# QTW - Assignment 5 - Working with Missing Data

**Utilizing the California Housing dataset**

# Setup

In [157]:

```
# Import package dependencies
import pandas as pd
import numpy as np
import statistics
from sklearn.linear_model import LinearRegression
from sklearn.metrics import mean_squared_error, r2_score, mean_absolute_error
from ml_metrics import rmse
import matplotlib.pyplot as plt
from sklearn import datasets
import seaborn as sn
from IPython.display import display, HTML


from pandas.plotting import scatter_matrix
```

# Load dataset

In [158]:

```
# Load in the dataset
california = datasets.fetch_california_housing()
print(california.data.shape)
```

```
(20640, 8)
```

In [159]:

```
print(california.keys())
```

```
dict_keys(['data', 'target', 'frame', 'target_names', 'feature_names', 'DE
SCR'])
```

In [160]:

```
print(california.DESCR)
```

```
.. _california_housing_dataset:

California Housing dataset
--------------------------

**Data Set Characteristics:**

    :Number of Instances: 20640

    :Number of Attributes: 8 numeric, predictive attributes and the target

    :Attribute Information:
        - MedInc        median income in block
        - HouseAge      median house age in block
        - AveRooms      average number of rooms
        - AveBedrms     average number of bedrooms
        - Population    block population
        - AveOccup      average house occupancy
        - Latitude      house block latitude
        - Longitude     house block longitude

    :Missing Attribute Values: None

This dataset was obtained from the StatLib repository.
http://lib.stat.cmu.edu/datasets/

The target variable is the median house value for California districts.

This dataset was derived from the 1990 U.S. census, using one row per cens
us
block group. A block group is the smallest geographical unit for which the
U.S.
Census Bureau publishes sample data (a block group typically has a populat
ion
of 600 to 3,000 people).

It can be downloaded/loaded using the
:func:`sklearn.datasets.fetch_california_housing` function.

.. topic:: References

    - Pace, R. Kelley and Ronald Barry, Sparse Spatial Autoregressions,
      Statistics and Probability Letters, 33 (1997) 291-297
```

In [161]:

```
california.feature_names
```

Out[161]:

```
['MedInc',
 'HouseAge',
 'AveRooms',
 'AveBedrms',
 'Population',
 'AveOccup',
 'Latitude',
 'Longitude']
```

In [ ]:

```

```

In [162]:

```
# Convert the matrix to pandas
cal = pd.DataFrame(california.data)
cal.columns = california.feature_names
cal['MedInc'] = california.target
cal.head()
```

Out[162]:

| | MedInc | HouseAge | AveRooms | AveBedrms | Population | AveOccup | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| **0** | 4.526 | 41.0 | 6.984127 | 1.023810 | 322.0 | 2.555556 | 37.88 | -122.23 |
| **1** | 3.585 | 21.0 | 6.238137 | 0.971880 | 2401.0 | 2.109842 | 37.86 | -122.22 |
| **2** | 3.521 | 52.0 | 8.288136 | 1.073446 | 496.0 | 2.802260 | 37.85 | -122.24 |
| **3** | 3.413 | 52.0 | 5.817352 | 1.073059 | 558.0 | 2.547945 | 37.85 | -122.25 |
| **4** | 3.422 | 52.0 | 6.281853 | 1.081081 | 565.0 | 2.181467 | 37.85 | -122.25 |

# Exploratory Data Analysis

In [163]:

```
cal.describe()
```

Out[163]:

| | MedInc | HouseAge | AveRooms | AveBedrms | Population | AveOccup |
|---|---|---|---|---|---|---|
| **count** | 20640.000000 | 20640.000000 | 20640.000000 | 20640.000000 | 20640.000000 | 20640.000000 |
| **mean** | 2.068558 | 28.639486 | 5.429000 | 1.096675 | 1425.476744 | 3.070655 |
| **std** | 1.153956 | 12.585558 | 2.474173 | 0.473911 | 1132.462122 | 10.386050 |
| **min** | 0.149990 | 1.000000 | 0.846154 | 0.333333 | 3.000000 | 0.692308 |
| **25%** | 1.196000 | 18.000000 | 4.440716 | 1.006079 | 787.000000 | 2.429741 |
| **50%** | 1.797000 | 29.000000 | 5.229129 | 1.048780 | 1166.000000 | 2.818116 |
| **75%** | 2.647250 | 37.000000 | 6.052381 | 1.099526 | 1725.000000 | 3.282261 |
| **max** | 5.000010 | 52.000000 | 141.909091 | 34.066667 | 35682.000000 | 1243.333333 |

In [164]:

```
cal.info()
```

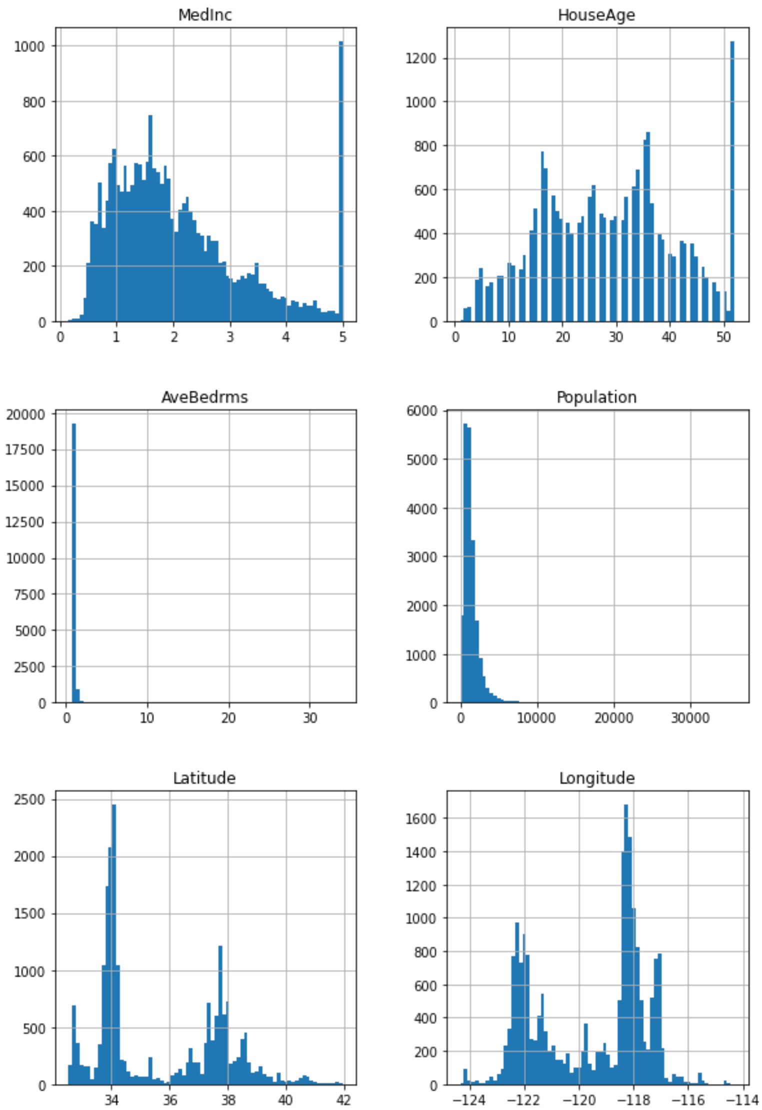
```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 20640 entries, 0 to 20639
Data columns (total 8 columns):
 #   Column      Non-Null Count  Dtype  
---  ------      --------------  -----  
 0   MedInc      20640 non-null  float64
 1   HouseAge    20640 non-null  float64
 2   AveRooms    20640 non-null  float64
 3   AveBedrms   20640 non-null  float64
 4   Population  20640 non-null  float64
 5   AveOccup    20640 non-null  float64
 6   Latitude    20640 non-null  float64
 7   Longitude   20640 non-null  float64
dtypes: float64(8)
memory usage: 1.3 MB
```

In [165]:

```
cal.hist(bins=75, figsize=(15,15))
```

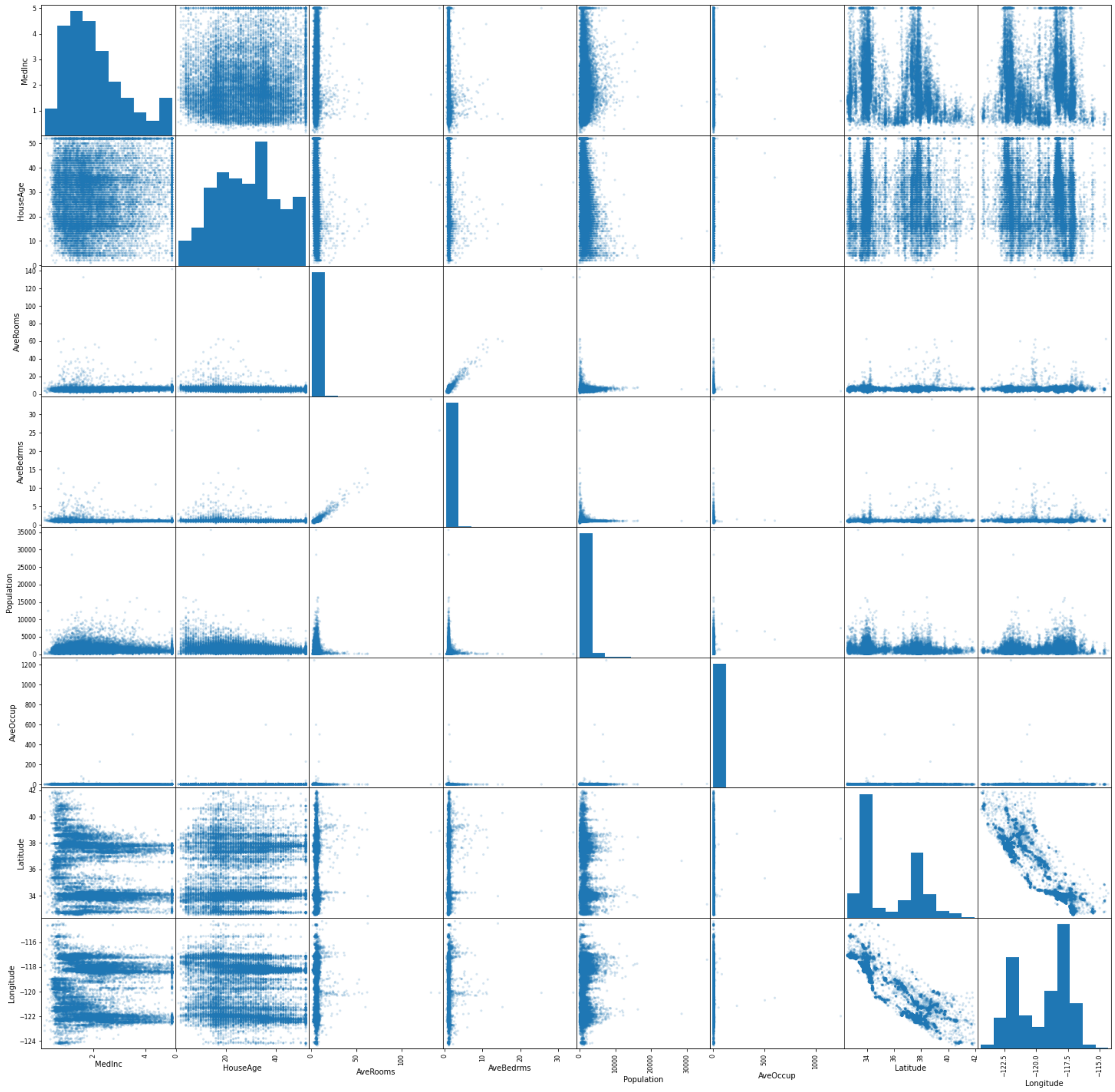
Out[165]:

```
array([[<AxesSubplot:title={'center':'MedInc'}>,
        <AxesSubplot:title={'center':'HouseAge'}>,
        <AxesSubplot:title={'center':'AveRooms'}>],
       [<AxesSubplot:title={'center':'AveBedrms'}>,
        <AxesSubplot:title={'center':'Population'}>,
        <AxesSubplot:title={'center':'AveOccup'}>],
       [<AxesSubplot:title={'center':'Latitude'}>,
        <AxesSubplot:title={'center':'Longitude'}>, <AxesSubplot:>]],
      dtype=object)
```



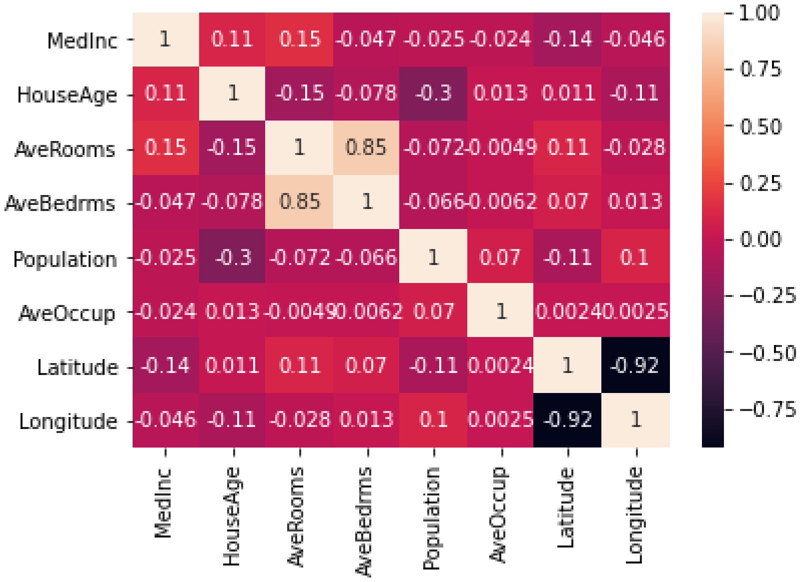
In [166]:

```
scatter_matrix(cal, alpha=0.2, figsize=(25, 25))
plt.show()
```



In [167]:

```
corrMatrix = cal.corr()
sn.heatmap(corrMatrix, annot=True)
plt.show()
```




In [168]:

```
cal.corr()['MedInc'].sort_values(ascending=False)
```

Out[168]:

```
MedInc        1.000000
AveRooms      0.151948
HouseAge      0.105623
AveOccup     -0.023737
Population   -0.024650
Longitude    -0.045967
AveBedrms    -0.046701
Latitude     -0.144160
Name: MedInc, dtype: float64
```

# Functions

In [169]:

```
def get_train_test_matrix(train_set,test_set):
    # Converting the training and testing datasets back to matrix-formats
    X_train = train_set.iloc[:, 1:].values # returns the data; excluding the target
    Y_train = train_set.iloc[:, 0].values # returns the target-only
    X_test = test_set.iloc[:, 1:].values # ""
    Y_test = test_set.iloc[:, 0].values # ""
    return X_train,Y_train,X_test,Y_test
```

In [170]:

```
def get_train_test_split(inputDF,split_fraction=0.7):
    # Create training and testing sets (cross-validation not needed)
    train_set = inputDF.sample(frac=split_fraction, random_state=100)
    test_set = inputDF[~inputDF.isin(train_set)].dropna()
    #print(train_set.shape[0])
    #print(test_set.shape[0])
    return train_set,test_set
```

In [171]:

```
def get_row_indices(train_set,test_set):
    # Get the training and testing row indices for later use
    train_index = train_set.index.values.astype(int)
    test_index = test_set.index.values.astype(int)
    return train_index,test_index
```

In [172]:

```
def get_LR_model(X_train,Y_train):
    # Fit a linear regression to the training data
    reg = LinearRegression(normalize=True).fit(X_train, Y_train)
    print("Regression Score : ",reg.score(X_train, Y_train)) #Return the coefficient of
determination R^2 of the prediction.
    print("Estimated coefficients of regression : ",reg.coef_)
    print("Regression intercept : ",reg.intercept_)
    print("Parameters for the esitmator : ",reg.get_params())
    return reg
```

In [173]:

```
def print_model_params(reg,df):
    # Find the variable with the largest "normalized" coefficient value
    print('The positive(max) coef-value is {}'.format(max(reg.coef_))) # Positive Max
    #print('The abs(max) coef-value is {}'.format(max(reg.coef_, key=abs))) # ABS Max
    max_var = max(reg.coef_) # Positive Max
    #max_var = max(reg.coef_, key=abs) # ABS Max
    var_index = reg.coef_.tolist().index(max_var)
    print('The variable associated with this coef-value is {}'.format(df.columns[var_in
dex+1]))
```

In [174]:

```
def get_printStr(feature,coeff):
    s=[]
    for i in range(len(feature)):
        s.append(feature[i]+" : "+str(coeff[i]))
    s1 = " ".join(s)
    return s1
#get_printStr(["a","b","c","d"],[1.0,2.3,3.0,4.4])
```

In [175]:

```
def get_all_error_calc(model,X_test,Y_test,colNames):
    result = {}
    Y_pred = model.predict(X_test)
    mae = mean_absolute_error(Y_test,Y_pred)
    mse = mean_squared_error(Y_test,Y_pred)
    rmse_val = rmse(Y_test,Y_pred)
    r2 = r2_score(Y_test,Y_pred)
    coeff = model.coef_.tolist()
    intercept = model.intercept_
    feature = colNames[1:]
    result["mae"]=mae
    result["mse"]=mse
    result["rmse_val"]=rmse_val
    result["r2"]=r2
    coeff_feat_df=pd.DataFrame({"Feature":feature,"Coefficients":coeff})
    result["co_efficient_feature_df"] = display(HTML(coeff_feat_df.to_html()))
    cf_list = list(zip(feature,np.round_(coeff, decimals = 4)))
    cf_str = get_printStr(feature,np.round_(coeff, decimals = 3))
    result["co_efficient_feature"]= cf_str #'\n'.join(map(str, cf_list)) #print(*cf_lis
t, sep = "\n")
    #result["features"] = feature
    result["intercept"]=intercept
    for k, v in result.items():
      print(k, v)
    #print("MAE: %.3f"%mae)
    #print("MSE:  %.3f"%mse)
    #print("RMSE:  %.3f"%rmse_val)
    #print("R2:  %.3f"%r2)
    #print("coefficients {0}".format(coeff))
    #print("features {0}".format(feature))
    #print("intercept {0}".format(intercept))
    return result
```

In [176]:

```
def run_all_model(imputed_df_dict,df):
    ## Get the dictionay with imputed df (Imputing HouseAge with median)
    model_result = {}
    for k in imputed_df_dict:
        imputed_df = imputed_df_dict[k]
        keyVal=["",0]
        if k==0.0:
            train_set,test_set = get_train_test_split(imputed_df)
            train_index,test_index = get_row_indices(train_set,test_set)
        else:
            train_set = imputed_df.iloc[train_index]
            test_set = imputed_df.iloc[test_index]
            keyVal = k.split("-")
        printString = "Handling data with {}% imputation".format(int(float(keyVal[1])*1
00))
        print("\n"+printString)
        print("-"*len(printString))
        X_train,Y_train,X_test,Y_test = get_train_test_matrix(train_set,test_set)
        model = get_LR_model(X_train,Y_train)
        print_model_params(model,df)
        result = get_all_error_calc(model,X_test,Y_test,df.columns.tolist())
        model_result[k] = result
    return model_result
```

In [185]:

```
def get_model_result_df(model_result):
    cols = ["data_imputation_percent","missing_type","mae","mse","rmse","r2","mae_diff"
,"mse_diff","rmse_diff","r2_diff","features_coefficient","intercept"]
    df_index = range(len(model_result))
    result_df = pd.DataFrame(columns=cols, index=df_index)
    indx=0
    base_mae = base_mse = base_rmse_val = base_r2 = mae_diff = mse_diff = rmse_diff = r
2_diff = 0
    for k in model_result:
        result = model_result[k]
        coeff_features = intercept = data = imputation=""
        mae = result["mae"]
        mse = result["mse"]
        rmse_val = result["rmse_val"]
        r2 = result["r2"]
        coeff_features = result["co_efficient_feature"]
        intercept = result["intercept"]
        keyVal=["",0]
        if k==0.0:
            data = "Original (0%)"
            imputation="None"
            base_mae = mae
            base_mse=mse
            base_rmse_val=rmse_val
            base_r2=r2
            mae_diff = np.nan
            mse_diff = np.nan
            rmse_diff = np.nan
            r2_diff = np.nan
        else:
            keyVal = k.split("-")
            data= str(int(float(keyVal[1])*100))+"%"
            imputation=keyVal[0]
            mae_diff = mae-base_mae
            mse_diff = mse-base_mse
            rmse_diff = rmse_val-base_rmse_val
            r2_diff = r2-base_r2
        result_df.loc[indx].data_imputation_percent = data
        result_df.loc[indx].missing_type = imputation
        result_df.loc[indx].mae = round(mae,3)
        result_df.loc[indx].mse = round(mse,3)
        result_df.loc[indx].rmse = round(rmse_val,3)
        result_df.loc[indx].r2 = round(r2,3)
        result_df.loc[indx].mae_diff = round(mae_diff,3)
        result_df.loc[indx].mse_diff = round(mse_diff,3)
        result_df.loc[indx].rmse_diff = round(rmse_diff,3)
        result_df.loc[indx].r2_diff = round(r2_diff,3)
        result_df.loc[indx].features_coefficient = coeff_features
        result_df.loc[indx].intercept = round(intercept,3)

        #pd.DataFrame({"Feature":X_train.columns.tolist(),"Coefficients":logreg.coef_
[0]})
        indx=indx+1
    return result_df
```

# Case 1 - Missing completely at Random (MCAR)

In [191]:

```
#case 1 - Missing completely at Random
def get_mcar_imputed_df(impute_fractions,housing_df,impute_variable,impute_with="media
n"):
    imputed_df = {}
    for percent in impute_fractions:
        print("Percentage Imputed : {}%".format(int(percent*100)))
        if percent == 0.0:
            #Run Baseline model
            imputed_df[percent] = housing_df
            #imputed_df.append(housing_df)
        else:
            in_sample = housing_df.sample(frac=percent, random_state=100)
            print("Imputed sample shape : {}".format(in_sample.shape))
            out_sample = housing_df[~housing_df.isin(in_sample)].dropna()
            print("Un Imputed sample shape : {}".format(out_sample.shape))
            #print("Un imputed sample shape : {}".format(out_sample.shape))
            #print("Mean",np.mean(housing_df[impute_variable]))
            #print("Median",np.median(housing_df[impute_variable]))
            #print("Std.Dev",statistics.stdev(housing_df[impute_variable]))

            in_sample[impute_variable] = np.nan
            fill_value = 0
            if(impute_with == "median"):
                fill_value = out_sample[impute_variable].median()
                in_sample[impute_variable] = in_sample[impute_variable].fillna(fill_val
ue)
            if(impute_with == "mean"):
                fill_value = out_sample[impute_variable].mean()
                in_sample[impute_variable] = in_sample[impute_variable].fillna(fill_val
ue)
            print("Imputed value ",fill_value)
            imputed_data = pd.concat([in_sample, out_sample])
            print("Imputed sample shape : {}".format(imputed_data.shape))
            #print("Mean",np.mean(imputed_data[impute_variable]))
            #print("Median",np.median(imputed_data[impute_variable]))
            #print("Std.Dev",statistics.stdev(imputed_data[impute_variable]))

            imputed_data = imputed_data.sort_index()
            imputed_df["MCAR-"+str(percent)] = imputed_data
            #imputed_df.append(imputed_data)
    return imputed_df
```

In [192]:

```
#Evaluating Case 1 - MIssing completely at random
mcar_impute_fraction_list = [0.0,0.01,0.05,0.1,0.2,0.33,0.5]
cols = ["AveBedrms"]#cal.columns[1:]
#imputed_df_dict = {}
results = pd.DataFrame()
for c in cols:
    imputed_df_dict = get_mcar_imputed_df(mcar_impute_fraction_list,cal,c,"median")
    model_result = run_all_model(imputed_df_dict,cal)
    model_result_df = get_model_result_df(model_result)
    model_result_df['Imputed_columnName'] = c
    results = results.append(model_result_df)

#todo - add coeeff for each var
```

```
Percentage Imputed : 0%
Percentage Imputed : 1%
Imputed sample shape : (206, 8)
Un Imputed sample shape : (20434, 8)
Imputed value  1.048780487804878
Imputed sample shape : (20640, 8)
Percentage Imputed : 5%
Imputed sample shape : (1032, 8)
Un Imputed sample shape : (19608, 8)
Imputed value  1.0488485720778729
Imputed sample shape : (20640, 8)
Percentage Imputed : 10%
Imputed sample shape : (2064, 8)
Un Imputed sample shape : (18576, 8)
Imputed value  1.0492558095378741
Imputed sample shape : (20640, 8)
Percentage Imputed : 20%
Imputed sample shape : (4128, 8)
Un Imputed sample shape : (16512, 8)
Imputed value  1.0491803278688525
Imputed sample shape : (20640, 8)
Percentage Imputed : 33%
Imputed sample shape : (6811, 8)
Un Imputed sample shape : (13829, 8)
Imputed value  1.049792531120332
Imputed sample shape : (20640, 8)
Percentage Imputed : 50%
Imputed sample shape : (10320, 8)
Un Imputed sample shape : (10320, 8)
Imputed value  1.049390957490646
Imputed sample shape : (20640, 8)

Handling data with 0% imputation
--------------------------------
Regression Score :  0.4021408992488681
Estimated coefficients of regression :  [ 5.39413657e-03  3.64187452e-01 -
1.38129627e+00 -1.17589393e-05
 -1.24751112e-03 -7.30902386e-01 -7.23704703e-01]
Regression intercept :  -59.014861272508455
Parameters for the esitmator :  {'copy_X': True, 'fit_intercept': True, 'n
_jobs': None, 'normalize': True}
The positive(max) coef-value is 0.3641874520685189
The variable associated with this coef-value is AveRooms
```

| | Feature | Coefficients |
|---|---|---|
| **0** | HouseAge | 0.005394 |
| **1** | AveRooms | 0.364187 |
| **2** | AveBedrms | -1.381296 |
| **3** | Population | -0.000012 |
| **4** | AveOccup | -0.001248 |
| **5** | Latitude | -0.730902 |
| **6** | Longitude | -0.723705 |

```
mae 0.678032824552321
mse 0.8082703428884797
rmse_val 0.8990385658515877
r2 0.39003766493623837
co_efficient_feature_df None
co_efficient_feature HouseAge : 0.005 AveRooms : 0.364 AveBedrms : -1.381
Population : -0.0 AveOccup : -0.001 Latitude : -0.731 Longitude : -0.724
intercept -59.014861272508455

Handling data with 1% imputation
--------------------------------
Regression Score :  0.3834293533184935
Estimated coefficients of regression :  [ 4.47096999e-03  3.17888393e-01 -
1.17920535e+00 -1.46831934e-05
 -1.20526961e-03 -7.36913647e-01 -7.31598564e-01]
Regression intercept :  -59.6864456964893
Parameters for the esitmator :  {'copy_X': True, 'fit_intercept': True, 'n
_jobs': None, 'normalize': True}
The positive(max) coef-value is 0.31788839331251983
The variable associated with this coef-value is AveRooms
```

| | Feature | Coefficients |
|---|---|---|
| **0** | HouseAge | 0.004471 |
| **1** | AveRooms | 0.317888 |
| **2** | AveBedrms | -1.179205 |
| **3** | Population | -0.000015 |
| **4** | AveOccup | -0.001205 |
| **5** | Latitude | -0.736914 |
| **6** | Longitude | -0.731599 |

```
mae 0.6789545945206058
mse 0.8044361662050437
rmse_val 0.8969036549178756
r2 0.3929311316871251
co_efficient_feature_df None
co_efficient_feature HouseAge : 0.004 AveRooms : 0.318 AveBedrms : -1.179
Population : -0.0 AveOccup : -0.001 Latitude : -0.737 Longitude : -0.732
intercept -59.6864456964893

Handling data with 5% imputation
--------------------------------
Regression Score :  0.3635746502071524
Estimated coefficients of regression :  [ 3.67873527e-03  2.68263312e-01 -
9.58633277e-01 -1.61975718e-05
 -1.14496694e-03 -7.46859319e-01 -7.45435822e-01]
Regression intercept :  -60.93834995598618
Parameters for the esitmator :  {'copy_X': True, 'fit_intercept': True, 'n
_jobs': None, 'normalize': True}
The positive(max) coef-value is 0.268263312326713
The variable associated with this coef-value is AveRooms
```

| | Feature | Coefficients |
|---|---|---|
| 0 | HouseAge | 0.003679 |
| 1 | AveRooms | 0.268263 |
| 2 | AveBedrms | -0.958633 |
| 3 | Population | -0.000016 |
| 4 | AveOccup | -0.001145 |
| 5 | Latitude | -0.746859 |
| 6 | Longitude | -0.745436 |

```
mae 0.6833996799173918
mse 0.8096166910066835
rmse_val 0.8997870253602702
r2 0.3890216414618973
co_efficient_feature_df None
co_efficient_feature HouseAge : 0.004 AveRooms : 0.268 AveBedrms : -0.959
Population : -0.0 AveOccup : -0.001 Latitude : -0.747 Longitude : -0.745
intercept -60.93834995598618

Handling data with 10% imputation
---------------------------------
Regression Score :  0.3601112825002488
Estimated coefficients of regression :  [ 3.64489916e-03  2.58323355e-01 -
9.13502893e-01 -1.57215498e-05
 -1.17726906e-03 -7.51382231e-01 -7.49919195e-01]
Regression intercept :  -61.310314097504445
Parameters for the esitmator :  {'copy_X': True, 'fit_intercept': True, 'n
_jobs': None, 'normalize': True}
The positive(max) coef-value is 0.25832335525924105
The variable associated with this coef-value is AveRooms
```

| | Feature | Coefficients |
|---|---|---|
| 0 | HouseAge | 0.003645 |
| 1 | AveRooms | 0.258323 |
| 2 | AveBedrms | -0.913503 |
| 3 | Population | -0.000016 |
| 4 | AveOccup | -0.001177 |
| 5 | Latitude | -0.751382 |
| 6 | Longitude | -0.749919 |

```
mae 0.6847687473270112
mse 0.8119513035148301
rmse_val 0.9010834054152979
r2 0.38725982289529104
co_efficient_feature_df None
co_efficient_feature HouseAge : 0.004 AveRooms : 0.258 AveBedrms : -0.914
Population : -0.0 AveOccup : -0.001 Latitude : -0.751 Longitude : -0.75
intercept -61.310314097504445

Handling data with 20% imputation
---------------------------------
Regression Score :  0.3484599239483177
Estimated coefficients of regression :  [ 3.20363086e-03  2.25966274e-01 -
7.42346031e-01 -1.67421379e-05
 -1.12971553e-03 -7.58780769e-01 -7.59179774e-01]
Regression intercept :  -62.15494381632978
Parameters for the esitmator :  {'copy_X': True, 'fit_intercept': True, 'n
_jobs': None, 'normalize': True}
The positive(max) coef-value is 0.22596627383027854
The variable associated with this coef-value is AveRooms
```

| | Feature | Coefficients |
|---|---|---|
| **0** | HouseAge | 0.003204 |
| **1** | AveRooms | 0.225966 |
| **2** | AveBedrms | -0.742346 |
| **3** | Population | -0.000017 |
| **4** | AveOccup | -0.001130 |
| **5** | Latitude | -0.758781 |
| **6** | Longitude | -0.759180 |

```
mae 0.6903627561271287
mse 0.8244530932300194
rmse_val 0.9079939940495307
r2 0.37782532995088636
co_efficient_feature_df None
co_efficient_feature HouseAge : 0.003 AveRooms : 0.226 AveBedrms : -0.742
Population : -0.0 AveOccup : -0.001 Latitude : -0.759 Longitude : -0.759
intercept -62.15494381632978

Handling data with 33% imputation
---------------------------------
Regression Score :  0.34073634329616564
Estimated coefficients of regression :  [ 2.98870644e-03  2.02899030e-01 -
6.55433197e-01 -1.57219424e-05
 -1.13833201e-03 -7.67921888e-01 -7.69900407e-01]
Regression intercept :  -63.08064220074559
Parameters for the esitmator :  {'copy_X': True, 'fit_intercept': True, 'n
_jobs': None, 'normalize': True}
The positive(max) coef-value is 0.20289902965276516
The variable associated with this coef-value is AveRooms
```

| | Feature | Coefficients |
|---|---|---|
| 0 | HouseAge | 0.002989 |
| 1 | AveRooms | 0.202899 |
| 2 | AveBedrms | -0.655433 |
| 3 | Population | -0.000016 |
| 4 | AveOccup | -0.001138 |
| 5 | Latitude | -0.767922 |
| 6 | Longitude | -0.769900 |

```
mae 0.6949475162874661
mse 0.8325437200406556
rmse_val 0.9124383376648832
r2 0.37171972720922286
co_efficient_feature_df None
co_efficient_feature HouseAge : 0.003 AveRooms : 0.203 AveBedrms : -0.655
Population : -0.0 AveOccup : -0.001 Latitude : -0.768 Longitude : -0.77
intercept -63.08064220074559

Handling data with 50% imputation
---------------------------------
Regression Score :  0.3371263415410476
Estimated coefficients of regression :  [ 2.99727301e-03  1.90977120e-01 -
6.63818984e-01 -1.44316081e-05
 -1.13484496e-03 -7.74878537e-01 -7.77416419e-01]
Regression intercept :  -63.666484259907065
Parameters for the esitmator :  {'copy_X': True, 'fit_intercept': True, 'n
_jobs': None, 'normalize': True}
The positive(max) coef-value is 0.19097711984241372
The variable associated with this coef-value is AveRooms
```

| | Feature | Coefficients |
|---|---|---|
| 0 | HouseAge | 0.002997 |
| 1 | AveRooms | 0.190977 |
| 2 | AveBedrms | -0.663819 |
| 3 | Population | -0.000014 |
| 4 | AveOccup | -0.001135 |
| 5 | Latitude | -0.774879 |
| 6 | Longitude | -0.777416 |

```
mae 0.6970374684121459
mse 0.8347808018444229
rmse_val 0.913663396357993
r2 0.3700315103239191
co_efficient_feature_df None
co_efficient_feature HouseAge : 0.003 AveRooms : 0.191 AveBedrms : -0.664
Population : -0.0 AveOccup : -0.001 Latitude : -0.775 Longitude : -0.777
intercept -63.666484259907065
```

In [187]:

```
HTML(results.to_html(classes= 'table table-striped table-hover'))
```

Out[187]:

| | data_impmissingmissing_type | | mae | mse | rmse | r2 | mae_diff | mse_diff | rmse_diff | r2_diff | features_coefficients | intercept | feature_importance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0** | Original (0%) | None | 0.678 | 0.808 | 0.899 | 0.39 | NaN | NaN | NaN | NaN | HouseAge : 0.005 AveRooms : 0.364 AveBedrms : -1.381 Population : -0.0 AveOccup : -0.001 Latitude : -0.731 Longitude : -0.724 | -59.015 | AveBec |
| **1** | 1% | MCAR | 0.679 | 0.804 | 0.897 | 0.393 | 0.001 | -0.004 | -0.002 | 0.003 | HouseAge : 0.004 AveRooms : 0.318 AveBedrms : -1.179 Population : -0.0 AveOccup : -0.001 Latitude : -0.737 Longitude : -0.732 | -59.686 | AveBec |

| | missing_percentage | missing_type | mae | mse | rmse | r2 | mae_diff | mse_diff | rmse_diff | r2_diff | features_coefficient | intercept | data_impute |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2** | 5% | MCAR | 0.683 | 0.81 | 0.9 | 0.389 | 0.005 | 0.001 | 0.001 | -0.001 | HouseAge : 0.004 AveRooms : 0.268 AveBedrms : -0.959 Population : -0.0 AveOccup : -0.001 Latitude : -0.747 Longitude : -0.745 | -60.938 | AveBec |
| **3** | 10% | MCAR | 0.685 | 0.812 | 0.901 | 0.387 | 0.007 | 0.004 | 0.002 | -0.003 | HouseAge : 0.004 AveRooms : 0.258 AveBedrms : -0.914 Population : -0.0 AveOccup : -0.001 Latitude : -0.751 Longitude : -0.75 | -61.31 | AveBec |

| | missing_percent | missing_type | mae | mse | rmse | r2 | mae_diff | mse_diff | rmse_diff | r2_diff | features | intercept | coefficients |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **4** | 20% | MCAR | 0.69 | 0.824 | 0.908 | 0.378 | 0.012 | 0.016 | 0.009 | -0.012 | HouseAge : 0.003 AveRooms : 0.226 AveBedrms : -0.742 Population : -0.0 AveOccup : -0.001 Latitude : -0.759 Longitude : -0.759 | -62.155 | AveBec |
| **5** | 33% | MCAR | 0.695 | 0.833 | 0.912 | 0.372 | 0.017 | 0.024 | 0.013 | -0.018 | HouseAge : 0.003 AveRooms : 0.203 AveBedrms : -0.655 Population : -0.0 AveOccup : -0.001 Latitude : -0.768 Longitude : -0.77 | -63.081 | AveBec |

| | data_impmissingmapercemse | | | | rmse | r2 | mae_diffmse_diffmse_dif2_diff | | | | features | intercoefficient | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 50% | MCAR | 0.697 | 0.835 | 0.914 | 0.37 | 0.019 | 0.027 | 0.015 | -0.02 | HouseAge : 0.003 AveRooms : 0.191 AveBedrms : -0.664 Population : -0.0 AveOccup : -0.001 Latitude : -0.775 Longitude : -0.777 | -63.666 | AveBec |

# Case 2 : Mossing at Random (MAR)

In [188]:

```
#Case2 : if z > 30 then impute x - Missing at Random
def get_mar_imputed_df(impute_fractions,housing_df,impute_variable,reference_variable,r
ef_variable_threshold,impute_with="median"):
    imputed_df = {}
    for percent in impute_fractions:
        print("Percentage Imputed : {}%".format(int(percent*100)))
        if percent == 0.0:
            #Run Baseline model
            imputed_df[percent] = housing_df
            #imputed_df.append(housing_df)
        else:
            print("Imputing variable {0} when ever variable {1} is > {2}".format(impute
_variable,reference_variable,ref_variable_threshold))
            housing_df_sub = housing_df[housing_df[reference_variable] > ref_variable_t
hreshold]
            print("Sub dataframe shape where variable {0} is > {1}".format(reference_va
riable,ref_variable_threshold))
            print(housing_df_sub.shape)
            in_sample = housing_df_sub.sample(frac=percent, random_state=100)
            print("Imputed sample shape : {}".format(in_sample.shape))
            out_sample = housing_df[~housing_df.isin(in_sample)].dropna()
            print("Un imputed sample shape : {}".format(out_sample.shape))
            in_sample[impute_variable] = np.nan
            fill_value = 0
            if(impute_with == "median"):
                fill_value = out_sample[impute_variable].median()
                in_sample[impute_variable] = in_sample[impute_variable].fillna(fill_val
ue)
            if(impute_with == "mean"):
                fill_value = out_sample[impute_variable].mean()
                in_sample[impute_variable] = in_sample[impute_variable].fillna(fill_val
ue)
            if(impute_with == "zero"):
                in_sample[impute_variable] = in_sample[impute_variable].fillna(0)
            print("Imputed value ",fill_value)
            imputed_data = pd.concat([in_sample, out_sample])
            imputed_data = imputed_data.sort_index()
            print("Final Imputed Data : {}".format(imputed_data.shape))
            imputed_df["MAR-"+str(percent)] = imputed_data
            #imputed_df.append(imputed_data)
    return imputed_df
```

In [189]:

```
#Evaluating Case 2 - Missing at random
mar_impute_fraction_list = [0.0,0.1,0.2,0.3]
mar_imputed_df_dict = get_mar_imputed_df(mar_impute_fraction_list,cal,'AveBedrms','AveR
ooms',3,"median")#'AveBedrms','AveRooms',4,
model_result = run_all_model(mar_imputed_df_dict,cal)
model_result_df = get_model_result_df(model_result)
#display(model_result_df)
```

```
Percentage Imputed : 0%
Percentage Imputed : 10%
Imputing variable AveBedrms when ever variable AveRooms is > 3
Sub dataframe shape where variable AveRooms is > 3
(20185, 8)
Imputed sample shape : (2018, 8)
Un imputed sample shape : (18622, 8)
Imputed value  1.0487096237096236
Final Imputed Data : (20640, 8)
Percentage Imputed : 20%
Imputing variable AveBedrms when ever variable AveRooms is > 3
Sub dataframe shape where variable AveRooms is > 3
(20185, 8)
Imputed sample shape : (4037, 8)
Un imputed sample shape : (16603, 8)
Imputed value  1.048951048951049
Final Imputed Data : (20640, 8)
Percentage Imputed : 30%
Imputing variable AveBedrms when ever variable AveRooms is > 3
Sub dataframe shape where variable AveRooms is > 3
(20185, 8)
Imputed sample shape : (6056, 8)
Un imputed sample shape : (14584, 8)
Imputed value  1.0485732957726372
Final Imputed Data : (20640, 8)

Handling data with 0% imputation
--------------------------------
Regression Score :  0.4021408992488681
Estimated coefficients of regression :  [ 5.39413657e-03  3.64187452e-01 -
1.38129627e+00 -1.17589393e-05
 -1.24751112e-03 -7.30902386e-01 -7.23704703e-01]
Regression intercept :  -59.014861272508455
Parameters for the esitmator :  {'copy_X': True, 'fit_intercept': True, 'n
_jobs': None, 'normalize': True}
The positive(max) coef-value is 0.3641874520685189
The variable associated with this coef-value is AveRooms
```

| | Feature | Coefficients |
|---|---|---|
| **0** | HouseAge | 0.005394 |
| **1** | AveRooms | 0.364187 |
| **2** | AveBedrms | -1.381296 |
| **3** | Population | -0.000012 |
| **4** | AveOccup | -0.001248 |
| **5** | Latitude | -0.730902 |
| **6** | Longitude | -0.723705 |

```
mae 0.678032824552321
mse 0.8082703428884797
rmse_val 0.8990385658515877
r2 0.39003766493623837
co_efficient_feature_df None
co_efficient_feature HouseAge : 0.005 AveRooms : 0.364 AveBedrms : -1.381
Population : -0.0 AveOccup : -0.001 Latitude : -0.731 Longitude : -0.724
intercept -59.014861272508455

Handling data with 10% imputation
---------------------------------
Regression Score :  0.3832103711667604
Estimated coefficients of regression :  [ 4.69740240e-03  3.14399664e-01 -
1.14658937e+00 -1.21187567e-05
 -1.20421882e-03 -7.44842083e-01 -7.40519554e-01]
Regression intercept :  -60.500851161089415
Parameters for the esitmator :  {'copy_X': True, 'fit_intercept': True, 'n
_jobs': None, 'normalize': True}
The positive(max) coef-value is 0.3143996641291375
The variable associated with this coef-value is AveRooms
```

| | Feature | Coefficients |
|---|---|---|
| **0** | HouseAge | 0.004697 |
| **1** | AveRooms | 0.314400 |
| **2** | AveBedrms | -1.146589 |
| **3** | Population | -0.000012 |
| **4** | AveOccup | -0.001204 |
| **5** | Latitude | -0.744842 |
| **6** | Longitude | -0.740520 |

```
mae 0.6842521589593245
mse 0.8499146917894628
rmse_val 0.9219081796954959
r2 0.35861069929120737
co_efficient_feature_df None
co_efficient_feature HouseAge : 0.005 AveRooms : 0.314 AveBedrms : -1.147
Population : -0.0 AveOccup : -0.001 Latitude : -0.745 Longitude : -0.741
intercept -60.500851161089415

Handling data with 20% imputation
---------------------------------
Regression Score :  0.38082688396199427
Estimated coefficients of regression :  [ 4.74034521e-03  3.09278015e-01 -
1.12474212e+00 -1.19636230e-05
 -1.05466494e-03 -7.49775964e-01 -7.45728030e-01]
Regression intercept :  -60.948254551762496
Parameters for the esitmator :  {'copy_X': True, 'fit_intercept': True, 'n
_jobs': None, 'normalize': True}
The positive(max) coef-value is 0.3092780154601371
The variable associated with this coef-value is AveRooms
```

| | Feature | Coefficients |
|---|---|---|
| 0 | HouseAge | 0.004740 |
| 1 | AveRooms | 0.309278 |
| 2 | AveBedrms | -1.124742 |
| 3 | Population | -0.000012 |
| 4 | AveOccup | -0.001055 |
| 5 | Latitude | -0.749776 |
| 6 | Longitude | -0.745728 |

```
mae 0.6867045628963675
mse 0.8658171101448153
rmse_val 0.9304929393309845
r2 0.346609917227959
co_efficient_feature_df None
co_efficient_feature HouseAge : 0.005 AveRooms : 0.309 AveBedrms : -1.125
Population : -0.0 AveOccup : -0.001 Latitude : -0.75 Longitude : -0.746
intercept -60.948254551762496

Handling data with 30% imputation
---------------------------------
Regression Score :  0.36865004613154606
Estimated coefficients of regression :  [ 4.15394094e-03  2.74855620e-01 -
9.66598055e-01 -1.33389973e-05
 -1.03825020e-03 -7.55381798e-01 -7.52968296e-01]
Regression intercept :  -61.58517190062545
Parameters for the esitmator :  {'copy_X': True, 'fit_intercept': True, 'n
_jobs': None, 'normalize': True}
The positive(max) coef-value is 0.27485562036693595
The variable associated with this coef-value is AveRooms
```

| | Feature | Coefficients |
|---|---|---|
| 0 | HouseAge | 0.004154 |
| 1 | AveRooms | 0.274856 |
| 2 | AveBedrms | -0.966598 |
| 3 | Population | -0.000013 |
| 4 | AveOccup | -0.001038 |
| 5 | Latitude | -0.755382 |
| 6 | Longitude | -0.752968 |

```
mae 0.6929651341178028
mse 0.8760332937593536
rmse_val 0.935966502477174
r2 0.3389002600967884
co_efficient_feature_df None
co_efficient_feature HouseAge : 0.004 AveRooms : 0.275 AveBedrms : -0.967
Population : -0.0 AveOccup : -0.001 Latitude : -0.755 Longitude : -0.753
intercept -61.58517190062545
```

In [190]:

```
display(HTML(model_result_df.to_html()))
```

| | data_imputation_percent | missing_type | mae | mse | rmse | r2 | mae_diff | mse_diff | rm |
|---|---|---|---|---|---|---|---|---|---|
| **0** | Original (0%) | None | 0.678 | 0.808 | 0.899 | 0.39 | NaN | NaN | |
| **1** | 10% | MAR | 0.684 | 0.85 | 0.922 | 0.359 | 0.006 | 0.042 | |
| **2** | 20% | MAR | 0.687 | 0.866 | 0.93 | 0.347 | 0.009 | 0.058 | |
| **3** | 30% | MAR | 0.693 | 0.876 | 0.936 | 0.339 | 0.015 | 0.068 | |

In [ ]:

```
#Case 3 : Impute 25 % of x -Missing not at random
def get_mnar_imputed_df(impute_fractions,housing_df,impute_variable,impute_with="media
n"):
    imputed_df = {}
    for percent in impute_fractions:
        print("Percentage Imputed : {}%".format(int(percent*100)))
        if percent == 0.0:
            #Run Baseline model
            imputed_df[percent] = housing_df
            #imputed_df.append(housing_df)
        else:
            var_threshold = np.quantile(housing_df[impute_variable],percent)
            print("Imputing variable {0} when < {1}".format(impute_variable,var_thresho
ld))
            in_sample = housing_df[housing_df[impute_variable] < var_threshold]
            print(in_sample.shape)

            #in_sample = housing_df_sub #housing_df_sub.sample(frac=percent, random_sta
te=99)
            print("Imputed sample shape : {}".format(in_sample.shape))
            out_sample = housing_df[~housing_df.isin(in_sample)].dropna()
            print("Un imputed sample shape : {}".format(out_sample.shape))
            in_sample[impute_variable] = np.nan
            fill_value = 0
            if(impute_with == "median"):
                fill_value = out_sample[impute_variable].median()
                in_sample[impute_variable] = in_sample[impute_variable].fillna(fill_val
ue)
            if(impute_with == "mean"):
                fill_value = out_sample[impute_variable].mean()
                in_sample[impute_variable] = in_sample[impute_variable].fillna(fill_val
ue)
            if(impute_with == "zero"):
                in_sample[impute_variable] = in_sample[impute_variable].fillna(0)
            imputed_data = pd.concat([in_sample, out_sample])
            imputed_data = imputed_data.sort_index()
            imputed_df["mnar-"+str(percent)] = imputed_data
            #imputed_df.append(imputed_data)
    return imputed_df
```

In [ ]:

```
#Evaluating Case 3 - Missing Not at random
mnar_imputed_df_dict = get_mnar_imputed_df([0.0,0.25],cal,'AveBedrms',"median") #'AveBe
drms','AveRooms',4,
model_result = run_all_model(mnar_imputed_df_dict,cal)
model_result_df3 = get_model_result_df(model_result)
#display(model_result_df3)
```

In [ ]:

```
display(HTML(model_result_df3.to_html()))
```

In [ ]:

```
boxplot = cal.boxplot(by='AveRooms')
boxplot
```