1.698
Prob(Omnibus):	0.000	Jarque-Bera (JB):	1112.744
Skew:	2.027	Prob(JB):	2.35e-242
Kurtosis:	11.076	Cond. No.	5.22e+03

For Time Period : 4

OLS Regression Results

Dep. Variable:	('bike_number', 4)	R-squared:	0.355
Model:	OLS	Adj. R-squared:	0.325
Method:	Least Squares	F-statistic:	12.16
Date:	Sat, 21 May 2016	Prob (F-statistic):	1.58e-22
Time:	17:34:44	Log-Likelihood:	-583.90
No. Observations:	325	AIC:	1198.
Df Residuals:	310	BIC:	1255.
Df Model:	14		
Covariance Type:	nonrobust		

coef	std err	t	P>|t|	[95.0% Conf. Int.]	
const	-0.2914	0.647	-0.451	0.652	-1.564	0.981
bus	1.2551	3.188	0.394	0.694	-5.018	7.528
education	0.0850	0.069	1.227	0.221	-0.051	0.221
leisure	-0.6839	0.495	-1.381	0.168	-1.658	0.291

pubs	0.1453	0.044	3.298	0.001	0.059	0.232
shop	-0.0141	0.034	-0.415	0.678	-0.081	0.053
tourism	0.0415	0.063	0.657	0.511	-0.083	0.166
D1B	0.0102	0.004	2.289	0.023	0.001	0.019
D1C	-0.0043	0.001	-3.725	0.000	-0.007	-0.002
D4b050	-0.5955	0.277	-2.153	0.032	-1.140	-0.051
D5br	1.3577	0.500	2.718	0.007	0.375	2.341
D5be	2.6626	0.855	3.113	0.002	0.980	4.346
PCT_AO0	0.0200	0.622	0.032	0.974	-1.203	1.243
PCT_AO1	-0.9745	0.628	-1.553	0.122	-2.209	0.261
PCT_AO2P	-0.6196	0.815	-0.760	0.448	-2.223	0.984

Omnibus:	168.375	Durbin-Watson:	1.581
Prob(Omnibus):	0.000	Jarque-Bera (JB):	1038.437
Skew:	2.111	Prob(JB):	3.21e-226
Kurtosis:	10.671	Cond. No.	5.22e+03

Attraction: Weekday

For Time Period : 0

OLS Regression Results

Dep. Variable:	('bike_number', 0)	R-squared:	0.309
Model:	OLS	Adj. R-squared:	0.278
Method:	Least Squares	F-statistic:	9.763
Date:	Sat, 21 May 2016	Prob (F-statistic):	5.77e-18
Time:	17:08:27	Log-Likelihood:	-314.23
No. Observations:	320	AIC:	658.5
Df Residuals:	305	BIC:	715.0
Df Model:	14		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[95.0% Conf. Int.]	
const	-0.1796	0.288	-0.624	0.533	-0.746	0.387
bus	-0.0436	1.413	-0.031	0.975	-2.823	2.736
education	0.0058	0.031	0.188	0.851	-0.055	0.067
leisure	-0.2555	0.220	-1.163	0.246	-0.688	0.177
pubs	0.0541	0.020	2.742	0.006	0.015	0.093
shop	-0.0042	0.015	-0.276	0.783	-0.034	0.026
tourism	0.0299	0.028	1.069	0.286	-0.025	0.085
D1B	-0.0018	0.002	-0.931	0.353	-0.006	0.002
D1C	-0.0009	0.001	-1.767	0.078	-0.002	0.000
D4b050	-0.0766	0.123	-0.621	0.535	-0.320	0.166
D5br	0.5221	0.222	2.347	0.020	0.084	0.960
D5be	0.5430	0.379	1.432	0.153	-0.203	1.289
PCT_AO0	0.5366	0.276	1.945	0.053	-0.006	1.079
PCT_AO1	-0.1223	0.279	-0.438	0.662	-0.672	0.427
PCT_AO2P	-0.1841	0.363	-0.508	0.612	-0.898	0.529

Omnibus:	334.312	Durbin-Watson:	1.606
Prob(Omnibus):	0.000	Jarque-Bera (JB):	17600.694
Skew:	4.306	Prob(JB):	0.00
Kurtosis:	38.297	Cond. No.	5.22e+03

For Time Period : 1

OLS Regression Results

Dep. Variable:	('bike_number', 1)	R-squared:	0.465
Model:	OLS	Adj. R-squared:	0.441
Method:	Least Squares	F-statistic:	19.33
Date:	Sat, 21 May 2016	Prob (F-statistic):	1.28e-34
Time:	17:08:27	Log-Likelihood:	-929.19
No. Observations:	326	AIC:	1888.
Df Residuals:	311	BIC:	1945.

```
Df Model:                          14
Covariance Type:            nonrobust
==============================================================================
coef    std err          t      P>|t|      [95.0% Conf. Int.]
------------------------------------------------------------------------------
const         -2.3081      1.855     -1.244      0.214        -5.959     1.342
bus           -1.2696      9.142     -0.139      0.890       -19.257    16.718
education     -0.0846      0.199     -0.426      0.670        -0.475     0.306
leisure       -1.5068      1.421     -1.060      0.290        -4.302     1.289
pubs           0.2627      0.127      2.076      0.039         0.014     0.512
shop           0.0164      0.097      0.169      0.866        -0.175     0.208
tourism        0.2098      0.181      1.159      0.247        -0.146     0.566
D1B           -0.0360      0.013     -2.823      0.005        -0.061    -0.011
D1C            0.0071      0.003      2.139      0.033         0.001     0.014
D4b050        -0.7434      0.793     -0.937      0.349        -2.304     0.817
D5br           5.6585      1.433      3.948      0.000         2.839     8.478
D5be          -0.9108      2.453     -0.371      0.711        -5.737     3.915
PCT_AO0        4.5297      1.783      2.541      0.012         1.022     8.038
PCT_AO1        0.1660      1.799      0.092      0.927        -3.373     3.705
PCT_AO2P       0.6498      2.325      0.280      0.780        -3.924     5.224
==============================================================================
Omnibus:                      327.994   Durbin-Watson:                   1.464
Prob(Omnibus):                  0.000   Jarque-Bera (JB):            14836.097
Skew:                           4.122   Prob(JB):                         0.00
Kurtosis:                      35.004   Cond. No.                     5.22e+03
==============================================================================
```

```
For Time Period : 2
OLS Regression Results
==============================================================================
Dep. Variable:     ('bike_number', 2)   R-squared:                       0.461
Model:                            OLS   Adj. R-squared:                  0.437
Method:                 Least Squares   F-statistic:                     19.05
Date:                Sat, 21 May 2016   Prob (F-statistic):           3.17e-34
```

Time:	17:08:27	Log-Likelihood:	-799.10
No. Observations:	327	AIC:	1628.
Df Residuals:	312	BIC:	1685.
Df Model:	14		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[95.0% Conf. Int.]	
const	0.4300	1.233	0.349	0.727	-1.995	2.855
bus	0.4032	6.088	0.066	0.947	-11.575	12.381
education	0.0689	0.132	0.521	0.603	-0.191	0.329
leisure	-0.8215	0.945	-0.869	0.386	-2.682	1.039
pubs	0.1860	0.084	2.216	0.027	0.021	0.351
shop	-0.0132	0.065	-0.204	0.839	-0.141	0.114
tourism	0.1228	0.121	1.019	0.309	-0.114	0.360
D1B	-0.0108	0.008	-1.278	0.202	-0.028	0.006
D1C	0.0002	0.002	0.113	0.910	-0.004	0.005
D4b050	-0.9967	0.527	-1.890	0.060	-2.034	0.041
D5br	4.6122	0.953	4.839	0.000	2.737	6.488
D5be	0.4657	1.633	0.285	0.776	-2.748	3.679
PCT_AO0	0.0126	1.186	0.011	0.992	-2.321	2.347
PCT_AO1	-2.0760	1.198	-1.733	0.084	-4.433	0.280
PCT_AO2P	-1.9542	1.547	-1.263	0.208	-4.999	1.091

Omnibus:	231.804	Durbin-Watson:	1.576
Prob(Omnibus):	0.000	Jarque-Bera (JB):	3856.048
Skew:	2.705	Prob(JB):	0.00
Kurtosis:	18.929	Cond. No.	5.22e+03

For Time Period : 3

OLS Regression Results

Dep. Variable:	('bike_number', 3)	R-squared:	0.333

Model:	OLS	Adj. R-squared:	0.303
Method:	Least Squares	F-statistic:	11.13
Date:	Sat, 21 May 2016	Prob (F-statistic):	1.20e-20
Time:	17:08:27	Log-Likelihood:	-1006.2
No. Observations:	327	AIC:	2042.
Df Residuals:	312	BIC:	2099.
Df Model:	14		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[95.0% Conf. Int.]	
const	-2.3748	2.322	-1.023	0.307	-6.944	2.195
bus	0.4026	11.469	0.035	0.972	-22.164	22.969
education	0.2215	0.249	0.889	0.375	-0.269	0.712
leisure	-2.9082	1.781	-1.633	0.104	-6.413	0.597
pubs	0.4965	0.158	3.139	0.002	0.185	0.808
shop	-0.0017	0.122	-0.014	0.989	-0.242	0.238
tourism	0.1992	0.227	0.877	0.381	-0.248	0.646
D1B	0.0103	0.016	0.646	0.519	-0.021	0.042
D1C	-0.0136	0.004	-3.281	0.001	-0.022	-0.005
D4b050	-1.7588	0.994	-1.770	0.078	-3.714	0.196
D5br	4.9690	1.796	2.767	0.006	1.436	8.502
D5be	8.7653	3.077	2.849	0.005	2.712	14.819
PCT_AO0	2.5224	2.235	1.129	0.260	-1.875	6.920
PCT_AO1	-0.8075	2.256	-0.358	0.721	-5.247	3.632
PCT_AO2P	-0.7679	2.915	-0.263	0.792	-6.504	4.968

Omnibus:	242.931	Durbin-Watson:	1.504
Prob(Omnibus):	0.000	Jarque-Bera (JB):	4099.848
Skew:	2.894	Prob(JB):	0.00
Kurtosis:	19.352	Cond. No.	5.22e+03

For Time Period : 4

OLS Regression Results

Dep. Variable:	('bike_number', 4)	R-squared:	0.367
Model:	OLS	Adj. R-squared:	0.339
Method:	Least Squares	F-statistic:	12.93
Date:	Sat, 21 May 2016	Prob (F-statistic):	6.13e-24
Time:	17:08:27	Log-Likelihood:	-708.31
No. Observations:	327	AIC:	1447.
Df Residuals:	312	BIC:	1503.
Df Model:	14		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[95.0% Conf. Int.]	
const	-1.0586	0.934	-1.134	0.258	-2.896	0.779
bus	1.6777	4.612	0.364	0.716	-7.396	10.752
education	0.1258	0.100	1.256	0.210	-0.071	0.323
leisure	-1.2044	0.716	-1.682	0.094	-2.614	0.205
pubs	0.2408	0.064	3.786	0.000	0.116	0.366
shop	-0.0107	0.049	-0.218	0.828	-0.107	0.086
tourism	0.1122	0.091	1.229	0.220	-0.067	0.292
D1B	0.0171	0.006	2.669	0.008	0.004	0.030
D1C	-0.0070	0.002	-4.226	0.000	-0.010	-0.004
D4b050	-0.6074	0.399	-1.520	0.129	-1.393	0.179
D5br	1.1103	0.722	1.538	0.125	-0.310	2.531
D5be	4.4712	1.237	3.614	0.000	2.037	6.905
PCT_AO0	0.9623	0.899	1.071	0.285	-0.806	2.731
PCT_AO1	-0.7006	0.907	-0.772	0.441	-2.486	1.085
PCT_AO2P	-0.1678	1.172	-0.143	0.886	-2.474	2.139

Omnibus:	145.825	Durbin-Watson:	1.477
Prob(Omnibus):	0.000	Jarque-Bera (JB):	741.986
Skew:	1.832	Prob(JB):	7.58e-162
Kurtosis:	9.406	Cond. No.	5.22e+03

Production: Weekend

For Time Period : 0

OLS Regression Results

Dep. Variable:	('bike_number', 0)	R-squared:	0.286
Model:	OLS	Adj. R-squared:	0.253
Method:	Least Squares	F-statistic:	8.701
Date:	Sat, 21 May 2016	Prob (F-statistic):	6.76e-16
Time:	16:48:17	Log-Likelihood:	-558.82
No. Observations:	319	AIC:	1148.
Df Residuals:	304	BIC:	1204.
Df Model:	14		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[95.0% Conf.	Int.]
const	-0.5496	0.625	-0.879	0.380	-1.780	0.681
bus	-2.3874	3.052	-0.782	0.435	-8.393	3.618
education	0.0946	0.066	1.425	0.155	-0.036	0.225
leisure	-0.8051	0.498	-1.616	0.107	-1.786	0.176
pubs	0.1643	0.043	3.853	0.000	0.080	0.248
shop	-0.0194	0.033	-0.590	0.556	-0.084	0.045
tourism	0.0531	0.061	0.877	0.381	-0.066	0.172
D1B	0.0081	0.004	1.900	0.058	-0.000	0.017
D1C	-0.0029	0.001	-2.642	0.009	-0.005	-0.001
D4b050	-0.3527	0.266	-1.324	0.186	-0.877	0.171
D5br	0.0358	0.484	0.074	0.941	-0.916	0.987
D5be	3.6841	0.821	4.490	0.000	2.069	5.299
PCT_AO0	-0.1522	0.598	-0.254	0.799	-1.330	1.025
PCT_AO1	-0.4484	0.605	-0.742	0.459	-1.638	0.741
PCT_AO2P	-0.3219	0.791	-0.407	0.684	-1.877	1.234

Omnibus:	284.596	Durbin-Watson:	1.586
Prob(Omnibus):	0.000	Jarque-Bera (JB):	6364.005
Skew:	3.673	Prob(JB):	0.00
Kurtosis:	23.611	Cond. No.	5.22e+03

For Time Period : 1

OLS Regression Results

Dep. Variable:	('bike_number', 1)	R-squared:	0.384
Model:	OLS	Adj. R-squared:	0.356
Method:	Least Squares	F-statistic:	13.90
Date:	Sat, 21 May 2016	Prob (F-statistic):	1.14e-25
Time:	16:48:17	Log-Likelihood:	-702.18
No. Observations:	327	AIC:	1434.
Df Residuals:	312	BIC:	1491.
Df Model:	14		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[95.0% Conf. Int.]	
const	0.0286	0.916	0.031	0.975	-1.775	1.832
bus	2.2788	4.526	0.504	0.615	-6.626	11.184
education	0.1570	0.098	1.598	0.111	-0.036	0.350
leisure	-0.9323	0.703	-1.326	0.186	-2.315	0.451
pubs	0.2207	0.062	3.535	0.000	0.098	0.343
shop	-0.0102	0.048	-0.212	0.832	-0.105	0.084
tourism	0.2213	0.090	2.470	0.014	0.045	0.398
D1B	0.0203	0.006	3.223	0.001	0.008	0.033
D1C	-0.0066	0.002	-4.043	0.000	-0.010	-0.003
D4b050	-0.2967	0.392	-0.757	0.450	-1.068	0.475
D5br	0.9076	0.709	1.281	0.201	-0.487	2.302
D5be	3.5511	1.214	2.925	0.004	1.162	5.940

```
PCT_AO0       -0.3294      0.882     -0.374      0.709        -2.065     1.406
PCT_AO1       -1.6948      0.890     -1.903      0.058        -3.447     0.057
PCT_AO2P      -1.1716      1.150     -1.018      0.309        -3.435     1.092
==============================================================================
Omnibus:                      109.149   Durbin-Watson:                   1.460
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              325.512
Skew:                           1.520   Prob(JB):                     2.07e-71
Kurtosis:                       6.827   Cond. No.                     5.22e+03
==============================================================================
```

```
For Time Period : 2
OLS Regression Results
==============================================================================
Dep. Variable:     ('bike_number', 2)   R-squared:                       0.374
Model:                            OLS   Adj. R-squared:                  0.346
Method:                 Least Squares   F-statistic:                     13.32
Date:                Sat, 21 May 2016   Prob (F-statistic):           1.21e-24
Time:                        16:48:17   Log-Likelihood:                -1081.2
No. Observations:                 327   AIC:                             2192.
Df Residuals:                     312   BIC:                             2249.
Df Model:                          14
Covariance Type:            nonrobust
==============================================================================
coef    std err          t      P>|t|      [95.0% Conf. Int.]
------------------------------------------------------------------------------
const          3.5157      2.920      1.204      0.230        -2.230     9.262
bus            5.5000     14.422      0.381      0.703       -22.877    33.877
education      0.4531      0.313      1.447      0.149        -0.163     1.069
leisure       -2.1087      2.240     -0.941      0.347        -6.516     2.299
pubs           0.5501      0.199      2.765      0.006         0.159     0.941
shop          -0.0477      0.153     -0.311      0.756        -0.349     0.254
tourism        0.4185      0.286      1.466      0.144        -0.143     0.980
D1B            0.0106      0.020      0.529      0.597        -0.029     0.050
D1C           -0.0185      0.005     -3.561      0.000        -0.029    -0.008
```

D4b050	-1.6280	1.249	-1.303	0.194	-4.086	0.830
D5br	8.1693	2.258	3.618	0.000	3.726	12.612
D5be	5.7426	3.869	1.484	0.139	-1.870	13.355
PCT_AO0	-4.9980	2.810	-1.778	0.076	-10.528	0.532
PCT_AO1	-7.0981	2.837	-2.502	0.013	-12.681	-1.515
PCT_AO2P	-8.1053	3.666	-2.211	0.028	-15.319	-0.892

Omnibus:	183.647	Durbin-Watson:	1.777
Prob(Omnibus):	0.000	Jarque-Bera (JB):	1524.897
Skew:	2.207	Prob(JB):	0.00
Kurtosis:	12.614	Cond. No.	5.22e+03

For Time Period : 3

OLS Regression Results

Dep. Variable:	('bike_number', 3)	R-squared:	0.422
Model:	OLS	Adj. R-squared:	0.396
Method:	Least Squares	F-statistic:	16.26
Date:	Sat, 21 May 2016	Prob (F-statistic):	1.03e-29
Time:	16:48:17	Log-Likelihood:	-945.23
No. Observations:	327	AIC:	1920.
Df Residuals:	312	BIC:	1977.
Df Model:	14		
Covariance Type:	nonrobust		

coef	std err	t	P>|t|	[95.0% Conf. Int.]	
const	1.8498	1.927	0.960	0.338	-1.942	5.642
bus	2.4167	9.517	0.254	0.800	-16.309	21.143
education	0.2279	0.207	1.102	0.271	-0.179	0.635
leisure	-0.9741	1.478	-0.659	0.510	-3.882	1.934
pubs	0.2460	0.131	1.874	0.062	-0.012	0.504
shop	0.0473	0.101	0.468	0.640	-0.152	0.246

tourism	0.3234	0.188	1.716	0.087	-0.047	0.694
D1B	0.0007	0.013	0.056	0.955	-0.025	0.027
D1C	-0.0113	0.003	-3.297	0.001	-0.018	-0.005
D4b050	-1.5866	0.824	-1.924	0.055	-3.209	0.036
D5br	7.1922	1.490	4.827	0.000	4.260	10.124
D5be	3.0895	2.553	1.210	0.227	-1.934	8.113
PCT_AO0	-3.2077	1.855	-1.730	0.085	-6.857	0.441
PCT_AO1	-4.7064	1.872	-2.514	0.012	-8.391	-1.022
PCT_AO2P	-5.0497	2.419	-2.087	0.038	-9.810	-0.290

Omnibus:	140.938	Durbin-Watson:	1.771
Prob(Omnibus):	0.000	Jarque-Bera (JB):	778.469
Skew:	1.723	Prob(JB):	9.07e-170
Kurtosis:	9.728	Cond. No.	5.22e+03

For Time Period : 4

OLS Regression Results

Dep. Variable:	('bike_number', 4)	R-squared:	0.361
Model:	OLS	Adj. R-squared:	0.333
Method:	Least Squares	F-statistic:	12.53
Date:	Sat, 21 May 2016	Prob (F-statistic):	3.43e-23
Time:	16:48:17	Log-Likelihood:	-699.39
No. Observations:	325	AIC:	1429.
Df Residuals:	310	BIC:	1486.
Df Model:	14		
Covariance Type:	nonrobust		

coef	std err	t	P>|t|	[95.0% Conf. Int.]	
const	-0.5085	0.921	-0.552	0.581	-2.322	1.305
bus	0.5691	4.548	0.125	0.901	-8.381	9.519
education	0.1270	0.099	1.283	0.200	-0.068	0.322

leisure	-0.9589	0.742	-1.293	0.197	-2.418	0.501
pubs	0.1560	0.063	2.484	0.014	0.032	0.280
shop	0.0212	0.049	0.438	0.662	-0.074	0.117
tourism	0.1508	0.090	1.674	0.095	-0.026	0.328
D1B	0.0076	0.006	1.202	0.230	-0.005	0.020
D1C	-0.0049	0.002	-2.965	0.003	-0.008	-0.002
D4b050	-0.6951	0.394	-1.764	0.079	-1.471	0.080
D5br	2.1047	0.713	2.952	0.003	0.702	3.507
D5be	3.6565	1.222	2.992	0.003	1.252	6.061
PCT_AO0	-0.3877	0.887	-0.437	0.662	-2.132	1.357
PCT_AO1	-1.3787	0.899	-1.534	0.126	-3.147	0.390
PCT_AO2P	-0.9708	1.166	-0.832	0.406	-3.266	1.324

Omnibus:	194.766	Durbin-Watson:	1.683
Prob(Omnibus):	0.000	Jarque-Bera (JB):	1604.230
Skew:	2.410	Prob(JB):	0.00
Kurtosis:	12.758	Cond. No.	5.22e+03

Origin: Weekday

For Time Period : 0

OLS Regression Results

Dep. Variable:	('bike_number', 0)	R-squared:	0.281
Model:	OLS	Adj. R-squared:	0.248
Method:	Least Squares	F-statistic:	8.579
Date:	Sat, 21 May 2016	Prob (F-statistic):	1.09e-15
Time:	15:16:37	Log-Likelihood:	-424.21
No. Observations:	323	AIC:	878.4

Df Residuals:	308	BIC:	935.1
Df Model:	14		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[95.0% Conf.	Int.]
const	-0.3899	0.401	-0.973	0.331	-1.178	0.398
bus	-0.5191	1.966	-0.264	0.792	-4.388	3.350
education	0.0622	0.043	1.455	0.147	-0.022	0.146
leisure	-0.2678	0.306	-0.875	0.382	-0.870	0.334
pubs	0.0762	0.027	2.789	0.006	0.022	0.130
shop	-0.0070	0.021	-0.335	0.738	-0.048	0.034
tourism	0.0695	0.039	1.784	0.075	-0.007	0.146
D1B	0.0060	0.003	2.172	0.031	0.001	0.011
D1C	-0.0023	0.001	-3.186	0.002	-0.004	-0.001
D4b050	-0.1136	0.171	-0.664	0.507	-0.450	0.223
D5br	0.0674	0.309	0.218	0.828	-0.541	0.675
D5be	1.9359	0.528	3.669	0.000	0.898	2.974
PCT_AO0	0.3482	0.384	0.907	0.365	-0.407	1.104
PCT_AO1	-0.1545	0.388	-0.399	0.690	-0.917	0.608
PCT_AO2P	-0.0688	0.502	-0.137	0.891	-1.056	0.919

Omnibus:	361.755	Durbin-Watson:	1.536
Prob(Omnibus):	0.000	Jarque-Bera (JB):	27321.823
Skew:	4.697	Prob(JB):	0.00
Kurtosis:	47.066	Cond. No.	5.22e+03

For Time Period : 1

OLS Regression Results

Dep. Variable:	('bike_number', 1)	R-squared:	0.305
Model:	OLS	Adj. R-squared:	0.274
Method:	Least Squares	F-statistic:	9.801

Date:	Sat, 21 May 2016	Prob (F-statistic):	4.11e-18
Time:	15:16:37	Log-Likelihood:	-965.74
No. Observations:	327	AIC:	1961.
Df Residuals:	312	BIC:	2018.
Df Model:	14		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[95.0% Conf. Int.]	
const	-2.4319	2.052	-1.185	0.237	-6.469	1.605
bus	4.3090	10.133	0.425	0.671	-15.630	24.247
education	0.2478	0.220	1.126	0.261	-0.185	0.681
leisure	-2.3898	1.574	-1.518	0.130	-5.486	0.707
pubs	0.4699	0.140	3.362	0.001	0.195	0.745
shop	0.0240	0.108	0.223	0.824	-0.188	0.236
tourism	0.3049	0.201	1.520	0.130	-0.090	0.700
D1B	0.0156	0.014	1.108	0.269	-0.012	0.043
D1C	-0.0131	0.004	-3.576	0.000	-0.020	-0.006
D4b050	-0.4974	0.878	-0.567	0.571	-2.225	1.230
D5br	1.1585	1.587	0.730	0.466	-1.963	4.280
D5be	9.5694	2.718	3.520	0.000	4.221	14.918
PCT_AO0	2.6053	1.975	1.319	0.188	-1.280	6.491
PCT_AO1	-0.2627	1.994	-0.132	0.895	-4.185	3.660
PCT_AO2P	0.2805	2.576	0.109	0.913	-4.788	5.349

Omnibus:	319.268	Durbin-Watson:	1.551
Prob(Omnibus):	0.000	Jarque-Bera (JB):	14191.940
Skew:	3.926	Prob(JB):	0.00
Kurtosis:	34.304	Cond. No.	5.22e+03

For Time Period : 2

OLS Regression Results

Dep. Variable:	('bike_number', 2)	R-squared:	0.496
Model:	OLS	Adj. R-squared:	0.474
Method:	Least Squares	F-statistic:	21.95
Date:	Sat, 21 May 2016	Prob (F-statistic):	1.26e-38
Time:	15:16:37	Log-Likelihood:	-825.68
No. Observations:	327	AIC:	1681.
Df Residuals:	312	BIC:	1738.
Df Model:	14		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[95.0% Conf. Int.]	
const	1.4130	1.337	1.057	0.291	-1.218	4.044
bus	0.3916	6.603	0.059	0.953	-12.600	13.384
education	0.1237	0.143	0.863	0.389	-0.158	0.406
leisure	-0.7009	1.025	-0.683	0.495	-2.719	1.317
pubs	0.2511	0.091	2.757	0.006	0.072	0.430
shop	-0.0426	0.070	-0.606	0.545	-0.181	0.096
tourism	0.2463	0.131	1.884	0.060	-0.011	0.504
D1B	-0.0087	0.009	-0.949	0.343	-0.027	0.009
D1C	0.0003	0.002	0.138	0.890	-0.004	0.005
D4b050	-0.9029	0.572	-1.578	0.115	-2.028	0.223
D5br	4.3036	1.034	4.163	0.000	2.270	6.338
D5be	1.3519	1.771	0.763	0.446	-2.133	4.837
PCT_AO0	-0.7207	1.287	-0.560	0.576	-3.252	1.811
PCT_AO1	-3.3157	1.299	-2.552	0.011	-5.872	-0.760
PCT_AO2P	-3.1588	1.678	-1.882	0.061	-6.461	0.144

Omnibus:	175.517	Durbin-Watson:	1.531
Prob(Omnibus):	0.000	Jarque-Bera (JB):	1675.501
Skew:	2.021	Prob(JB):	0.00
Kurtosis:	13.326	Cond. No.	5.22e+03

For Time Period : 3

OLS Regression Results

Dep. Variable:	('bike_number', 3)	R-squared:	0.465
Model:	OLS	Adj. R-squared:	0.441
Method:	Least Squares	F-statistic:	19.39
Date:	Sat, 21 May 2016	Prob (F-statistic):	9.36e-35
Time:	15:16:37	Log-Likelihood:	-1039.0
No. Observations:	327	AIC:	2108.
Df Residuals:	312	BIC:	2165.
Df Model:	14		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[95.0% Conf. Int.]	
const	-2.1002	2.567	-0.818	0.414	-7.151	2.951
bus	-0.4375	12.677	-0.035	0.972	-25.382	24.507
education	0.1375	0.275	0.500	0.618	-0.404	0.679
leisure	-1.9333	1.969	-0.982	0.327	-5.807	1.941
pubs	0.4903	0.175	2.804	0.005	0.146	0.834
shop	-0.0403	0.135	-0.299	0.765	-0.306	0.225
tourism	0.4455	0.251	1.775	0.077	-0.048	0.939
D1B	-0.0179	0.018	-1.015	0.311	-0.053	0.017
D1C	0.0031	0.005	0.679	0.497	-0.006	0.012
D4b050	-1.0587	1.098	-0.964	0.336	-3.220	1.102
D5br	7.3950	1.985	3.726	0.000	3.490	11.300
D5be	2.5858	3.401	0.760	0.448	-4.106	9.277
PCT_AO0	3.5152	2.470	1.423	0.156	-1.346	8.376
PCT_AO1	-1.9300	2.494	-0.774	0.440	-6.837	2.977
PCT_AO2P	-0.9946	3.223	-0.309	0.758	-7.335	5.346

Omnibus:	291.970	Durbin-Watson:	1.432
Prob(Omnibus):	0.000	Jarque-Bera (JB):	9643.446
Skew:	3.509	Prob(JB):	0.00
Kurtosis:	28.662	Cond. No.	5.22e+03

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For Time Period : 4

OLS Regression Results

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Dep. Variable:	('bike_number', 4)	R-squared:	0.371
Model:	OLS	Adj. R-squared:	0.343
Method:	Least Squares	F-statistic:	13.16
Date:	Sat, 21 May 2016	Prob (F-statistic):	2.36e-24
Time:	15:16:37	Log-Likelihood:	-757.94
No. Observations:	327	AIC:	1546.
Df Residuals:	312	BIC:	1603.
Df Model:	14		
Covariance Type:	nonrobust		

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	coef	std err	t	P>|t|	[95.0% Conf.	Int.]
const	-1.5290	1.087	-1.407	0.160	-3.667	0.609
bus	-0.9601	5.367	-0.179	0.858	-11.521	9.601
education	0.1450	0.117	1.244	0.214	-0.084	0.374
leisure	-1.3169	0.834	-1.580	0.115	-2.957	0.323
pubs	0.2814	0.074	3.801	0.000	0.136	0.427
shop	-0.0224	0.057	-0.392	0.695	-0.135	0.090
tourism	0.1558	0.106	1.467	0.144	-0.053	0.365
D1B	0.0078	0.007	1.040	0.299	-0.007	0.022
D1C	-0.0035	0.002	-1.796	0.073	-0.007	0.000
D4b050	-0.6280	0.465	-1.351	0.178	-1.543	0.287
D5br	2.0298	0.840	2.415	0.016	0.376	3.683
D5be	3.5588	1.440	2.472	0.014	0.726	6.392
PCT_AO0	1.0514	1.046	1.005	0.316	-1.007	3.109
PCT_AO1	-0.6775	1.056	-0.642	0.522	-2.755	1.400
PCT_AO2P	0.0619	1.364	0.045	0.964	-2.623	2.747

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Omnibus:	259.282	Durbin-Watson:	1.611

Prob(Omnibus):	0.000	Jarque-Bera (JB):	4933.441
Skew:	3.138	Prob(JB):	0.00
Kurtosis:	20.964	Cond. No.	5.22e+03