
DNSC 6219 Group Project

Bike Sharing -- Washington DC

Team Member: Kewei Chen, Peijia Wu, Vi Pham, Yixuan Yang



Contents

- Data Introduction & Cleaning
- Overview of series
- Univariate Time Series Models
- Multivariate Time Series Models
- Conclusion



Data Introduction & Cleaning

- Website: Kaggle
- Data size: 409 KB
- 2922 rows, 29 columns
- 2011-01-01 to 2018-12-31
- 365 hold-out samples

Source															
	date	temp_avg	temp_min	temp_max	temp_observ	precip	wind	wt_fog	wt_heavy_fog	wt_thunder	wt_sleet	wt_hail	wt_glaze	wt_haze	wt_drifts
1	2011-01-01	-1.566666667	11.973333333	27.727272727	0.069333333	2.575	1	*	*	*	*	*	*	*	*
2	2011-01-02	*	0.88	13.806666667	7.3272727273	3.925	1	1	*	*	*	*	*	*	*
3	2011-01-03	-3.442857143	7.4642857143	*	-3.06	1.8788235294	3.625	*	*	*	*	*	*	*	*
4	2011-01-04	-5.957142857	4.6428571429	*	-3.1	0	1.8	*	*	*	*	*	*	*	*
5	2011-01-05	-4.293333333	6.1133333333	-1.772727273	0	2.95	*	*	*	*	*	*	*	*	*
6	2011-01-06	-4.993333333	4.2333333333	-4.245454545	0	0	1.6	*	*	*	*	*	*	*	*
7	2011-01-07	-3.885714288	2.8571428571	*	-1.57	0.1012048193	2.55	1	*	*	*	*	*	*	1
8	2011-01-08	*	-3.98	0.4866666667	-2.472727273	2.8650574713	4.575	1	1	*	*	*	*	*	1
9	2011-01-09	-6.293333333	0.2266666667	-6.072727273	0.2835294118	6.425	*	*	*	*	*	*	*	*	*
10	2011-01-10	-6.28461538	0.5076923077	-5.177777778	0	2.975	*	*	*	*	*	*	*	*	*
11	2011-01-11	-5.914285714	0.5642857143	*	-3.1	0.4602409639	1.35	1	*	*	*	1	*	*	1
12	2011-01-12	-5.114285714	0.1928571429	*	-3.38	3.5268817204	5.675	1	*	*	*	*	*	1	1
13	2011-01-13	*	-4.6	1.0357142857	-4.16	0	5.025	*	*	*	*	*	*	*	*
14	2011-01-14	-7.342857143	1.1615384615	*	-5.83	0.0037974684	2.125	1	*	*	*	*	*	*	*
15	2011-01-15	*	-5.66	2.78	-3.945454545	0	2.2	1	*	*	*	*	*	*	1
16	2011-01-16	*	-4.08	5.6266666667	0.4090909091	0	3.3	*	*	*	*	*	*	*	*
17	2011-01-17	-3.371428571	2.1857142857	*	-2.12	0.4205128205	3.1	1	*	*	1	*	*	*	*
18	2011-01-18	-3.242857143	0.4857142857	*	-1.77	10.541573034	3.25	1	1	*	1	*	1	1	
19	2011-01-19	-1.061538462	4.8	1.122222222	0.8845238095	3.275	1	1	*	*	*	*	*	*	1
20	2011-01-20	-1.107142857	8.0642857143	-0.44	0.0402597403	3.275	*	*	*	*	*	*	*	*	1
21	2011-01-21	-3.413333333	4.5285714286	-1.472727273	0.8318181818	6.125	1	*	*	*	*	*	*	*	*
22	2011-01-22	-10.21333333	-0.513333333	-9.590909091	0	2.375	*	*	*	*	*	*	*	*	*
23	2011-01-23	*	-11	-3.1	-8.072727273	0	3.625	*	*	*	*	*	*	*	*
24	2011-01-24	-12.546666667	-1.7	-11.87272727	0	2.55	*	*	*	*	*	*	*	*	*
25	2011-01-25	-9.4066666667	1.3666666667	-2.081818182	0	1.575	*	*	*	*	*	*	*	*	*
26	2011-01-26	-1.785714286	5.4857142857	0.5	9.01625	5.075	1	1	1	1	1	*	*	*	1
27	2011-01-27	*	-1.78	1.7066666667	-1.318181818	29.529113924	3.2	1	*	1	1	*	*	*	1
28	2011-01-28	-2.806666667	1.86	-1.863636364	0.1341772152	1.675	1	*	*	*	*	*	*	*	1
29	2011-01-29	-5.235714286	1.7857142857	-4.22	1.44	1.875	1	*	*	*	*	*	*	*	1
30	2011-01-30	-6.342857143	3.6642857143	-4.6	0	1.2	1	*	*	*	*	*	*	*	1
31	2011-01-31	-4.907142857	4.1857142857	-2.94	0	2.675	*	*	*	1	*	*	*	*	*
32	2011-02-01	-3.0866666667	0.0733333333	-3.081818182	0.4974688354	1.2	1	1	*	*	*	*	*	1	1
33	2011-02-02	-1.673333333	4.8533333333	0.7181818182	19.680681818	4.65	1	1	*	*	*	*	*	1	*
34	2011-02-03	*	-3.48	6.34	-2.472727273	0.3848101266	4.2	1	*	*	*	*	*	*	*
35	2011-02-04	*	-5.22	3.12	-3.281818182	0	1.875	*	*	*	*	*	*	*	*
36	2011-02-05	*	-2.3	4.6933333333	0.9727272727	1.9923076923	2.4	1	1	*	*	*	*	*	*
37	2011-02-06	-0.133333333	6.26	1.9272727273	2.756	2.725	1	*	*	*	*	*	*	*	1
38	2011-02-07	*	-3.02	8.1466666667	-1.72	0	0.975	1	*	*	*	*	*	*	*
39	2011-02-08	*	2.512222222	7.2366666667	1.2000000001	0.2004117247	6.555	1	*	*	*	*	*	*	*

newsharedbike... ▾

Source ▾

Columns (15/0)

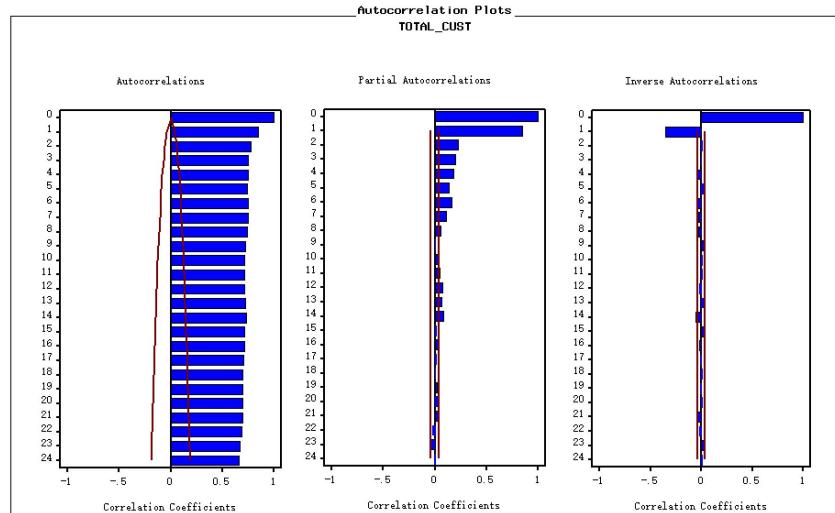
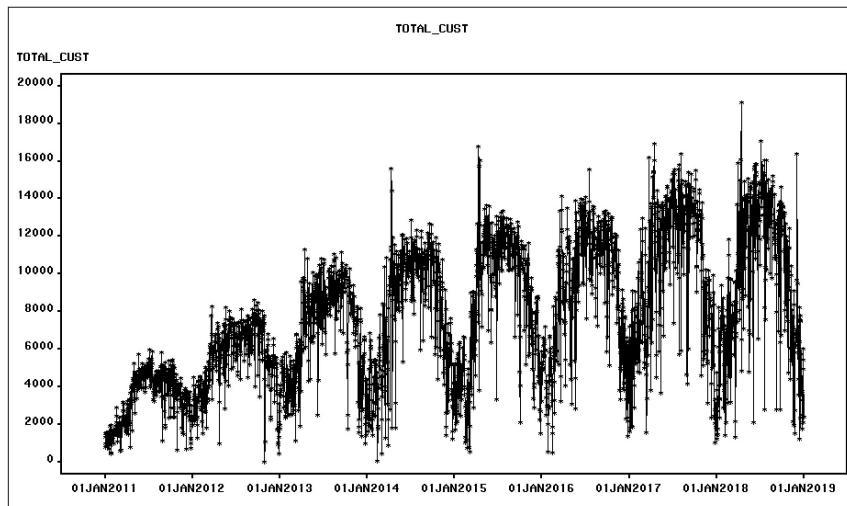
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- temp_max
- temp_observ
- precip
- wind
- wt_fog
- wt_thunder
- wt_rain
- wt_snow
- casual
- registered
- total_cust
- holiday
- week
- month

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35	-5.22	3.12
36	-2.3	4.69333333
37	-0.13333333	6.26
38	-3.02	8.146666667

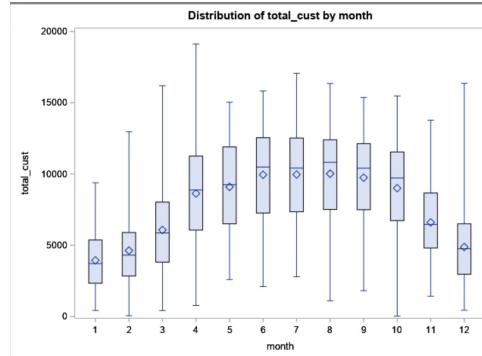
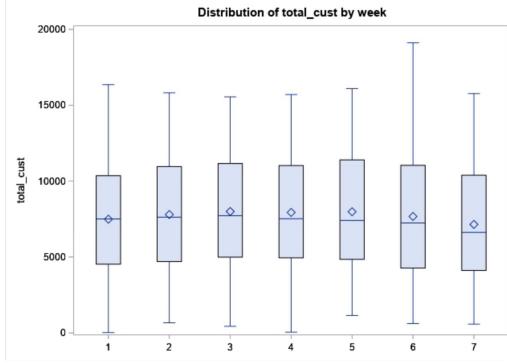
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1	-1.566666667	11.97333333	2.772727273	0.069333333	2.575	1	0	1	0	330	629	959	0	6	1	
2	0.88	13.80666667	7.327272727	1.037349398	3.925	1	0	1	0	130	651	781	0	7	1	
3	-3.442857143	7.464285714	-3.06	1.878823529	3.625	0	0	0	0	120	1181	1301	0	1	1	
4	-5.957142857	4.642857143	-3.1	0	1.8	0	0	0	0	107	1429	1536	0	2	1	
5	-4.293333333	6.113333333	-1.772727273	0	2.95	0	0	0	0	82	1489	1571	0	3	1	
6	-4.993333333	4.233333333	-4.245454545	0	1.6	0	0	0	0	1	88	1485	1573	0	4	1
7	-3.885714286	2.857142857	-1.57	0.101204819	2.55	1	0	0	1	148	1345	1493	0	5	1	
8	-3.98	0.486666667	-2.472727273	0.285054741	4.575	1	0	0	1	68	871	939	0	6	1	
9	-6.293333333	0.226666667	-6.072727273	0.283529412	6.425	0	0	0	0	54	748	802	0	7	1	
10	-6.238461538	0.507692308	-5.177777778	0	2.975	0	0	0	0	41	1257	1298	0	1	1	
11	-5.914285714	0.564285714	-3.1	0.460240964	1.35	1	0	1	1	43	1188	1231	0	2	1	
12	-5.114285714	0.192857143	-3.38	3.52688172	5.675	1	0	0	0	25	1116	1141	0	3	1	
13	-4.6	1.035714286	-4.16	0	5.025	0	0	0	0	37	1346	1383	0	4	1	
14	-7.342857143	1.161538462	-5.83	0.003797468	2.125	1	0	0	1	54	1330	1384	0	5	1	
15	-5.66	2.78	-3.945454545	0	2.2	1	0	0	0	222	1018	1240	0	6	1	
16	-5.408	5.626666667	0.409090909	0	3.3	0	0	0	0	251	937	1188	0	7	1	
17	-3.371428571	2.185714286	-2.12	0.420512821	3.1	1	0	1	1	117	876	993	1	1	1	
18	-3.242857143	0.485714286	-1.77	10.54157303	3.25	1	0	1	0	9	663	672	0	2	1	
19	-1.061538462	4.8	1.122222222	0.88452381	3.275	1	0	1	0	78	1553	1631	0	3	1	
20	-1.107142857	8.064285714	-0.44	0.04025974	3.275	0	0	1	1	81	1815	1896	0	4	1	
21	-3.413333333	4.528571429	-1.472727273	0.831818182	6.125	1	0	1	1	73	1449	1522	0	5	1	
22	-10.213333333	-0.513333333	-9.590909091	0	2.375	0	0	0	0	93	876	969	0	6	1	
23	-11	-3.1	-8.072727273	0	3.625	0	0	0	1	150	827	977	0	7	1	
24	-12.546666667	-1.7	-11.87272727	0	2.55	0	0	0	0	86	1319	1405	0	1	1	
25	-9.406666667	1.366666667	-2.081818182	0	1.575	0	0	0	0	186	1785	1971	0	2	1	
26	-1.785714286	5.485714286	0.5	9.01625	5.075	1	1	0	1	34	466	500	0	3	1	
27	-1.78	1.706666667	-1.318181818	29.52911392	3.2	1	1	0	1	15	409	424	0	4	1	
28	-2.806666667	1.86	-1.863636364	0.134177215	1.675	1	0	0	1	38	1113	1151	0	5	1	
29	-5.235714286	1.785714286	-4.22	1.44	1.875	1	0	0	1	123	947	1070	0	6	1	
30	-6.342857143	3.664285714	-4.6	0	1.2	1	0	0	0	140	944	1084	0	7	1	
31	-4.907142857	4.185714286	-2.94	0	2.675	0	0	1	1	42	1376	1418	0	1	1	
32	-3.086666667	0.073333333	-3.081818182	0.497468354	1.2	1	0	1	0	47	1284	1331	0	2	2	
33	-1.673333333	4.853333333	0.718181818	18.68068182	4.65	1	0	1	0	72	1430	1502	0	3	2	
34	-3.48	6.34	-2.472727273	0.384810127	4.2	1	0	0	0	61	1473	1534	0	4	2	
35	-5.22	3.12	-3.981818182	0	1.875	0	0	0	0	88	1603	1691	0	5	2	
36	-2.3	4.693333333	0.972727273	1.992307692	2.4	1	0	1	0	100	892	992	0	6	2	
37	-0.133333333	6.26	1.927272727	2.756	2.725	1	0	0	0	354	1249	1603	0	7	2	
38	-3.02	8.146666667	-1.72	0	0.975	1	0	1	0	119	1568	1687	0	1	2	

Overview of the series

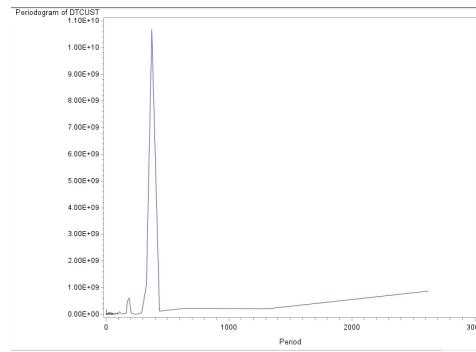




Boxplot



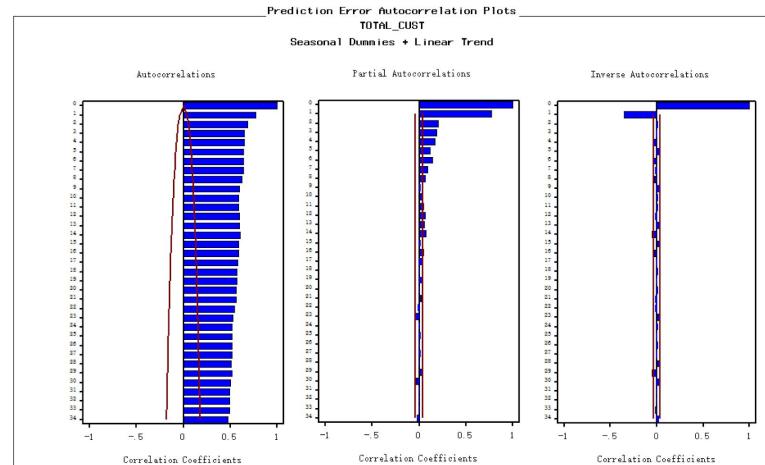
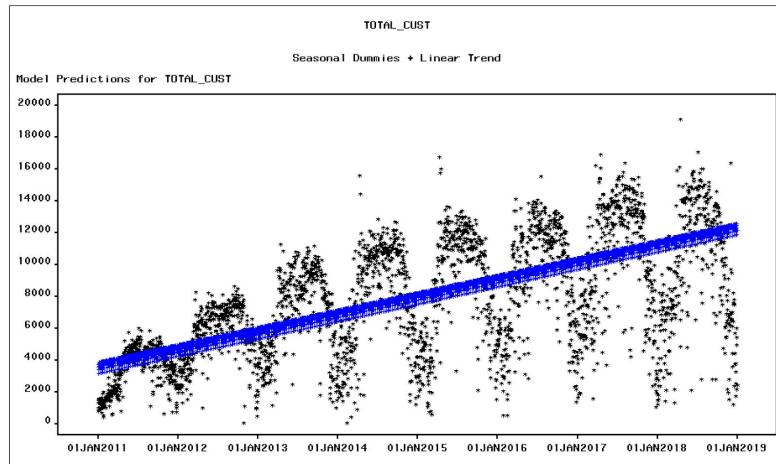
Periodogram



Obs	FREQ	PERIOD	P_01	i
8	0.01677	374.57	10671409977	7
9	0.01917	327.75	1112456073	8
2	0.0024	2622	864563388.1	1
15	0.03355	187.29	620352481.4	14
16	0.03594	174.8	479175432.1	15
5	0.00959	655.5	240672435.1	4
4	0.00719	874	223681600.9	3
3	0.00479	1311	201618353.4	2
376	0.89862	6.99	182483062.4	375
6	0.01198	524.4	166117946.5	5
7	0.01438	437	118203080.1	6
24	0.05512	114	108478002.4	23

Univariate Time Series Models

- ❑ seasonal dummies+linear trend
 - MAPE: 74.99
 - Model Variance: 8294278
 - Reference group: Sunday
 - The errors are not White Noise



Parameter Estimates

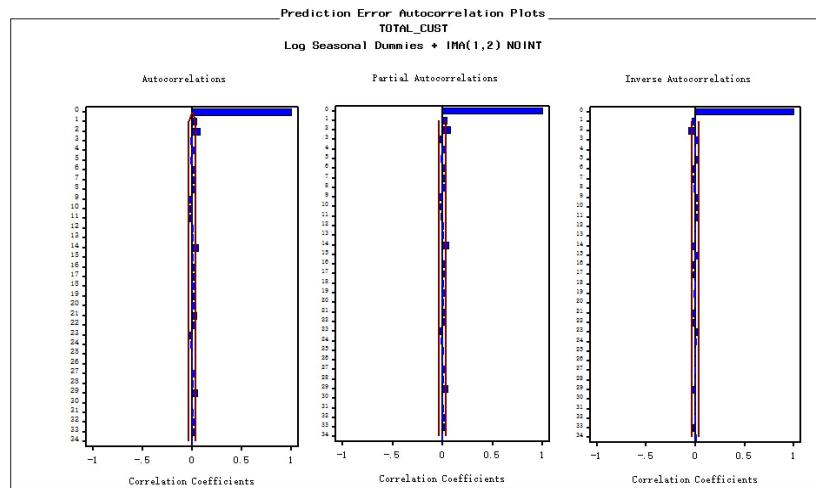
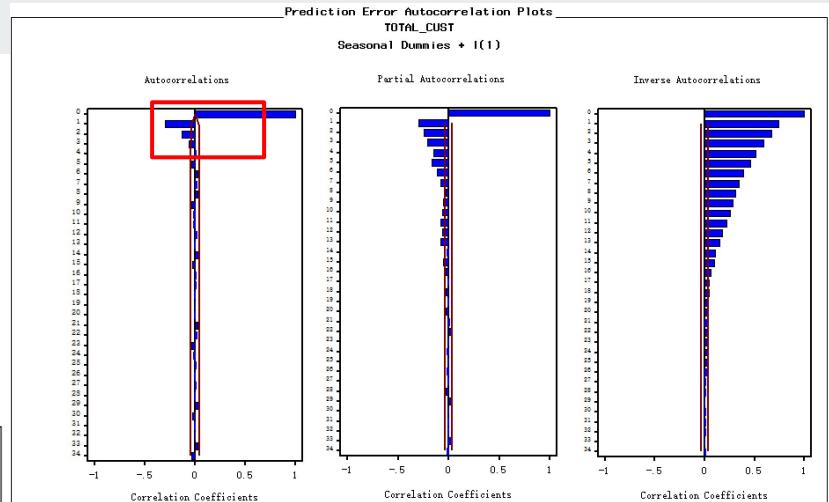
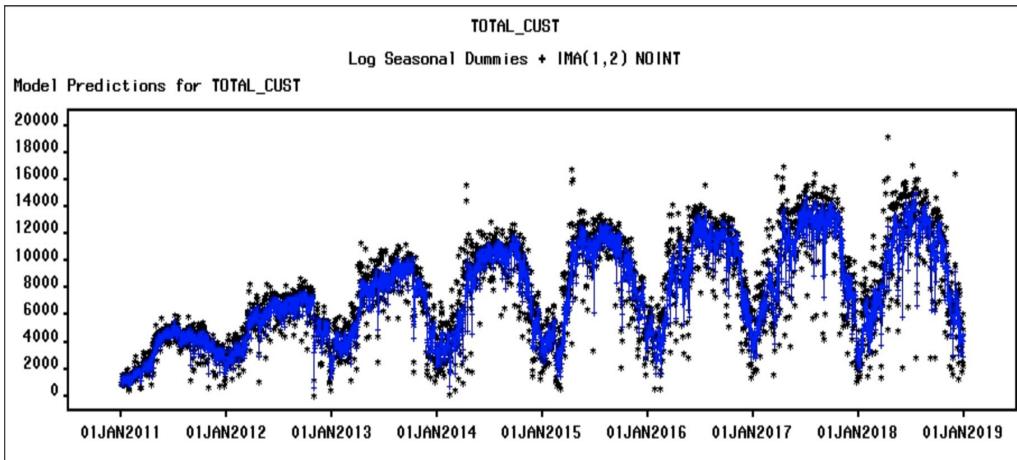
TOTAL_CUST

Seasonal Dummies + Linear Trend

Model Parameter	Estimate	Std. Error	T	Prob> T
Intercept	3576	179.9813	19.8688	<.0001
Seasonal Dummy 1	-417.64114	212.8942	-1.9617	0.0506
Seasonal Dummy 2	-159.47294	213.0400	-0.7486	0.4546
Seasonal Dummy 3	119.79918	213.0399	0.5623	0.5742
Seasonal Dummy 4	284.61103	213.0399	1.3360	0.1824
Seasonal Dummy 5	207.89411	213.0400	0.9758	0.3298
Seasonal Dummy 6	282.45391	213.0400	1.3258	0.1857
Linear Trend	2.98267	0.0772	38.6564	<.0001
Model Variance (sigma squared)	8294278	.	.	.

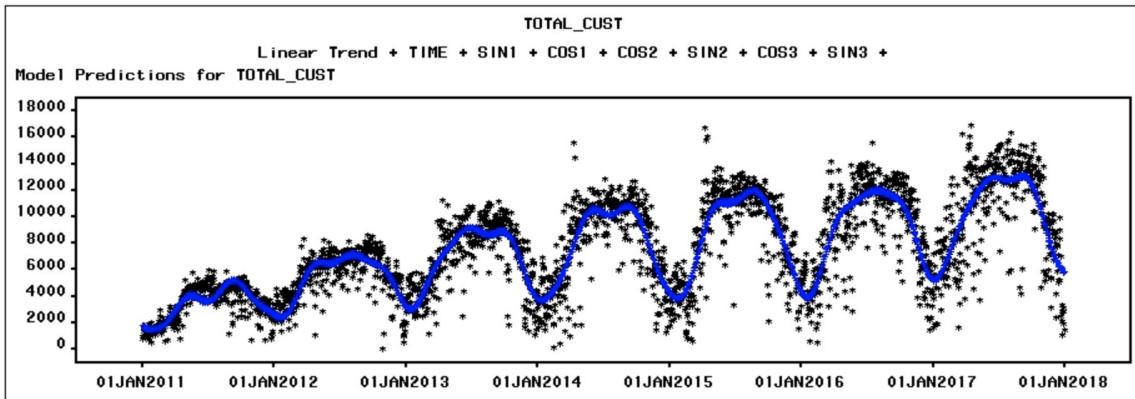
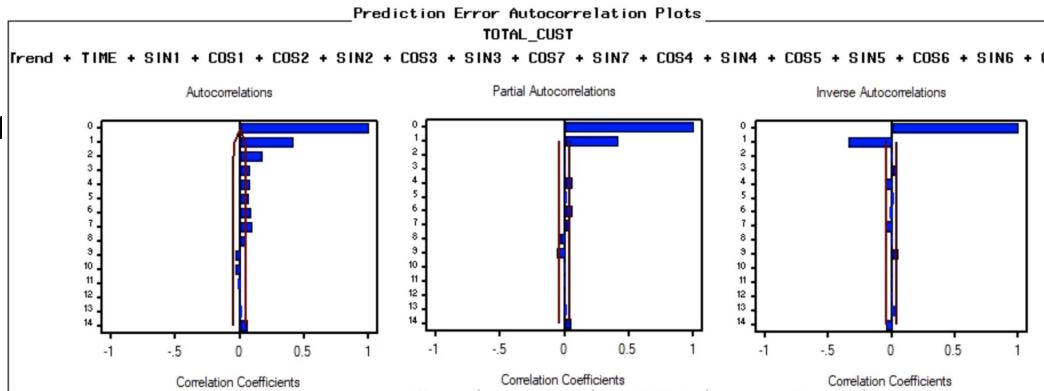
❑ Log seasonal dummy + First difference + MA(2)

- Stabilize+seasonality+differencing+error model
- MAPE: 30.29561
- Model Variance: 0.11984
- The errors are White Noise finally



❑ Cyclical trend model

- 12 harmonics
- Their periods: 2622, 374.57, 655.5, 327.75, 174.8, 874, 1311, 6.99, 524.4, 437, 114
- MAPE: 43.15
- Model Variance: 3213355
- The errors are not White Noise

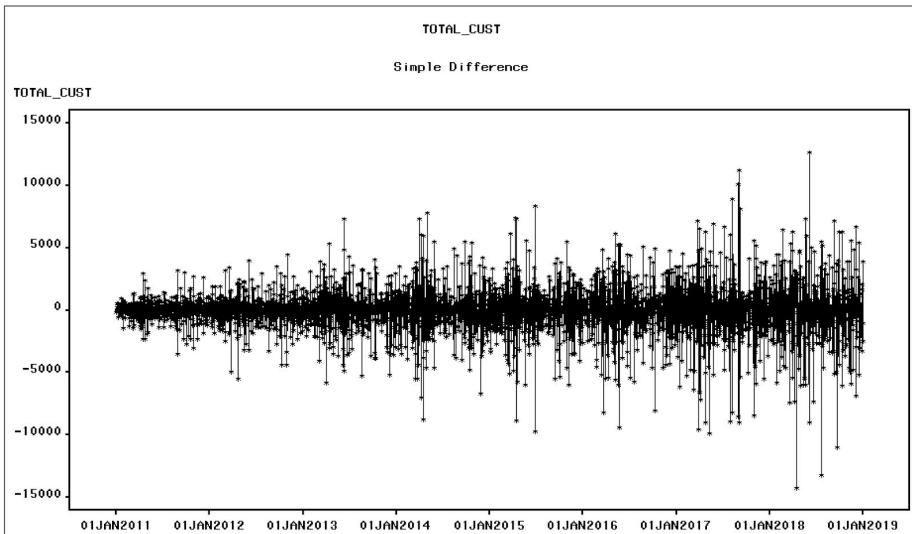


Obs	FREQ	PERIOD	P_01	i
8	0.01677	374.57	10671409977	7
9	0.01917	327.75	1112456073	8
2	0.0024	2622	864563388.1	1
15	0.03355	187.29	620352481.4	14
16	0.03594	174.8	479175432.1	15
5	0.00959	655.5	240672435.1	4
4	0.00719	874	223681600.9	3
3	0.00479	1311	201618353.4	2
376	0.89862	6.99	182483062.4	375
6	0.01198	524.4	166117946.5	5
7	0.01438	437	118203080.1	6
24	0.05512	114	108478002.4	23

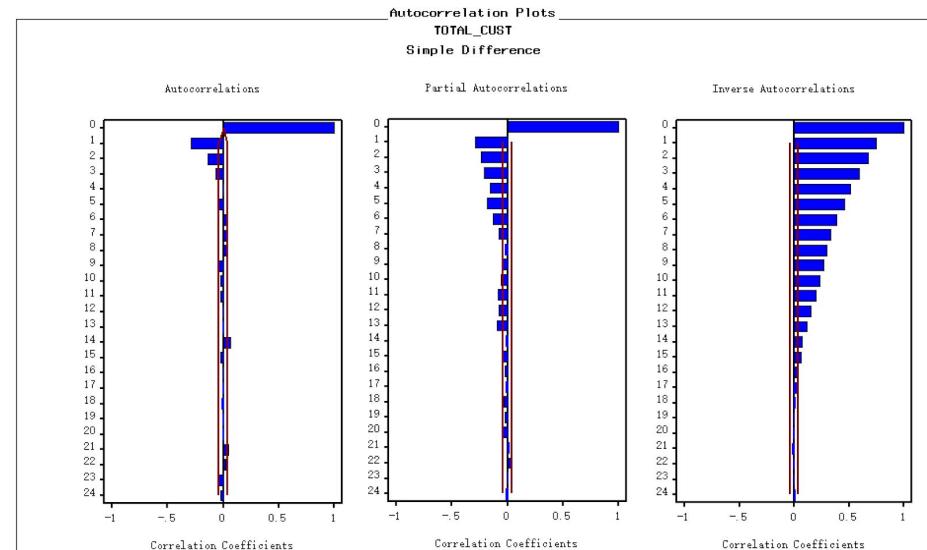
Univariate Time Series Models



1. Studies on the differenced series
2. ARIMA(1,1,1) & ARIMA(0,1,2)
3. Add Regressor -- Holiday



Time Series

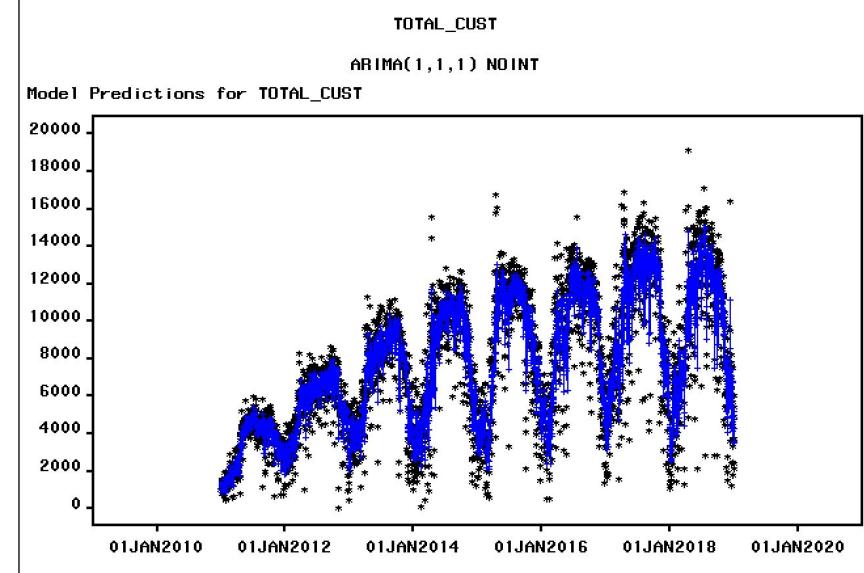
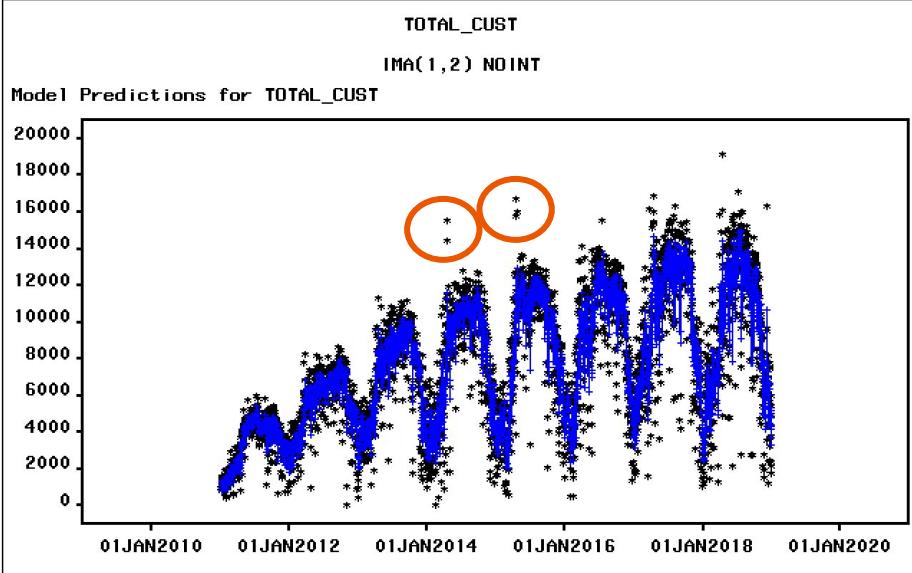


ACF & PACF

❑ ARIMA models

- ❖ ARIMA(0, 1, 2) V.S. ARIMA(1, 1, 1)
 - MAPE
 - Model Fit

Forecast	Model	Model Title	Mean Absolute Percent Error
<input type="checkbox"/>	ARIMA(1,1,1) NOINT		32.05796
<input checked="" type="checkbox"/>	IMA(1,2) NOINT		31.99756



❑ ARIMA models

- ❖ ARIMA(0, 1, 2) V.S. ARIMA(1, 1, 1)
 - ACF, PACF
 - Parameter Estimates
 - Model Variance

Parameter Estimates

TOTAL_CUST
IMA(1,2) Noint

Model Parameter	Estimate	Std. Error	T	Prob> T
Moving Average, Lag 1	0.55146	0.0191	28.8222	<.0001
Moving Average, Lag 2	0.25592	0.0192	13.3543	<.0001
Model Variance (sigma squared)	2838646	.	.	.

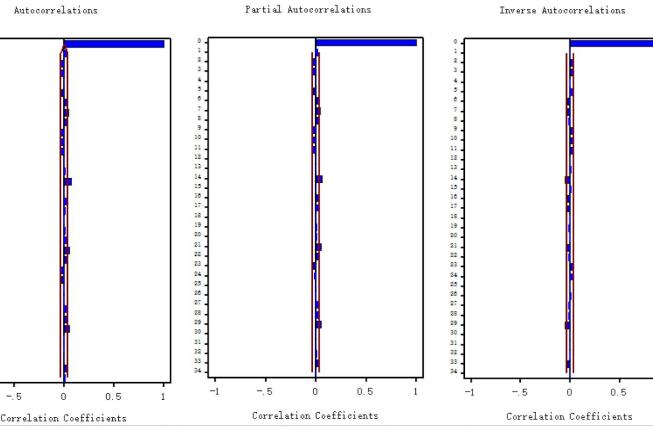
Parameter Estimates

TOTAL_CUST
ARIMA(1,1,1) Noint

Model Parameter	Estimate	Std. Error	T	Prob> T
Moving Average, Lag 1	0.88541	0.0120	73.7741	<.0001
Autoregressive, Lag 1	0.34822	0.0240	14.5240	<.0001
Model Variance (sigma squared)	2823398	.	.	.

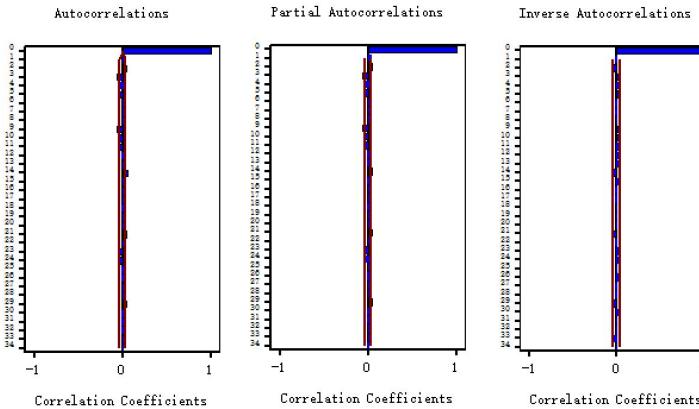
Prediction Error Autocorrelation Plots

TOTAL_CUST
ARIMA(1,1,1) Noint



Prediction Error Autocorrelation Plots

TOTAL_CUST
IMA(1,2) Noint

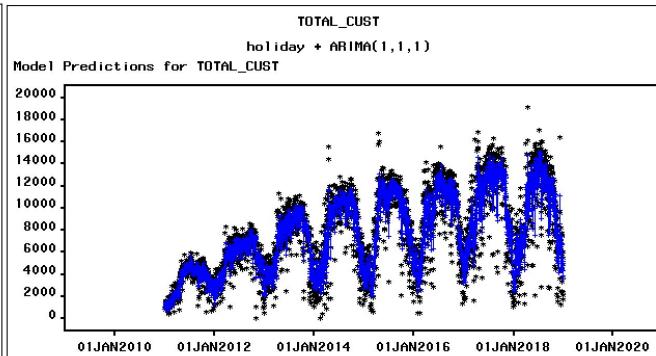
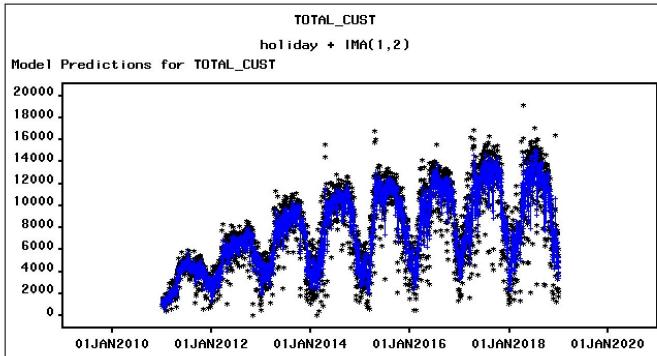


□ ARIMA models

- ❖ Add Regressor -- Holiday
 - MAPE
 - Parameter Estimates
 - Model Variance

Variance without holiday:

- IMA(1,2): 2838646
- ARIMA(1,1,1): 2823398



Parameter Estimates
TOTAL_CUST
holiday + IMA(1,2) NOINT

Model Parameter	Estimate	Std. Error	T	Prob> T
Moving Average, Lag 1	0.55223	0.0191	28.8550	<.0001
Moving Average, Lag 2	0.25600	0.0192	13.3554	<.0001
holiday	-614.56009	172.9115	-3.5542	0.0004
Model Variance (sigma squared)	2825779	.	.	.

Parameter Estimates
TOTAL_CUST
holiday + ARIMA(1,1,1) NOINT

Model Parameter	Estimate	Std. Error	T	Prob> T
Moving Average, Lag 1	0.88487	0.0120	73.5834	<.0001
Autoregressive, Lag 1	0.34506	0.0240	14.3690	<.0001
holiday	-553.65801	172.4905	-3.2098	0.0014
Model Variance (sigma squared)	2813158	.	.	.

Forecast
Model Model Title

- ARIMA(1,1,1) NOINT
- holiday + ARIMA(1,1,1) NOINT
- IMA(1,2) NOINT
- holiday + IMA(1,2) NOINT

Mean Absolute Percent Error

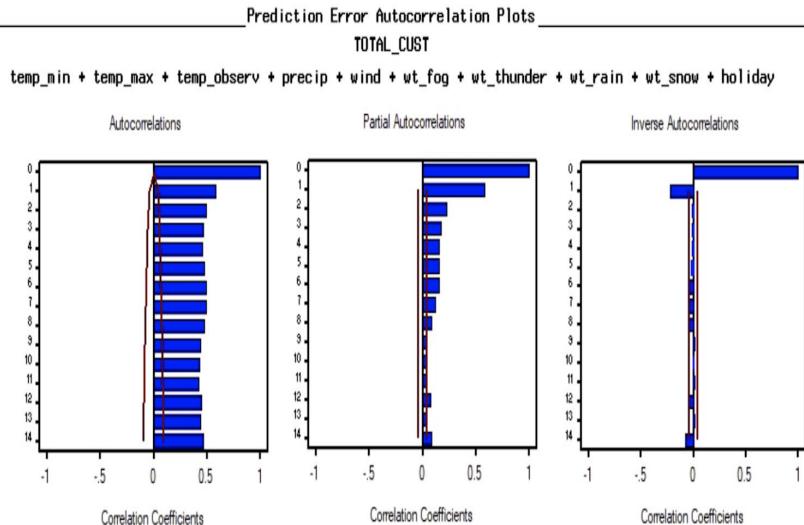
32.05796
31.75055
31.99756
31.63643

Multivariate Time Series Models

1. Regression model with all predictors
2. The first difference of the regression model with all predictors.
3. Add Error model on the previous model

MAPE: 33.223

Model Variance: 6206423



Parameter Estimates

TOTAL_CUST

temp_min + temp_max + temp_observ + precip + wind + wt_fog + wt_thunder + wt_rain + wt_snow + holiday

Model Parameter	Estimate	Std. Error	T	Prob> T
Intercept	4464	259.0970	17.2306	<.0001
temp_min	41.67714	30.3712	1.3723	0.1709
temp_max	233.75476	19.3429	12.0848	<.0001
temp_observ	-41.03328	32.3822	-1.2672	0.2059
precip	-23.26286	7.1165	-3.2689	0.0012
wind	-120.15714	38.1360	-3.1508	0.0018
wt_fog	-304.53220	108.2488	-2.8133	0.0052
wt_thunder	-553.31404	141.6272	-3.9068	0.0001
wt_rain	-3812	142.9994	-26.6592	<.0001
wt_snow	-340.95146	294.0481	-1.1595	0.2470
holiday	-1177	286.9407	-4.1034	<.0001
Model Variance (sigma squared)	6206425	.	.	.

Fit Range: 01JAN2011 to 31DEC2017

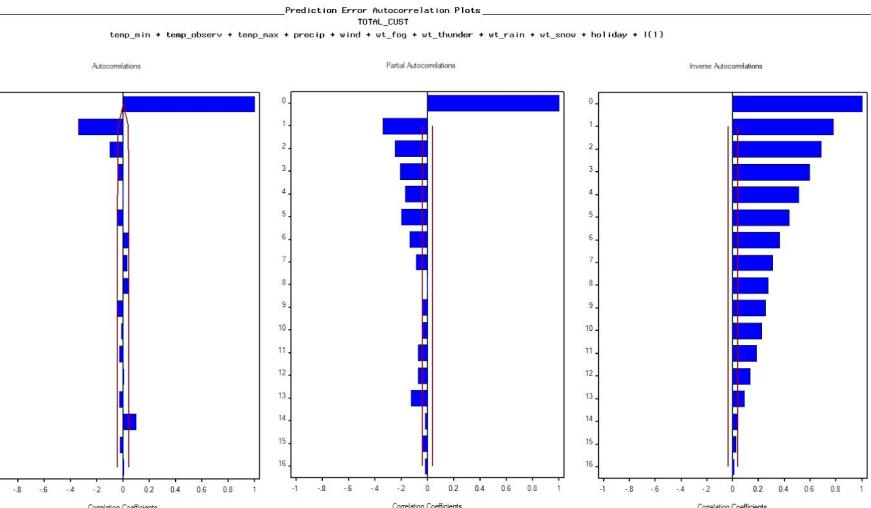
Multivariate Time Series Models

2. The first difference of the regression model with all predictors.

MAPE: 27.653

Model Variance: 3281918

MA(2)



Parameter Estimates

TOTAL_CUST

temp_min + temp_observ + temp_max + precip + wind + wt_fog + wt_thunder + wt_rain + wt_snow + holiday + I(1)

Model Parameter	Estimate	Std. Error	T	Prob> T
Intercept	0.59977	35.8331	0.0167	0.9867
temp_min	-128.27730	23.4920	-5.4605	<.0001
temp_observ	67.42115	17.2370	3.9114	0.0001
temp_max	132.36679	14.9336	8.8637	<.0001
precip	17.07048	3.9785	4.2907	<.0001
wind	-190.70868	24.7971	-7.6908	<.0001
wt_fog	-737.22077	63.8478	-11.5465	<.0001
wt_thunder	-374.65273	87.3508	-4.2891	<.0001
wt_rain	-303.92515	106.0016	-2.8672	0.0044
wt_snow	-220.28856	181.4580	-1.2140	0.2256
holiday	-438.17744	146.1307	-2.9985	0.0029
Model Variance (sigma squared)	3281918	.	.	.

Fit Range: 01JAN2011 to 31DEC2017

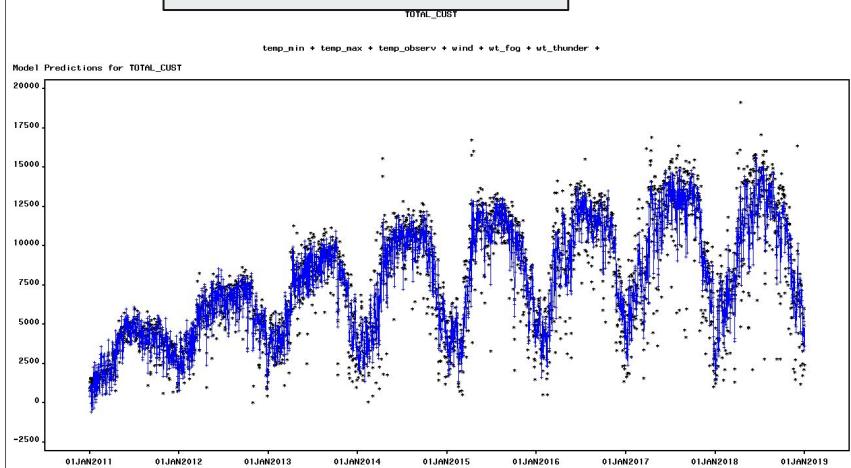
Multivariate Time Series Models

3. Add Error model on the previous model

- Regression model with IMA(1,2) and without wt_snow, wt_rain, precip and Intercept.

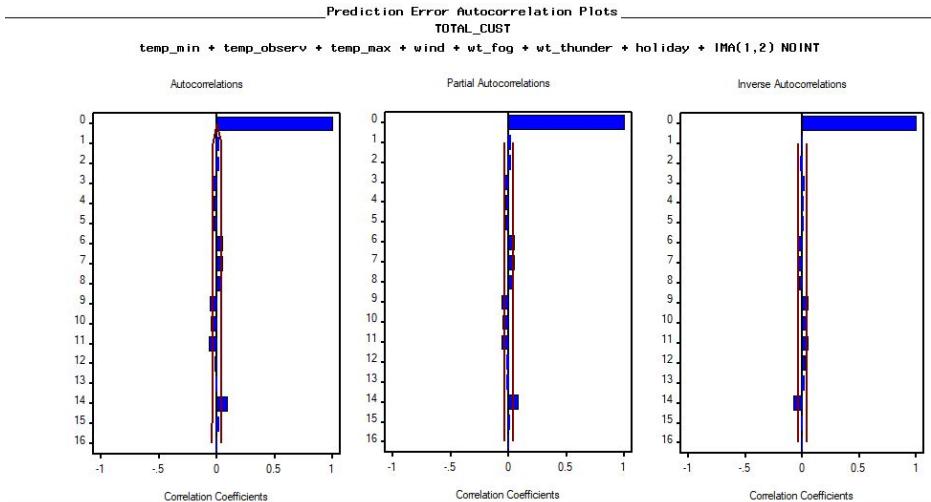
MAPE: 27.69

Model Variance: 2260948



Parameter Estimates				
TOTAL_CUST				
Model Parameter	Estimate	Std. Error	t	Prob> t
Moving Average, Lag 1	0.59458	0.0304	33.9817	<.0001
Moving Average, Lag 2	0.15675	0.0202	7.7697	<.0001
temp_min	-113.16541	20.8292	-5.4330	<.0001
temp_observ	49.47041	18.7934	2.6323	.0080
temp_max	150.34939	12.7090	11.7445	<.0001
wind	-250.34958	22.7090	-10.5235	<.0001
wt_fog	-738.77668	65.5138	-11.2767	<.0001
wt_thunder	-507.00391	86.1223	-5.8870	<.0001
holiday	-729.18579	161.7985	-4.5068	<.0001
Model Variance (sigma squared)	2260948			

Fit Range: 01JAN2011 to 31DEC2017

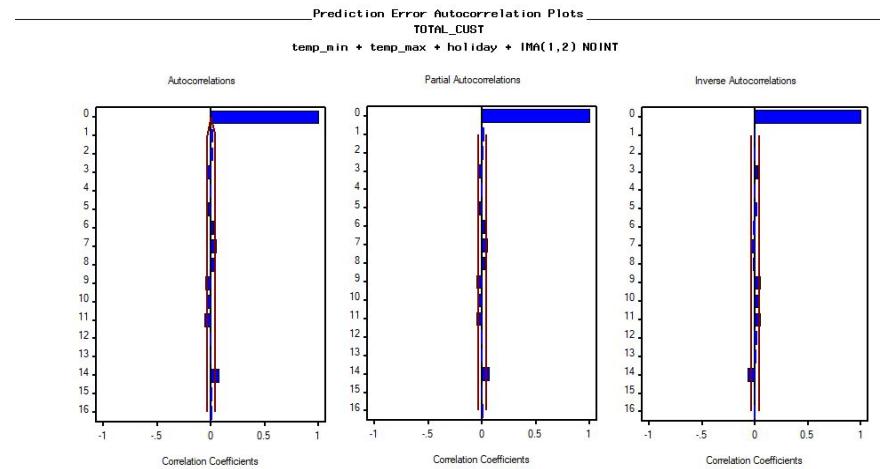
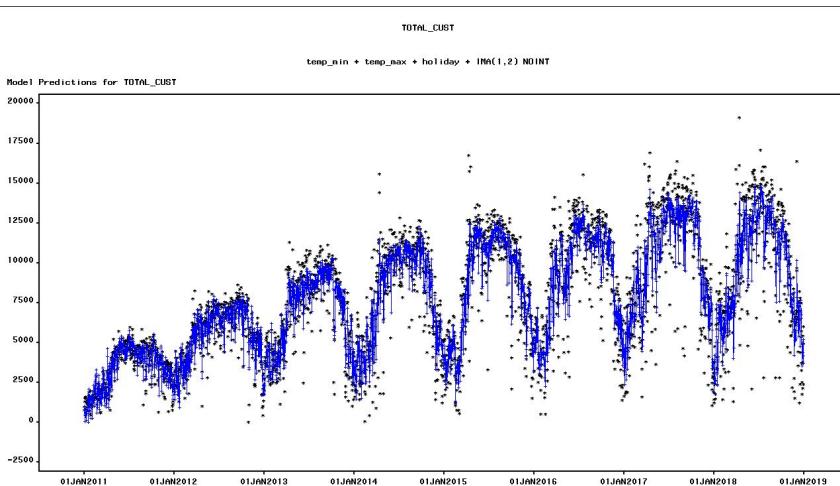


Multivariate Time Series Models

3. Add Error model on the previous model

- Regression model with IMA(1,2) and with temperature and holiday variables

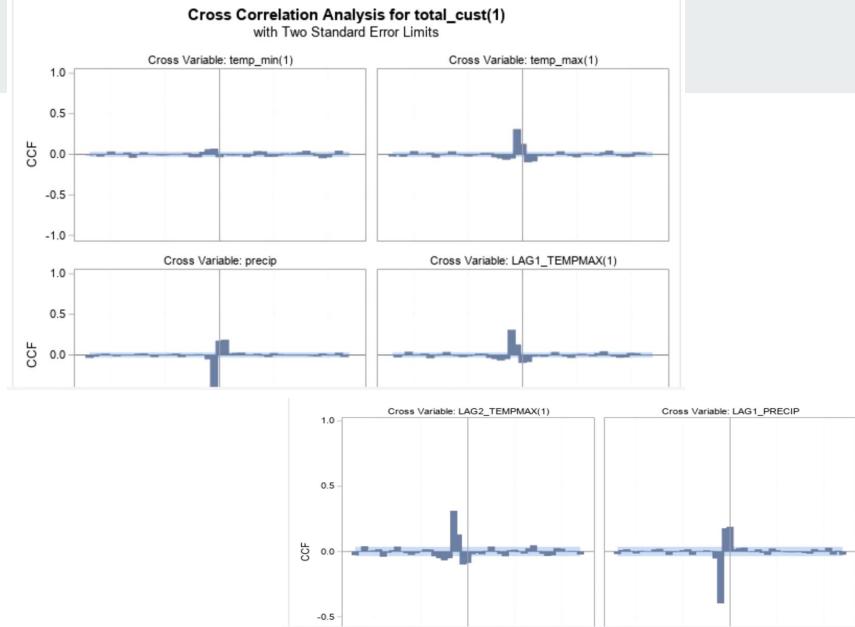
MAPE: 29.91
Model Variance: 2510664



❑ Cross correlation analysis

temp_min+temp_max+precip+lag1_tempmax+lag2_temp
max+lag1_precip+MA(2)

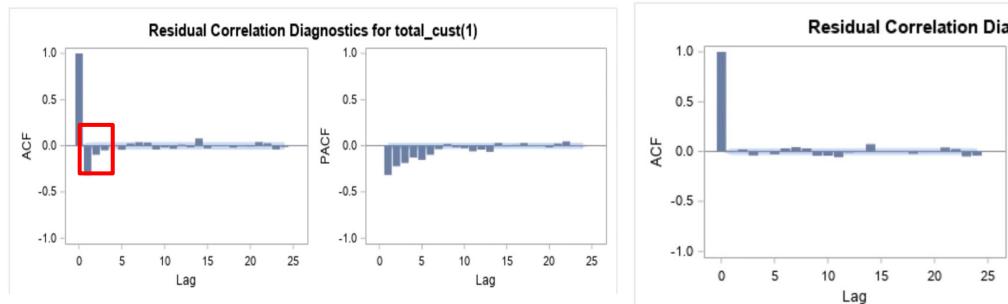
- Non-stationary: temp_min, temp_max; Stationary: precip
- total_cust and temp_min: The correlation of all the lags are not significant. So we can not use useful lag values as our predictors into model.
- total_cust and temp_max: Choose temp_max at (t-1), (t-2) as our predictors
- total_cust and precip: Choose precip at (t-1) as our predictors
- Variance Estimate: 2816670



0	890.003	0.13089		. ***	
1	-682.212	-.10033		** .	
2	-604.157	-.08885		** .	

-2	5881.441	0.28333		. *****	
-1	-9870.966	-0.47553		***** .	
0	-200.755	-.00967		. .	
1	2972.243	0.14319		. ***	

Differencing the variables+distributed lag as regressors+error model



Conclusion

- ❑ Comparison of all the models
- ❑ Any business insights?
- Demands of shared bike are mainly influenced by temperature, wind, fog, thunder, holiday.
- At the beginning of Jan 2019, the predicted demands will decrease to around 4000 bikes per day, decrease supply.

DATE	ACTUAL	PREDICT
15DEC2018	1208	6460
16DEC2018	2363	4544
17DEC2018	7772	5602
18DEC2018	7514	6778
19DEC2018	7466	7200
20DEC2018	4399	7165
21DEC2018	5696	6538
22DEC2018	3710	6202
23DEC2018	3270	6045
24DEC2018	2492	4505
25DEC2018	1744	3933
26DEC2018	3752	4716 ~ + wind + wt_fog + wt_thunder + holiday + IMA(1,2) NOINT

Forecast Data Set

DATE	ACTUAL	PREDICT	U95	L95	ERROR	NERROR	temp_min	temp_max
30DEC2018	4929	5957	8904	3010	-1028	-0.6837	0.8167	11.0667
31DEC2018	2401	3614	6561	667.1366	-1213	-0.8069	0.2500	8.5167
01JAN2019	.	3895	6842	948.1407	.	.	0.5949	8.5192
02JAN2019	.	4064	7145	982.1459	.	.	0.7873	8.5192
03JAN2019	.	4069	7182	956.5515	.	.	0.6469	8.5192
04JAN2019	.	4101	7245	958.2272	.	.	0.3918	8.5192
05JAN2019	.	4166	7339	991.9998	.	.	-0.0207	8.5192
06JAN2019	.	4168	7371	963.8883	.	.	-0.0537	8.5192
07JAN2019	.	4041	7274	807.1414	.	.	0.2509	8.5192
08JAN2019	.	4085	7348	822.3702	.	.	0.5949	8.5192
09JAN2019	.	4064	7356	771.3093	.	.	0.7873	8.5192
10JAN2019	.	4069	7390	747.6817	.	.	0.6469	8.5192
11JAN2019	.	4101	7452	751.2702	.	.	0.3918	8.5192

Model	MAPE	Model Variance
seasonal dummies+linear trend	74.98789	8294278
Log seasonal dummy + First difference + MA(2)	30.29561	0.11984
Cyclical trend model	43.15	3213355
ARIMA(1,1,1)	32.06	2823398
ARIMA(0,1,2)	31.99756	2838646
holiday+ARIMA(1,1,1)	31.75055	2825779
holiday+ARIMA(0,1,2)	31.63643	2813158
Regression model with all predictors	33.223	6206420
Regression model with all predictors + first difference	27.653	3281918
Regression model + IMA(1,2) + no wt_snow, wt_rain, precip+ no Intercept	27.69	2260940
Regression model + IMA(1,2)+Temperature, Precip + No intercept	29.91	2510664



Q & A

Thank You !