Robert Kaszubski CSC 578 - FInal Project

Note: Some of the runtimes may differ from what is reported in my documentation. I reran the whole notebook prior to submission and ran out of GPU runtime on google colab, so the run times will be longer in most cases but results should be similar

I organized everything in sections so it should all be very clear!

In [1]:
```
import os
import datetime

import IPython
import IPython.display
import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import seaborn as sns
import tensorflow as tf
```

In [2]:
```
#Import CSV - taken from assignment instructions
csv_path = tf.keras.utils.get_file(
    origin='https://reed.cs.depaul.edu/peterh/Essays/Metro_Interstate_reduced.csv',
    fname='Metro_Interstate_reduced.csv',
    cache_dir='/content', cache_subdir='sample_data')

csv_path
# should be '/content/sample_data/Metro_Interstate_reduced.csv'
```

Out[2]: '/content/sample_data/Metro_Interstate_reduced.csv'

EXPLORATORY DATA ANALYSIS

RK. The first step is to examine the variables and variable types in the dataset:

In [3]:
```
#RK
df = pd.read_csv(csv_path)
df.head()
```

Out[3]:

	holiday	temp	rain_1h	snow_1h	clouds_all	weather_main	weather_description	date_time	traffic_volume
0	None	288.28	0.0	0.0	40	Clouds	scattered clouds	2012-10-02 09:00:00	5545
1	None	289.36	0.0	0.0	75	Clouds	broken clouds	2012-10-02 10:00:00	4516
2	None	289.58	0.0	0.0	90	Clouds	overcast clouds	2012-10-02 11:00:00	4767
3	None	290.13	0.0	0.0	90	Clouds	overcast clouds	2012-10-02 12:00:00	5026
4	None	291.14	0.0	0.0	75	Clouds	broken clouds	2012-10-02 13:00:00	4918

RK. The categorical variables: Holiday, Weather_Main, Weather Description will have to be transformed. I will be converting these into dummy variables or a one hot vector.

The Date_Time object will also have to be transformed

Distribution of Numeric Variables

TF. Here is the evolution of a few features over time:

In [4]:
```
#FROM TF TUTORIAL - MODIFIED
plot_cols = ['temp', 'rain_1h', 'snow_1h', 'clouds_all']
plot_features = df[plot_cols]
plot_features.index = df['date_time']
_ = plot_features.plot(subplots=True)
```

In [5]:
```
df.describe().transpose()
```

Out[5]:

	count	mean	std	min	25%	50%	75%	max
temp	40575.0	281.316763	13.816618	0.0	271.84	282.86	292.28	310.07
rain_1h	40575.0	0.318632	48.812640	0.0	0.00	0.00	0.00	9831.30
snow_1h	40575.0	0.000117	0.005676	0.0	0.00	0.00	0.00	0.51
clouds_all	40575.0	44.199162	38.683447	0.0	1.00	40.00	90.00	100.00
traffic_volume	40575.0	3290.650474	1984.772909	0.0	1248.50	3427.00	4952.00	7280.00

RK. We can see a very large max value for rain_1h. It is impossible for it to rain almost 10,000 mm in an hour. We also see a min of 0 for temp, temp is in Kelvin, this figure is also not possible.

Both of these will have to be fixed.

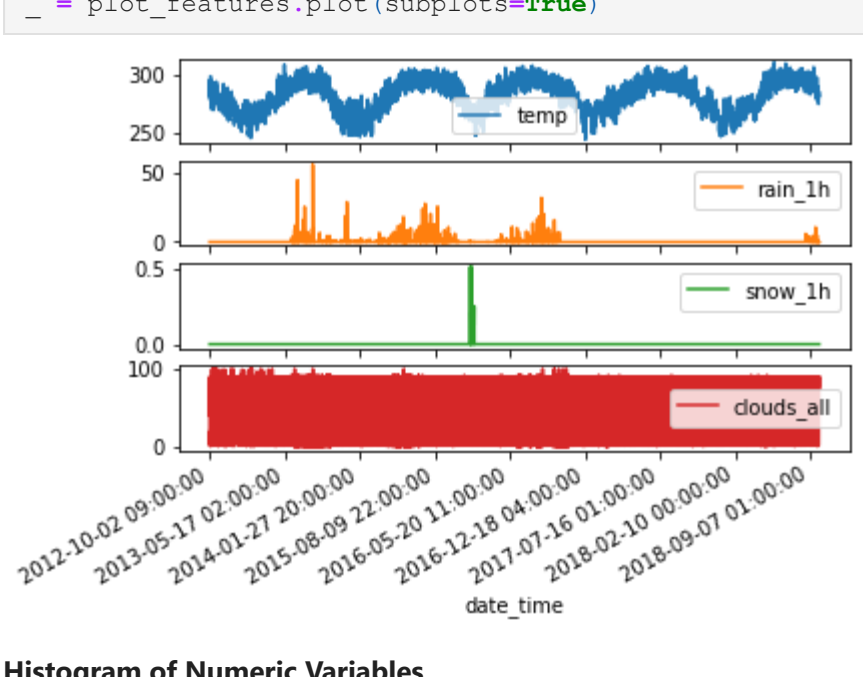
We also get a good idea of how the data is distributed. We can see the statistical summary for each variable which is particularly imporant for numeric variables. For instance, we can see that the vast majority of hours have no rain or snow as the 75 percentile is still 0.

In [6]:
```
#rk
#setting rain anomaly to 0:
df.loc[df['rain_1h'] >= 400, 'rain_1h'] = 0
```

In [7]:
```
#rk
#setting temp anomaly to avg temp:
df.loc[df['temp'] == 0, 'temp'] = 281.3
```

RK. Confirming the values were properly removed:

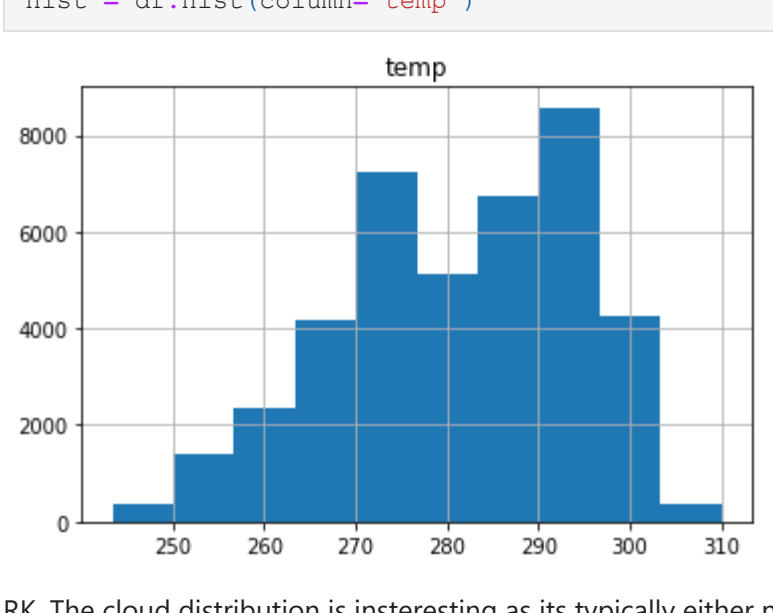
In [8]:
```
#FROM TF TUTORIAL - MODIFIED
plot_cols = ['temp', 'rain_1h', 'snow_1h', 'clouds_all']
plot_features = df[plot_cols]
plot_features.index = df['date_time']
_ = plot_features.plot(subplots=True)
```



Histogram of Numeric Variables

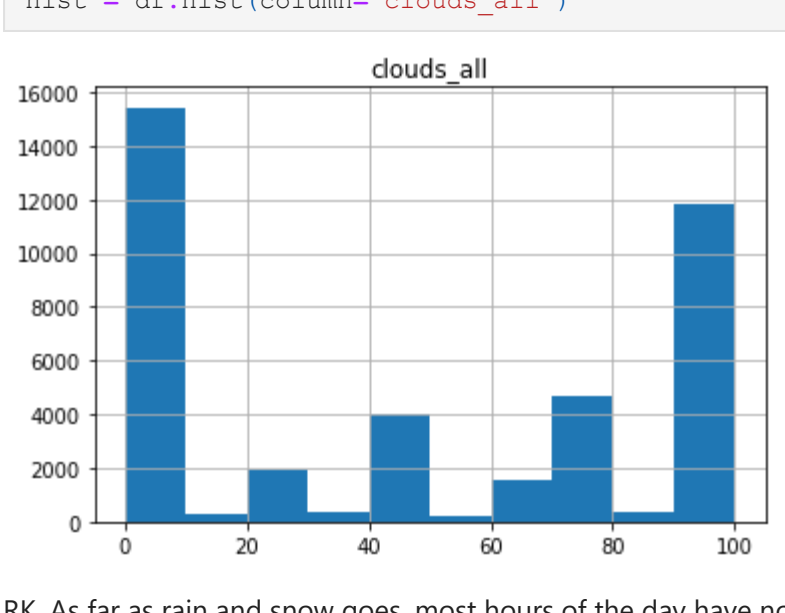
RK. The temperature distribution is almost symetric, it is very close to a normal distribution but perhaps slightly left skewed. Most days the temperature is fairly similar with a few days that were more extreme.

In [9]:
```
hist = df.hist(column='temp')
```



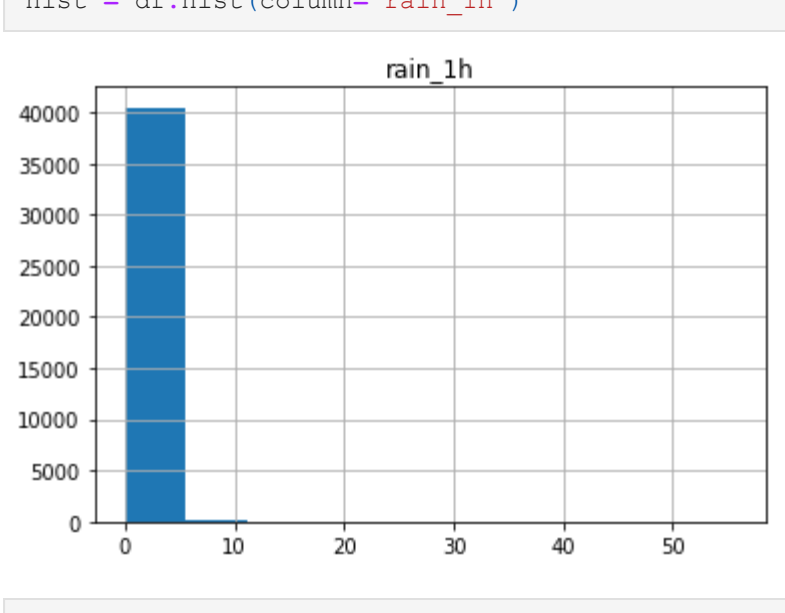
RK. The cloud distribution is interesting as its typically either no clouds or 100% clouds with a few days falling in between.

In [10]:
```
hist = df.hist(column='clouds_all')
```

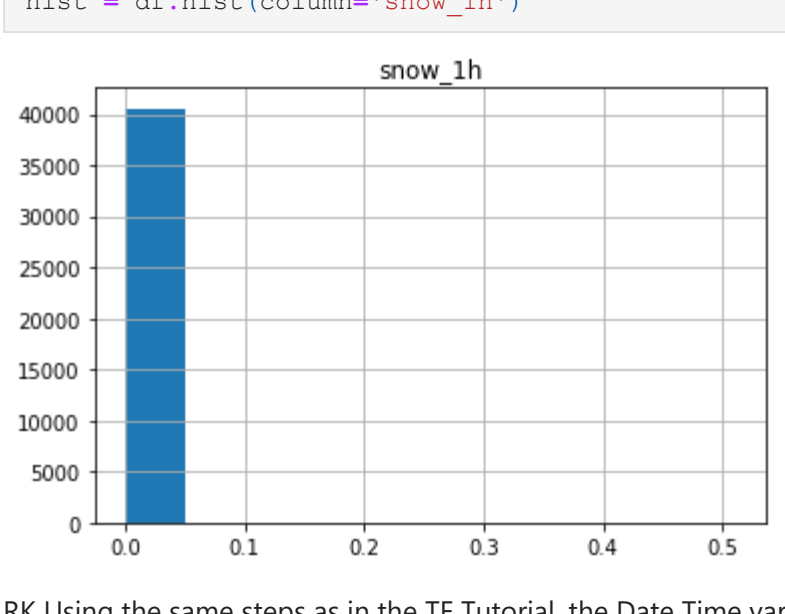


RK. As far as rain and snow goes, most hours of the day have no snow or rain. It's fairly rare in this dataset.

In [11]:
```
hist = df.hist(column='rain_1h')
```



In [12]:
```
hist = df.hist(column='snow_1h')
```



RK Using the same steps as in the TF Tutorial, the Date Time variable is converted into time of day and time of year variables. This is an example of feature engineering.

TF. You can get usable signals by using sine and cosine transforms to clear "Time of day" and "Time of year" signals

In [13]:
```
#FROM TF TUTORIAL
date_time = pd.to_datetime(df.pop('date_time'), format='%Y.%m.%d %H:%M:%S')
timestamp_s = date_time.map(pd.Timestamp.timestamp)
day = 24*60*60
year = (365.2425)*day

df['Day sin'] = np.sin(timestamp_s * (2 * np.pi / day))
df['Day cos'] = np.cos(timestamp_s * (2 * np.pi / day))
df['Year sin'] = np.sin(timestamp_s * (2 * np.pi / year))
df['Year cos'] = np.cos(timestamp_s * (2 * np.pi / year))
```

RK Converting categorical variables to dummy variables (one hot encoding)

In [14]:
```
#RK
#Converting Categorical variables to dummy variables.
df = pd.get_dummies(df, columns=['holiday','weather_main','weather_description'])
```

In [15]:
```
#RK
#not enough instances when splitting dataset, column has to be dropped
#it was resulting in errors when training the model - it only has a single row were it is true (= to 1) so it
df = df.drop(columns=["weather_description_proximity thunderstorm with drizzle"])
```

SPLIT TRAINING/VALIDATION/TEST

In [16]:
```
#RK
column_indices = {name: i for i, name in enumerate(df.columns)}

#last 5000 records become test set
test_df = df.iloc[-5000:]
rest_df = df.iloc[:-5000, :]

#next 7000 records from the back become validation set
val_df = rest_df.iloc[-7000:]
train_df = rest_df.iloc[:-7000, :] #rest becomes train set

num_features = df.shape[1]
```

RK. Verify that the number of rows matches the original dataset

In [17]:
```
len(train_df) + len(val_df) + len(test_df) == len(df)
```

Out[17]: True

Normalize

In [18]:
```
# FROM TF TUTORIAL
train_mean = train_df.mean()
train_std = train_df.std()

train_df = (train_df - train_mean) / train_std
val_df = (val_df - train_mean) / train_std
test_df = (test_df - train_mean) / train_std
```

Sample Plot

In [19]:
```
# FROM TF TUTORIAL
class WindowGenerator():
  def __init__(self, input_width, label_width, shift,
               train_df=train_df, val_df=val_df, test_df=test_df,
               label_columns=None):
    # Store the raw data.
    self.train_df = train_df
    self.val_df = val_df
    self.test_df = test_df

    # Work out the label column indices.
    self.label_columns = label_columns
    if label_columns is not None:
      self.label_columns_indices = {name: i for i, name in
                                    enumerate(label_columns)}
    self.column_indices = {name: i for i, name in
                           enumerate(train_df.columns)}

    # Work out the window parameters.
    self.input_width = input_width
    self.label_width = label_width
    self.shift = shift

    self.total_window_size = input_width + shift

    self.input_slice = slice(0, input_width)
    self.input_indices = np.arange(self.total_window_size)[self.input_slice]

    self.label_start = self.total_window_size - self.label_width
    self.labels_slice = slice(self.label_start, None)
    self.label_indices = np.arange(self.total_window_size)[self.labels_slice]

  def __repr__(self):
    return '\n'.join([
        f'Total window size: {self.total_window_size}',
        f'Input indices: {self.input_indices}',
        f'Label indices: {self.label_indices}',
        f'Label column name(s): {self.label_columns}'])
```

In [20]:
```
# FROM TF TUTORIAL
def split_window(self, features):
  inputs = features[:, self.input_slice, :]
  labels = features[:, self.labels_slice, :]
  if self.label_columns is not None:
    labels = tf.stack(
        [labels[:, :, self.column_indices[name]] for name in self.label_columns],
        axis=-1)
  #TF
  # Slicing doesn't preserve static shape information, so set the shapes
  # manually. This way the `tf.data.Datasets` are easier to inspect.
  inputs.set_shape([None, self.input_width, None])
  labels.set_shape([None, self.label_width, None])

  return inputs, labels

WindowGenerator.split_window = split_window
```

In [21]:
```
# FROM TF TUTORIAL
def plot(self, model=None, plot_col='traffic_volume', max_subplots=3):
  inputs, labels = self.example
  plt.figure(figsize=(12, 8))
  plot_col_index = self.column_indices[plot_col]
  max_n = min(max_subplots, len(inputs))
  for n in range(max_n):
    plt.subplot(max_n, 1, n+1)
    plt.ylabel(f'{plot_col} [normed]')
    plt.plot(self.input_indices, inputs[n, :, plot_col_index],
             label='Inputs', marker='.', zorder=-10)

    if self.label_columns:
      label_col_index = self.label_columns_indices.get(plot_col, None)
    else:
      label_col_index = plot_col_index

    if label_col_index is None:
      continue

    plt.scatter(self.label_indices, labels[n, :, label_col_index],
                edgecolors='k', label='Labels', c='#2ca02c', s=64)
    if model is not None:
      predictions = model(inputs)
      plt.scatter(self.label_indices, predictions[n, :, label_col_index],
                  marker='X', edgecolors='k', label='Predictions',
                  c='#ff7f0e', s=64)

    if n == 0:
      plt.legend()

  plt.xlabel('Time [h]')
WindowGenerator.plot = plot
```

CREATE WINDOW - 7,1,3

RK. The window has 7 inputs, and a single output that is offset by 3 hours. The total window size should be 10.

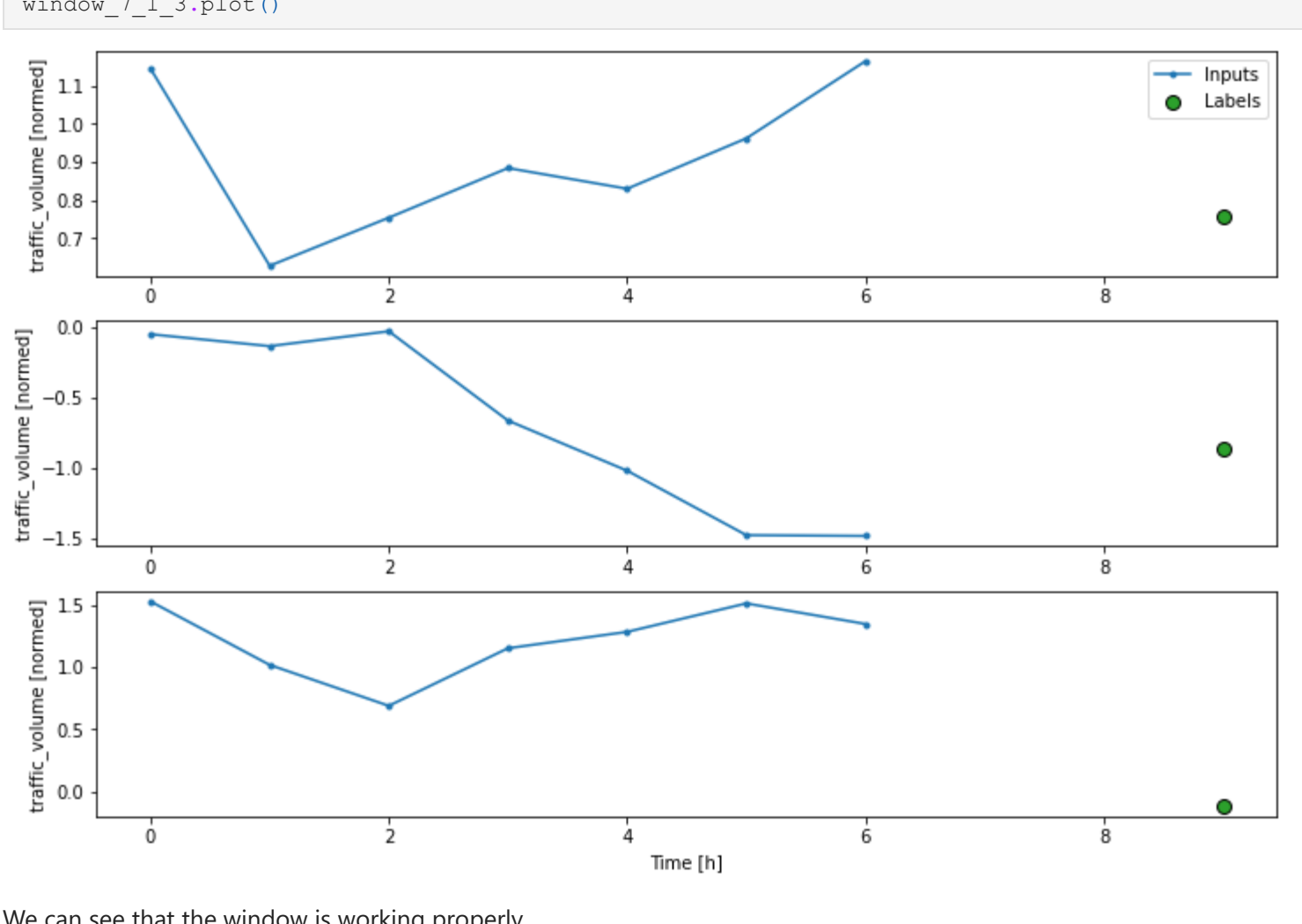
In [22]:
```
window_7_1_3 = WindowGenerator(input_width=7, label_width=1, shift=3, label_columns=['traffic_volume'])
window_7_1_3
```

Out[22]:
```
Total window size: 10
Input indices: [0 1 2 3 4 5 6]
Label indices: [9]
Label column name(s): ['traffic_volume']
```

Sample Test Plot using TF Tutorial Code

In [23]:
```
#FROM TF TUTORIAL - MODIFIED
window_size = window_7_1_3.total_window_size #retreive total window size - 10
sample_window = tf.stack([np.array(train_df[:window_size]), #retrieve first 10 rows from training data
                          np.array(train_df[100:100+window_size]), #retrieve rows 101-110 from training data
                          np.array(train_df[200:200+window_size])]) #retrieve rows 201-210 from training data
sample_inputs, sample_labels = window_7_1_3.split_window(sample_window) #retrieve inputs and labels from rows

window_7_1_3.example = sample_inputs, sample_labels
window_7_1_3.plot()
```



We can see that the window is working properly.

MODEL FUNCTIONS

RK. Tutorial code to turn our split data into batches.

In [24]:
```
#FROM TF TUTORIAL - MODIFIED
#RK. Changed for only the validation and testing data, that data IS NOT shuffled
def make_dataset(self, data):
  data = np.array(data, dtype=np.float32)
  ds = tf.keras.preprocessing.timeseries_dataset_from_array(
      data=data,
      targets=None,
      sequence_length=self.total_window_size,
      sequence_stride=1,
      shuffle=False,
      batch_size=32,)

  ds = ds.map(self.split_window)

  return ds

#RK
#created a new function for just the training dataset
#this one shuffles the data
def make_train_dataset(self, data):
  data = np.array(data, dtype=np.float32)
  ds = tf.keras.preprocessing.timeseries_dataset_from_array(
      data=data,
      targets=None,
      sequence_length=self.total_window_size,
      sequence_stride=1,
      shuffle=True,
      batch_size=32,)

  ds = ds.map(self.split_window)

  return ds

WindowGenerator.make_dataset = make_dataset
#RK. additional variable in the class for the train dataset function
WindowGenerator.make_train_dataset = make_train_dataset
```

In [25]:
```
#FROM TF TUTORIAL - slightly modified
@property
def train(self):
  return self.make_train_dataset(self.train_df)
  #RK. Modified so train uses the new train_dataset function

@property
def val(self):
  return self.make_dataset(self.val_df)

@property
def test(self):
  return self.make_dataset(self.test_df)

WindowGenerator.train = train
WindowGenerator.val = val
WindowGenerator.test = test
```

RK. Tutorial function to train and evaluate a model. Uses early stopage that I modified to restore the best weights and I parameterized total epochs for ease of testing

In [26]:
```
#FROM TF TUTORIAL - MODIFIED
#RK. ADDED restore best weights, and turned max epochs into a parameter for easier testing
def compile_and_fit(model, window, patience=10, epochs=50):
  early_stopping = tf.keras.callbacks.EarlyStopping(monitor='val_loss', patience=patience, mode='min', restore_

  model.compile(loss=tf.losses.MeanSquaredError(), optimizer=tf.optimizers.Adam(), metrics=[tf.metrics.MeanAbso

  history = model.fit(window.train, epochs=epochs, validation_data=window.val, callbacks=[early_stopping])

  return history
```

RK. Function I created to create prediction CSV. Takes in a model and window object. Creates prediction set, denormalizes it and outputs it in the proper format for KAGGLE.

In [27]:
```
#RK. I wrote this function to take in a model and window and return a csv with the predictions
def make_predictions(model,window):
  #RK make predictions
  prediction = model.predict(window.test)

  #RK denormalize predictions
  predictions = (prediction * train_std['traffic_volume']) + train_mean['traffic_volume']

  #RK add ID and format rows for output
  output = []
  output.append(['id','prediction'])
  count = 1
  for row in predictions:
    prediction = [count] + row.tolist()
    output.append(prediction)
    count += 1

  #RK write to csv for submission
  import csv
  with open('FinalPredictions.csv','w') as f:
    writer = csv.writer(f)
    for row in output:
      writer.writerow(row)
```

RK. Function I created to plot MAE of training vs validation, as well as loss of training vs validation

In [28]:
```
def plot_results(history):
  plt.plot(history.history['mean_absolute_error'], label='training MAE')
  plt.plot(history.history['val_mean_absolute_error'], label = 'valid. MAE')
  plt.xlabel('Epoch')
  plt.ylabel('MAE')
  plt.ylim([0.0, 0.5])
  plt.legend(loc='upper right')

  plt.plot(history.history['loss'], label='training loss')
  plt.plot(history.history['val_loss'], label = 'valid. loss')
  plt.xlabel('Epoch')
  plt.ylabel('value')
  plt.ylim([0.0, 0.5])
  plt.legend(loc='upper right')
```

BUILDING MODELS - ALL CODE FROM THIS POINT IS COMPLETLY MINE

BASELINE MODEL

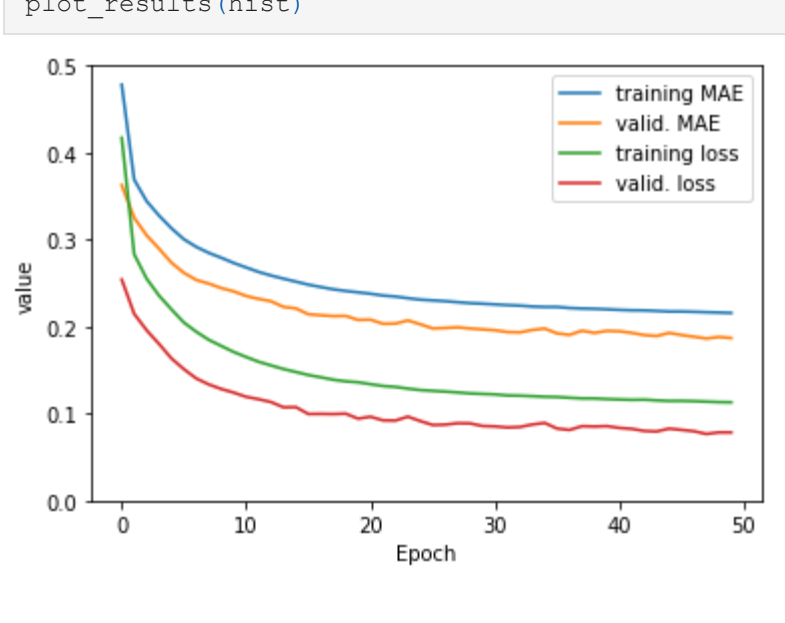
In [29]:
```
baseline_model = tf.keras.models.Sequential([
    tf.keras.layers.LSTM(7),
    tf.keras.layers.Dense(units=1)
])
```

In [30]:
```
hist = compile_and_fit(baseline_model, window_7_1_3, 10, 50)
```

```
Epoch 1/50
893/893 [==============================] - 6s 5ms/step - loss: 0.4171 - mean_absolute_error: 0.4782 - val_loss:
0.2542 - val_mean_absolute_error: 0.3627
Epoch 2/50
893/893 [==============================] - 4s 4ms/step - loss: 0.2832 - mean_absolute_error: 0.3690 - val_loss:
0.2147 - val_mean_absolute_error: 0.3251
Epoch 3/50
893/893 [==============================] - 4s 4ms/step - loss: 0.2552 - mean_absolute_error: 0.3443 - val_loss:
0.1959 - val_mean_absolute_error: 0.3050
Epoch 4/50
893/893 [==============================] - 4s 4ms/step - loss: 0.2356 - mean_absolute_error: 0.3277 - val_loss:
0.1801 - val_mean_absolute_error: 0.2896
Epoch 5/50
893/893 [==============================] - 4s 5ms/step - loss: 0.2198 - mean_absolute_error: 0.3130 - val_loss:
0.1634 - val_mean_absolute_error: 0.2735
Epoch 6/50
893/893 [==============================] - 4s 5ms/step - loss: 0.2047 - mean_absolute_error: 0.3004 - val_loss:
0.1511 - val_mean_absolute_error: 0.2618
Epoch 7/50
893/893 [==============================] - 4s 5ms/step - loss: 0.1941 - mean_absolute_error: 0.2916 - val_loss:
0.1404 - val_mean_absolute_error: 0.2536
Epoch 8/50
893/893 [==============================] - 4s 5ms/step - loss: 0.1848 - mean_absolute_error: 0.2848 - val_loss:
0.1335 - val_mean_absolute_error: 0.2495
Epoch 9/50
893/893 [==============================] - 4s 5ms/step - loss: 0.1778 - mean_absolute_error: 0.2792 - val_loss:
0.1284 - val_mean_absolute_error: 0.2444
Epoch 10/50
893/893 [==============================] - 4s 5ms/step - loss: 0.1709 - mean_absolute_error: 0.2732 - val_loss:
0.1241 - val_mean_absolute_error: 0.2406
Epoch 11/50
893/893 [==============================] - 5s 5ms/step - loss: 0.1651 - mean_absolute_error: 0.2680 - val_loss:
0.1193 - val_mean_absolute_error: 0.2352
Epoch 12/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1596 - mean_absolute_error: 0.2629 - val_loss:
0.1166 - val_mean_absolute_error: 0.2319
Epoch 13/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1554 - mean_absolute_error: 0.2588 - val_loss:
0.1133 - val_mean_absolute_error: 0.2292
Epoch 14/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1513 - mean_absolute_error: 0.2552 - val_loss:
0.1073 - val_mean_absolute_error: 0.2227
Epoch 15/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1479 - mean_absolute_error: 0.2517 - val_loss:
0.1074 - val_mean_absolute_error: 0.2210
Epoch 16/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1444 - mean_absolute_error: 0.2483 - val_loss:
0.0996 - val_mean_absolute_error: 0.2142
Epoch 17/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1418 - mean_absolute_error: 0.2455 - val_loss:
0.0997 - val_mean_absolute_error: 0.2131
Epoch 18/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1390 - mean_absolute_error: 0.2430 - val_loss:
0.0995 - val_mean_absolute_error: 0.2122
Epoch 19/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1371 - mean_absolute_error: 0.2410 - val_loss:
0.1000 - val_mean_absolute_error: 0.2123
Epoch 20/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1361 - mean_absolute_error: 0.2394 - val_loss:
0.0942 - val_mean_absolute_error: 0.2078
Epoch 21/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1338 - mean_absolute_error: 0.2378 - val_loss:
0.0964 - val_mean_absolute_error: 0.2080
Epoch 22/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1318 - mean_absolute_error: 0.2358 - val_loss:
0.0923 - val_mean_absolute_error: 0.2033
Epoch 23/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1307 - mean_absolute_error: 0.2346 - val_loss:
0.0920 - val_mean_absolute_error: 0.2035
Epoch 24/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1287 - mean_absolute_error: 0.2327 - val_loss:
0.0965 - val_mean_absolute_error: 0.2071
Epoch 25/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1271 - mean_absolute_error: 0.2310 - val_loss:
0.0915 - val_mean_absolute_error: 0.2027
Epoch 26/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1262 - mean_absolute_error: 0.2302 - val_loss:
0.0869 - val_mean_absolute_error: 0.1979
Epoch 27/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1253 - mean_absolute_error: 0.2293 - val_loss:
0.0873 - val_mean_absolute_error: 0.1985
Epoch 28/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1244 - mean_absolute_error: 0.2281 - val_loss:
0.0890 - val_mean_absolute_error: 0.1992
Epoch 29/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1232 - mean_absolute_error: 0.2270 - val_loss:
0.0888 - val_mean_absolute_error: 0.1979
Epoch 30/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1227 - mean_absolute_error: 0.2264 - val_loss:
0.0858 - val_mean_absolute_error: 0.1969
Epoch 31/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1221 - mean_absolute_error: 0.2256 - val_loss:
0.0853 - val_mean_absolute_error: 0.1959
Epoch 32/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1209 - mean_absolute_error: 0.2247 - val_loss:
0.0841 - val_mean_absolute_error: 0.1938
Epoch 33/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1206 - mean_absolute_error: 0.2242 - val_loss:
0.0846 - val_mean_absolute_error: 0.1934
Epoch 34/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1201 - mean_absolute_error: 0.2231 - val_loss:
0.0875 - val_mean_absolute_error: 0.1961
Epoch 35/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1194 - mean_absolute_error: 0.2226 - val_loss:
0.0893 - val_mean_absolute_error: 0.1978
Epoch 36/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1191 - mean_absolute_error: 0.2227 - val_loss:
0.0828 - val_mean_absolute_error: 0.1922
Epoch 37/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1182 - mean_absolute_error: 0.2214 - val_loss:
0.0812 - val_mean_absolute_error: 0.1906
Epoch 38/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1175 - mean_absolute_error: 0.2208 - val_loss:
0.0856 - val_mean_absolute_error: 0.1953
Epoch 39/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1175 - mean_absolute_error: 0.2205 - val_loss:
0.0852 - val_mean_absolute_error: 0.1928
Epoch 40/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1167 - mean_absolute_error: 0.2199 - val_loss:
0.0856 - val_mean_absolute_error: 0.1951
Epoch 41/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1162 - mean_absolute_error: 0.2193 - val_loss:
0.0836 - val_mean_absolute_error: 0.1947
Epoch 42/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1159 - mean_absolute_error: 0.2188 - val_loss:
0.0825 - val_mean_absolute_error: 0.1928
Epoch 43/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1160 - mean_absolute_error: 0.2187 - val_loss:
0.0801 - val_mean_absolute_error: 0.1903
Epoch 44/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1152 - mean_absolute_error: 0.2181 - val_loss:
0.0795 - val_mean_absolute_error: 0.1892
Epoch 45/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1146 - mean_absolute_error: 0.2174 - val_loss:
0.0827 - val_mean_absolute_error: 0.1928
Epoch 46/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1147 - mean_absolute_error: 0.2174 - val_loss:
0.0813 - val_mean_absolute_error: 0.1903
Epoch 47/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1143 - mean_absolute_error: 0.2171 - val_loss:
0.0798 - val_mean_absolute_error: 0.1884
Epoch 48/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1138 - mean_absolute_error: 0.2166 - val_loss:
0.0766 - val_mean_absolute_error: 0.1864
Epoch 49/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1132 - mean_absolute_error: 0.2162 - val_loss:
0.0784 - val_mean_absolute_error: 0.1881
Epoch 50/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1130 - mean_absolute_error: 0.2157 - val_loss:
0.0784 - val_mean_absolute_error: 0.1869
```

In [31]:
```
make_predictions(baseline_model, window_7_1_3)
```

In [32]:
```
plot_results(hist)
```



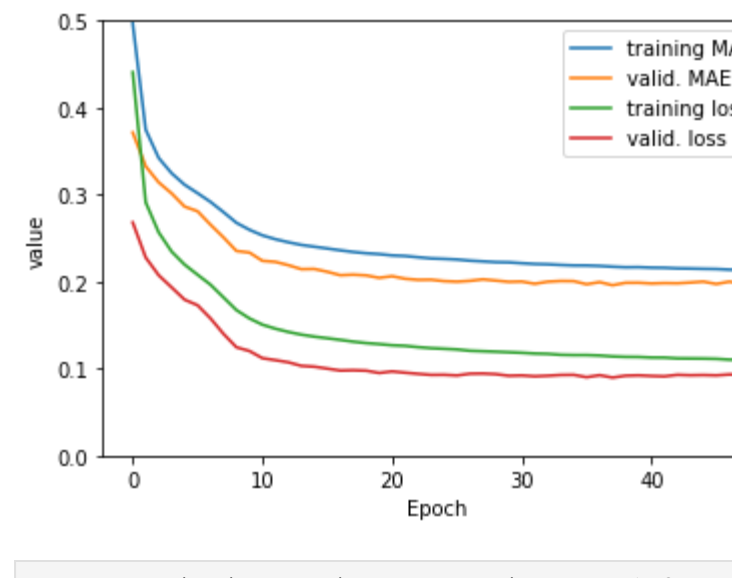
PARAMETER TUNING: NUMBER OF UNITS

In [33]:
```
unit_model = tf.keras.models.Sequential([
    tf.keras.layers.LSTM(9),
    tf.keras.layers.Dense(units=1)
])
```

In [34]:
```
hist = compile_and_fit(unit_model, window_7_1_3, 10, 50)
```

```
Epoch 1/50
893/893 [==============================] - 7s 5ms/step - loss: 0.4408 - mean_absolute_error: 0.4968 - val_loss:
0.2681 - val_mean_absolute_error: 0.3714
Epoch 2/50
893/893 [==============================] - 5s 6ms/step - loss: 0.2912 - mean_absolute_error: 0.3747 - val_loss:
0.2277 - val_mean_absolute_error: 0.3326
Epoch 3/50
893/893 [==============================] - 5s 6ms/step - loss: 0.2567 - mean_absolute_error: 0.3422 - val_loss:
0.2074 - val_mean_absolute_error: 0.3141
Epoch 4/50
893/893 [==============================] - 5s 6ms/step - loss: 0.2345 - mean_absolute_error: 0.3246 - val_loss:
0.1934 - val_mean_absolute_error: 0.3015
Epoch 5/50
893/893 [==============================] - 6s 6ms/step - loss: 0.2196 - mean_absolute_error: 0.3114 - val_loss:
0.1793 - val_mean_absolute_error: 0.2863
Epoch 6/50
893/893 [==============================] - 6s 6ms/step - loss: 0.2079 - mean_absolute_error: 0.3017 - val_loss:
0.1729 - val_mean_absolute_error: 0.2809
Epoch 7/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1965 - mean_absolute_error: 0.2917 - val_loss:
0.1577 - val_mean_absolute_error: 0.2655
Epoch 8/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1819 - mean_absolute_error: 0.2799 - val_loss:
0.1399 - val_mean_absolute_error: 0.2509
Epoch 9/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1672 - mean_absolute_error: 0.2676 - val_loss:
0.1245 - val_mean_absolute_error: 0.2352
Epoch 10/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1577 - mean_absolute_error: 0.2596 - val_loss:
0.1202 - val_mean_absolute_error: 0.2334
Epoch 11/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1505 - mean_absolute_error: 0.2532 - val_loss:
0.1120 - val_mean_absolute_error: 0.2239
Epoch 12/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1459 - mean_absolute_error: 0.2488 - val_loss:
0.1097 - val_mean_absolute_error: 0.2227
Epoch 13/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1422 - mean_absolute_error: 0.2453 - val_loss:
0.1073 - val_mean_absolute_error: 0.2189
Epoch 14/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1391 - mean_absolute_error: 0.2422 - val_loss:
0.1032 - val_mean_absolute_error: 0.2143
Epoch 15/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1368 - mean_absolute_error: 0.2402 - val_loss:
0.1022 - val_mean_absolute_error: 0.2146
Epoch 16/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1349 - mean_absolute_error: 0.2381 - val_loss:
0.1000 - val_mean_absolute_error: 0.2114
Epoch 17/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1330 - mean_absolute_error: 0.2360 - val_loss:
0.0978 - val_mean_absolute_error: 0.2074
Epoch 18/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1310 - mean_absolute_error: 0.2341 - val_loss:
0.0981 - val_mean_absolute_error: 0.2080
Epoch 19/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1294 - mean_absolute_error: 0.2326 - val_loss:
0.0976 - val_mean_absolute_error: 0.2072
Epoch 20/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1282 - mean_absolute_error: 0.2317 - val_loss:
0.0950 - val_mean_absolute_error: 0.2044
Epoch 21/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1269 - mean_absolute_error: 0.2301 - val_loss:
0.0968 - val_mean_absolute_error: 0.2063
Epoch 22/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1262 - mean_absolute_error: 0.2295 - val_loss:
0.0953 - val_mean_absolute_error: 0.2033
Epoch 23/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1247 - mean_absolute_error: 0.2280 - val_loss:
0.0940 - val_mean_absolute_error: 0.2021
Epoch 24/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1235 - mean_absolute_error: 0.2267 - val_loss:
0.0928 - val_mean_absolute_error: 0.2022
Epoch 25/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1228 - mean_absolute_error: 0.2262 - val_loss:
0.0929 - val_mean_absolute_error: 0.2006
Epoch 26/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1220 - mean_absolute_error: 0.2255 - val_loss:
0.0921 - val_mean_absolute_error: 0.1999
Epoch 27/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1205 - mean_absolute_error: 0.2241 - val_loss:
0.0941 - val_mean_absolute_error: 0.2009
Epoch 28/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1200 - mean_absolute_error: 0.2233 - val_loss:
0.0943 - val_mean_absolute_error: 0.2026
Epoch 29/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1194 - mean_absolute_error: 0.2224 - val_loss:
0.0936 - val_mean_absolute_error: 0.2012
Epoch 30/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1188 - mean_absolute_error: 0.2222 - val_loss:
0.0918 - val_mean_absolute_error: 0.1998
Epoch 31/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1182 - mean_absolute_error: 0.2212 - val_loss:
0.0921 - val_mean_absolute_error: 0.2001
Epoch 32/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1173 - mean_absolute_error: 0.2203 - val_loss:
0.0912 - val_mean_absolute_error: 0.1975
Epoch 33/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1169 - mean_absolute_error: 0.2200 - val_loss:
0.0918 - val_mean_absolute_error: 0.1999
Epoch 34/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1159 - mean_absolute_error: 0.2192 - val_loss:
0.0927 - val_mean_absolute_error: 0.2007
Epoch 35/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1156 - mean_absolute_error: 0.2186 - val_loss:
0.0928 - val_mean_absolute_error: 0.2006
Epoch 36/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1156 - mean_absolute_error: 0.2186 - val_loss:
0.0901 - val_mean_absolute_error: 0.1970
Epoch 37/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1150 - mean_absolute_error: 0.2180 - val_loss:
0.0924 - val_mean_absolute_error: 0.1995
Epoch 38/50
893/893 [==============================] - 6s 6ms/step - loss: 0.1140 - mean_absolute_error: 0.2172 - val_loss:
0.0897 - val_mean_absolute_error: 0.1959
Epoch 39/50
893/893 [==============================] - 5s 6ms/step - loss: 0.1135 - mean_absolute_error: 0.2165 - val_loss:
0.0918 - val_mean_absolute_error: 0.1987
Epoch 40/50
893/893 [==============================] - 6s 7ms/step - loss: 0.1134 - mean_absolute_error: 0.2166 - val_loss:
0.0922 - val_mean_absolute_error: 0.1987
Epoch 41/50
893/893 [==============================] - 7s 7ms/step - loss: 0.1127 - mean_absolute_error: 0.2161 - val_loss:
0.0916 - val_mean_absolute_error: 0.1979
Epoch 42/50
893/893 [==============================] - 7s 8ms/step - loss: 0.1126 - mean_absolute_error: 0.2159 - val_loss:
0.0911 - val_mean_absolute_error: 0.1983
Epoch 43/50
893/893 [==============================] - 7s 7ms/step - loss: 0.1118 - mean_absolute_error: 0.2153 - val_loss:
0.0929 - val_mean_absolute_error: 0.1981
Epoch 44/50
893/893 [==============================] - 6s 7ms/step - loss: 0.1116 - mean_absolute_error: 0.2151 - val_loss:
0.0924 - val_mean_absolute_error: 0.1990
Epoch 45/50
893/893 [==============================] - 6s 7ms/step - loss: 0.1115 - mean_absolute_error: 0.2147 - val_loss:
0.0926 - val_mean_absolute_error: 0.2000
Epoch 46/50
893/893 [==============================] - 6s 7ms/step - loss: 0.1112 - mean_absolute_error: 0.2145 - val_loss:
0.0922 - val_mean_absolute_error: 0.1973
Epoch 47/50
893/893 [==============================] - 7s 7ms/step - loss: 0.1103 - mean_absolute_error: 0.2138 - val_loss:
0.0933 - val_mean_absolute_error: 0.2000
Epoch 48/50
893/893 [==============================] - 7s 7ms/step - loss: 0.1101 - mean_absolute_error: 0.2134 - val_loss:
0.0930 - val_mean_absolute_error: 0.1975
```

In [35]:
```
plot_results(hist)
```



In [36]:
```
make_predictions(unit_model, window_7_1_3)
```

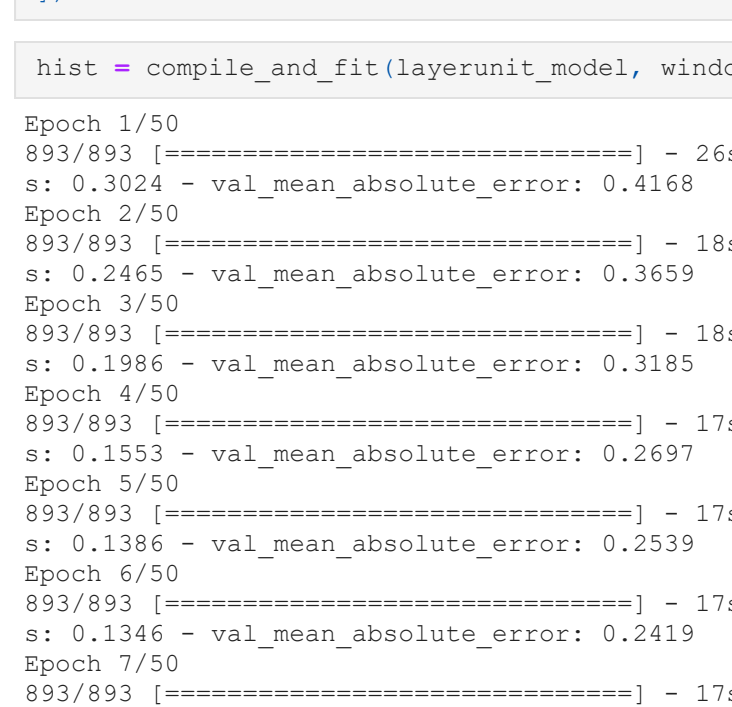
PARAMETER TUNING: ADDITION OF RECURENT LAYERS

In [37]:
```
layer_model = tf.keras.models.Sequential([
    tf.keras.layers.LSTM(9, return_sequences=True),
    tf.keras.layers.LSTM(9, return_sequences=True),
    tf.keras.layers.LSTM(9, return_sequences=True),
    tf.keras.layers.LSTM(9, return_sequences=True),
    tf.keras.layers.LSTM(9),
    tf.keras.layers.Dense(units=1)
])
```

In [38]:
```
hist = compile_and_fit(layer_model, window_7_1_3, 10, 50)
```

```
Epoch 1/50
893/893 [==============================] - 33s 26ms/step - loss: 0.4687 - mean_absolute_error: 0.5163 - val_los
s: 0.2741 - val_mean_absolute_error: 0.3954
Epoch 2/50
893/893 [==============================] - 22s 25ms/step - loss: 0.3397 - mean_absolute_error: 0.4107 - val_los
s: 0.2350 - val_mean_absolute_error: 0.3573
Epoch 3/50
893/893 [==============================] - 23s 26ms/step - loss: 0.2836 - mean_absolute_error: 0.3682 - val_los
s: 0.2011 - val_mean_absolute_error: 0.3273
Epoch 4/50
893/893 [==============================] - 23s 26ms/step - loss: 0.2399 - mean_absolute_error: 0.3360 - val_los
s: 0.1701 - val_mean_absolute_error: 0.2936
Epoch 5/50
893/893 [==============================] - 23s 26ms/step - loss: 0.2066 - mean_absolute_error: 0.3064 - val_los
s: 0.1527 - val_mean_absolute_error: 0.2782
Epoch 6/50
893/893 [==============================] - 23s 26ms/step - loss: 0.1861 - mean_absolute_error: 0.2868 - val_los
s: 0.1321 - val_mean_absolute_error: 0.2545
Epoch 7/50
893/893 [==============================] - 23s 26ms/step - loss: 0.1737 - mean_absolute_error: 0.2757 - val_los
s: 0.1242 - val_mean_absolute_error: 0.2447
Epoch 8/50
893/893 [==============================] - 23s 26ms/step - loss: 0.1642 - mean_absolute_error: 0.2666 - val_los
s: 0.1120 - val_mean_absolute_error: 0.2300
Epoch 9/50
893/893 [==============================] - 23s 26ms/step - loss: 0.1560 - mean_absolute_error: 0.2587 - val_los
s: 0.1274 - val_mean_absolute_error: 0.2491
Epoch 10/50
893/893 [==============================] - 23s 26ms/step - loss: 0.1492 - mean_absolute_error: 0.2515 - val_los
s: 0.1124 - val_mean_absolute_error: 0.2331
Epoch 11/50
893/893 [==============================] - 24s 27ms/step - loss: 0.1441 - mean_absolute_error: 0.2470 - val_los
s: 0.1115 - val_mean_absolute_error: 0.2351
Epoch 12/50
893/893 [==============================] - 23s 26ms/step - loss: 0.1403 - mean_absolute_error: 0.2430 - val_los
s: 0.0986 - val_mean_absolute_error: 0.2146
Epoch 13/50
893/893 [==============================] - 23s 26ms/step - loss: 0.1358 - mean_absolute_error: 0.2385 - val_los
s: 0.1097 - val_mean_absolute_error: 0.2311
Epoch 14/50
893/893 [==============================] - 23s 26ms/step - loss: 0.1325 - mean_absolute_error: 0.2351 - val_los
s: 0.0936 - val_mean_absolute_error: 0.2139
Epoch 15/50
893/893 [==============================] - 23s 26ms/step - loss: 0.1303 - mean_absolute_error: 0.2324 - val_los
s: 0.0953 - val_mean_absolute_error: 0.2130
Epoch 16/50
893/893 [==============================] - 24s 26ms/step - loss: 0.1263 - mean_absolute_error: 0.2283 - val_los
s: 0.0945 - val_mean_absolute_error: 0.2087
Epoch 17/50
893/893 [==============================] - 23s 26ms/step - loss: 0.1243 - mean_absolute_error: 0.2260 - val_los
s: 0.0922 - val_mean_absolute_error: 0.2119
Epoch 18/50
893/893 [==============================] - 23s 26ms/step - loss: 0.1210 - mean_absolute_error: 0.2232 - val_los
s: 0.0918 - val_mean_absolute_error: 0.2048
Epoch 19/50
893/893 [==============================] - 23s 26ms/step - loss: 0.1210 - mean_absolute_error: 0.2225 - val_los
s: 0.0952 - val_mean_absolute_error: 0.2158
Epoch 20/50
893/893 [==============================] - 23s 26ms/step - loss: 0.1170 - mean_absolute_error: 0.2187 - val_los
s: 0.0841 - val_mean_absolute_error: 0.1970
Epoch 21/50
893/893 [==============================] - 23s 26ms/step - loss: 0.1172 - mean_absolute_error: 0.2183 - val_los
s: 0.0842 - val_mean_absolute_error: 0.2015
Epoch 22/50
893/893 [==============================] - 23s 26ms/step - loss: 0.1146 - mean_absolute_error: 0.2157 - val_los
s: 0.0844 - val_mean_absolute_error: 0.1989
Epoch 23/50
893/893 [==============================] - 23s 25ms/step - loss: 0.1134 - mean_absolute_error: 0.2146 - val_los
s: 0.0844 - val_mean_absolute_error: 0.1973
Epoch 24/50
893/893 [==============================] - 21s 24ms/step - loss: 0.1117 - mean_absolute_error: 0.2130 - val_los
s: 0.0835 - val_mean_absolute_error: 0.1938
Epoch 25/50
893/893 [==============================] - 23s 26ms/step - loss: 0.1109 - mean_absolute_error: 0.2122 - val_los
s: 0.0907 - val_mean_absolute_error: 0.2022
Epoch 26/50
893/893 [==============================] - 23s 26ms/step - loss: 0.1100 - mean_absolute_error: 0.2108 - val_los
s: 0.0844 - val_mean_absolute_error: 0.1963
Epoch 27/50
893/893 [==============================] - 22s 25ms/step - loss: 0.1091 - mean_absolute_error: 0.2099 - val_los
s: 0.0877 - val_mean_absolute_error: 0.1987
Epoch 28/50
893/893 [==============================] - 22s 24ms/step - loss: 0.1084 - mean_absolute_error: 0.2090 - val_los
s: 0.0896 - val_mean_absolute_error: 0.1997
Epoch 29/50
893/893 [==============================] - 21s 24ms/step - loss: 0.1065 - mean_absolute_error: 0.2072 - val_los
s: 0.0773 - val_mean_absolute_error: 0.1891
Epoch 30/50
893/893 [==============================] - 22s 24ms/step - loss: 0.1073 - mean_absolute_error: 0.2076 - val_los
s: 0.0895 - val_mean_absolute_error: 0.1983
Epoch 31/50
893/893 [==============================] - 21s 24ms/step - loss: 0.1057 - mean_absolute_error: 0.2064 - val_los
s: 0.0811 - val_mean_absolute_error: 0.1883
Epoch 32/50
893/893 [==============================] - 21s 24ms/step - loss: 0.1042 - mean_absolute_error: 0.2046 - val_los
s: 0.0772 - val_mean_absolute_error: 0.1827
Epoch 33/50
893/893 [==============================] - 21s 23ms/step - loss: 0.1041 - mean_absolute_error: 0.2044 - val_los
s: 0.0789 - val_mean_absolute_error: 0.1889
Epoch 34/50
893/893 [==============================] - 21s 24ms/step - loss: 0.1033 - mean_absolute_error: 0.2038 - val_los
s: 0.0751 - val_mean_absolute_error: 0.1845
Epoch 35/50
893/893 [==============================] - 21s 23ms/step - loss: 0.1036 - mean_absolute_error: 0.2033 - val_los
s: 0.0829 - val_mean_absolute_error: 0.1906
Epoch 36/50
893/893 [==============================] - 21s 23ms/step - loss: 0.1023 - mean_absolute_error: 0.2024 - val_los
s: 0.0781 - val_mean_absolute_error: 0.1902
Epoch 37/50
893/893 [==============================] - 21s 24ms/step - loss: 0.1004 - mean_absolute_error: 0.2006 - val_los
s: 0.0925 - val_mean_absolute_error: 0.2063
Epoch 38/50
893/893 [==============================] - 21s 23ms/step - loss: 0.1011 - mean_absolute_error: 0.2010 - val_los
s: 0.0749 - val_mean_absolute_error: 0.1800
Epoch 39/50
893/893 [==============================] - 20s 22ms/step - loss: 0.1001 - mean_absolute_error: 0.1997 - val_los
s: 0.0900 - val_mean_absolute_error: 0.2030
Epoch 40/50
893/893 [==============================] - 20s 23ms/step - loss: 0.1000 - mean_absolute_error: 0.2003 - val_los
s: 0.0833 - val_mean_absolute_error: 0.1893
Epoch 41/50
893/893 [==============================] - 21s 23ms/step - loss: 0.0993 - mean_absolute_error: 0.1989 - val_los
s: 0.0757 - val_mean_absolute_error: 0.1819
Epoch 42/50
893/893 [==============================] - 21s 23ms/step - loss: 0.0975 - mean_absolute_error: 0.1976 - val_los
s: 0.0746 - val_mean_absolute_error: 0.1813
Epoch 43/50
893/893 [==============================] - 21s 24ms/step - loss: 0.0967 - mean_absolute_error: 0.1968 - val_los
s: 0.0826 - val_mean_absolute_error: 0.1866
Epoch 44/50
893/893 [==============================] - 21s 24ms/step - loss: 0.0964 - mean_absolute_error: 0.1964 - val_los
s: 0.0780 - val_mean_absolute_error: 0.1841
Epoch 45/50
893/893 [==============================] - 22s 24ms/step - loss: 0.0971 - mean_absolute_error: 0.1972 - val_los
s: 0.0774 - val_mean_absolute_error: 0.1823
Epoch 46/50
893/893 [==============================] - 21s 24ms/step - loss: 0.0958 - mean_absolute_error: 0.1958 - val_los
s: 0.0773 - val_mean_absolute_error: 0.1826
Epoch 47/50
893/893 [==============================] - 21s 24ms/step - loss: 0.0958 - mean_absolute_error: 0.1953 - val_los
s: 0.0785 - val_mean_absolute_error: 0.1815
Epoch 48/50
893/893 [==============================] - 21s 24ms/step - loss: 0.0958 - mean_absolute_error: 0.1954 - val_los
s: 0.0767 - val_mean_absolute_error: 0.1796
Epoch 49/50
893/893 [==============================] - 21s 24ms/step - loss: 0.0938 - mean_absolute_error: 0.1939 - val_los
s: 0.0800 - val_mean_absolute_error: 0.1833
Epoch 50/50
893/893 [==============================] - 21s 23ms/step - loss: 0.0946 - mean_absolute_error: 0.1945 - val_los
s: 0.0798 - val_mean_absolute_error: 0.1819
```

In [39]:
```
plot_results(hist)
```



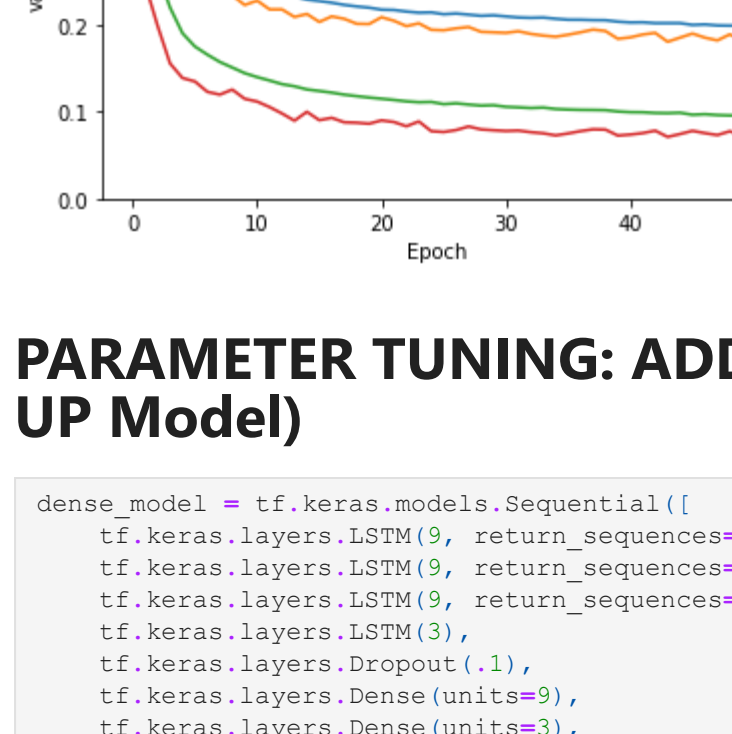
PARAMETER TUNING: LAYERS AND UNITS

In [40]:
```
layerunit_model = tf.keras.models.Sequential([
    tf.keras.layers.LSTM(9, return_sequences=True),
    tf.keras.layers.LSTM(9, return_sequences=True),
    tf.keras.layers.LSTM(9, return_sequences=True),
    tf.keras.layers.LSTM(3),
    tf.keras.layers.Dense(units=1)
])
```

In [41]:
```
hist = compile_and_fit(layerunit_model, window_7_1_3, 20, 50)
```

```
Epoch 1/50
893/893 [==============================] - 26s 21ms/step - loss: 0.4475 - mean_absolute_error: 0.5038 - val_los
s: 0.3024 - val_mean_absolute_error: 0.4168
Epoch 2/50
893/893 [==============================] - 18s 20ms/step - loss: 0.3111 - mean_absolute_error: 0.3877 - val_los
s: 0.2465 - val_mean_absolute_error: 0.3659
Epoch 3/50
893/893 [==============================] - 18s 20ms/step - loss: 0.2609 - mean_absolute_error: 0.3479 - val_los
s: 0.1986 - val_mean_absolute_error: 0.3185
Epoch 4/50
893/893 [==============================] - 17s 19ms/step - loss: 0.2197 - mean_absolute_error: 0.3146 - val_los
s: 0.1553 - val_mean_absolute_error: 0.2697
Epoch 5/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1901 - mean_absolute_error: 0.2881 - val_los
s: 0.1386 - val_mean_absolute_error: 0.2539
Epoch 6/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1749 - mean_absolute_error: 0.2742 - val_los
s: 0.1346 - val_mean_absolute_error: 0.2419
Epoch 7/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1655 - mean_absolute_error: 0.2655 - val_los
s: 0.1228 - val_mean_absolute_error: 0.2367
Epoch 8/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1571 - mean_absolute_error: 0.2579 - val_los
s: 0.1195 - val_mean_absolute_error: 0.2346
Epoch 9/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1507 - mean_absolute_error: 0.2522 - val_los
s: 0.1253 - val_mean_absolute_error: 0.2338
Epoch 10/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1442 - mean_absolute_error: 0.2461 - val_los
s: 0.1148 - val_mean_absolute_error: 0.2226
Epoch 11/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1397 - mean_absolute_error: 0.2416 - val_los
s: 0.1116 - val_mean_absolute_error: 0.2277
Epoch 12/50
893/893 [==============================] - 16s 18ms/step - loss: 0.1358 - mean_absolute_error: 0.2382 - val_los
s: 0.1052 - val_mean_absolute_error: 0.2175
Epoch 13/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1316 - mean_absolute_error: 0.2346 - val_los
s: 0.0979 - val_mean_absolute_error: 0.2175
Epoch 14/50
893/893 [==============================] - 16s 18ms/step - loss: 0.1291 - mean_absolute_error: 0.2325 - val_los
s: 0.0896 - val_mean_absolute_error: 0.2088
Epoch 15/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1255 - mean_absolute_error: 0.2288 - val_los
s: 0.0998 - val_mean_absolute_error: 0.2123
Epoch 16/50
893/893 [==============================] - 16s 18ms/step - loss: 0.1237 - mean_absolute_error: 0.2272 - val_los
s: 0.0902 - val_mean_absolute_error: 0.2031
Epoch 17/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1218 - mean_absolute_error: 0.2252 - val_los
s: 0.0928 - val_mean_absolute_error: 0.2095
Epoch 18/50
893/893 [==============================] - 17s 18ms/step - loss: 0.1195 - mean_absolute_error: 0.2227 - val_los
s: 0.0877 - val_mean_absolute_error: 0.2067
Epoch 19/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1178 - mean_absolute_error: 0.2209 - val_los
s: 0.0872 - val_mean_absolute_error: 0.2010
Epoch 20/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1162 - mean_absolute_error: 0.2195 - val_los
s: 0.0861 - val_mean_absolute_error: 0.2007
Epoch 21/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1148 - mean_absolute_error: 0.2172 - val_los
s: 0.0899 - val_mean_absolute_error: 0.2086
Epoch 22/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1134 - mean_absolute_error: 0.2169 - val_los
s: 0.0880 - val_mean_absolute_error: 0.2044
Epoch 23/50
893/893 [==============================] - 17s 18ms/step - loss: 0.1118 - mean_absolute_error: 0.2151 - val_los
s: 0.0832 - val_mean_absolute_error: 0.1983
Epoch 24/50
893/893 [==============================] - 17s 18ms/step - loss: 0.1108 - mean_absolute_error: 0.2138 - val_los
s: 0.0887 - val_mean_absolute_error: 0.2015
Epoch 25/50
893/893 [==============================] - 16s 18ms/step - loss: 0.1111 - mean_absolute_error: 0.2141 - val_los
s: 0.0775 - val_mean_absolute_error: 0.1941
Epoch 26/50
893/893 [==============================] - 16s 18ms/step - loss: 0.1086 - mean_absolute_error: 0.2120 - val_los
s: 0.0766 - val_mean_absolute_error: 0.1935
Epoch 27/50
893/893 [==============================] - 16s 18ms/step - loss: 0.1096 - mean_absolute_error: 0.2128 - val_los
s: 0.0788 - val_mean_absolute_error: 0.1957
Epoch 28/50
893/893 [==============================] - 17s 18ms/step - loss: 0.1081 - mean_absolute_error: 0.2115 - val_los
s: 0.0829 - val_mean_absolute_error: 0.1973
Epoch 29/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1069 - mean_absolute_error: 0.2102 - val_los
s: 0.0796 - val_mean_absolute_error: 0.1918
Epoch 30/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1074 - mean_absolute_error: 0.2107 - val_los
s: 0.0786 - val_mean_absolute_error: 0.1912
Epoch 31/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1055 - mean_absolute_error: 0.2094 - val_los
s: 0.0778 - val_mean_absolute_error: 0.1906
Epoch 32/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1049 - mean_absolute_error: 0.2083 - val_los
s: 0.0782 - val_mean_absolute_error: 0.1924
Epoch 33/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1041 - mean_absolute_error: 0.2078 - val_los
s: 0.0763 - val_mean_absolute_error: 0.1894
Epoch 34/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1047 - mean_absolute_error: 0.2082 - val_los
s: 0.0751 - val_mean_absolute_error: 0.1874
Epoch 35/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1030 - mean_absolute_error: 0.2067 - val_los
s: 0.0727 - val_mean_absolute_error: 0.1861
Epoch 36/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1024 - mean_absolute_error: 0.2057 - val_los
s: 0.0749 - val_mean_absolute_error: 0.1884
Epoch 37/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1020 - mean_absolute_error: 0.2056 - val_los
s: 0.0776 - val_mean_absolute_error: 0.1912
Epoch 38/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1019 - mean_absolute_error: 0.2052 - val_los
s: 0.0796 - val_mean_absolute_error: 0.1943
Epoch 39/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1017 - mean_absolute_error: 0.2051 - val_los
s: 0.0793 - val_mean_absolute_error: 0.1927
Epoch 40/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1002 - mean_absolute_error: 0.2034 - val_los
s: 0.0725 - val_mean_absolute_error: 0.1837
Epoch 41/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0994 - mean_absolute_error: 0.2025 - val_los
s: 0.0736 - val_mean_absolute_error: 0.1854
Epoch 42/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0992 - mean_absolute_error: 0.2027 - val_los
s: 0.0753 - val_mean_absolute_error: 0.1886
Epoch 43/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0984 - mean_absolute_error: 0.2017 - val_los
s: 0.0781 - val_mean_absolute_error: 0.1905
Epoch 44/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0982 - mean_absolute_error: 0.2018 - val_los
s: 0.0709 - val_mean_absolute_error: 0.1803
Epoch 45/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0987 - mean_absolute_error: 0.2017 - val_los
s: 0.0742 - val_mean_absolute_error: 0.1851
Epoch 46/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0964 - mean_absolute_error: 0.1997 - val_los
s: 0.0779 - val_mean_absolute_error: 0.1897
Epoch 47/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0970 - mean_absolute_error: 0.2002 - val_los
s: 0.0753 - val_mean_absolute_error: 0.1850
Epoch 48/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0960 - mean_absolute_error: 0.1991 - val_los
s: 0.0730 - val_mean_absolute_error: 0.1819
Epoch 49/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0956 - mean_absolute_error: 0.1989 - val_los
s: 0.0774 - val_mean_absolute_error: 0.1888
Epoch 50/50
893/893 [==============================] - 16s 18ms/step - loss: 0.0958 - mean_absolute_error: 0.1991 - val_los
s: 0.0723 - val_mean_absolute_error: 0.1813
```

In [42]:
```
plot_results(hist)
```



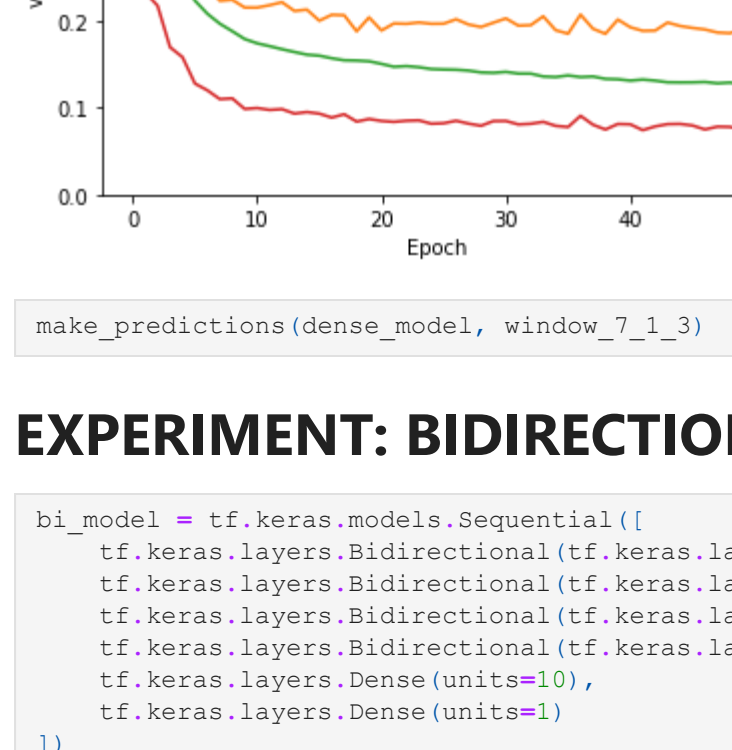
PARAMETER TUNING: ADDITIONAL DENSE LAYERS (Runner UP Model)

In [43]:
```
dense_model = tf.keras.models.Sequential([
    tf.keras.layers.LSTM(9, return_sequences=True),
    tf.keras.layers.LSTM(9, return_sequences=True),
    tf.keras.layers.LSTM(9, return_sequences=True),
    tf.keras.layers.LSTM(3),
    tf.keras.layers.Dropout(.1),
    tf.keras.layers.Dense(units=9),
    tf.keras.layers.Dense(units=3),
    tf.keras.layers.Dense(units=1)
])
```

In [44]:
```
hist = compile_and_fit(dense_model, window_7_1_3, 20, 50)
```

```
Epoch 1/50
893/893 [==============================] - 25s 20ms/step - loss: 0.4594 - mean_absolute_error: 0.5078 - val_los
s: 0.2477 - val_mean_absolute_error: 0.3691
Epoch 2/50
893/893 [==============================] - 17s 19ms/step - loss: 0.3520 - mean_absolute_error: 0.4273 - val_los
s: 0.2329 - val_mean_absolute_error: 0.3488
Epoch 3/50
893/893 [==============================] - 17s 19ms/step - loss: 0.3141 - mean_absolute_error: 0.4003 - val_los
s: 0.2171 - val_mean_absolute_error: 0.3414
Epoch 4/50
893/893 [==============================] - 17s 19ms/step - loss: 0.2771 - mean_absolute_error: 0.3747 - val_los
s: 0.1694 - val_mean_absolute_error: 0.2934
Epoch 5/50
893/893 [==============================] - 17s 19ms/step - loss: 0.2486 - mean_absolute_error: 0.3528 - val_los
s: 0.1580 - val_mean_absolute_error: 0.2766
Epoch 6/50
893/893 [==============================] - 17s 18ms/step - loss: 0.2230 - mean_absolute_error: 0.3306 - val_los
s: 0.1277 - val_mean_absolute_error: 0.2504
Epoch 7/50
893/893 [==============================] - 17s 19ms/step - loss: 0.2079 - mean_absolute_error: 0.3167 - val_los
s: 0.1199 - val_mean_absolute_error: 0.2402
Epoch 8/50
893/893 [==============================] - 17s 18ms/step - loss: 0.1965 - mean_absolute_error: 0.3058 - val_los
s: 0.1098 - val_mean_absolute_error: 0.2228
Epoch 9/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1879 - mean_absolute_error: 0.2985 - val_los
s: 0.1106 - val_mean_absolute_error: 0.2240
Epoch 10/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1789 - mean_absolute_error: 0.2902 - val_los
s: 0.0985 - val_mean_absolute_error: 0.2151
Epoch 11/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1739 - mean_absolute_error: 0.2860 - val_los
s: 0.0995 - val_mean_absolute_error: 0.2150
Epoch 12/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1707 - mean_absolute_error: 0.2830 - val_los
s: 0.0974 - val_mean_absolute_error: 0.2178
Epoch 13/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1671 - mean_absolute_error: 0.2801 - val_los
s: 0.0982 - val_mean_absolute_error: 0.2212
Epoch 14/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1640 - mean_absolute_error: 0.2771 - val_los
s: 0.0932 - val_mean_absolute_error: 0.2111
Epoch 15/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1609 - mean_absolute_error: 0.2743 - val_los
s: 0.0949 - val_mean_absolute_error: 0.2127
Epoch 16/50
893/893 [==============================] - 17s 20ms/step - loss: 0.1597 - mean_absolute_error: 0.2742 - val_los
s: 0.0931 - val_mean_absolute_error: 0.1999
Epoch 17/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1567 - mean_absolute_error: 0.2714 - val_los
s: 0.0885 - val_mean_absolute_error: 0.2067
Epoch 18/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1544 - mean_absolute_error: 0.2687 - val_los
s: 0.0924 - val_mean_absolute_error: 0.2062
Epoch 19/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1541 - mean_absolute_error: 0.2694 - val_los
s: 0.0840 - val_mean_absolute_error: 0.1877
Epoch 20/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1533 - mean_absolute_error: 0.2684 - val_los
s: 0.0869 - val_mean_absolute_error: 0.2037
Epoch 21/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1503 - mean_absolute_error: 0.2650 - val_los
s: 0.0847 - val_mean_absolute_error: 0.1887
Epoch 22/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1469 - mean_absolute_error: 0.2622 - val_los
s: 0.0837 - val_mean_absolute_error: 0.1968
Epoch 23/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1477 - mean_absolute_error: 0.2627 - val_los
s: 0.0849 - val_mean_absolute_error: 0.1964
Epoch 24/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1465 - mean_absolute_error: 0.2610 - val_los
s: 0.0853 - val_mean_absolute_error: 0.1979
Epoch 25/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1444 - mean_absolute_error: 0.2599 - val_los
s: 0.0815 - val_mean_absolute_error: 0.1964
Epoch 26/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1438 - mean_absolute_error: 0.2603 - val_los
s: 0.0820 - val_mean_absolute_error: 0.1965
Epoch 27/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1435 - mean_absolute_error: 0.2593 - val_los
s: 0.0849 - val_mean_absolute_error: 0.2016
Epoch 28/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1425 - mean_absolute_error: 0.2585 - val_los
s: 0.0816 - val_mean_absolute_error: 0.1955
Epoch 29/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1405 - mean_absolute_error: 0.2563 - val_los
s: 0.0791 - val_mean_absolute_error: 0.1927
Epoch 30/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1400 - mean_absolute_error: 0.2560 - val_los
s: 0.0845 - val_mean_absolute_error: 0.1977
Epoch 31/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1411 - mean_absolute_error: 0.2563 - val_los
s: 0.0846 - val_mean_absolute_error: 0.2026
Epoch 32/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1391 - mean_absolute_error: 0.2547 - val_los
s: 0.0807 - val_mean_absolute_error: 0.1943
Epoch 33/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1391 - mean_absolute_error: 0.2550 - val_los
s: 0.0814 - val_mean_absolute_error: 0.1948
Epoch 34/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1358 - mean_absolute_error: 0.2522 - val_los
s: 0.0836 - val_mean_absolute_error: 0.2050
Epoch 35/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1352 - mean_absolute_error: 0.2515 - val_los
s: 0.0790 - val_mean_absolute_error: 0.1890
Epoch 36/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1370 - mean_absolute_error: 0.2539 - val_los
s: 0.0777 - val_mean_absolute_error: 0.1850
Epoch 37/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1351 - mean_absolute_error: 0.2514 - val_los
s: 0.0906 - val_mean_absolute_error: 0.2070
Epoch 38/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1358 - mean_absolute_error: 0.2531 - val_los
s: 0.0804 - val_mean_absolute_error: 0.1907
Epoch 39/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1330 - mean_absolute_error: 0.2495 - val_los
s: 0.0748 - val_mean_absolute_error: 0.1848
Epoch 40/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1326 - mean_absolute_error: 0.2493 - val_los
s: 0.0812 - val_mean_absolute_error: 0.2013
Epoch 41/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1310 - mean_absolute_error: 0.2483 - val_los
s: 0.0808 - val_mean_absolute_error: 0.1924
Epoch 42/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1322 - mean_absolute_error: 0.2491 - val_los
s: 0.0741 - val_mean_absolute_error: 0.1883
Epoch 43/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1310 - mean_absolute_error: 0.2478 - val_los
s: 0.0784 - val_mean_absolute_error: 0.1886
Epoch 44/50
893/893 [==============================] - 18s 20ms/step - loss: 0.1291 - mean_absolute_error: 0.2459 - val_los
s: 0.0810 - val_mean_absolute_error: 0.1978
Epoch 45/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1290 - mean_absolute_error: 0.2461 - val_los
s: 0.0812 - val_mean_absolute_error: 0.1939
Epoch 46/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1290 - mean_absolute_error: 0.2460 - val_los
s: 0.0795 - val_mean_absolute_error: 0.1916
Epoch 47/50
893/893 [==============================] - 17s 20ms/step - loss: 0.1295 - mean_absolute_error: 0.2463 - val_los
s: 0.0749 - val_mean_absolute_error: 0.1899
Epoch 48/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1280 - mean_absolute_error: 0.2445 - val_los
s: 0.0781 - val_mean_absolute_error: 0.1864
Epoch 49/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1288 - mean_absolute_error: 0.2456 - val_los
s: 0.0778 - val_mean_absolute_error: 0.1856
Epoch 50/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1272 - mean_absolute_error: 0.2449 - val_los
s: 0.0751 - val_mean_absolute_error: 0.1898
```

In [45]:
```
plot_results(hist)
```



In [46]:
```
make_predictions(dense_model, window_7_1_3)
```

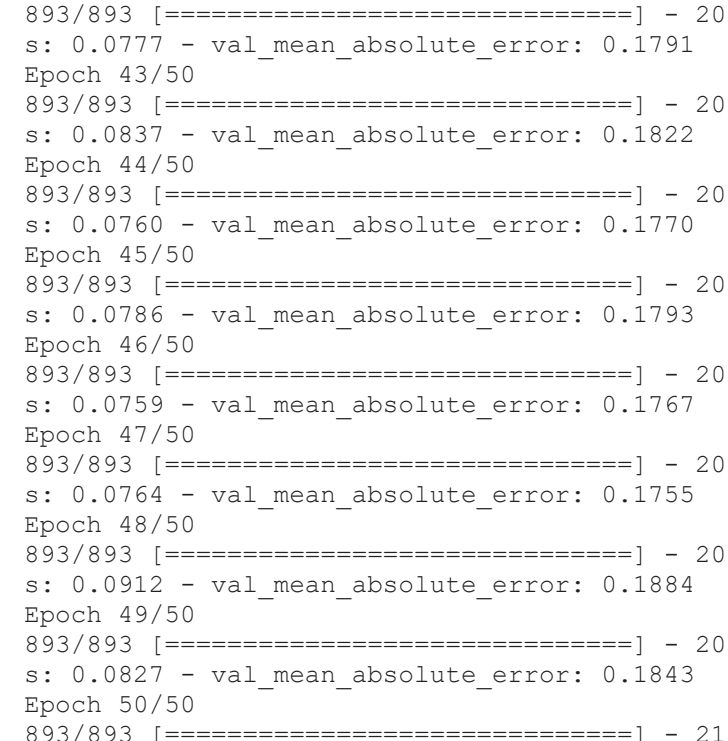
EXPERIMENT: BIDIRECTIONAL RNN

In [47]:
```
bi_model = tf.keras.models.Sequential([
    tf.keras.layers.Bidirectional(tf.keras.layers.LSTM(9, return_sequences=True)),
    tf.keras.layers.Bidirectional(tf.keras.layers.LSTM(9, return_sequences=True)),
    tf.keras.layers.Bidirectional(tf.keras.layers.LSTM(9, return_sequences=True)),
    tf.keras.layers.Bidirectional(tf.keras.layers.LSTM(3)),
    tf.keras.layers.Dense(units=10),
    tf.keras.layers.Dense(units=1)
])
```

In [48]:
```
hist = compile_and_fit(bi_model, window_7_1_3, 20, 50)
```

```
Epoch 1/50
893/893 [==============================] - 37s 26ms/step - loss: 0.3737 - mean_absolute_error: 0.4408 - val_los
s: 0.2256 - val_mean_absolute_error: 0.3339
Epoch 2/50
893/893 [==============================] - 21s 23ms/step - loss: 0.2519 - mean_absolute_error: 0.3400 - val_los
s: 0.1726 - val_mean_absolute_error: 0.2898
Epoch 3/50
893/893 [==============================] - 21s 23ms/step - loss: 0.2003 - mean_absolute_error: 0.2967 - val_los
s: 0.1235 - val_mean_absolute_error: 0.2387
Epoch 4/50
893/893 [==============================] - 21s 23ms/step - loss: 0.1718 - mean_absolute_error: 0.2700 - val_los
s: 0.1155 - val_mean_absolute_error: 0.2288
Epoch 5/50
893/893 [==============================] - 20s 23ms/step - loss: 0.1595 - mean_absolute_error: 0.2578 - val_los
s: 0.1050 - val_mean_absolute_error: 0.2153
Epoch 6/50
893/893 [==============================] - 21s 23ms/step - loss: 0.1512 - mean_absolute_error: 0.2492 - val_los
s: 0.1010 - val_mean_absolute_error: 0.2166
Epoch 7/50
893/893 [==============================] - 20s 22ms/step - loss: 0.1442 - mean_absolute_error: 0.2422 - val_los
s: 0.1053 - val_mean_absolute_error: 0.2148
Epoch 8/50
893/893 [==============================] - 20s 23ms/step - loss: 0.1370 - mean_absolute_error: 0.2359 - val_los
s: 0.1013 - val_mean_absolute_error: 0.2158
Epoch 9/50
893/893 [==============================] - 20s 22ms/step - loss: 0.1335 - mean_absolute_error: 0.2322 - val_los
s: 0.0878 - val_mean_absolute_error: 0.1990
Epoch 10/50
893/893 [==============================] - 20s 23ms/step - loss: 0.1304 - mean_absolute_error: 0.2289 - val_los
s: 0.1005 - val_mean_absolute_error: 0.1964
Epoch 11/50
893/893 [==============================] - 20s 23ms/step - loss: 0.1259 - mean_absolute_error: 0.2251 - val_los
s: 0.0871 - val_mean_absolute_error: 0.1924
Epoch 12/50
893/893 [==============================] - 20s 22ms/step - loss: 0.1239 - mean_absolute_error: 0.2230 - val_los
s: 0.0948 - val_mean_absolute_error: 0.1961
Epoch 13/50
893/893 [==============================] - 20s 23ms/step - loss: 0.1190 - mean_absolute_error: 0.2185 - val_los
s: 0.0839 - val_mean_absolute_error: 0.1871
Epoch 14/50
893/893 [==============================] - 20s 23ms/step - loss: 0.1166 - mean_absolute_error: 0.2160 - val_los
s: 0.0922 - val_mean_absolute_error: 0.1886
Epoch 15/50
893/893 [==============================] - 20s 23ms/step - loss: 0.1127 - mean_absolute_error: 0.2132 - val_los
s: 0.0985 - val_mean_absolute_error: 0.1937
Epoch 16/50
893/893 [==============================] - 20s 23ms/step - loss: 0.1128 - mean_absolute_error: 0.2133 - val_los
s: 0.0898 - val_mean_absolute_error: 0.1925
Epoch 17/50
893/893 [==============================] - 20s 23ms/step - loss: 0.1106 - mean_absolute_error: 0.2113 - val_los
s: 0.0892 - val_mean_absolute_error: 0.1929
Epoch 18/50
893/893 [==============================] - 20s 22ms/step - loss: 0.1079 - mean_absolute_error: 0.2081 - val_los
s: 0.0982 - val_mean_absolute_error: 0.1954
Epoch 19/50
893/893 [==============================] - 20s 22ms/step - loss: 0.1073 - mean_absolute_error: 0.2077 - val_los
s: 0.0846 - val_mean_absolute_error: 0.1863
Epoch 20/50
893/893 [==============================] - 20s 22ms/step - loss: 0.1073 - mean_absolute_error: 0.2072 - val_los
s: 0.0972 - val_mean_absolute_error: 0.1889
Epoch 21/50
893/893 [==============================] - 20s 23ms/step - loss: 0.1053 - mean_absolute_error: 0.2048 - val_los
s: 0.0856 - val_mean_absolute_error: 0.1853
Epoch 22/50
893/893 [==============================] - 20s 23ms/step - loss: 0.1031 - mean_absolute_error: 0.2030 - val_los
s: 0.0848 - val_mean_absolute_error: 0.1806
Epoch 23/50
893/893 [==============================] - 20s 23ms/step - loss: 0.1006 - mean_absolute_error: 0.2015 - val_los
s: 0.0898 - val_mean_absolute_error: 0.1852
Epoch 24/50
893/893 [==============================] - 20s 23ms/step - loss: 0.1016 - mean_absolute_error: 0.2012 - val_los
s: 0.0895 - val_mean_absolute_error: 0.1885
Epoch 25/50
893/893 [==============================] - 20s 22ms/step - loss: 0.0985 - mean_absolute_error: 0.1986 - val_los
s: 0.0838 - val_mean_absolute_error: 0.1812
Epoch 26/50
893/893 [==============================] - 20s 22ms/step - loss: 0.0988 - mean_absolute_error: 0.1988 - val_los
s: 0.0784 - val_mean_absolute_error: 0.1816
Epoch 27/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0974 - mean_absolute_error: 0.1974 - val_los
s: 0.0873 - val_mean_absolute_error: 0.1879
Epoch 28/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0979 - mean_absolute_error: 0.1972 - val_los
s: 0.0851 - val_mean_absolute_error: 0.1828
Epoch 29/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0952 - mean_absolute_error: 0.1953 - val_los
s: 0.0871 - val_mean_absolute_error: 0.1830
Epoch 30/50
893/893 [==============================] - 20s 22ms/step - loss: 0.0965 - mean_absolute_error: 0.1965 - val_los
s: 0.0776 - val_mean_absolute_error: 0.1754
Epoch 31/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0939 - mean_absolute_error: 0.1937 - val_los
s: 0.0842 - val_mean_absolute_error: 0.1821
Epoch 32/50
893/893 [==============================] - 21s 23ms/step - loss: 0.0925 - mean_absolute_error: 0.1924 - val_los
s: 0.0821 - val_mean_absolute_error: 0.1793
Epoch 33/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0921 - mean_absolute_error: 0.1921 - val_los
s: 0.0802 - val_mean_absolute_error: 0.1783
Epoch 34/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0937 - mean_absolute_error: 0.1939 - val_los
s: 0.0823 - val_mean_absolute_error: 0.1802
Epoch 35/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0892 - mean_absolute_error: 0.1895 - val_los
s: 0.0832 - val_mean_absolute_error: 0.1818
Epoch 36/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0911 - mean_absolute_error: 0.1911 - val_los
s: 0.0783 - val_mean_absolute_error: 0.1775
Epoch 37/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0874 - mean_absolute_error: 0.1884 - val_los
s: 0.0820 - val_mean_absolute_error: 0.1811
Epoch 38/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0892 - mean_absolute_error: 0.1893 - val_los
s: 0.0874 - val_mean_absolute_error: 0.1871
Epoch 39/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0871 - mean_absolute_error: 0.1877 - val_los
s: 0.0758 - val_mean_absolute_error: 0.1761
Epoch 40/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0879 - mean_absolute_error: 0.1884 - val_los
s: 0.0790 - val_mean_absolute_error: 0.1777
Epoch 41/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0846 - mean_absolute_error: 0.1857 - val_los
s: 0.0784 - val_mean_absolute_error: 0.1801
Epoch 42/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0857 - mean_absolute_error: 0.1861 - val_los
s: 0.0777 - val_mean_absolute_error: 0.1791
Epoch 43/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0852 - mean_absolute_error: 0.1864 - val_los
s: 0.0837 - val_mean_absolute_error: 0.1822
Epoch 44/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0845 - mean_absolute_error: 0.1853 - val_los
s: 0.0760 - val_mean_absolute_error: 0.1770
Epoch 45/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0844 - mean_absolute_error: 0.1852 - val_los
s: 0.0786 - val_mean_absolute_error: 0.1793
Epoch 46/50
893/893 [==============================] - 20s 22ms/step - loss: 0.0827 - mean_absolute_error: 0.1831 - val_los
s: 0.0759 - val_mean_absolute_error: 0.1767
Epoch 47/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0816 - mean_absolute_error: 0.1831 - val_los
s: 0.0764 - val_mean_absolute_error: 0.1755
Epoch 48/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0829 - mean_absolute_error: 0.1835 - val_los
s: 0.0912 - val_mean_absolute_error: 0.1884
Epoch 49/50
893/893 [==============================] - 20s 23ms/step - loss: 0.0807 - mean_absolute_error: 0.1819 - val_los
s: 0.0827 - val_mean_absolute_error: 0.1843
Epoch 50/50
893/893 [==============================] - 21s 23ms/step - loss: 0.0820 - mean_absolute_error: 0.1823 - val_los
s: 0.0792 - val_mean_absolute_error: 0.1802
```

In [49]:
```
plot_results(hist)
```



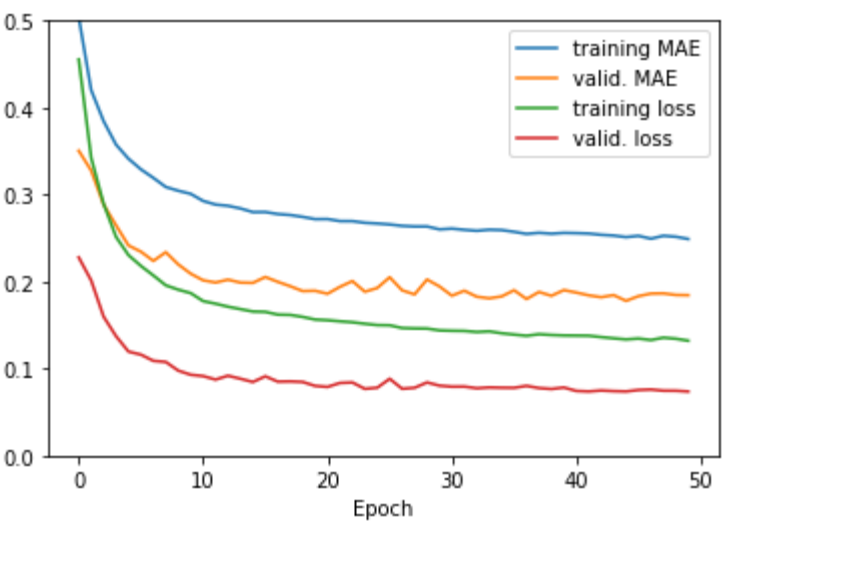
PARAMETER TUNING: DROPOUT

In [50]:
```
dropout_model = tf.keras.models.Sequential([
    tf.keras.layers.LSTM(9, recurrent_dropout=.5, return_sequences=True),
    tf.keras.layers.LSTM(9, return_sequences=True),
    tf.keras.layers.LSTM(9, return_sequences=True),
    tf.keras.layers.LSTM(3),
    tf.keras.layers.Dropout(.1),
    tf.keras.layers.Dense(units=9),
    tf.keras.layers.Dense(units=3),
    tf.keras.layers.Dense(units=1)
])
```

In [51]:
```
hist = compile_and_fit(dropout_model, window_7_1_3, 20, 50)
```

```
Epoch 1/50
893/893 [==============================] - 28s 22ms/step - loss: 0.4555 - mean_absolute_error: 0.5040 - val_los
s: 0.2279 - val_mean_absolute_error: 0.3506
Epoch 2/50
893/893 [==============================] - 19s 21ms/step - loss: 0.3424 - mean_absolute_error: 0.4203 - val_los
s: 0.2014 - val_mean_absolute_error: 0.3278
Epoch 3/50
893/893 [==============================] - 19s 21ms/step - loss: 0.2895 - mean_absolute_error: 0.3845 - val_los
s: 0.1597 - val_mean_absolute_error: 0.2886
Epoch 4/50
893/893 [==============================] - 19s 21ms/step - loss: 0.2514 - mean_absolute_error: 0.3575 - val_los
s: 0.1373 - val_mean_absolute_error: 0.2647
Epoch 5/50
893/893 [==============================] - 19s 21ms/step - loss: 0.2305 - mean_absolute_error: 0.3413 - val_los
s: 0.1196 - val_mean_absolute_error: 0.2416
Epoch 6/50
893/893 [==============================] - 19s 21ms/step - loss: 0.2180 - mean_absolute_error: 0.3291 - val_los
s: 0.1161 - val_mean_absolute_error: 0.2344
Epoch 7/50
893/893 [==============================] - 19s 21ms/step - loss: 0.2071 - mean_absolute_error: 0.3193 - val_los
s: 0.1089 - val_mean_absolute_error: 0.2238
Epoch 8/50
893/893 [==============================] - 19s 22ms/step - loss: 0.1958 - mean_absolute_error: 0.3088 - val_los
s: 0.1077 - val_mean_absolute_error: 0.2339
Epoch 9/50
893/893 [==============================] - 19s 22ms/step - loss: 0.1908 - mean_absolute_error: 0.3045 - val_los
s: 0.0977 - val_mean_absolute_error: 0.2198
Epoch 10/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1868 - mean_absolute_error: 0.3010 - val_los
s: 0.0930 - val_mean_absolute_error: 0.2092
Epoch 11/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1776 - mean_absolute_error: 0.2928 - val_los
s: 0.0914 - val_mean_absolute_error: 0.2015
Epoch 12/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1746 - mean_absolute_error: 0.2886 - val_los
s: 0.0874 - val_mean_absolute_error: 0.1990
Epoch 13/50
893/893 [==============================] - 20s 22ms/step - loss: 0.1712 - mean_absolute_error: 0.2872 - val_los
s: 0.0918 - val_mean_absolute_error: 0.2023
Epoch 14/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1684 - mean_absolute_error: 0.2842 - val_los
s: 0.0884 - val_mean_absolute_error: 0.1989
Epoch 15/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1656 - mean_absolute_error: 0.2799 - val_los
s: 0.0846 - val_mean_absolute_error: 0.1986
Epoch 16/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1652 - mean_absolute_error: 0.2800 - val_los
s: 0.0912 - val_mean_absolute_error: 0.2053
Epoch 17/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1621 - mean_absolute_error: 0.2777 - val_los
s: 0.0850 - val_mean_absolute_error: 0.1998
Epoch 18/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1618 - mean_absolute_error: 0.2766 - val_los
s: 0.0853 - val_mean_absolute_error: 0.1948
Epoch 19/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1595 - mean_absolute_error: 0.2745 - val_los
s: 0.0847 - val_mean_absolute_error: 0.1892
Epoch 20/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1564 - mean_absolute_error: 0.2719 - val_los
s: 0.0802 - val_mean_absolute_error: 0.1895
Epoch 21/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1556 - mean_absolute_error: 0.2719 - val_los
s: 0.0790 - val_mean_absolute_error: 0.1861
Epoch 22/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1544 - mean_absolute_error: 0.2696 - val_los
s: 0.0835 - val_mean_absolute_error: 0.1940
Epoch 23/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1533 - mean_absolute_error: 0.2695 - val_los
s: 0.0841 - val_mean_absolute_error: 0.2007
Epoch 24/50
893/893 [==============================] - 19s 22ms/step - loss: 0.1516 - mean_absolute_error: 0.2677 - val_los
s: 0.0768 - val_mean_absolute_error: 0.1884
Epoch 25/50
893/893 [==============================] - 19s 22ms/step - loss: 0.1501 - mean_absolute_error: 0.2668 - val_los
s: 0.0780 - val_mean_absolute_error: 0.1927
Epoch 26/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1498 - mean_absolute_error: 0.2658 - val_los
s: 0.0883 - val_mean_absolute_error: 0.2051
Epoch 27/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1467 - mean_absolute_error: 0.2641 - val_los
s: 0.0768 - val_mean_absolute_error: 0.1900
Epoch 28/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1462 - mean_absolute_error: 0.2634 - val_los
s: 0.0780 - val_mean_absolute_error: 0.1853
Epoch 29/50
893/893 [==============================] - 20s 22ms/step - loss: 0.1460 - mean_absolute_error: 0.2634 - val_los
s: 0.0841 - val_mean_absolute_error: 0.2025
Epoch 30/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1439 - mean_absolute_error: 0.2601 - val_los
s: 0.0804 - val_mean_absolute_error: 0.1945
Epoch 31/50
893/893 [==============================] - 19s 22ms/step - loss: 0.1435 - mean_absolute_error: 0.2610 - val_los
s: 0.0793 - val_mean_absolute_error: 0.1838
Epoch 32/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1433 - mean_absolute_error: 0.2596 - val_los
s: 0.0793 - val_mean_absolute_error: 0.1895
Epoch 33/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1421 - mean_absolute_error: 0.2585 - val_los
s: 0.0774 - val_mean_absolute_error: 0.1827
Epoch 34/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1428 - mean_absolute_error: 0.2597 - val_los
s: 0.0783 - val_mean_absolute_error: 0.1808
Epoch 35/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1406 - mean_absolute_error: 0.2593 - val_los
s: 0.0780 - val_mean_absolute_error: 0.1830
Epoch 36/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1391 - mean_absolute_error: 0.2573 - val_los
s: 0.0779 - val_mean_absolute_error: 0.1901
Epoch 37/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1377 - mean_absolute_error: 0.2549 - val_los
s: 0.0802 - val_mean_absolute_error: 0.1800
Epoch 38/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1396 - mean_absolute_error: 0.2562 - val_los
s: 0.0776 - val_mean_absolute_error: 0.1881
Epoch 39/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1387 - mean_absolute_error: 0.2551 - val_los
s: 0.0766 - val_mean_absolute_error: 0.1837
Epoch 40/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1381 - mean_absolute_error: 0.2560 - val_los
s: 0.0783 - val_mean_absolute_error: 0.1903
Epoch 41/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1380 - mean_absolute_error: 0.2558 - val_los
s: 0.0743 - val_mean_absolute_error: 0.1874
Epoch 42/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1378 - mean_absolute_error: 0.2553 - val_los
s: 0.0737 - val_mean_absolute_error: 0.1843
Epoch 43/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1362 - mean_absolute_error: 0.2538 - val_los
s: 0.0748 - val_mean_absolute_error: 0.1821
Epoch 44/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1348 - mean_absolute_error: 0.2530 - val_los
s: 0.0741 - val_mean_absolute_error: 0.1845
Epoch 45/50
893/893 [==============================] - 19s 22ms/step - loss: 0.1336 - mean_absolute_error: 0.2512 - val_los
s: 0.0737 - val_mean_absolute_error: 0.1779
Epoch 46/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1346 - mean_absolute_error: 0.2526 - val_los
s: 0.0754 - val_mean_absolute_error: 0.1833
Epoch 47/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1329 - mean_absolute_error: 0.2494 - val_los
s: 0.0759 - val_mean_absolute_error: 0.1863
Epoch 48/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1356 - mean_absolute_error: 0.2527 - val_los
s: 0.0746 - val_mean_absolute_error: 0.1865
Epoch 49/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1344 - mean_absolute_error: 0.2516 - val_los
s: 0.0745 - val_mean_absolute_error: 0.1847
Epoch 50/50
893/893 [==============================] - 19s 21ms/step - loss: 0.1321 - mean_absolute_error: 0.2490 - val_los
s: 0.0737 - val_mean_absolute_error: 0.1844
```

In [52]:
```
plot_results(hist)
```



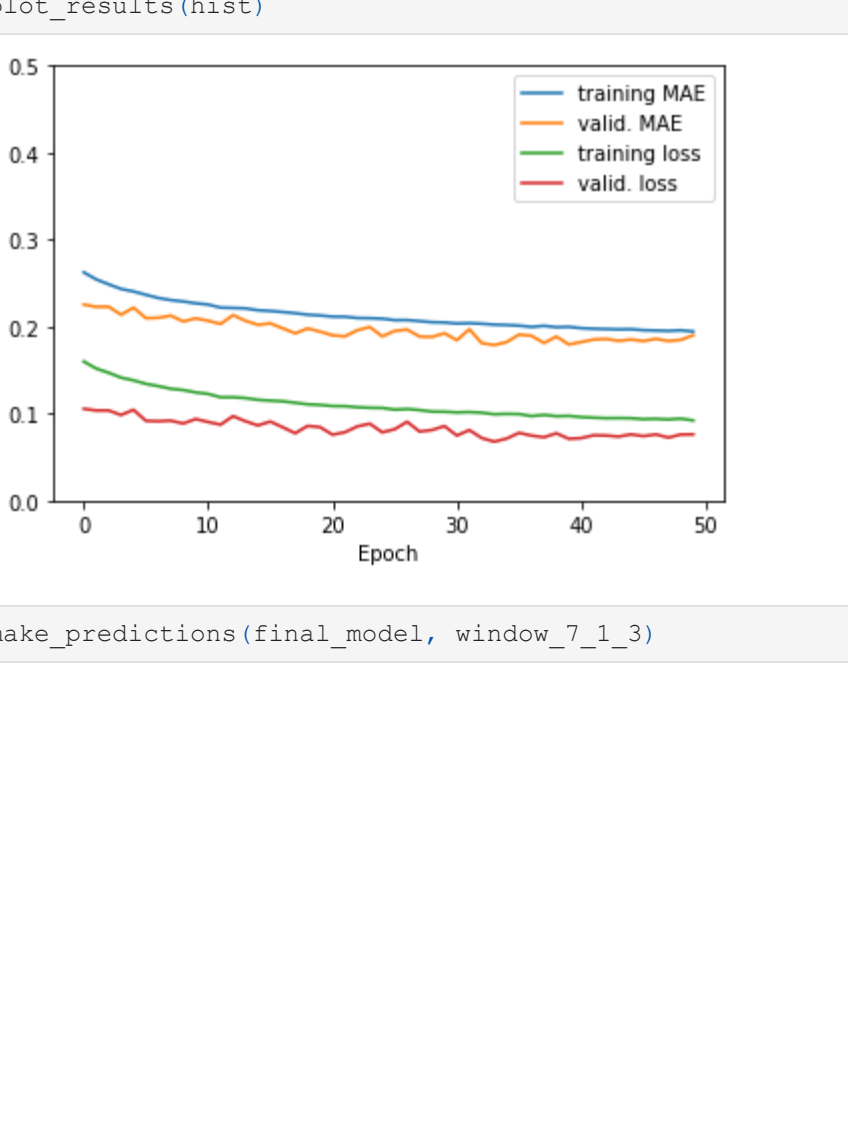
Best Model

In [57]:
```
final_model = tf.keras.models.Sequential([
    tf.keras.layers.LSTM(9, return_sequences=True),
    tf.keras.layers.LSTM(9, return_sequences=True),
    tf.keras.layers.LSTM(9, return_sequences=True),
    tf.keras.layers.LSTM(3),
    tf.keras.layers.Dense(units=10),
    tf.keras.layers.Dense(units=1)
])
```

In [59]:
```
hist = compile_and_fit(final_model, window_7_1_3, 20, 50)
```

```
Epoch 1/50
893/893 [==============================] - 24s 21ms/step - loss: 0.1599 - mean_absolute_error: 0.2624 - val_los
s: 0.1055 - val_mean_absolute_error: 0.2254
Epoch 2/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1519 - mean_absolute_error: 0.2544 - val_los
s: 0.1036 - val_mean_absolute_error: 0.2228
Epoch 3/50
893/893 [==============================] - 16s 18ms/step - loss: 0.1470 - mean_absolute_error: 0.2487 - val_los
s: 0.1036 - val_mean_absolute_error: 0.2229
Epoch 4/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1414 - mean_absolute_error: 0.2434 - val_los
s: 0.0984 - val_mean_absolute_error: 0.2136
Epoch 5/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1383 - mean_absolute_error: 0.2404 - val_los
s: 0.1044 - val_mean_absolute_error: 0.2219
Epoch 6/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1342 - mean_absolute_error: 0.2366 - val_los
s: 0.0917 - val_mean_absolute_error: 0.2098
Epoch 7/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1316 - mean_absolute_error: 0.2330 - val_los
s: 0.0913 - val_mean_absolute_error: 0.2102
Epoch 8/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1286 - mean_absolute_error: 0.2305 - val_los
s: 0.0919 - val_mean_absolute_error: 0.2127
Epoch 9/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1271 - mean_absolute_error: 0.2289 - val_los
s: 0.0887 - val_mean_absolute_error: 0.2060
Epoch 10/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1244 - mean_absolute_error: 0.2268 - val_los
s: 0.0938 - val_mean_absolute_error: 0.2095
Epoch 11/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1227 - mean_absolute_error: 0.2254 - val_los
s: 0.0904 - val_mean_absolute_error: 0.2068
Epoch 12/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1188 - mean_absolute_error: 0.2219 - val_los
s: 0.0873 - val_mean_absolute_error: 0.2031
Epoch 13/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1188 - mean_absolute_error: 0.2215 - val_los
s: 0.0971 - val_mean_absolute_error: 0.2132
Epoch 14/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1179 - mean_absolute_error: 0.2210 - val_los
s: 0.0913 - val_mean_absolute_error: 0.2067
Epoch 15/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1158 - mean_absolute_error: 0.2188 - val_los
s: 0.0864 - val_mean_absolute_error: 0.2021
Epoch 16/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1149 - mean_absolute_error: 0.2180 - val_los
s: 0.0909 - val_mean_absolute_error: 0.2037
Epoch 17/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1142 - mean_absolute_error: 0.2168 - val_los
s: 0.0843 - val_mean_absolute_error: 0.1980
Epoch 18/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1125 - mean_absolute_error: 0.2154 - val_los
s: 0.0774 - val_mean_absolute_error: 0.1923
Epoch 19/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1107 - mean_absolute_error: 0.2138 - val_los
s: 0.0859 - val_mean_absolute_error: 0.1979
Epoch 20/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1100 - mean_absolute_error: 0.2128 - val_los
s: 0.0845 - val_mean_absolute_error: 0.1943
Epoch 21/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1087 - mean_absolute_error: 0.2115 - val_los
s: 0.0758 - val_mean_absolute_error: 0.1901
Epoch 22/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1086 - mean_absolute_error: 0.2114 - val_los
s: 0.0786 - val_mean_absolute_error: 0.1888
Epoch 23/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1073 - mean_absolute_error: 0.2099 - val_los
s: 0.0853 - val_mean_absolute_error: 0.1960
Epoch 24/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1067 - mean_absolute_error: 0.2097 - val_los
s: 0.0884 - val_mean_absolute_error: 0.1995
Epoch 25/50
893/893 [==============================] - 17s 18ms/step - loss: 0.1065 - mean_absolute_error: 0.2092 - val_los
s: 0.0785 - val_mean_absolute_error: 0.1888
Epoch 26/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1046 - mean_absolute_error: 0.2075 - val_los
s: 0.0821 - val_mean_absolute_error: 0.1951
Epoch 27/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1052 - mean_absolute_error: 0.2075 - val_los
s: 0.0906 - val_mean_absolute_error: 0.1966
Epoch 28/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1041 - mean_absolute_error: 0.2064 - val_los
s: 0.0794 - val_mean_absolute_error: 0.1886
Epoch 29/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1023 - mean_absolute_error: 0.2051 - val_los
s: 0.0812 - val_mean_absolute_error: 0.1882
Epoch 30/50
893/893 [==============================] - 17s 18ms/step - loss: 0.1022 - mean_absolute_error: 0.2048 - val_los
s: 0.0857 - val_mean_absolute_error: 0.1924
Epoch 31/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1014 - mean_absolute_error: 0.2036 - val_los
s: 0.0748 - val_mean_absolute_error: 0.1844
Epoch 32/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1018 - mean_absolute_error: 0.2040 - val_los
s: 0.0811 - val_mean_absolute_error: 0.1970
Epoch 33/50
893/893 [==============================] - 17s 19ms/step - loss: 0.1010 - mean_absolute_error: 0.2034 - val_los
s: 0.0719 - val_mean_absolute_error: 0.1810
Epoch 34/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0993 - mean_absolute_error: 0.2023 - val_los
s: 0.0678 - val_mean_absolute_error: 0.1788
Epoch 35/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0997 - mean_absolute_error: 0.2019 - val_los
s: 0.0713 - val_mean_absolute_error: 0.1823
Epoch 36/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0994 - mean_absolute_error: 0.2011 - val_los
s: 0.0779 - val_mean_absolute_error: 0.1909
Epoch 37/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0971 - mean_absolute_error: 0.1997 - val_los
s: 0.0747 - val_mean_absolute_error: 0.1895
Epoch 38/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0985 - mean_absolute_error: 0.2009 - val_los
s: 0.0728 - val_mean_absolute_error: 0.1812
Epoch 39/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0971 - mean_absolute_error: 0.1994 - val_los
s: 0.0774 - val_mean_absolute_error: 0.1886
Epoch 40/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0974 - mean_absolute_error: 0.1997 - val_los
s: 0.0710 - val_mean_absolute_error: 0.1795
Epoch 41/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0960 - mean_absolute_error: 0.1982 - val_los
s: 0.0719 - val_mean_absolute_error: 0.1824
Epoch 42/50
893/893 [==============================] - 17s 18ms/step - loss: 0.0953 - mean_absolute_error: 0.1976 - val_los
s: 0.0751 - val_mean_absolute_error: 0.1852
Epoch 43/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0947 - mean_absolute_error: 0.1973 - val_los
s: 0.0748 - val_mean_absolute_error: 0.1858
Epoch 44/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0949 - mean_absolute_error: 0.1969 - val_los
s: 0.0736 - val_mean_absolute_error: 0.1837
Epoch 45/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0947 - mean_absolute_error: 0.1971 - val_los
s: 0.0761 - val_mean_absolute_error: 0.1852
Epoch 46/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0936 - mean_absolute_error: 0.1959 - val_los
s: 0.0741 - val_mean_absolute_error: 0.1834
Epoch 47/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0940 - mean_absolute_error: 0.1956 - val_los
s: 0.0761 - val_mean_absolute_error: 0.1859
Epoch 48/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0933 - mean_absolute_error: 0.1951 - val_los
s: 0.0725 - val_mean_absolute_error: 0.1835
Epoch 49/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0942 - mean_absolute_error: 0.1958 - val_los
s: 0.0760 - val_mean_absolute_error: 0.1848
Epoch 50/50
893/893 [==============================] - 17s 19ms/step - loss: 0.0921 - mean_absolute_error: 0.1944 - val_los
s: 0.0761 - val_mean_absolute_error: 0.1901
```

In [60]:
```
plot_results(hist)
```



In [61]:
```
make_predictions(final_model, window_7_1_3)
```