Residential Customer Count Forecast

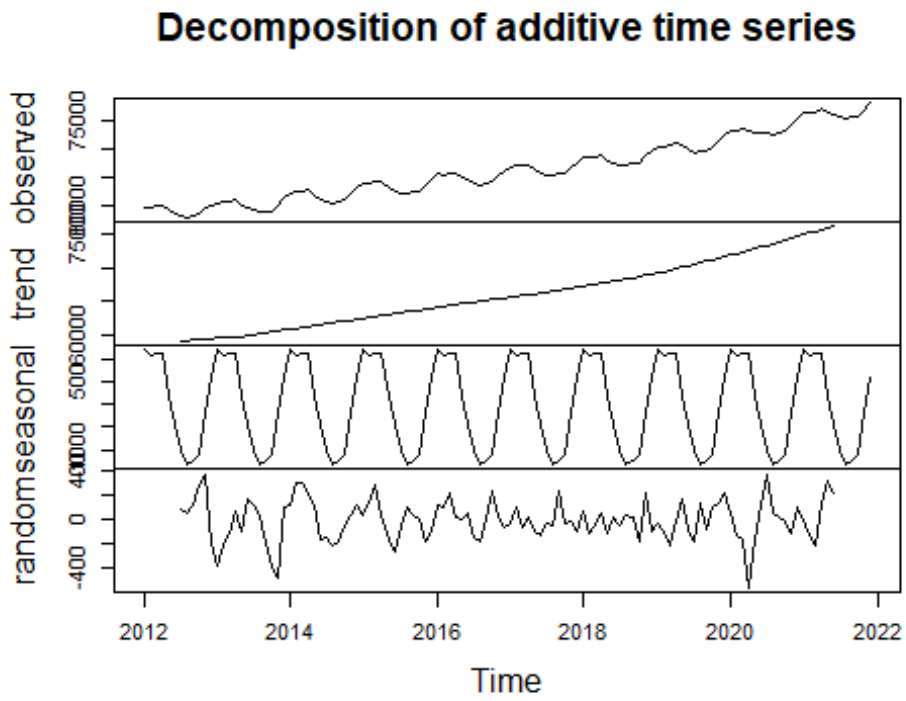
Overall Residential Customers Forecast Analysis

In this section we will forecast the total monthly Residential Customers. Residential customers are filtered by Rate Class: 10,22,I0, and RS. We also include only customers that have greater than 0 reported volume usage for the month.

Customer Time-Series Decomposition

In this section we decompose the Residential Customer time-series using an Additive Decomposition Model. This model evaluates time-series' by extracting the Seasonal, Trending, and Random components.

Here we can clearly see a linear trend and seasonal component within the Residential customers.



ARIMA Model: Expected Accuracy

In this section we evaluate the expected accuracy of a Seasonal ARIMA Model using cross-validation. ARIMA is an acronym for 'Autoregressive Integrated Moving Average' which is a widely used Time-Series forecasting model that utilizes the recent values to predict outward.

Here we evaluate model accuracy by using cross-validation and rolling forecasts throughout the time-series to determine our expected accuracy over a 24 Month period. Below we see that the ARIMA model is extremely accurate with a 1-Month Forecast Mean Absolute Error (MAE) of 162 clients, and a 24 MAE of 1,560 clients.

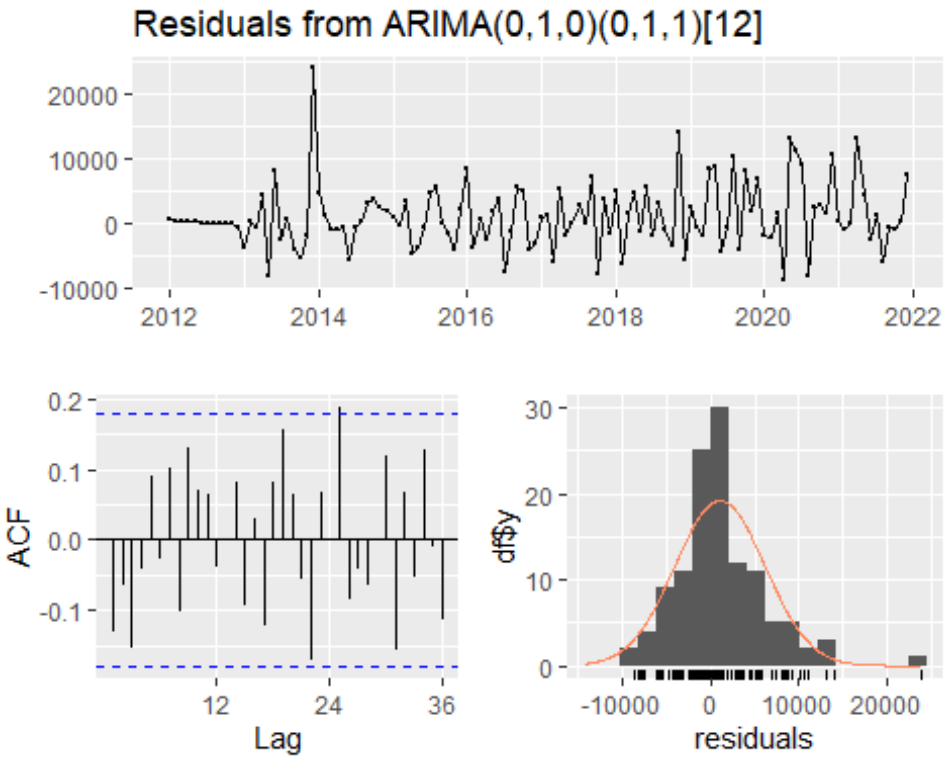
```
                       ME RMSE  MAE
Forecast Horizon  1   104  221  162
Forecast Horizon  2   147  259  199
```

```
Forecast Horizon  3   190  298  243
Forecast Horizon  4   222  360  286
Forecast Horizon  5   252  375  313
Forecast Horizon  6   297  415  333
Forecast Horizon  7   351  484  403
Forecast Horizon  8   392  550  457
Forecast Horizon  9   431  580  480
Forecast Horizon  10  463  622  518
Forecast Horizon  11  519  688  573
Forecast Horizon  12  574  728  609
Forecast Horizon  13  680  851  738
Forecast Horizon  14  759  949  812
Forecast Horizon  15  843 1029  893
Forecast Horizon  16  932 1108  968
Forecast Horizon  17 1006 1182 1039
Forecast Horizon  18 1082 1251 1116
Forecast Horizon  19 1160 1317 1189
Forecast Horizon  20 1224 1416 1284
Forecast Horizon  21 1282 1487 1346
Forecast Horizon  22 1341 1556 1417
Forecast Horizon  23 1413 1645 1503
Forecast Horizon  24 1478 1703 1560
```

ARIMA Model: Diagnostics

In this section we evaluate the diagnostics of the ARIMA Model. Below we see that the model fails the Ljung-Box Test and therefore we can determine the data is independently distributed. In addition, we see from the graphs that the lagged values are not auto-correlated with one another, and the residuals are normally distributed.

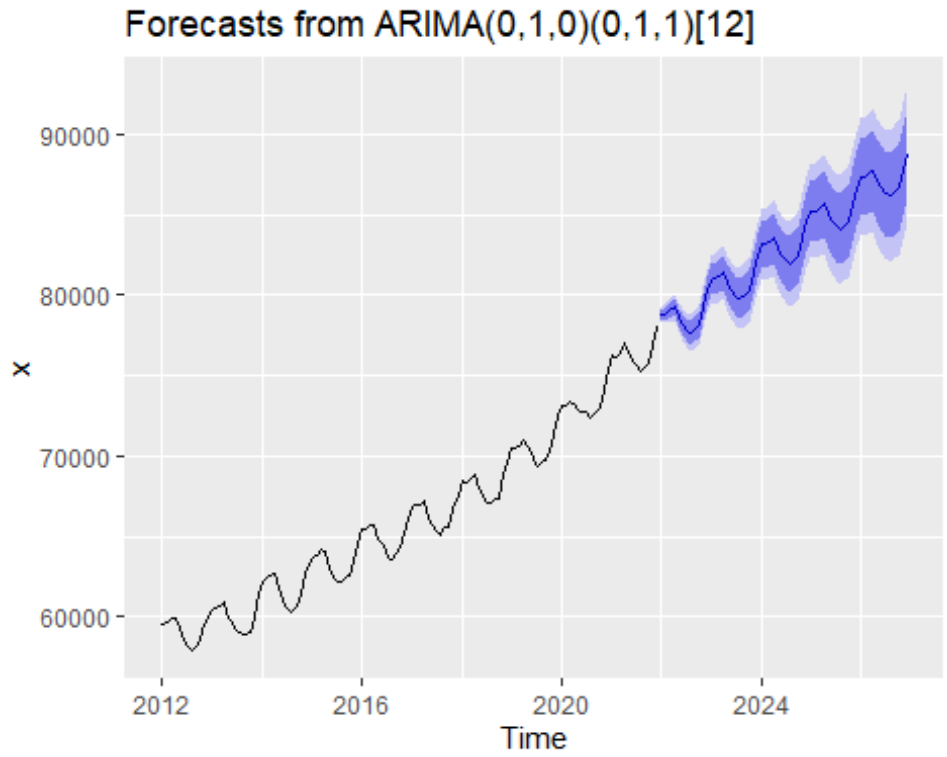
```
Series: x
ARIMA(0,1,0)(0,1,1)[12]
Box Cox transformation: lambda= 1.293615

Coefficients:
          sma1
      -0.7888
s.e.   0.1152

sigma^2 estimated as 30268293:  log likelihood=-1078.4
AIC=2160.81   AICc=2160.92   BIC=2166.15

Training set error measures:
                    ME     RMSE      MAE        MPE      MAPE       MASE
Training set 38.45578 197.6952 137.8342 0.05474795 0.2054131 0.07213338
                    ACF1
Training set -0.1321209
```




```
 Ljung-Box test

data:  Residuals from ARIMA(0,1,0)(0,1,1)[12]
Q* = 28.351, df = 23, p-value = 0.2028

Model df: 1.   Total lags used: 24
```

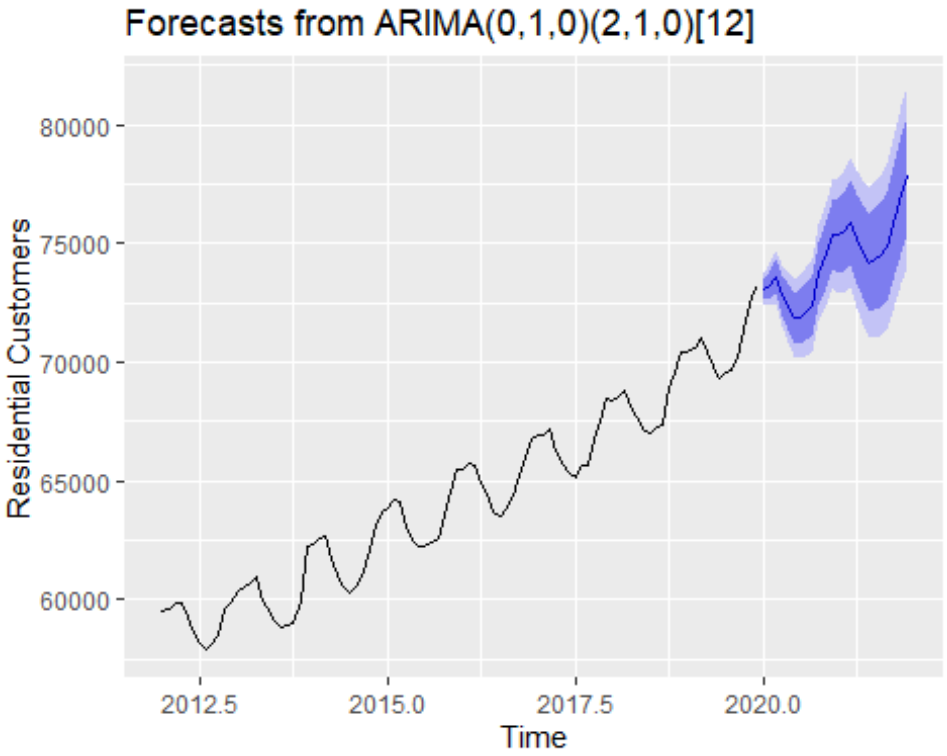
ARIMA Model: 5 Year Forecast

Below we fit & forecast 60 months into the future using an ARIMA (0,1,0)(0,1,1) model. This model only uses 1 difference,1 Seasonal Moving Average, 1 Seasonal Difference, and is expected to be extremely accurate as previously shown. In the graph below we see the 80% and 95% Prediction Intervals bounding our forecast.



2020-2021 Forecast Comparison

In this section we will evaluate the accuracy of our ARIMA(0,1,0)(2,1,0) model on data from January, 2020 through December 2021 by training on the previous data and forecasting the next 24 months. In particular we are interested on how close the forecasted accuracy follows our cross-validated results shown previously. Also, an area of interest is how well the model performs during the 2020 pandemic.



Test Results

Below we see that the model performs roughly as expected for a "normal" year of 2019, and continues to have a high degree of accuracy in 2020 and 2021.

```
[1] "Mean Absolute Error: 649.37"

[1] "Mean Accuracy: 99.13"

         Actual Forecast Absolute_Error Accuracy
Jan 2020  73165    73107       58.23296     99.9
Feb 2020  73112    73280      168.14732     99.8
Mar 2020  73344    73608      264.32012     99.6
Apr 2020  73209    72823      386.32510     99.5
May 2020  72899    72350      549.09457     99.2
Jun 2020  72794    71875      918.97981     98.7
Jul 2020  72695    71912      783.25405     98.9
Aug 2020  72316    72132      184.29423     99.7
Sep 2020  72637    72385      251.57844     99.7
Oct 2020  73012    73727      714.68991     99.0
Nov 2020  74155    74569      414.27708     99.4
Dec 2020  75425    75384       41.28152     99.9
Jan 2021  76201    75354      846.63259     98.9
Feb 2021  76179    75507      671.84671     99.1
Mar 2021  76369    75890      478.68527     99.4
Apr 2021  76975    75217     1757.53291     97.7
May 2021  76456    74662     1794.27204     97.7
Jun 2021  75940    74188     1751.68828     97.7
Jul 2021  75624    74318     1305.59829     98.3
Aug 2021  75267    74485      782.35634     99.0
Sep 2021  75495    74863      632.39268     99.2
Oct 2021  75748    76126      377.65818     99.5
Nov 2021  76845    77079      233.75445     99.7
Dec 2021  78065    77847      217.93362     99.7
```

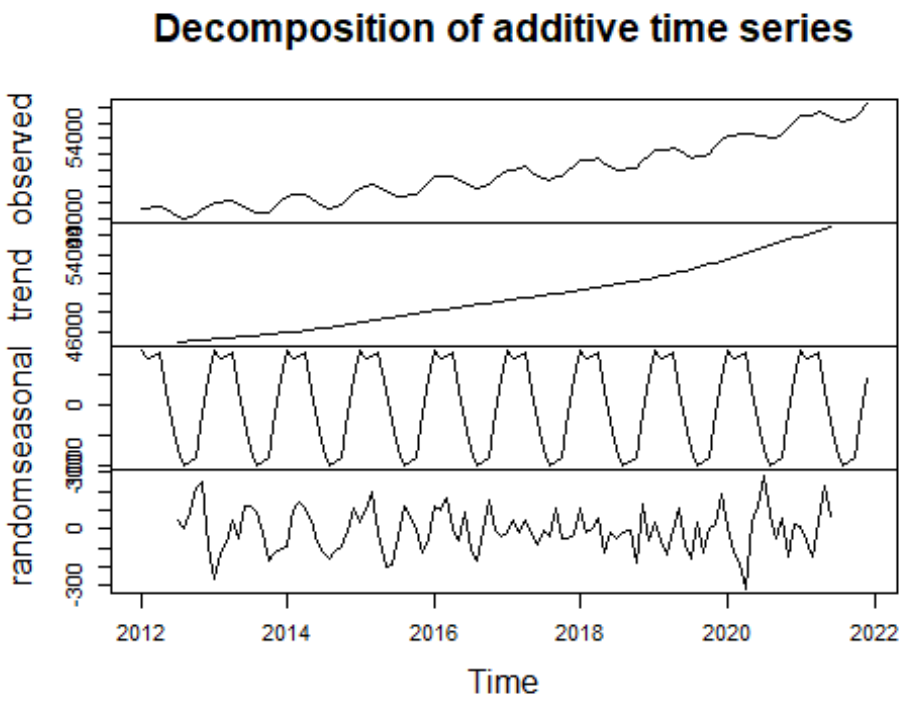
FPUC Residential Service (FPU-RS)

In this section we will forecast monthly client counts for FPU-RS. From the data given, these numbers are calculated by filtering for Tariff Schedule 'RS' and excluding Rate Class 22 which appears to be the Fort Meade residential clients.

Customer Time-Series Decomposition

In this section we decompose the Residential Customer time-series using an Additive Decomposition Model. This model evaluates time-series' by extracting the Seasonal, Trending, and Random components.

Here we can clearly see a linear trend and seasonal component within the Residential customers.



ARIMA Model: Expected Accuracy

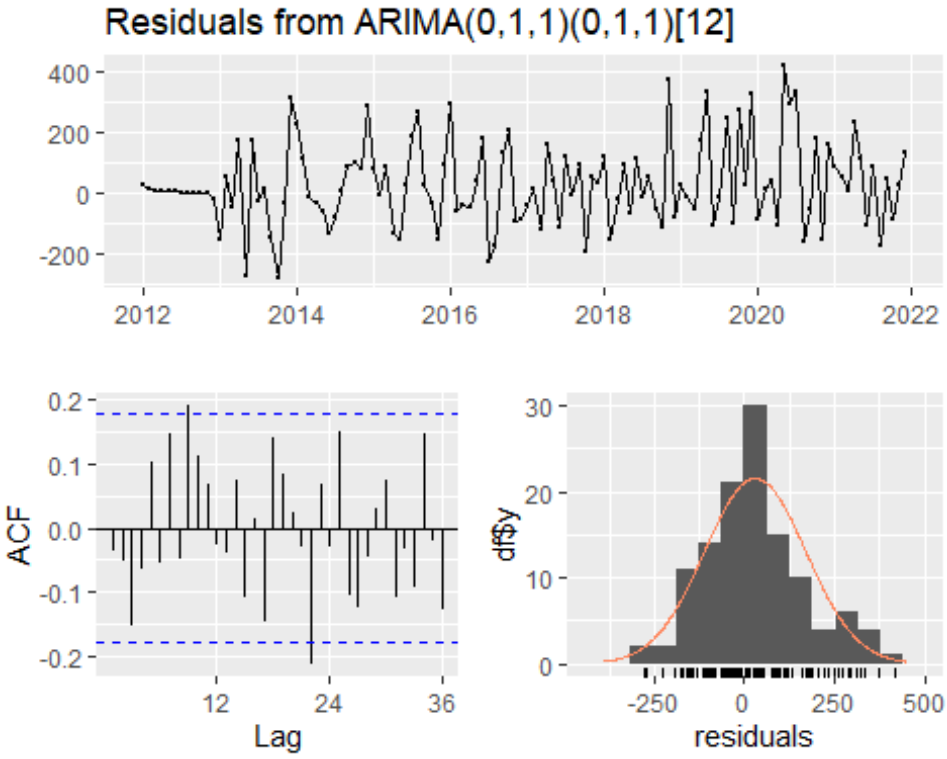
Here we evaluate model accuracy by using cross-validation and rolling forecasts throughout the time-series to determine our expected accuracy over a 24 Month period. Below we see that the ARIMA model is extremely accurate with a 1-Month Forecast Mean Absolute Error (MAE) of 124clients, and a 24-Month Forecast MAE of 1,362 clients.

	ME	RMSE	MAE
Forecast Horizon 1	58	162	124
Forecast Horizon 2	97	195	150
Forecast Horizon 3	134	239	182
Forecast Horizon 4	164	274	207
Forecast Horizon 5	191	309	223
Forecast Horizon 6	230	350	263
Forecast Horizon 7	288	401	293
Forecast Horizon 8	328	460	345
Forecast Horizon 9	366	508	389
Forecast Horizon 10	408	560	422
Forecast Horizon 11	449	620	477
Forecast Horizon 12	495	673	514
Forecast Horizon 13	570	767	607
Forecast Horizon 14	632	835	653
Forecast Horizon 15	695	908	716
Forecast Horizon 16	767	972	786
Forecast Horizon 17	830	1039	847
Forecast Horizon 18	906	1114	924
Forecast Horizon 19	987	1197	998
Forecast Horizon 20	1042	1265	1090
Forecast Horizon 21	1108	1329	1151
Forecast Horizon 22	1181	1406	1224
Forecast Horizon 23	1252	1474	1304
Forecast Horizon 24	1314	1537	1362

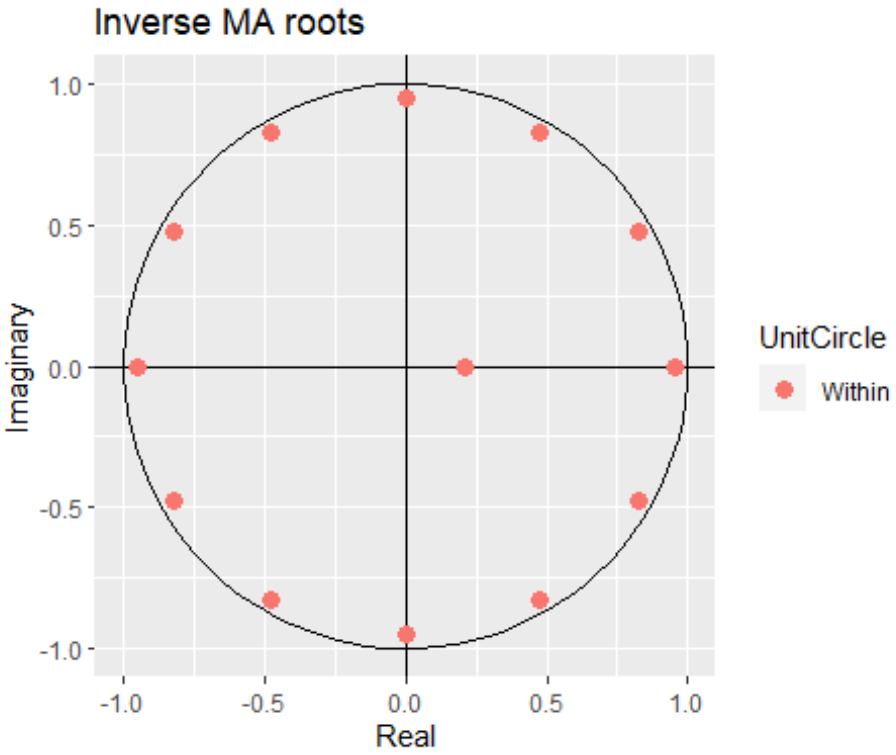
ARIMA Model: Diagnostics

Below we see that the model fails the Ljung-Box Test and therefore we can determine the data is independently distributed. In addition, we see from the graphs that the lagged values are not auto-correlated with one another, and the residuals are normally distributed. The unit circle below also showcases that we have a stationary model.

```
Series: x
ARIMA(0,1,1)(0,1,1)[12]

Coefficients:
          ma1     sma1
      -0.2087  -0.5582
s.e.   0.1053   0.1070

sigma^2 estimated as 23342:  log likelihood=-690.62
AIC=1387.25   AICc=1387.48   BIC=1395.27

Training set error measures:
                    ME     RMSE      MAE       MPE      MAPE       MASE
Training set 29.30466 142.9139 107.2376 0.0556097 0.2137368 0.08030996
                     ACF1
Training set -0.03563074
```

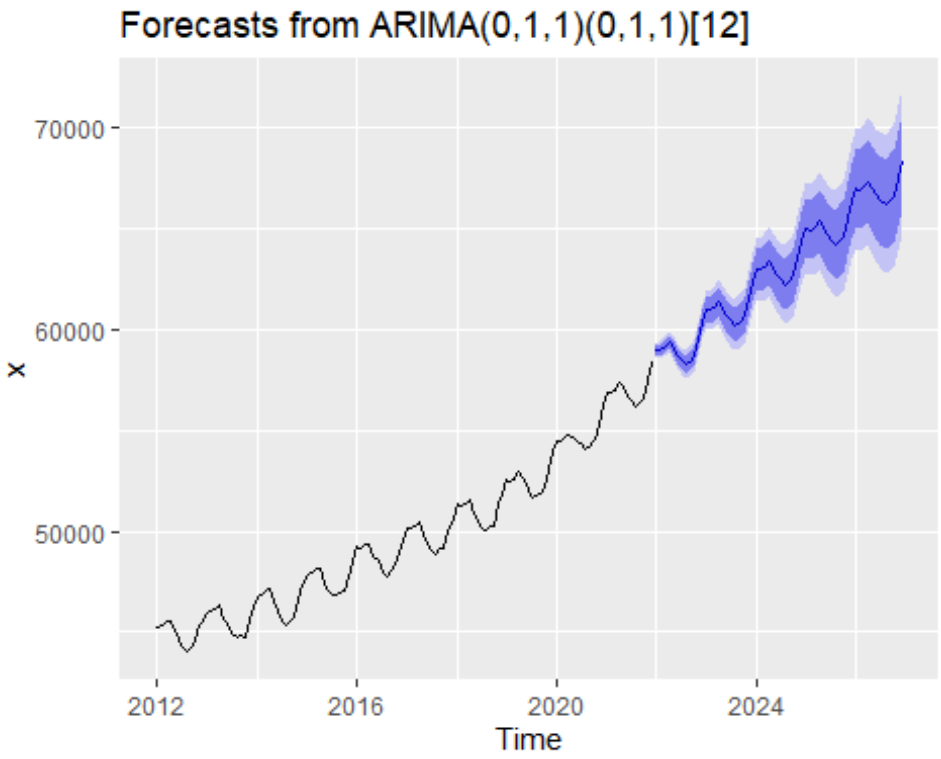



```
 Ljung-Box test

data:  Residuals from ARIMA(0,1,1)(0,1,1)[12]
Q* = 32.824, df = 22, p-value = 0.06439

Model df: 2.   Total lags used: 24
```



ARIMA Model: 5 Year Forecast

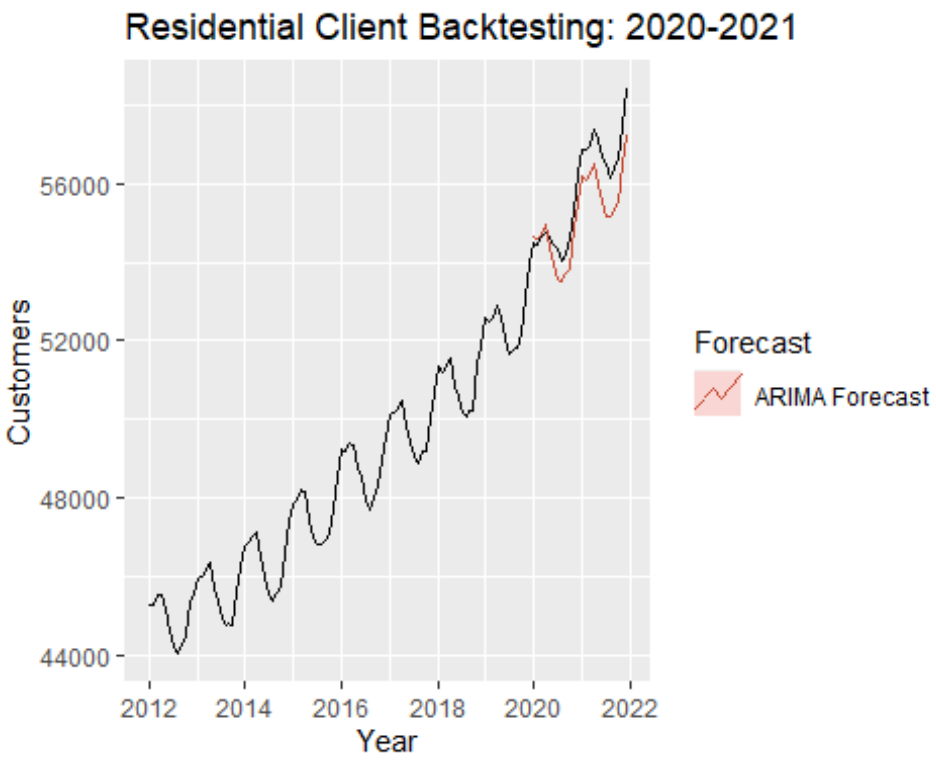
Below we fit & forecast 60 months into the future using an ARIMA (2,1,2)(1,1,1) model.



2020-2021 Back-Testing Evaluation

In this section we will evaluate the accuracy of our ARIMA(0,1,1)(0,1,1) model on data from January, 2020 through December 2021 by training on the previous data and forecasting the next 24 months. In

particular we are interested on how close the forecasted accuracy follows our cross-validated results shown previously. Also, an area of interest is how well the model performs during the 2020 pandemic.



Test Results

Below we see that the model performs roughly as expected for a "normal" year of 2019, and continues to have a high degree of accuracy in 2020 and 2021.

```
[1] "Mean Absolute Error: 704.83"

[1] "Mean Accuracy: 98.74"

         Actual Forecast Absolute_Error Accuracy
Jan 2020  54497    54661            164     99.7
Feb 2020  54470    54579            109     99.8
Mar 2020  54638    54699             61     99.9
Apr 2020  54741    54938            197     99.6
May 2020  54661    54382            279     99.5
Jun 2020  54452    53989            463     99.1
Jul 2020  54319    53591            728     98.7
Aug 2020  54049    53538            511     99.1
Sep 2020  54191    53709            482     99.1
Oct 2020  54579    53841            738     98.6
Nov 2020  55308    54839            469     99.2
Dec 2020  56226    55519            707     98.7
Jan 2021  56867    56195            672     98.8
Feb 2021  56857    56106            751     98.7
Mar 2021  56997    56224            773     98.6
Apr 2021  57398    56490            908     98.4
May 2021  57140    55998           1142     98.0
Jun 2021  56682    55575           1107     98.0
Jul 2021  56504    55170           1334     97.6
Aug 2021  56171    55172            999     98.2
```

```
Sep 2021  56407    55305           1102     98.0
Oct 2021  56591    55513           1078     98.1
Nov 2021  57472    56498            974     98.3
Dec 2021  58412    57244           1168     98.0
```

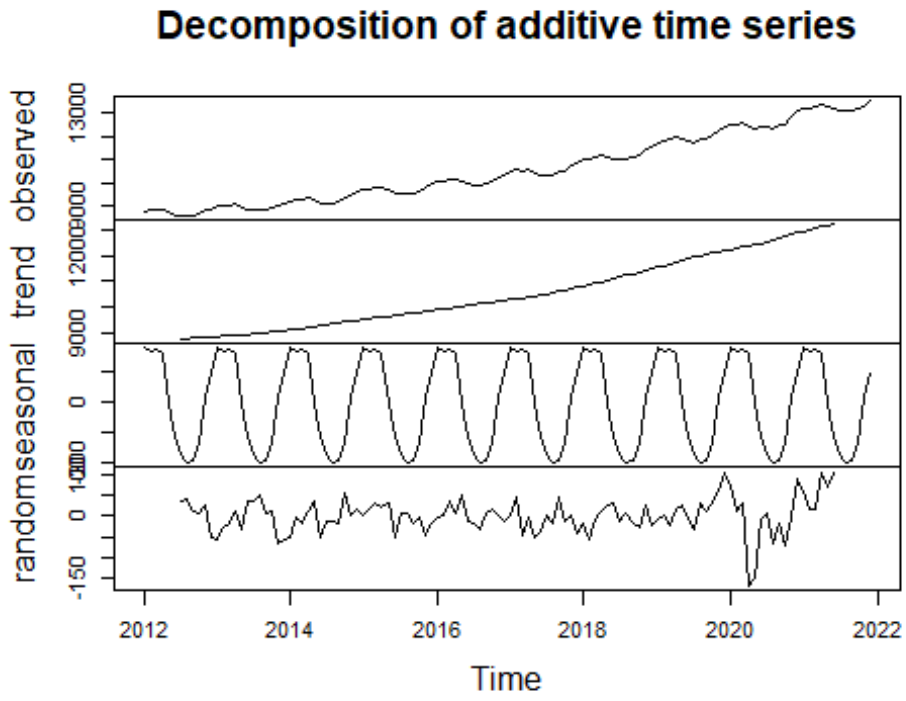
CFG Firm Transportation Service (FTS-1)

In this section we will forecast monthly client counts for FTS-1 & FTS-2. From the data given, these numbers are calculated by filtering for Tariff Schedule 'FTS-1'.

Customer Time-Series Decomposition

In this section we decompose the Residential Customer time-series using an Additive Decomposition Model. This model evaluates time-series' by extracting the Seasonal, Trending, and Random components.

Here we can clearly see a linear trend and seasonal component within the Residential customers.



ARIMA Model: Expected Accuracy

Here we evaluate model accuracy by using cross-validation and rolling forecasts throughout the time-series to determine our expected accuracy over a 24 Month period. Below we see that the ARIMA model is extremely accurate with a 1-Month Forecast Mean Absolute Error (MAE) of 37 clients, and a 24-Month Forecast MAE of 418 clients.

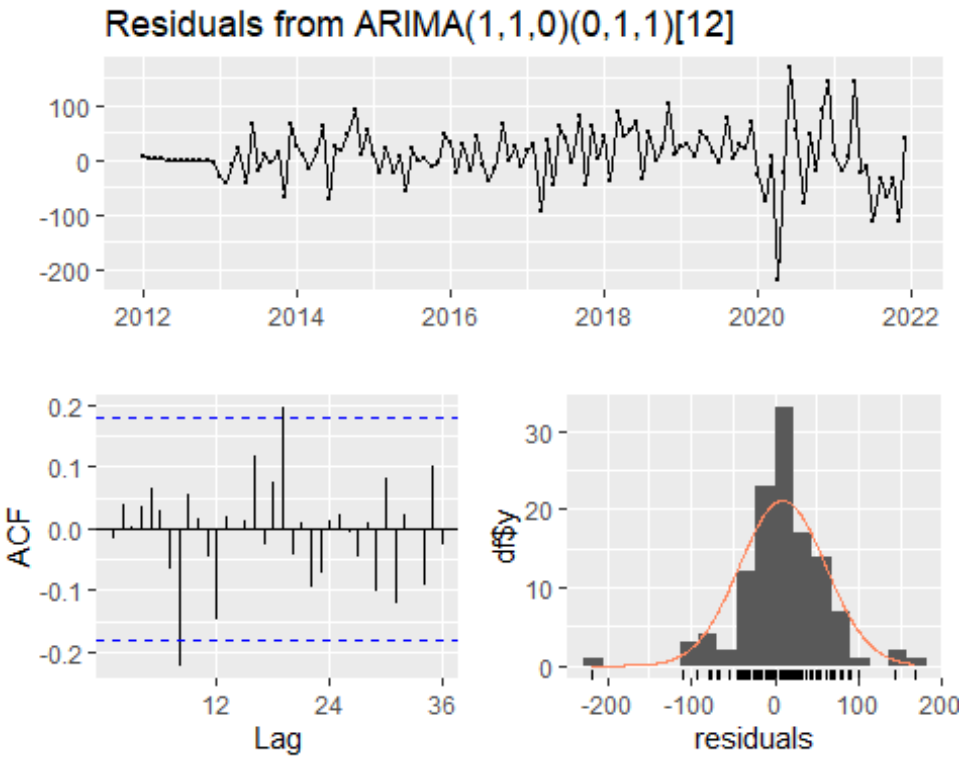
```
                      ME RMSE MAE
Forecast Horizon  1   22   46  37
Forecast Horizon  2   29   57  48
Forecast Horizon  3   45   78  64
Forecast Horizon  4   53  107  86
Forecast Horizon  5   59  132 108
Forecast Horizon  6   75  149 128
```

```
Forecast Horizon  7   86  163 145
Forecast Horizon  8   97  187 165
Forecast Horizon  9  108  203 187
Forecast Horizon  10 116  220 203
Forecast Horizon  11 127  241 223
Forecast Horizon  12 139  258 239
Forecast Horizon  13 160  277 255
Forecast Horizon  14 175  301 272
Forecast Horizon  15 193  322 286
Forecast Horizon  16 210  336 296
Forecast Horizon  17 224  355 310
Forecast Horizon  18 240  374 318
Forecast Horizon  19 252  391 321
Forecast Horizon  20 261  414 339
Forecast Horizon  21 268  434 358
Forecast Horizon  22 273  448 369
Forecast Horizon  23 276  470 396
Forecast Horizon  24 278  484 418
```

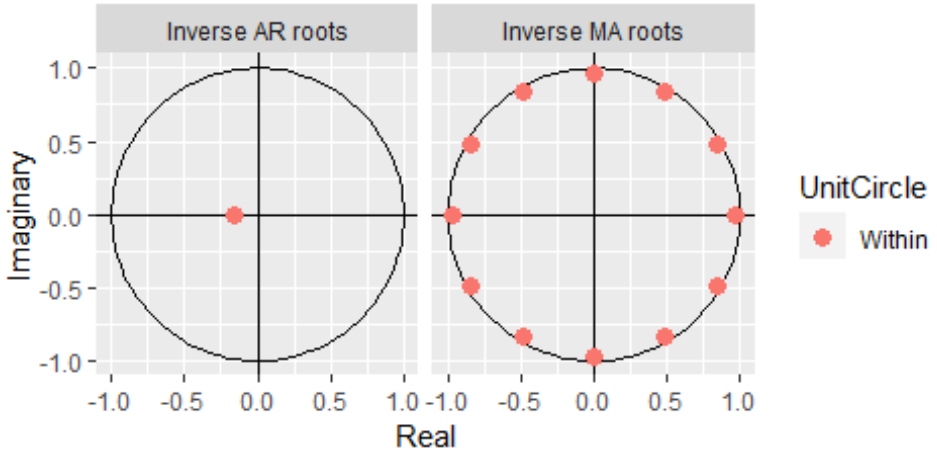
ARIMA Model: Diagnostics

Below we see that the model fails the Ljung-Box Test and therefore we can determine the data is independently distributed. In addition, we see from the graphs that the lagged values are not auto-correlated with one another, and the residuals are normally distributed. The unit circle below also showcases that we have a stationary model.

```
Series: x
ARIMA(1,1,0)(0,1,1)[12]

Coefficients:
          ar1     sma1
      -0.1614  -0.6902
s.e.   0.0966   0.0900

sigma^2 estimated as 3085:  log likelihood=-584.39
AIC=1174.77   AICc=1175.01   BIC=1182.79

Training set error measures:
                    ME     RMSE      MAE         MPE      MAPE       MASE
Training set 9.149053 51.95495 36.56615 0.08530551 0.3326049 0.07359568
                     ACF1
Training set -0.01699744
```

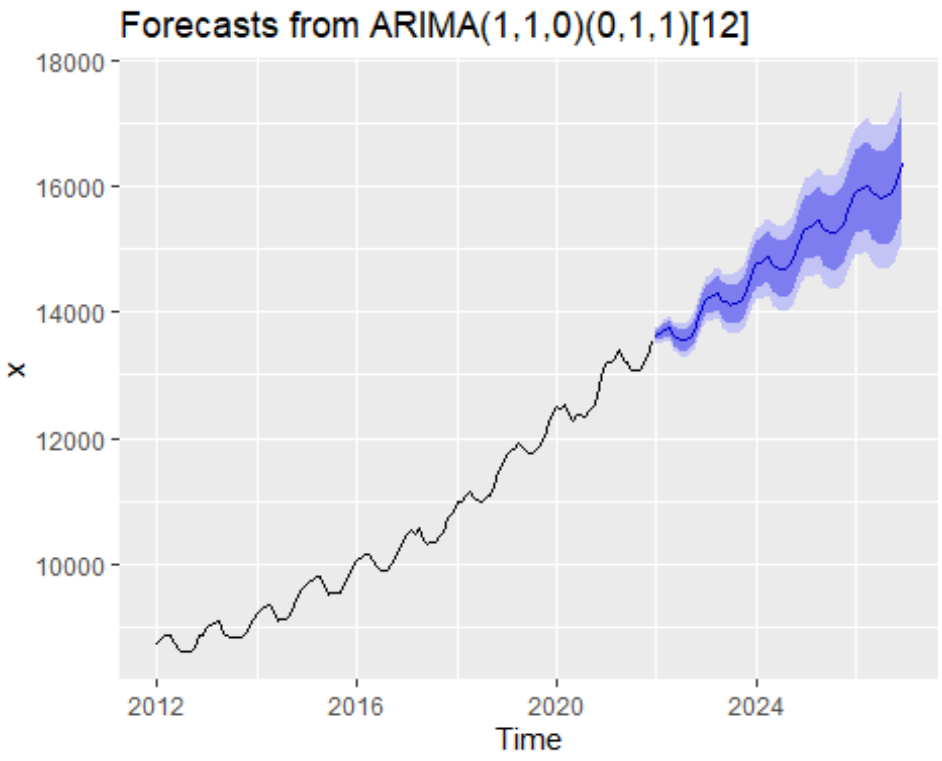



```
 Ljung-Box test

data:  Residuals from ARIMA(1,1,0)(0,1,1)[12]
Q* = 22.615, df = 22, p-value = 0.4237

Model df: 2.   Total lags used: 24
```



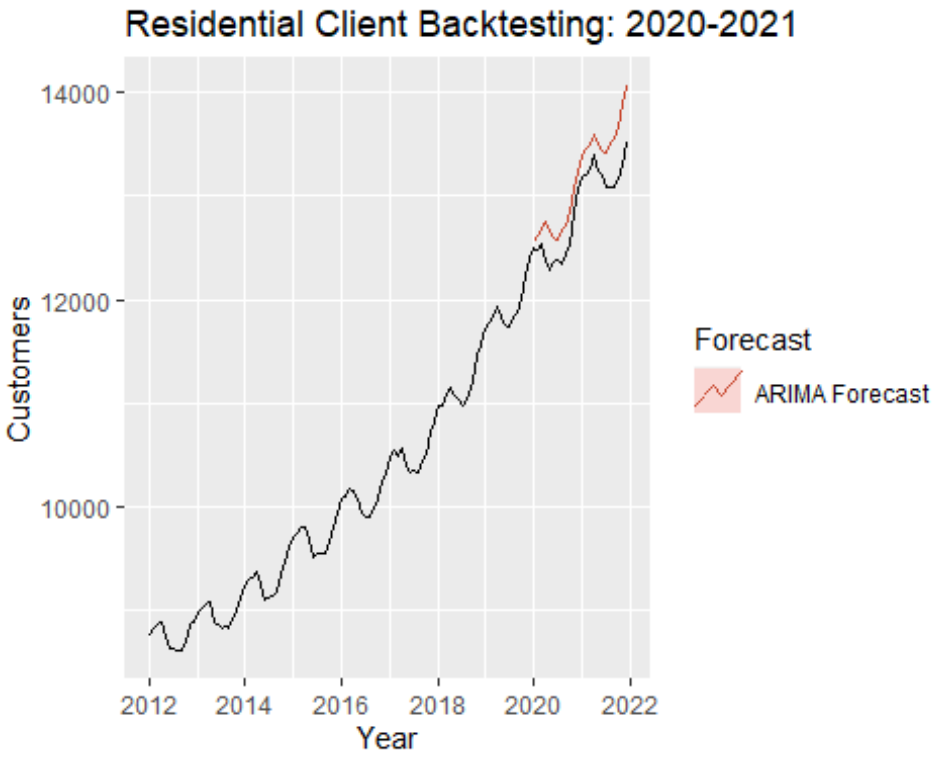
ARIMA Model: 5 Year Forecast

Below we fit & forecast 60 months into the future using an ARIMA(1,1,0)(0,1,1) model.



2020-2021 Back-Testing Evaluation

In this section we will evaluate the accuracy of our ARIMA(1,1,0)(0,1,1) model on data from January, 2020 through December 2021 by training on the previous data and forecasting the next 24months. In particular we are interested on how close the forecasted accuracy follows our cross-validated results shown previously. Also, an area of interest is how well the model performs during the 2020 pandemic.



Back-Test Results

Below we see that the model performs roughly as expected for a "normal" year of 2019, and continues to have a high degree of accuracy in 2020 and 2021.

```
[1] "Overall Mean Absolute Error: 296.83"

[1] "Overall Mean Accuracy: 97.71"

         Actual Forecast Absolute_Error Accuracy
Jan 2020  12502    12557             55     99.6
Feb 2020  12477    12620            143     98.9
Mar 2020  12543    12671            128     99.0
Apr 2020  12380    12764            384     96.9
May 2020  12279    12672            393     96.8
Jun 2020  12365    12598            233     98.1
Jul 2020  12378    12581            203     98.4
Aug 2020  12336    12675            339     97.3
Sep 2020  12449    12719            270     97.8
Oct 2020  12527    12848            321     97.4
Nov 2020  12824    13062            238     98.1
Dec 2020  13072    13228            156     98.8
Jan 2021  13193    13390            197     98.5
Feb 2021  13198    13453            255     98.1
Mar 2021  13261    13504            243     98.2
Apr 2021  13391    13597            206     98.5
May 2021  13236    13505            269     98.0
Jun 2021  13205    13431            226     98.3
Jul 2021  13090    13414            324     97.5
Aug 2021  13087    13508            421     96.8
Sep 2021  13093    13552            459     96.5
Oct 2021  13170    13681            511     96.1
```

```
Nov 2021   13294    13895            601      95.5
Dec 2021   13512    14061            549      95.9
```

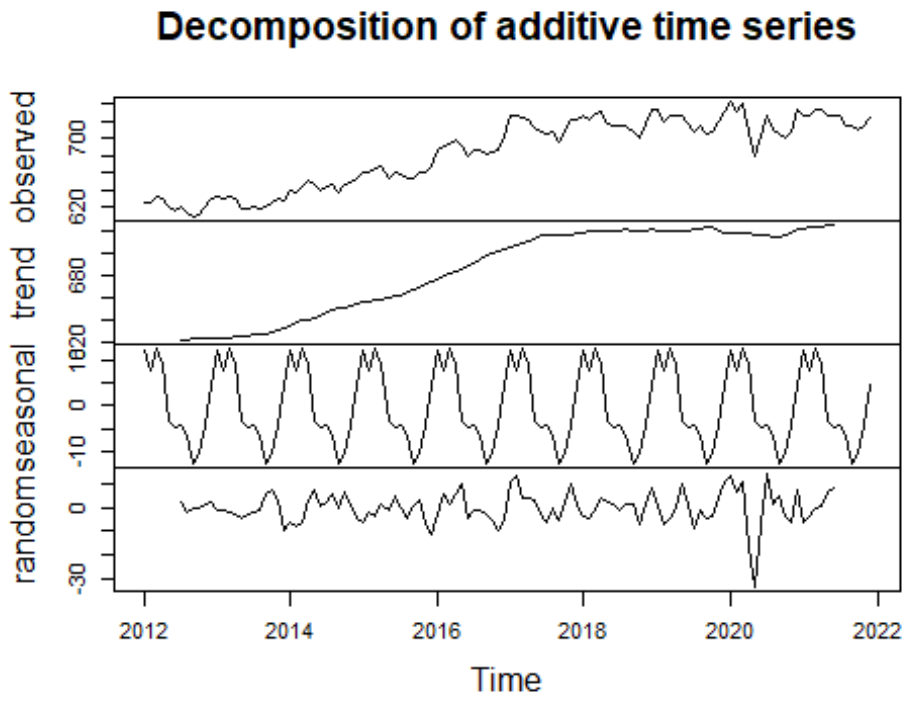
CFG Firm Transportation Service (FTS-2)

In this section we will forecast monthly client counts for FTS-2. From the data given, these numbers are calculated by filtering for Tariff Schedule 'FTS-2'.

Customer Time-Series Decomposition

In this section we decompose the Residential Customer time-series using an Additive Decomposition Model. This model evaluates time-series' by extracting the Seasonal, Trending, and Random components.

Here we can clearly see a linear trend and seasonal component within the Residential customers.



ARIMA Model: Expected Accuracy

Here we evaluate model accuracy by using cross-validation and rolling forecasts throughout the time-series to determine our expected accuracy over a 24 Month period. Below we see that the ARIMA model is extremely accurate with a 1-Month Forecast Mean Absolute Error (MAE) of 137 clients, and a 24-Month Forecast MAE of 1,383 clients.

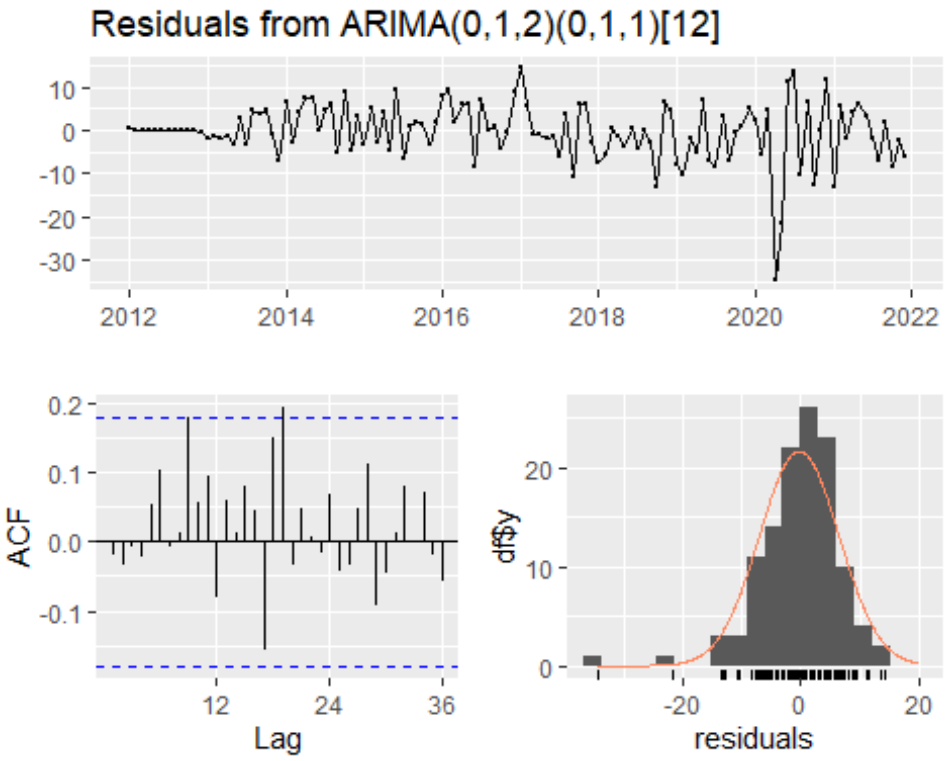
```
                      ME RMSE MAE
Forecast Horizon  1   -2    8   7
Forecast Horizon  2   -4   11   9
Forecast Horizon  3   -6   12   9
Forecast Horizon  4   -8   13  11
Forecast Horizon  5  -11   16  13
Forecast Horizon  6  -13   18  14
Forecast Horizon  7  -14   19  15
Forecast Horizon  8  -15   20  16
```

```
Forecast Horizon  9  -16   20  17
Forecast Horizon  10 -18   21  19
Forecast Horizon  11 -19   24  21
Forecast Horizon  12 -20   25  22
Forecast Horizon  13 -23   26  23
Forecast Horizon  14 -25   28  25
Forecast Horizon  15 -26   30  27
Forecast Horizon  16 -28   32  28
Forecast Horizon  17 -29   34  30
Forecast Horizon  18 -30   34  30
Forecast Horizon  19 -31   34  31
Forecast Horizon  20 -32   37  32
Forecast Horizon  21 -33   38  33
Forecast Horizon  22 -34   40  35
Forecast Horizon  23 -35   41  36
Forecast Horizon  24 -37   42  37
```

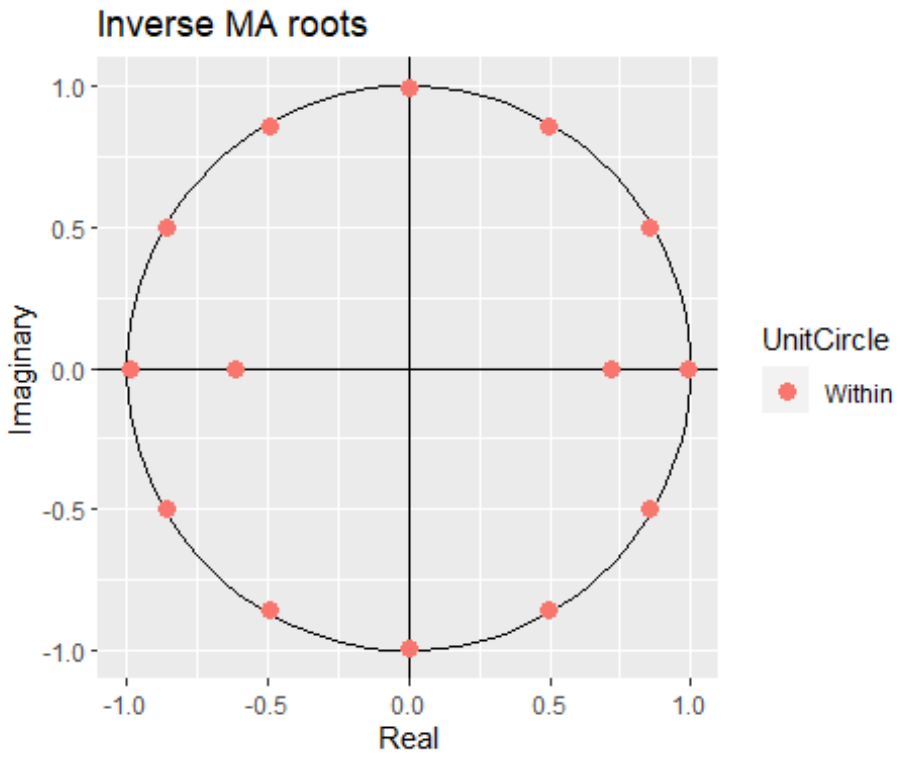
ARIMA Model: Diagnostics

Below we see that the model fails the Ljung-Box Test and therefore we can determine the data is independently distributed. In addition, we see from the graphs that the lagged values are not auto-correlated with one another, and the residuals are normally distributed. The unit circle below also showcases that we have a stationary model.

```
Series: x
ARIMA(0,1,2)(0,1,1)[12]

Coefficients:
          ma1      ma2     sma1
      -0.1005  -0.4440  -0.8859
s.e.   0.0880   0.0823   0.1913

sigma^2 estimated as 52.4:  log likelihood=-370.96
AIC=749.92   AICc=750.32   BIC=760.62

Training set error measures:
                     ME     RMSE      MAE        MPE      MAPE      MASE
Training set -0.3033455 6.739131 4.817316 -0.0411651 0.6946601 0.3261882
                    ACF1
Training set -0.02026396
```

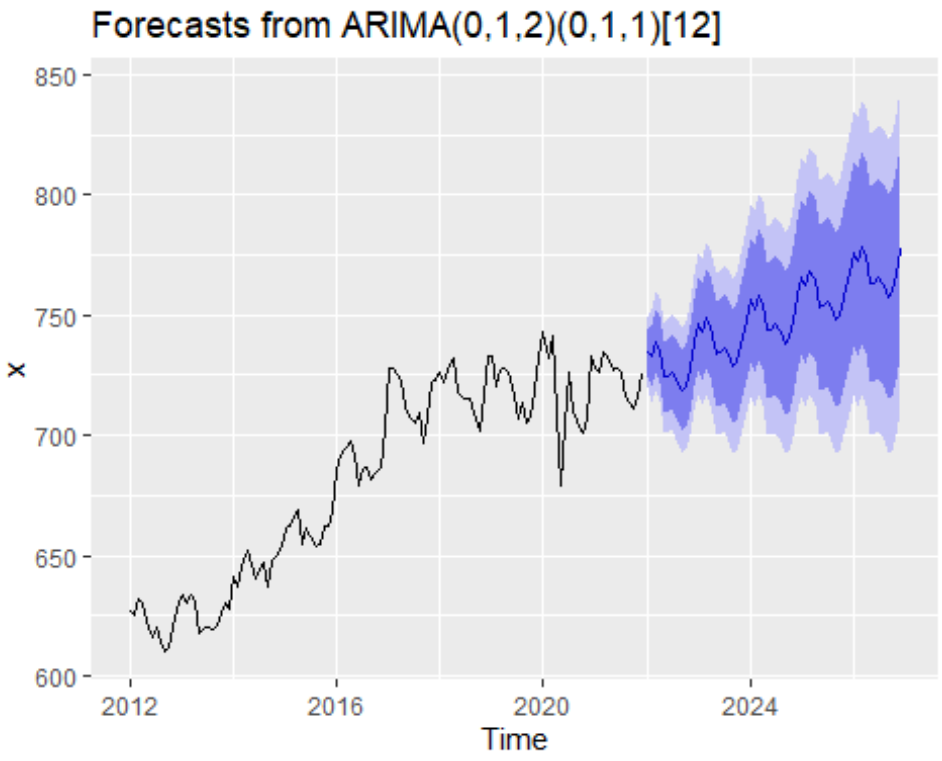



```
 Ljung-Box test

data:  Residuals from ARIMA(0,1,2)(0,1,1)[12]
Q* = 23.715, df = 21, p-value = 0.3071

Model df: 3.   Total lags used: 24
```



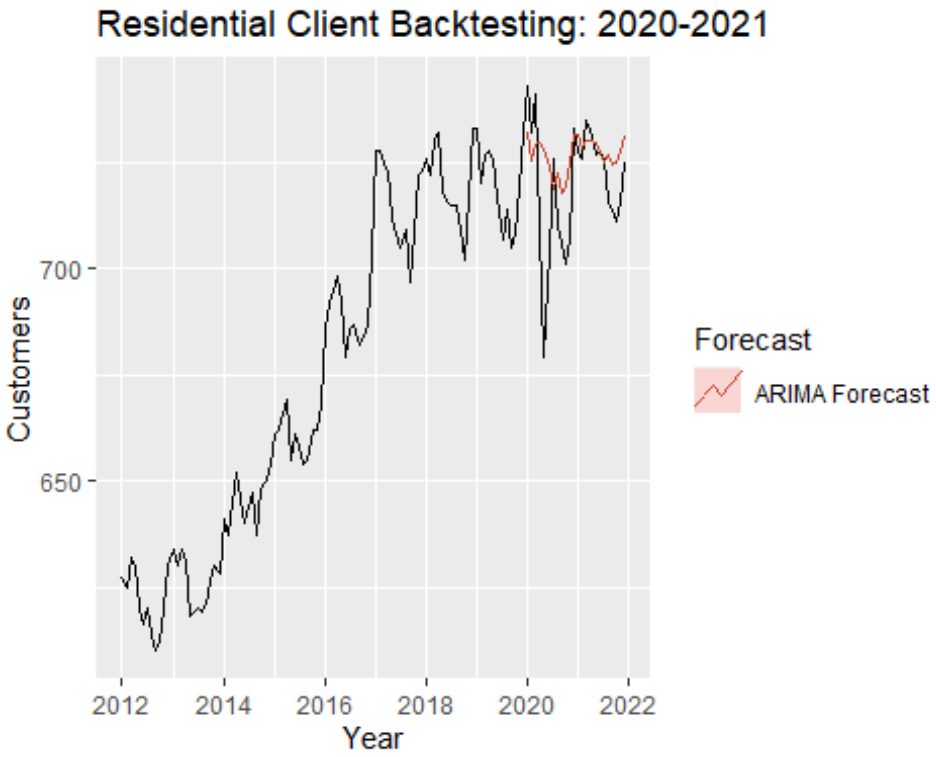
ARIMA Model: 5 Year Forecast

Below we fit & forecast 60 months into the future using an ARIMA(0,1,2)(0,1,1) model.



2020-2021 Back-Testing Evaluation

In this section we will evaluate the accuracy of our ARIMA(0,1,2)(0,1,1) model on data from January, 2020 through December 2021 by training on the previous data and forecasting the next 24months. In particular we are interested on how close the forecasted accuracy follows our cross-validated results shown previously. Also, an area of interest is how well the model performs during the 2020 pandemic.



Back-Test Results

Below we see that the model performs roughly as expected for a "normal" year of 2019, and continues to have a high degree of accuracy in 2020 and 2021.

```
[1] "Overall Mean Absolute Error: 10.79"

[1] "Overall Mean Accuracy: 98.48"

         Actual Forecast Absolute_Error Accuracy
Jan 2020    743      732              11     98.5
Feb 2020    732      725               7     99.0
Mar 2020    741      729              12     98.4
Apr 2020    709      729              20     97.2
May 2020    679      728              49     92.8
Jun 2020    704      724              20     97.2
Jul 2020    726      719               7     99.0
Aug 2020    710      722              12     98.3
Sep 2020    706      718              12     98.3
Oct 2020    701      719              18     97.4
Nov 2020    707      725              18     97.5
Dec 2020    733      731               2     99.7
Jan 2021    728      731               3     99.6
Feb 2021    726      728               2     99.7
Mar 2021    735      730               5     99.3
Apr 2021    733      730               3     99.6
May 2021    727      730               3     99.6
Jun 2021    728      727               1     99.9
Jul 2021    726      725               1     99.9
Aug 2021    716      727              11     98.5
Sep 2021    714      724              10     98.6
Oct 2021    711      725              14     98.0
```

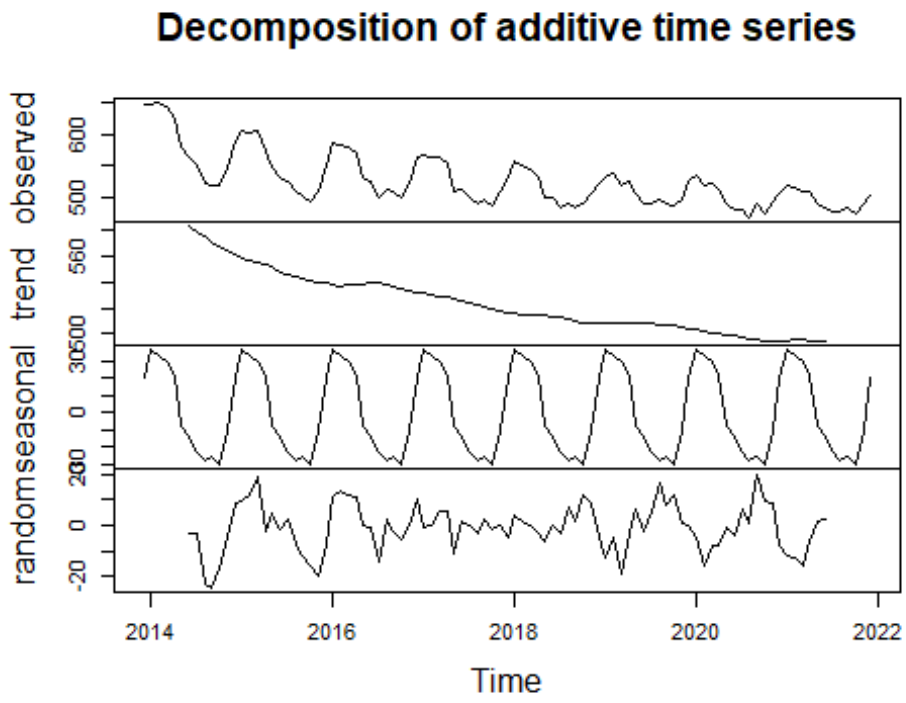
```
Nov 2021    716      728              12     98.3
Dec 2021    725      731               6     99.2
```

Ft. Meade Residential Service (FT-RS)

In this section we will forecast monthly client counts for FT-RS. From the data given, these numbers are calculated by filtering for Rate Class 22.

Customer Time-Series Decomposition

Here we see a downward sloping trend line for FT-RS. This tells us that this rate is gradually losing customers every month/year. This rate is also unique in that it begins in December 2013, whereas the previous rates have start dates in January 2012.



ARIMA Model: Expected Accuracy

Here we evaluate model accuracy by using cross-validation and rolling forecasts throughout the time-series to determine our expected accuracy over a 12 Month period.

Below we see that the ARIMA model is consistently accurate with a 1-Month Forecast MAE of 10, and a 12-Month Forecast MAE of 8.

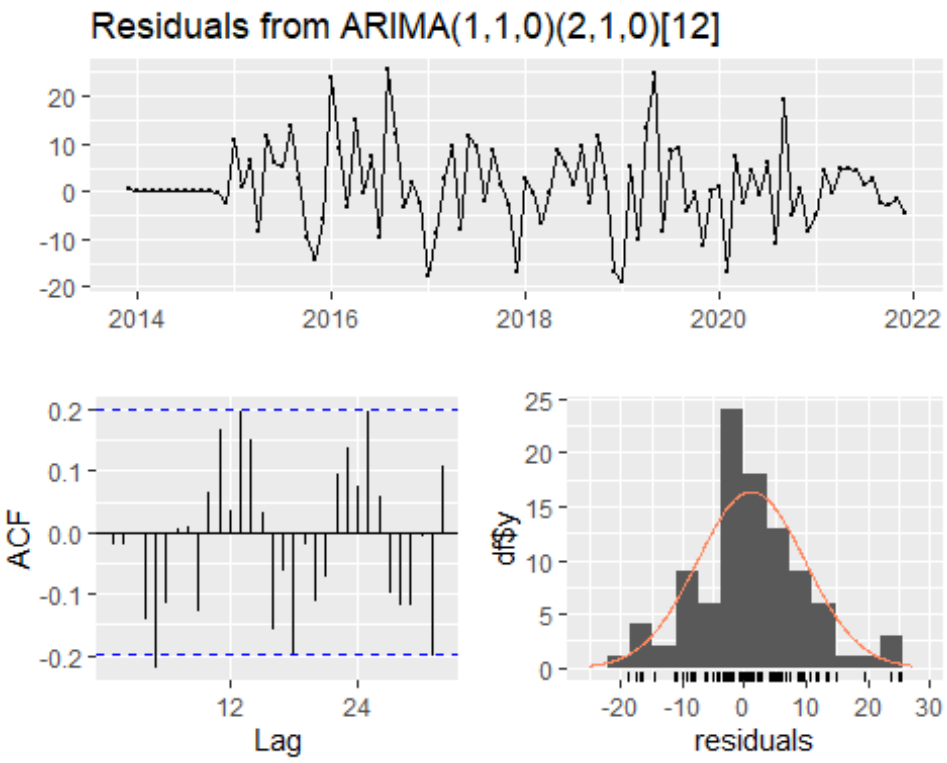
```
                      ME RMSE MAE
Forecast Horizon  1    2   11  10
Forecast Horizon  2    4   12   9
Forecast Horizon  3    5   12  10
Forecast Horizon  4    5   14  10
Forecast Horizon  5    6   12  10
Forecast Horizon  6    7   12   9
Forecast Horizon  7    7   12   9
Forecast Horizon  8    8   12  10
```

```
Forecast Horizon  9   7   11   9
Forecast Horizon  10  7   10   9
Forecast Horizon  11  7    9   8
Forecast Horizon  12  6   10   8
```

ARIMA Model: Diagnostics

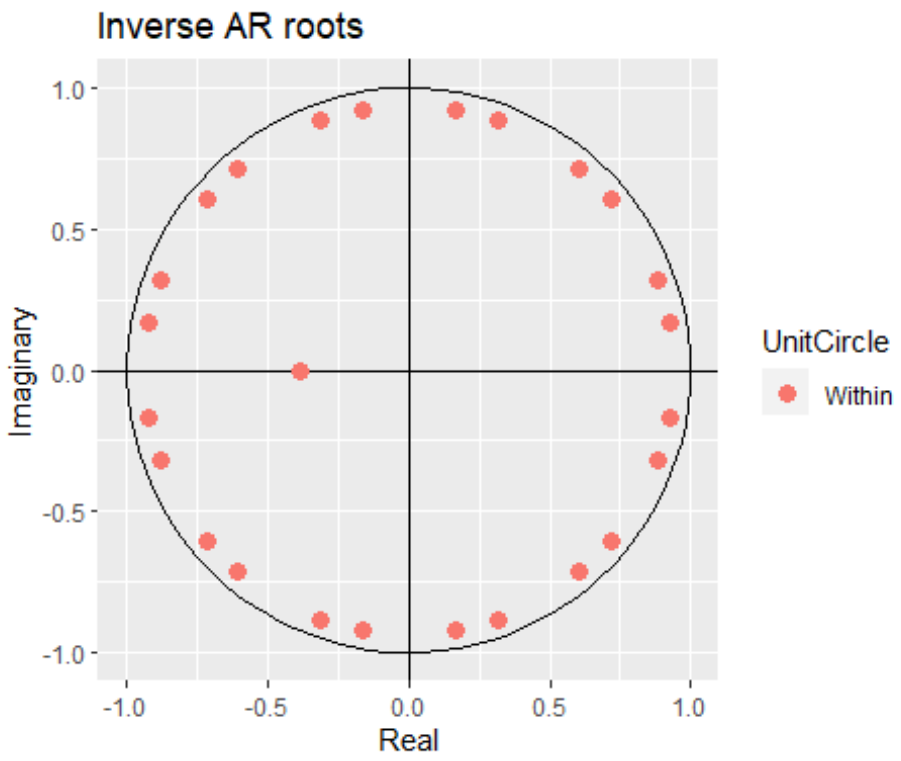
Below we see that the model fails the Ljung-Box Test and therefore we can determine the data is independently distributed. In addition, we see from the graphs that the lagged values are not auto-correlated with one another, and the residuals are normally distributed. The unit circle below also showcases that we have a stationary model.

```
Series: x
ARIMA(1,1,0)(2,1,0)[12]

Coefficients:
          ar1     sar1     sar2
      -0.3859  -0.4995  -0.2140
s.e.   0.1076   0.1161   0.1327

sigma^2 estimated as 91.68:  log likelihood=-309.16
AIC=626.32   AICc=626.83   BIC=636.04

Training set error measures:
                    ME     RMSE      MAE       MPE     MAPE     MASE         ACF1
Training set 1.075394 8.749893 6.358353 0.2036659 1.222169 0.433756 -0.01967509
```



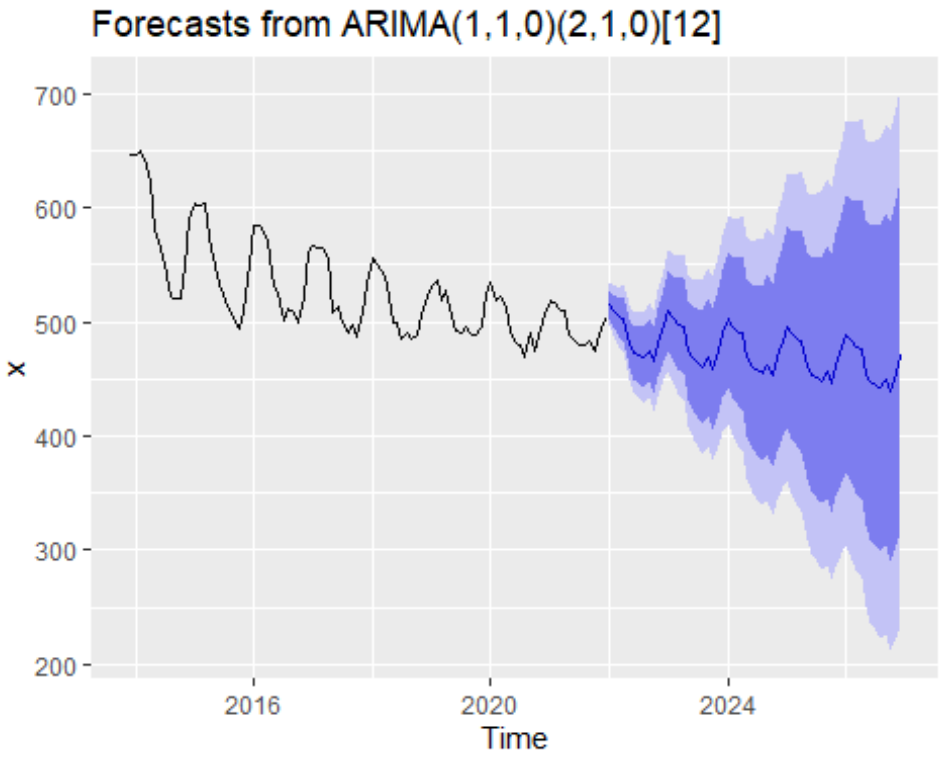

```
 Ljung-Box test

data:  Residuals from ARIMA(1,1,0)(2,1,0)[12]
Q* = 29.8, df = 16, p-value = 0.01907
```

```
Model df: 3.   Total lags used: 19
```



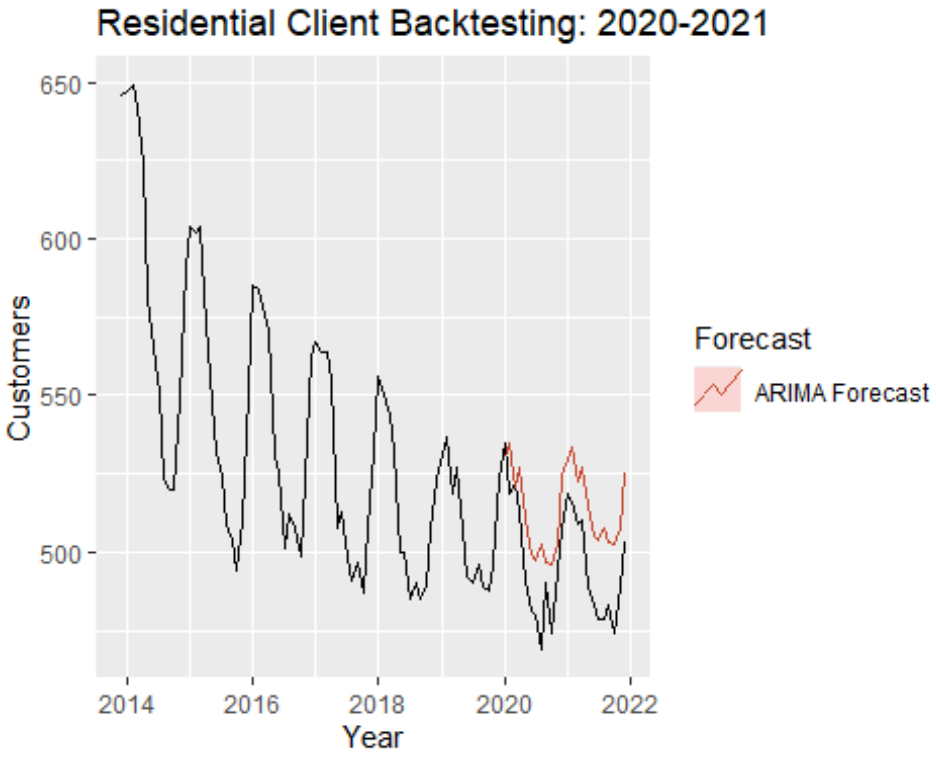
ARIMA Model: 5 Year Forecast

Below we fit & forecast 60 months into the future using an ARIMA(1,1,0)(2,1,0)model.



2020-2021 Back-Testing Evaluation

In this section we will evaluate the accuracy of our ARIMA(1,1,0)(2,1,0)model on data from January, 2020 through December 2021 by training on the previous data and forecasting the next 24months. In particular we are interested on how close the forecasted accuracy follows our cross-validated results shown previously. Also, an area of interest is how well the model performs during the 2020 pandemic.



Back-Test Results

Below we see that the model performs roughly as expected for a "normal" year of 2019, and continues to have a high degree of accuracy in 2020 and 2021.

```
[1] "Overall Mean Absolute Error: 17.96"

[1] "Overall Mean Accuracy: 96.34"

         Actual Forecast Absolute_Error Accuracy
Jan 2020    535      530              5     99.1
Feb 2020    519      535             16     96.9
Mar 2020    522      521              1     99.8
Apr 2020    513      527             14     97.3
May 2020    491      511             20     95.9
Jun 2020    481      499             18     96.3
Jul 2020    480      498             18     96.2
Aug 2020    469      502             33     93.0
Sep 2020    490      497              7     98.6
Oct 2020    474      496             22     95.4
Nov 2020    494      502              8     98.4
Dec 2020    507      525             18     96.4
Jan 2021    519      530             11     97.9
Feb 2021    516      534             18     96.5
Mar 2021    509      522             13     97.4
Apr 2021    510      527             17     96.7
```

May 2021	489	515	26	94.7
Jun 2021	483	505	22	95.4
Jul 2021	479	504	25	94.8
Aug 2021	479	508	29	93.9
Sep 2021	483	503	20	95.9
Oct 2021	474	503	29	93.9
Nov 2021	489	508	19	96.1
Dec 2021	503	525	22	95.6

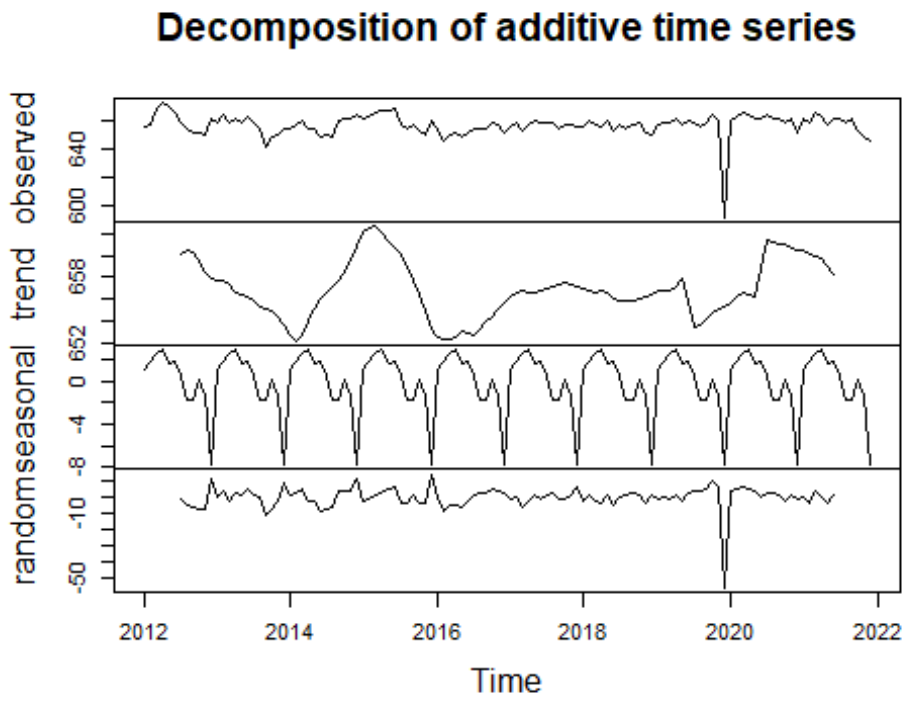
Indiantown Transportation Service 1 (IGC-TS1)

In this section we will forecast monthly client counts for IGC-TS1. From the data given, these numbers are calculated by filtering for Tariff Schedule 'TS-1' or Rate Class I0.

Customer Time-Series Decomposition

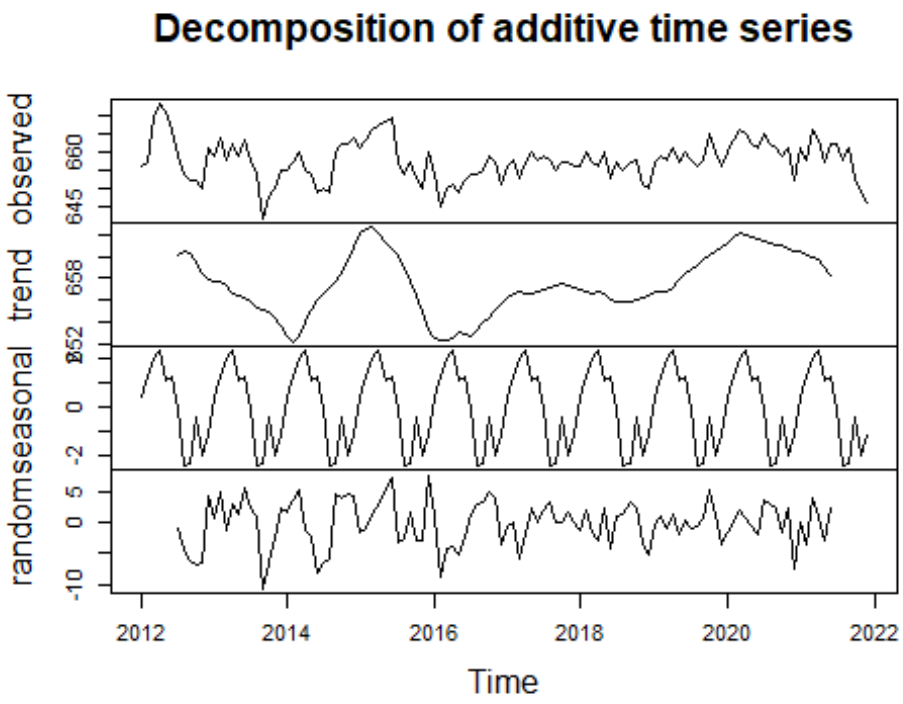
In the time-series decomposition below we see that there is a large drop off in customers for December 2019. This is likely due to an error when inputting the data. Therefore, we will calculate the average customers from the previous years in December and input this new value for December 2019. Another explanation may be due to the Covid-19 pandemic. However, this was ruled out since there was no significant drop in volume usage during this time.

Considering there is not much a trend this process is perfectly reasonable in order to generate a proper forecasting model.



New Time Series Decomposition

See below the updated time series decomposition by inputting 656 as the new value for December 2019.



ARIMA Model: Expected Accuracy

Here we evaluate model accuracy by using cross-validation and rolling forecasts throughout the time-series to determine our expected accuracy over a 12 Month period.

Below we see that the ARIMA model is consistently accurate with a 1-Month Forecast MAE of 2, and a 12-Month Forecast MAE of 4.

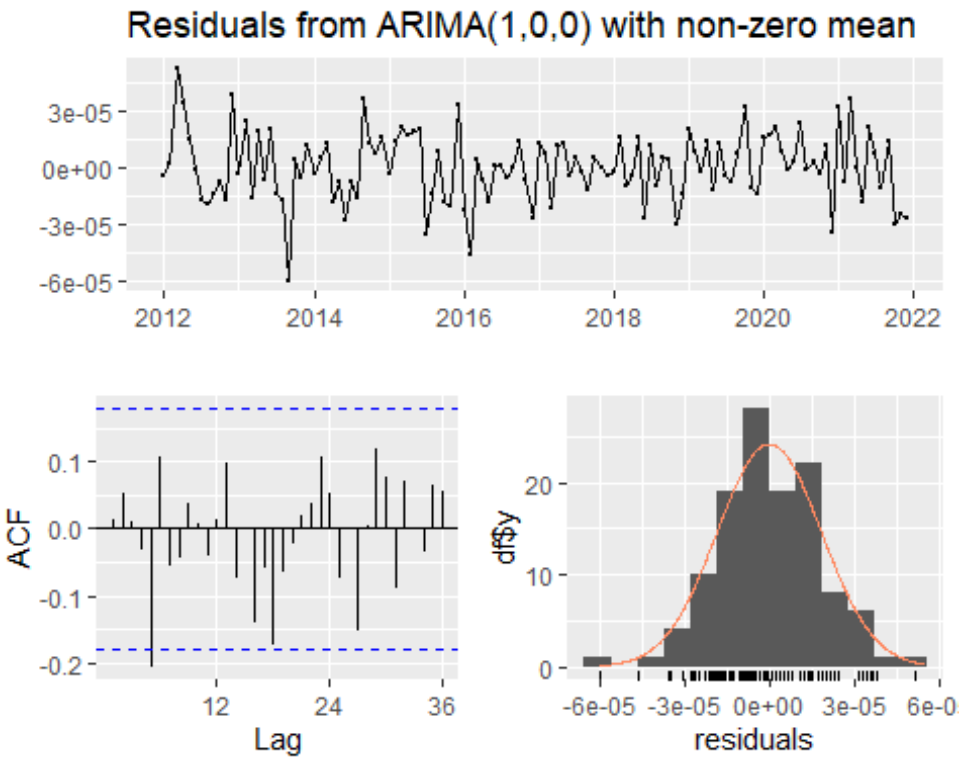
		ME	RMSE	MAE
Forecast Horizon	1	0	3	2
Forecast Horizon	2	1	3	2
Forecast Horizon	3	1	3	2
Forecast Horizon	4	1	4	3
Forecast Horizon	5	2	4	3
Forecast Horizon	6	2	4	3
Forecast Horizon	7	2	4	3
Forecast Horizon	8	2	4	3
Forecast Horizon	9	2	4	3
Forecast Horizon	10	2	4	3
Forecast Horizon	11	2	4	3
Forecast Horizon	12	2	4	3
Forecast Horizon	13	2	4	3
Forecast Horizon	14	2	4	4
Forecast Horizon	15	2	5	4
Forecast Horizon	16	3	5	4
Forecast Horizon	17	3	5	4
Forecast Horizon	18	3	5	4
Forecast Horizon	19	3	5	4
Forecast Horizon	20	3	5	4
Forecast Horizon	21	3	5	4
Forecast Horizon	22	3	5	4

```
Forecast Horizon  23  3    5   4
Forecast Horizon  24  3    5   4
```

ARIMA Model: Diagnostics

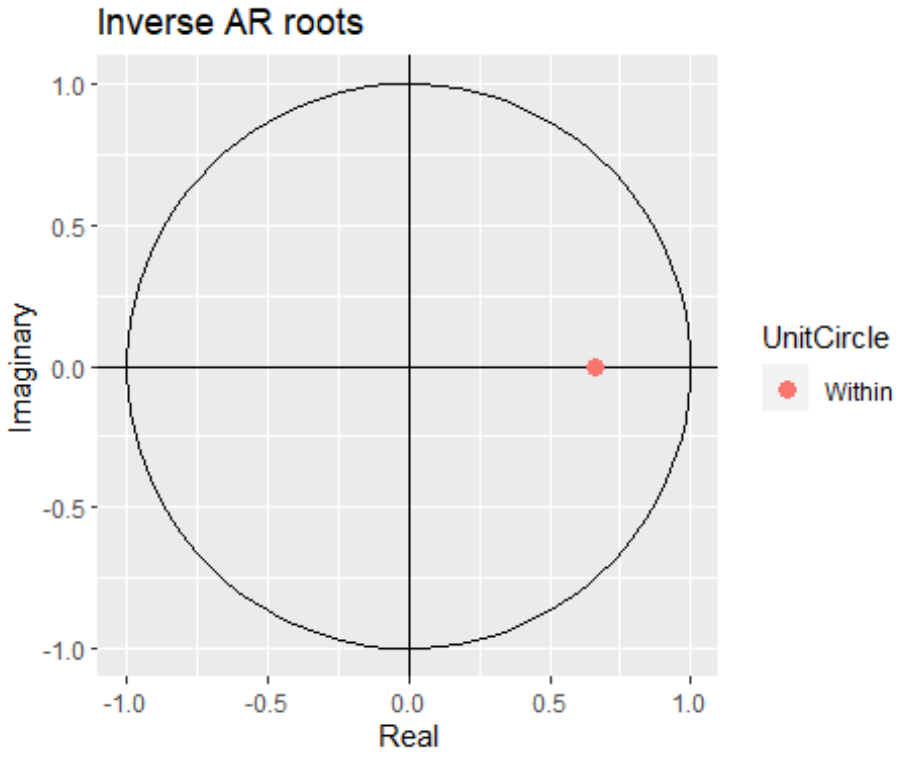
Below we see that the model fails the Ljung-Box Test and therefore we can determine the data is independently distributed. In addition, we see from the graphs that the lagged values are not auto-correlated with one another, and the residuals are normally distributed. The unit circle below also showcases that we have a stationary model.

```
Series: x
ARIMA(1,0,0) with non-zero mean
Box Cox transformation: lambda= -0.8999268

Coefficients:
         ar1    mean
      0.6608  1.1080
s.e.  0.0832  0.0001

sigma^2 estimated as 3.408e-10:  log likelihood=1138.43
AIC=-2270.87   AICc=-2270.66   BIC=-2262.51

Training set error measures:
                     ME     RMSE      MAE          MPE      MAPE      MASE
Training set 0.03556933 4.129816 3.268033 0.001432838 0.4970279 0.5638139
                    ACF1
Training set 0.01538297
```



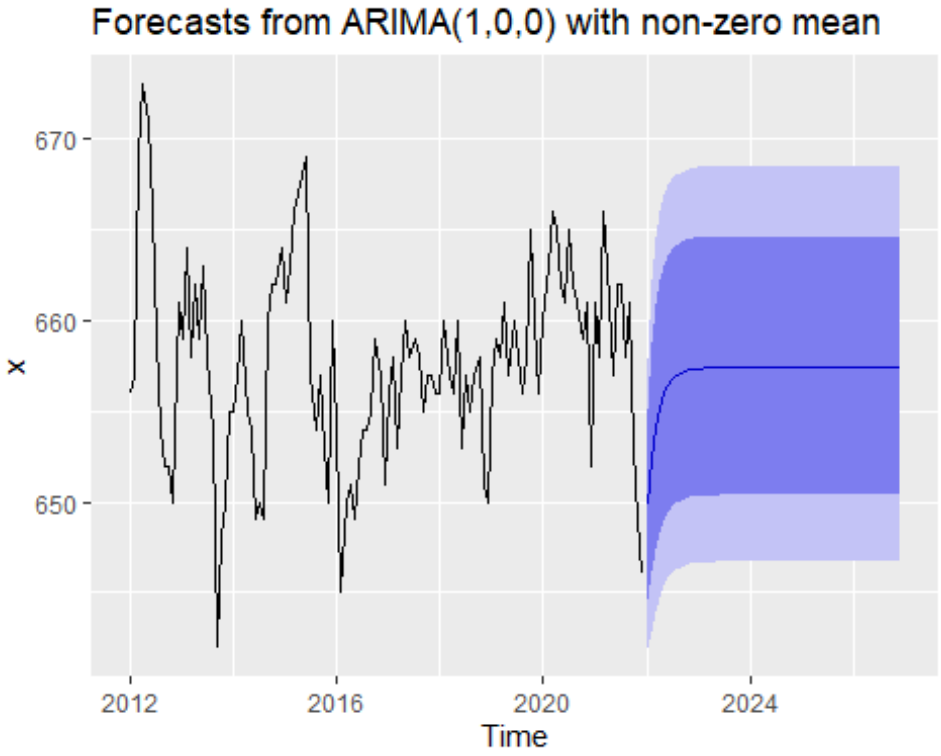

```
 Ljung-Box test

data:  Residuals from ARIMA(1,0,0) with non-zero mean
```

```
Q* = 21.135, df = 22, p-value = 0.5124

Model df: 2.   Total lags used: 24
```

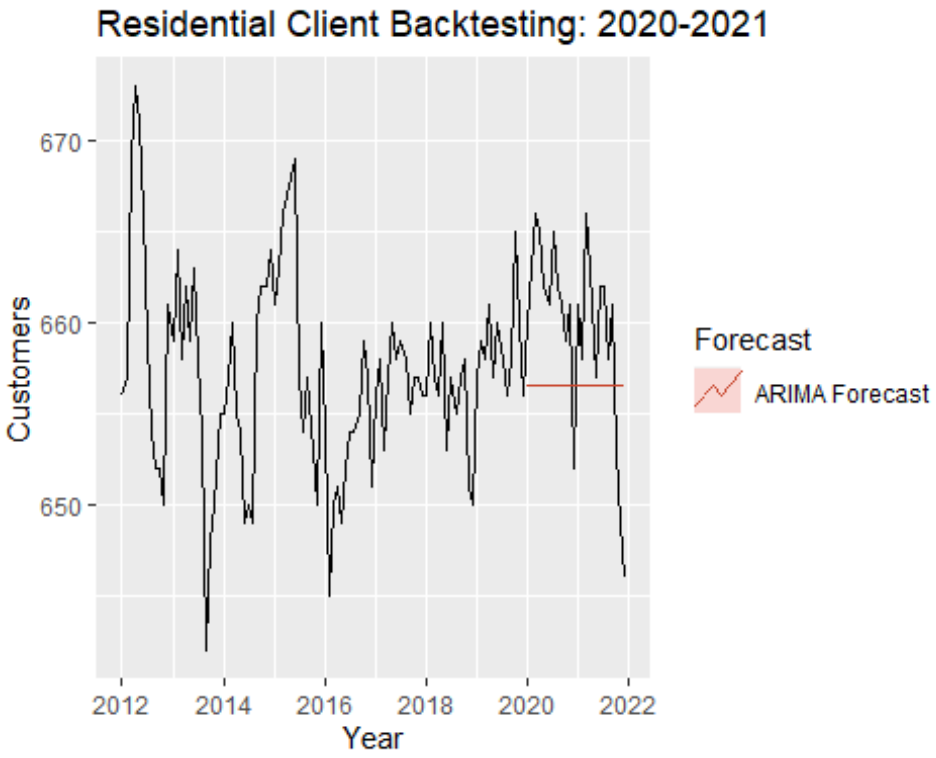


ARIMA Model: 5 Year Forecast

Below we fit & forecast 60 months into the future using an ARIMA(1,0,0) model.



2020-2021 Back-Testing Evaluation



Backtest Results

Below we see that the model performs roughly as expected for a "normal" year of 2019, and continues to have a high degree of accuracy in 2020 and 2021 that never dips below 98%.

```
[1] "Overall Mean Absolute Error: 5.04"

[1] "Overall Mean Accuracy: 99.22"

         Actual Forecast Absolute_Error Accuracy
Jan 2020    660      657              3     99.5
Feb 2020    663      657              6     99.1
Mar 2020    666      657              9     98.6
Apr 2020    665      657              8     98.8
May 2020    662      657              5     99.2
Jun 2020    661      657              4     99.4
Jul 2020    665      657              8     98.8
Aug 2020    662      657              5     99.2
Sep 2020    661      657              4     99.4
Oct 2020    659      657              2     99.7
Nov 2020    661      657              4     99.4
Dec 2020    652      657              5     99.2
Jan 2021    661      657              4     99.4
Feb 2021    658      657              1     99.8
Mar 2021    666      657              9     98.6
Apr 2021    663      657              6     99.1
May 2021    657      657              0    100.0
Jun 2021    662      657              5     99.2
Jul 2021    662      657              5     99.2
Aug 2021    658      657              1     99.8
Sep 2021    661      657              4     99.4
```

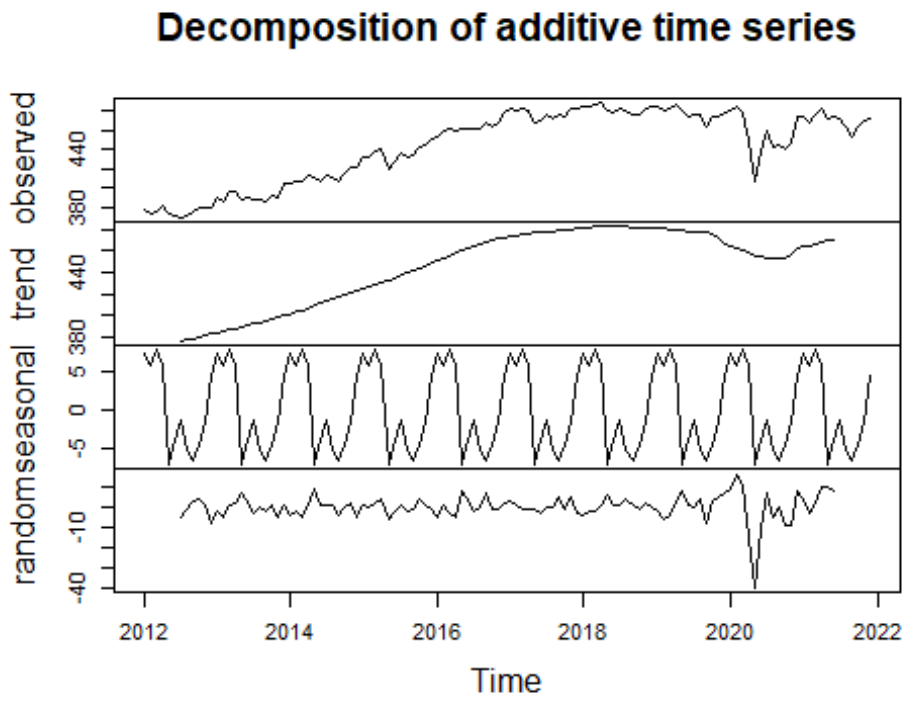
```
Oct 2021    653      657              4     99.4
Nov 2021    649      657              8     98.8
Dec 2021    646      657             11     98.3
```

CFG Firm Transportation Service 2.1 (FTS-2.1)

In this section we will forecast monthly client counts for FTS-2.1. From the data given, these numbers are calculated by filtering for Tariff Schedule 'FTS21'.

Customer Time-Series Decomposition

Below we have the time-series decomposition where we can see a linear upward trend with a large decrease at the start of 2020. Likely due to COVID-19.



ARIMA Model: Expected Accuracy

Here we evaluate model accuracy by using cross-validation and rolling forecasts throughout the time-series to determine our expected accuracy over a 24 Month period.

Below we see that the ARIMA model is consistently accurate with a 1-Month Forecast MAE of 4, and a 24-Month Forecast MAE of 38. It's worth noting that the Mean Error (ME) is also consistently negative, meaning the models over-predict the actual values.

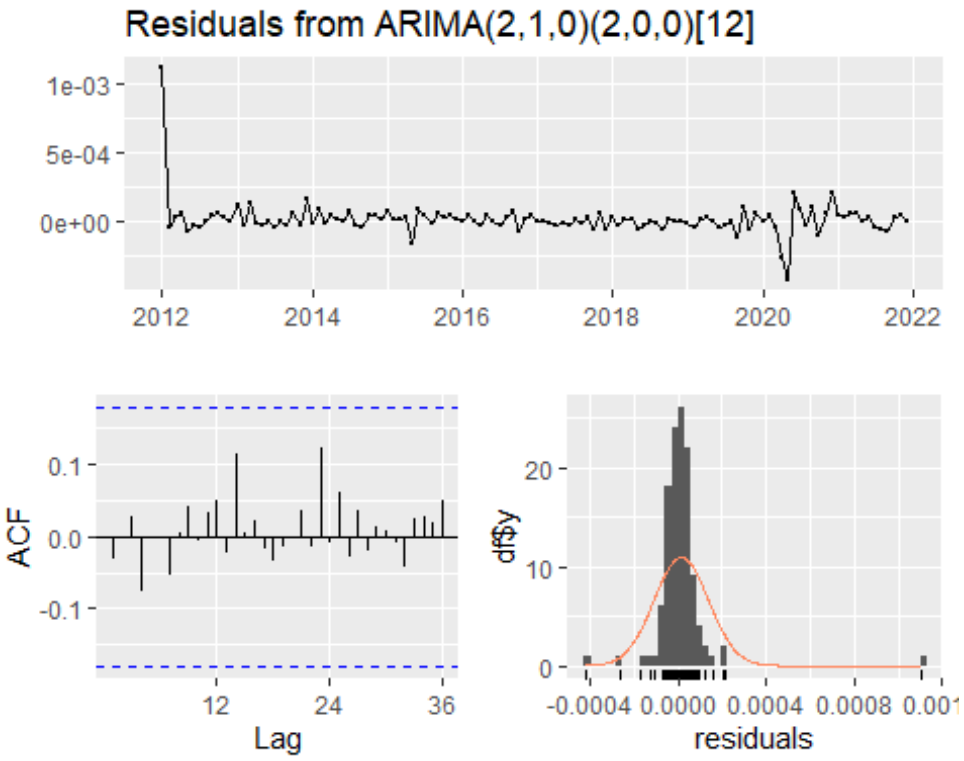
```
                     ME RMSE MAE
Forecast Horizon  1   -3    6   4
Forecast Horizon  2   -4    7   5
Forecast Horizon  3   -5    8   7
Forecast Horizon  4   -7   11   9
Forecast Horizon  5  -11   16  11
Forecast Horizon  6  -13   17  13
Forecast Horizon  7  -14   18  14
```

```
Forecast Horizon  8  -16   19  16
Forecast Horizon  9  -17   21  18
Forecast Horizon  10 -20   24  20
Forecast Horizon  11 -21   26  22
Forecast Horizon  12 -22   27  23
Forecast Horizon  13 -25   29  25
Forecast Horizon  14 -26   30  26
Forecast Horizon  15 -27   31  28
Forecast Horizon  16 -28   32  29
Forecast Horizon  17 -30   34  30
Forecast Horizon  18 -30   36  32
Forecast Horizon  19 -32   37  33
Forecast Horizon  20 -33   39  34
Forecast Horizon  21 -34   40  35
Forecast Horizon  22 -35   41  36
Forecast Horizon  23 -36   43  37
Forecast Horizon  24 -37   45  38
```

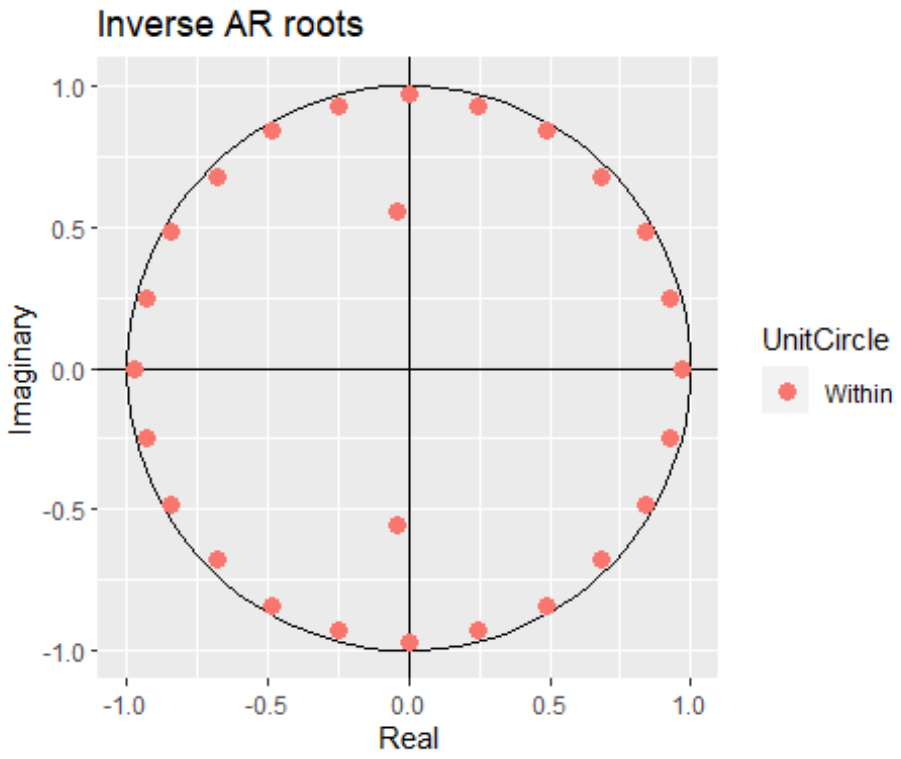
ARIMA Model: Diagnostics

Below we see that the model fails the Ljung-Box Test and therefore we can determine the data is independently distributed. In addition, we see from the graphs that the lagged values are not auto-correlated with one another, and the residuals are normally distributed. The unit circle below also showcases that we have a stationary model.

```
Series: x
ARIMA(2,1,0)(2,0,0)[12]
Box Cox transformation: lambda= -0.8999268

Coefficients:
          ar1      ar2    sar1    sar2
      -0.0892  -0.3118  0.0861  0.4350
s.e.   0.0884   0.0866  0.0807  0.1161

sigma^2 estimated as 1.608e-08:  log likelihood=962.66
AIC=-1915.32   AICc=-1914.79   BIC=-1901.43

Training set error measures:
                     ME     RMSE      MAE       MPE     MAPE      MASE
Training set 0.9673298 9.977111 5.503513 0.2398763 1.270684 0.3151535
                     ACF1
Training set -0.008770986
```

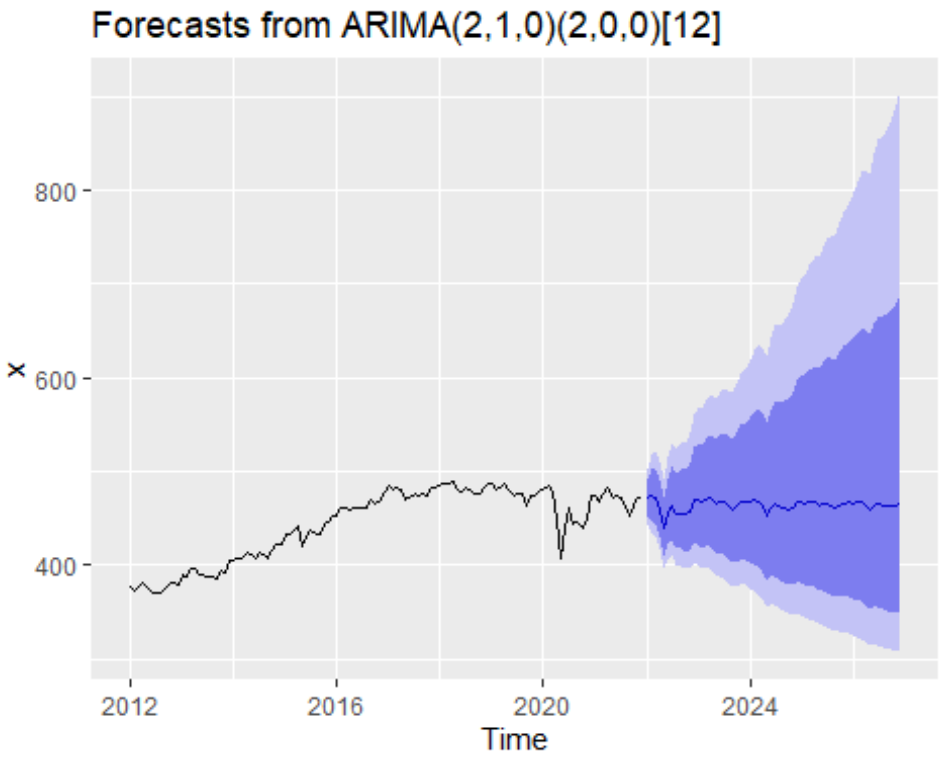



```
 Ljung-Box test

data:  Residuals from ARIMA(2,1,0)(2,0,0)[12]
Q* = 6.8096, df = 20, p-value = 0.9973

Model df: 4.   Total lags used: 24
```



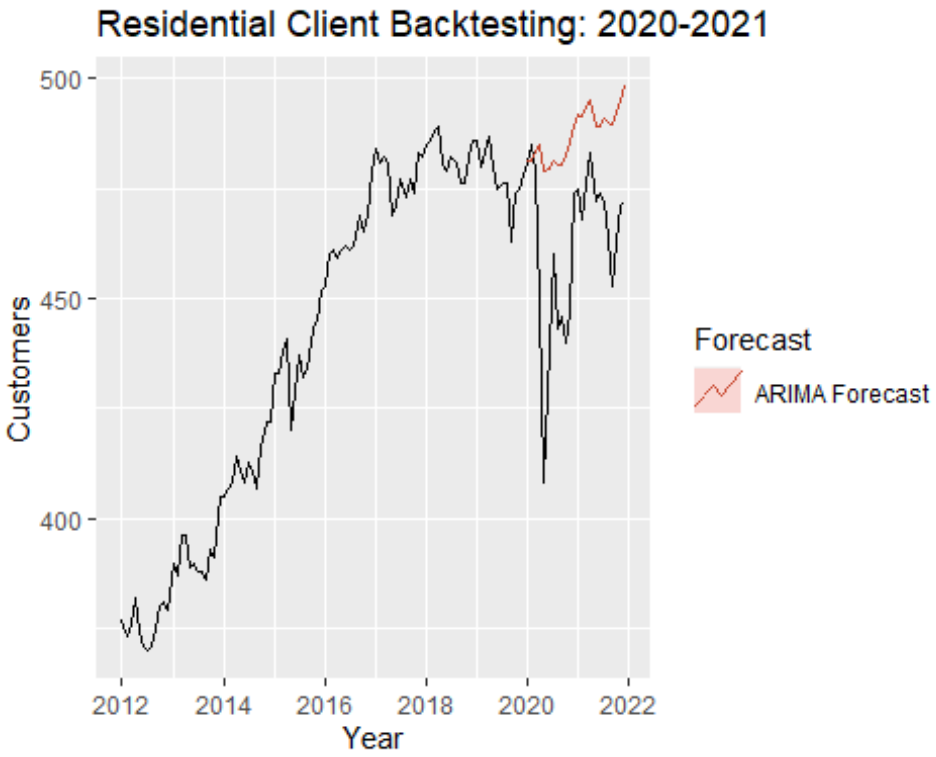
ARIMA Model: 5 Year Forecast

Below we fit & forecast 60 months into the future using an ARIMA(2,1,0)(2,0,0) model.



2020-2021 Back-Testing Evaluation

In this section we will evaluate the accuracy of our ARIMA(2,1,0)(2,0,0) model on data from January, 2020 through December 2021 by training on the previous data and forecasting the next 24 months. In particular we are interested on how close the forecasted accuracy follows our cross-validated results shown previously. Also, an area of interest is how well the model performs during the 2020 pandemic.



Back-Test Results

Below we see that the model performs roughly as expected for a "normal" year of 2019 with a high degree in accuracy. However, there is a large error in the beginning of 2020 likely due to the pandemic. Although, in the later months of 2020 customers started returning and we see the accuracy go back to expected levels.

```
[1] "Overall Mean Absolute Error: 25.33"

[1] "Overall Mean Accuracy: 94.38"

         Actual Forecast Absolute_Error Accuracy
Jan 2020    481      481              0    100.0
Feb 2020    485      481              4     99.2
Mar 2020    479      483              4     99.2
Apr 2020    449      485             36     92.0
May 2020    408      479             71     82.6
Jun 2020    439      479             40     90.9
Jul 2020    460      481             21     95.4
Aug 2020    443      480             37     91.6
Sep 2020    446      480             34     92.4
Oct 2020    440      483             43     90.2
Nov 2020    447      486             39     91.3
Dec 2020    474      489             15     96.8
Jan 2021    475      492             17     96.4
Feb 2021    468      492             24     94.9
Mar 2021    476      494             18     96.2
Apr 2021    483      495             12     97.5
May 2021    472      489             17     96.4
Jun 2021    474      489             15     96.8
Jul 2021    472      491             19     96.0
Aug 2021    464      490             26     94.4
Sep 2021    453      490             37     91.8
```

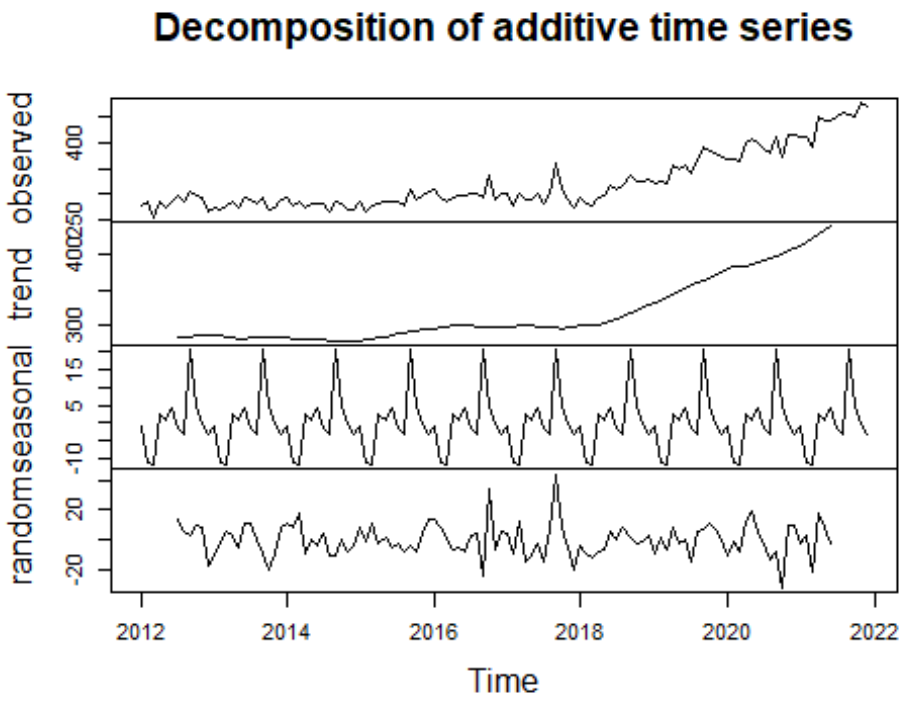
```
Oct 2021    463      492              29      93.7
Nov 2021    471      495              24      94.9
Dec 2021    472      498              26      94.5
```

FPUC Residential Standby Generator Service (FPU-RSGS)

In this section we will forecast monthly client counts for FPU-RSGS. From the data given, these numbers are calculated by filtering for Tariff Schedule 'RS-GS'.

Customer Time-Series Decomposition

Below we have the time-series decomposition where we can see a linear upward trend at the start of 2018.



ARIMA Model: Expected Accuracy

Here we evaluate model accuracy by using cross-validation and rolling forecasts throughout the time-series to determine our expected accuracy over a 24 Month period.

Below we see that the ARIMA model is consistently accurate with a 1-Month Forecast MAE of 15, and a 24-Month Forecast MAE of 68. It's worth noting that the Mean Error (ME) is also consistently positive, meaning the models under-predict the actual values.

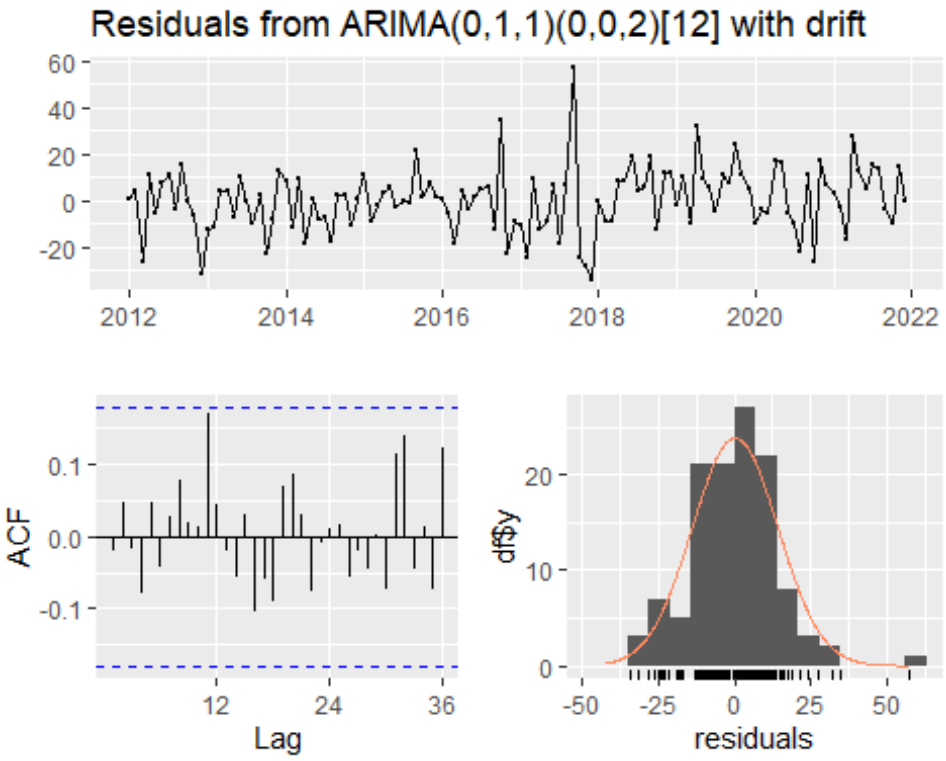
```
                    ME RMSE MAE
Forecast Horizon  1   4   21  15
Forecast Horizon  2   6   23  17
Forecast Horizon  3   9   23  18
Forecast Horizon  4  10   26  21
Forecast Horizon  5  13   27  22
Forecast Horizon  6  16   28  23
Forecast Horizon  7  17   30  24
```

```
Forecast Horizon  8  19   31  25
Forecast Horizon  9  22   33  27
Forecast Horizon  10 21   33  28
Forecast Horizon  11 24   36  30
Forecast Horizon  12 27   39  32
Forecast Horizon  13 31   42  34
Forecast Horizon  14 34   45  36
Forecast Horizon  15 36   47  39
Forecast Horizon  16 41   51  43
Forecast Horizon  17 44   52  46
Forecast Horizon  18 48   55  49
Forecast Horizon  19 51   57  51
Forecast Horizon  20 55   61  55
Forecast Horizon  21 58   64  58
Forecast Horizon  22 61   66  61
Forecast Horizon  23 65   69  65
Forecast Horizon  24 68   73  68
```

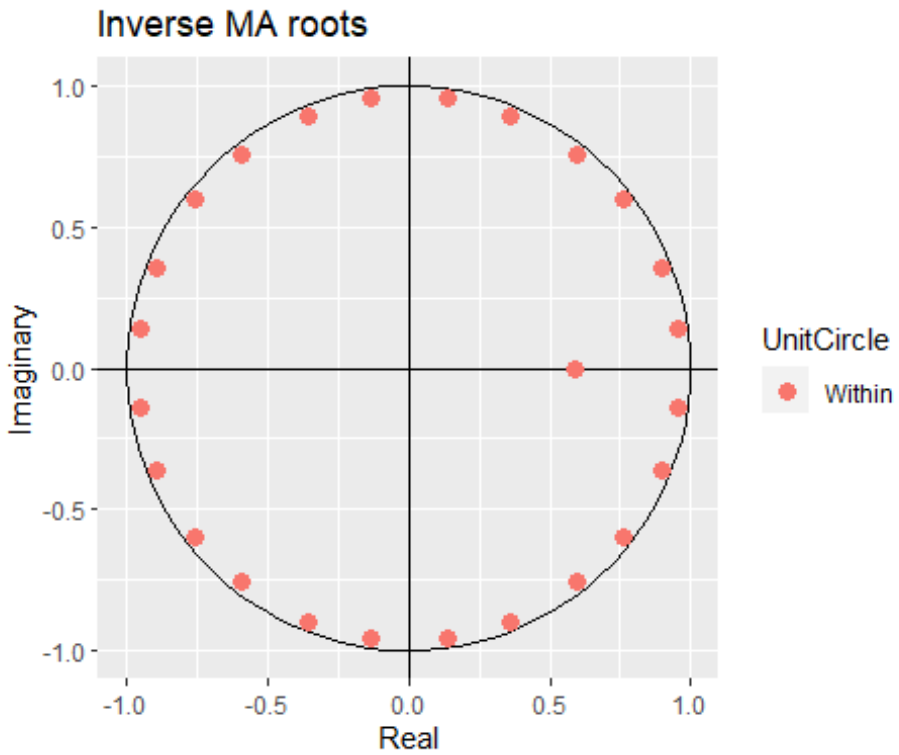
ARIMA Model: Diagnostics

Below we see that the model fails the Ljung-Box Test and therefore we can determine the data is independently distributed. In addition, we see from the graphs that the lagged values are not auto-correlated with one another, and the residuals are normally distributed. The unit circle below also showcases that we have a stationary model.

```
Series: x
ARIMA(0,1,1)(0,0,2)[12] with drift

Coefficients:
          ma1    sma1    sma2   drift
      -0.5923  0.1913  0.4248  1.5996
s.e.   0.0737  0.0865  0.1074  0.8087

sigma^2 estimated as 204.3:  log likelihood=-486.04
AIC=982.08   AICc=982.61   BIC=995.98

Training set error measures:
                    ME     RMSE     MAE         MPE     MAPE      MASE
Training set 0.1573346 13.99163 10.7337 -0.2049688 3.368332 0.4283961
                    ACF1
Training set -0.02021047
```

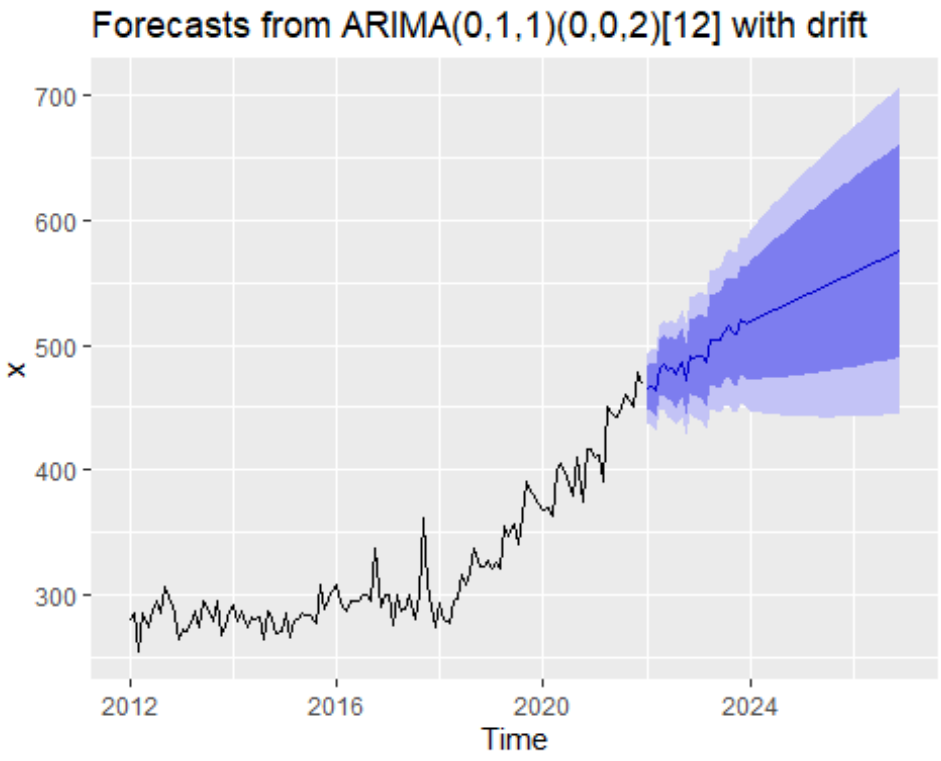



```
 Ljung-Box test

data:  Residuals from ARIMA(0,1,1)(0,0,2)[12] with drift
Q* = 13.527, df = 20, p-value = 0.8536

Model df: 4.   Total lags used: 24
```



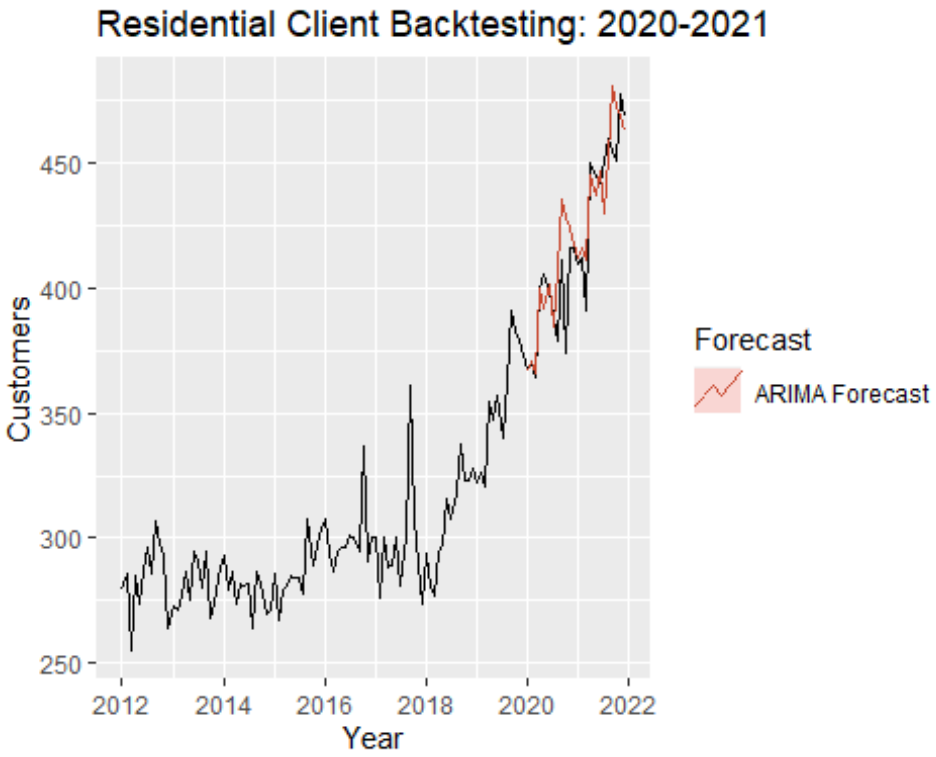
ARIMA Model: 5 Year Forecast

Below we fit & forecast 60 months into the future using an ARIMA(0,1,1)(2,0,0) model.



2020-2021 Back-Testing Evaluation

In this section we will evaluate the accuracy of our ARIMA(0,1,1)(0,0,2) model on data from January, 2020 through December 2021 by training on the previous data and forecasting the next 24months. In particular we are interested on how close the forecasted accuracy follows our cross-validated results shown previously. Also, an area of interest is how well the model performs during the 2020 pandemic.



Backtest Results

Below we see that the model performs well at first but then the accuracy deteriorates due to the explosion of customers that begins roughly at the start of our forecast.

```
[1] "Overall Mean Absolute Error: 11.62"

[1] "Overall Mean Accuracy: 97.17"

         Actual Forecast Absolute_Error Accuracy
Jan 2020    368      367              1     99.7
Feb 2020    370      371              1     99.7
Mar 2020    364      366              2     99.5
Apr 2020    399      400              1     99.7
May 2020    406      392             14     96.6
Jun 2020    399      402              3     99.2
Jul 2020    389      385              4     99.0
Aug 2020    379      408             29     92.3
Sep 2020    411      436             25     93.9
Oct 2020    374      428             54     85.6
Nov 2020    416      424              8     98.1
Dec 2020    416      418              2     99.5
Jan 2021    410      412              2     99.5
Feb 2021    412      416              4     99.0
Mar 2021    391      411             20     94.9
Apr 2021    450      445              5     98.9
May 2021    445      437              8     98.2
Jun 2021    442      447              5     98.9
Jul 2021    451      430             21     95.3
Aug 2021    460      453              7     98.5
Sep 2021    455      481             26     94.3
Oct 2021    451      473             22     95.1
```

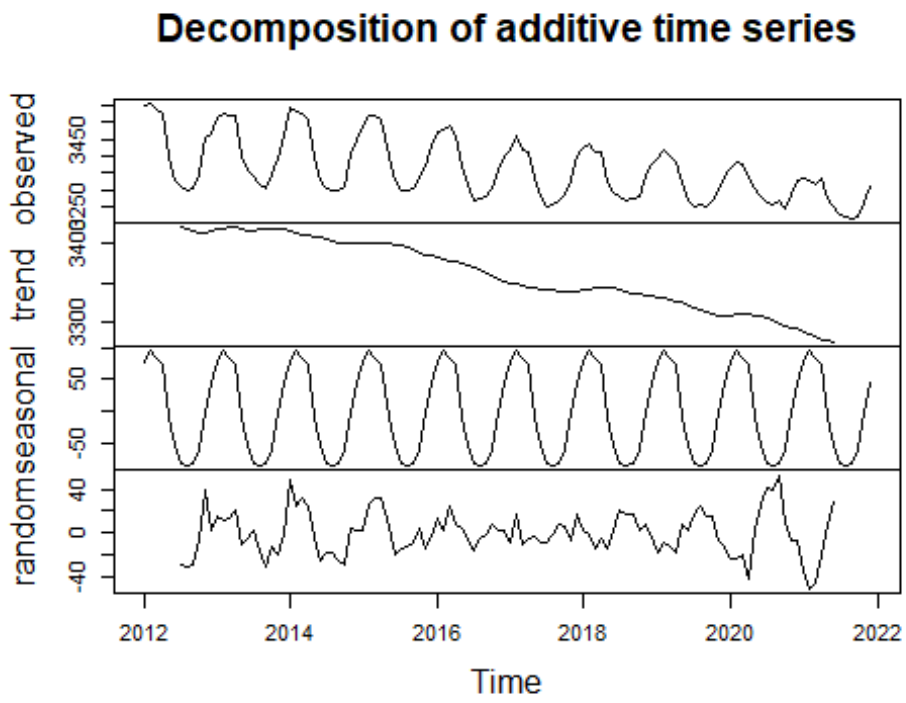
```
Nov 2021    478      469              9     98.1
Dec 2021    469      463              6     98.7
```

CFG Firm Transportation Service A & B (FTS-A & FTS-B)

In this section we will forecast monthly client counts for FTS-A & FTS-B from the data given, these numbers are calculated by filtering for Tariff Schedule 'FTS-A & FTS-B'.

Customer Time-Series Decomposition

Below we have the time-series decomposition where we can see a linear upward trend at the start of 2018.



ARIMA Model: Expected Accuracy

Here we evaluate model accuracy by using cross-validation and rolling forecasts throughout the time-series to determine our expected accuracy over a 24 Month period.

Below we see that the ARIMA model is consistently accurate with a 1-Month Forecast MAE of 13, and a 24-Month Forecast MAE of 27. It's worth noting that the Mean Error (ME) is also consistently positive, meaning the models under-predict the actual values.

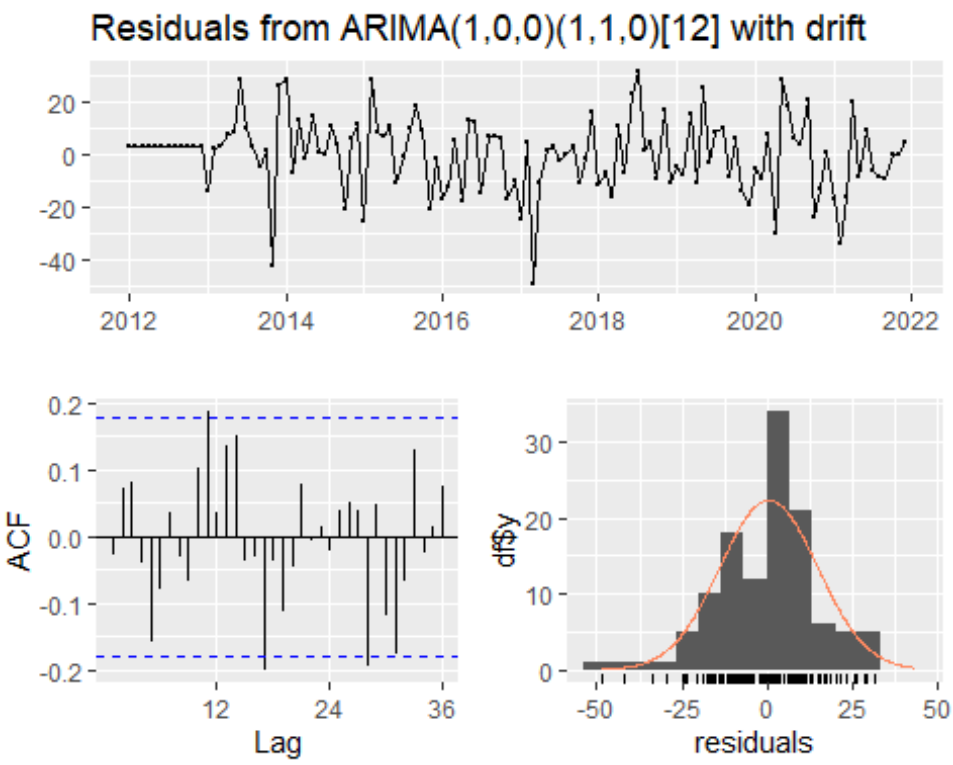
```
                     ME RMSE MAE
Forecast Horizon  1   1   16  13
Forecast Horizon  2   3   20  16
Forecast Horizon  3   4   24  19
Forecast Horizon  4   5   23  18
Forecast Horizon  5   7   23  19
Forecast Horizon  6   8   22  18
Forecast Horizon  7   9   22  18
Forecast Horizon  8  10   23  18
```

```
Forecast Horizon  9  11   24  19
Forecast Horizon  10 11   22  18
Forecast Horizon  11 11   22  18
Forecast Horizon  12 11   23  18
Forecast Horizon  13 12   29  24
Forecast Horizon  14 12   34  28
Forecast Horizon  15 11   38  31
Forecast Horizon  16 12   38  31
Forecast Horizon  17 12   37  31
Forecast Horizon  18 13   36  30
Forecast Horizon  19 12   34  29
Forecast Horizon  20 11   33  27
Forecast Horizon  21 10   31  26
Forecast Horizon  22  9   31  26
Forecast Horizon  23  9   31  26
Forecast Horizon  24  8   33  27
```

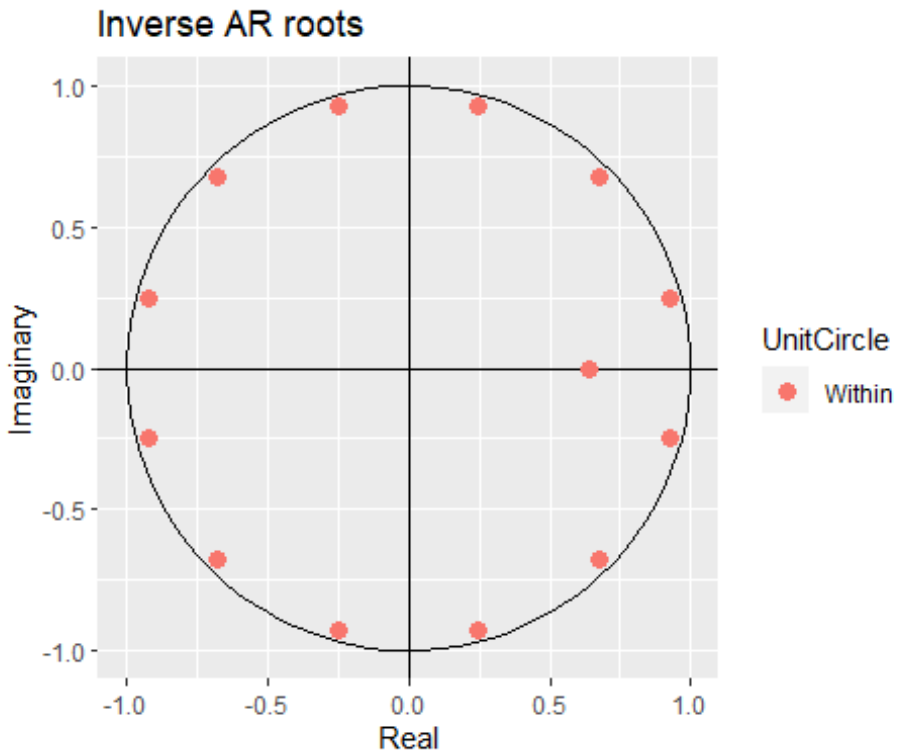
ARIMA Model: Diagnostics

Below we see that the model fails the Ljung-Box Test and therefore we can determine the data is independently distributed. In addition, we see from the graphs that the lagged values are not auto-correlated with one another, and the residuals are normally distributed. The unit circle below also showcases that we have a stationary model.

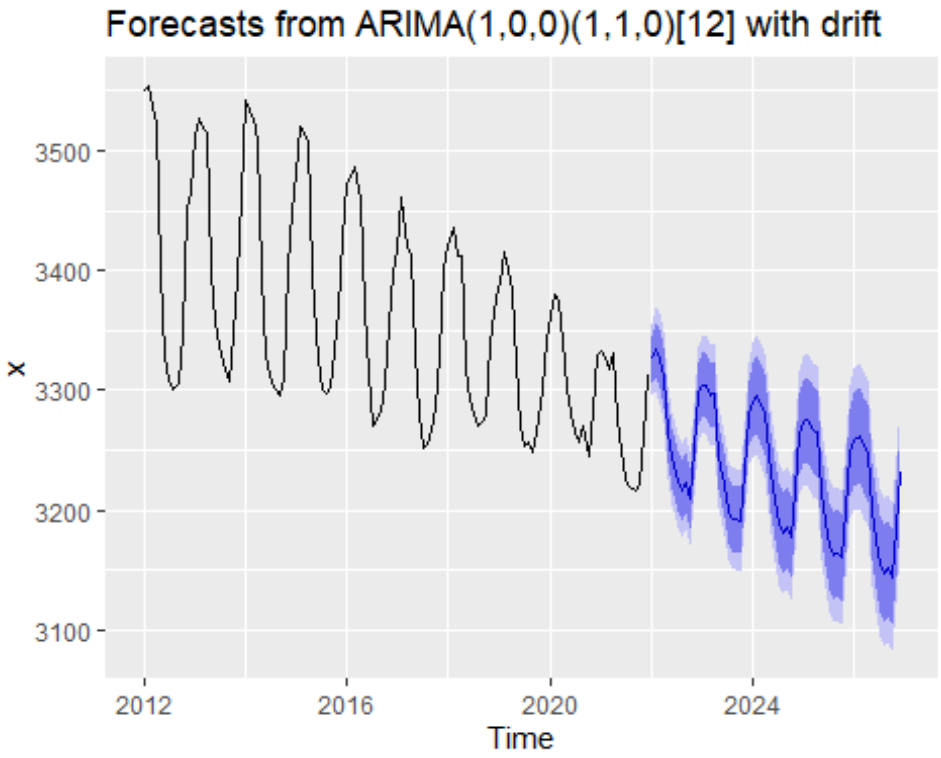
```
Series: x
ARIMA(1,0,0)(1,1,0)[12] with drift

Coefficients:
         ar1     sar1    drift
      0.6412  -0.6003  -1.3401
s.e.  0.0750   0.0820   0.2152

sigma^2 estimated as 233:  log likelihood=-448.71
AIC=905.43   AICc=905.82   BIC=916.16

Training set error measures:
                     ME     RMSE      MAE        MPE     MAPE      MASE
Training set 0.4033994 14.27886 10.95525 0.01194571 0.325548 0.5026199
                     ACF1
Training set -0.02871998
```



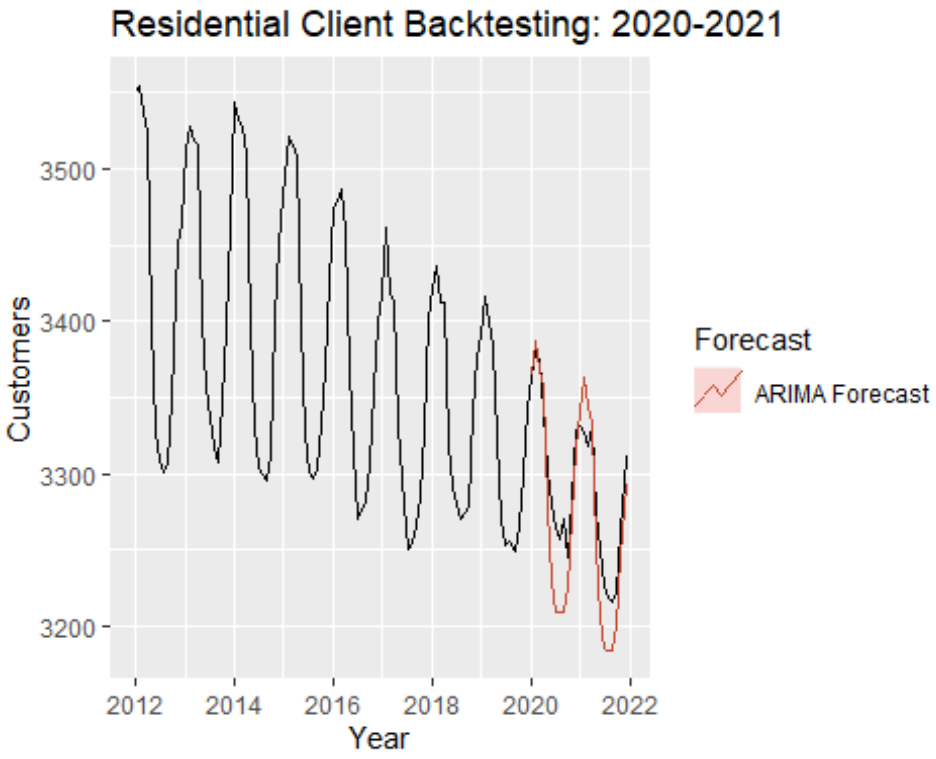

```
 Ljung-Box test

data:  Residuals from ARIMA(1,0,0)(1,1,0)[12] with drift
Q* = 27.867, df = 21, p-value = 0.144

Model df: 3.   Total lags used: 24
```



ARIMA Model: 5 Year Forecast



2020-2021 Back-Testing Evaluation



Backtest Results

Below we see that the model performs well at first but then the accuracy deteriorates due to the explosion of customers that begins roughly at the start of our forecast.

```
[1] "Overall Mean Absolute Error: 25.79"

[1] "Overall Mean Accuracy: 99.2"

   Actual Forecast Absolute_Error Accuracy
1    3363     3365              2     99.9
2    3380     3387              7     99.8
3    3375     3369              6     99.8
4    3341     3358             17     99.5
5    3302     3278             24     99.3
6    3281     3230             51     98.4
7    3265     3210             55     98.3
8    3257     3209             48     98.5
9    3271     3209             62     98.1
10   3245     3225             20     99.4
11   3284     3271             13     99.6
12   3329     3317             12     99.6
13   3332     3340              8     99.8
14   3328     3363             35     98.9
15   3318     3344             26     99.2
16   3331     3333              2     99.9
17   3275     3253             22     99.3
18   3250     3206             44     98.6
19   3227     3185             42     98.7
20   3219     3184             35     98.9
21   3216     3184             32     99.0
22   3222     3200             22     99.3
23   3262     3247             15     99.5
24   3312     3293             19     99.4
```