ANN

While the ANN model can be further fine-tuned to increase its accuracy, such as increasing the number of layers and dropout, it is time-consuming and inefficient. Therefore, we focused more on other ML models.

In [1]:
```
import pandas as pd
import numpy as np
import math
import tensorflow as tf
import tensorflow.keras as keras
from tensorflow.keras import layers
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Activation
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import MinMaxScaler
from sklearn.inspection import permutation_importance
from sklearn.preprocessing import StandardScaler
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.metrics import r2_score
from collections import defaultdict
from sklearn import metrics
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
```

In [2]:
```
# Import dataset
private_data = "../datasets/cleaned/cleaned_private.csv"

df = pd.read_csv(private_data, quotechar='"', escapechar='\\', thousands=',')
df['Sale Month-Year'] = pd.to_datetime(df['Sale Date']).dt.to_period('M').astype(str)
```

In [3]:
```
def remove_outliers_iqr(df, column):
    q1 = df[column].quantile(0.25)
    q3 = df[column].quantile(0.75)
    iqr = q3 - q1
    lower_bound = q1 - 1.5 * iqr
    upper_bound = q3 + 1.5 * iqr
    return df[(df[column] >= lower_bound) & (df[column] <= upper_bound)]


# Apply outlier removal to Price only
for col in ['Price']:
# for col in ['Price', 'Area (SQFT)', 'Remaining Lease Years']:
    df = remove_outliers_iqr(df, col)
```

In [ ]:
```
df_features=['Area (SQFT)', 'Lease_Category', 'Property Type', 'Postal District',
            'Type of Sale', 'Floor Level', 'Sale Month-Year',  'Distance to MRT (km)']
X = df[df_features]
y = df['Price'].values

categorical_cols = ['Property Type', 'Postal District', 'Type of Sale', 'Floor Level', 'Sale Month-Year', 'Lease_Cat
numerical_cols = ['Area (SQFT)', 'Distance to MRT (km)' ]

X_encoded = pd.get_dummies(X[categorical_cols], drop_first=True)

scaler = StandardScaler()
X_numerical_scaled = scaler.fit_transform(X[numerical_cols])
X_numerical_df = pd.DataFrame(X_numerical_scaled, columns=numerical_cols)
X_final = pd.concat([X_numerical_df, X_encoded], axis=1)
X_final = pd.concat([X[numerical_cols], X_encoded], axis=1)

x_train, x_test, y_train, y_test = train_test_split(X_final, y, test_size=0.25, random_state=40)
x_train = x_train.values.astype(np.float32)
x_test = x_test.values.astype(np.float32)
x_test = x_test.astype('float32') if isinstance(x_test, pd.DataFrame) else x_test.astype('float32')
y_test = y_test.astype('float32') if isinstance(y_test, pd.DataFrame) else y_test.astype('float32')
print(x_train.shape) # split all categorical data into several columns with 1/0 for each column
print(x_test.shape)
print(y_train.shape)
print(y_test.shape)
```

```
(88744, 41)
(29582, 41)
(88744,)
(29582,)
```

In [ ]:
```
# Define model builder
model=Sequential()
model.add(Dense(64, activation='relu'))
model.add(Dense(64, activation='relu'))
model.add(Dense(64, activation='relu'))
```

```
model.add(Dense(64, activation='relu'))
model.add(Dense(1))
model.compile(optimizer='adam',loss='mse')
model_result = model.fit(x_train, y_train, epochs=200)

class KerasModelWrapper:
    def __init__(self, model):
        self.model = model

    def fit(self, X, y):
        pass  # already trained outside

    def predict(self, X):
        return self.model.predict(X).flatten()

    def score(self, X, y):
        y_pred = self.predict(X)
        return r2_score(y, y_pred)

wrapped_model = KerasModelWrapper(model)

# Use sklearn's permutation importance
result = permutation_importance(wrapped_model, x_test, y_test, n_repeats=10, random_state=42)

# Sort and print feature importances
sorted_idx = result.importances_mean.argsort()[::-1]

print("Feature importances (descending):\n")
feature_names = X_final.columns

# Map each one-hot encoded column back to its base category
grouped_importances = defaultdict(float)

for i, col in enumerate(feature_names):
    # Split by underscore only if it's one-hot encoded
    if '_' in col:
        base_feature = col.split('_')[0]
    else:
        base_feature = col  # numerical feature (not one-hot encoded)

    grouped_importances[base_feature] += result.importances_mean[i]

# Sort and print the aggregated importances
sorted_importances = sorted(grouped_importances.items(), key=lambda x: x[1], reverse=True)

print("Aggregated Feature Importances:\n")
for feature, importance in sorted_importances:
    print(f"{feature}: {importance:.6f}")

features, importances = zip(*sorted_importances)

# Plot
plt.figure(figsize=(10, 6))
bars = plt.barh(features, importances, color='skyblue')
plt.xlabel("Importance")
plt.title("Aggregated Feature Importances")
plt.gca().invert_yaxis()  # Highest importance on top

for bar in bars:
    width = bar.get_width()
    plt.text(width + 0.001,
        bar.get_y() + bar.get_height() / 2,
        f"{width:.4f}",
        va='center')

plt.tight_layout()
plt.show()
```

```
Epoch 1/200
2774/2774 [==============================] - 14s 4ms/step - loss: 7974306709504.0000
Epoch 2/200
2774/2774 [==============================] - 11s 4ms/step - loss: 3807742001152.0000
Epoch 3/200
2774/2774 [==============================] - 11s 4ms/step - loss: 2851716726784.0000
Epoch 4/200
2774/2774 [==============================] - 15s 5ms/step - loss: 2777113165824.0000
Epoch 5/200
2774/2774 [==============================] - 14s 5ms/step - loss: 3047600422912.0000
Epoch 6/200
2774/2774 [==============================] - 13s 5ms/step - loss: 2311380533248.0000
Epoch 7/200
2774/2774 [==============================] - 15s 5ms/step - loss: 2068711342080.0000
Epoch 8/200
2774/2774 [==============================] - 9s 3ms/step - loss: 1952607764480.0000
Epoch 9/200
2774/2774 [==============================] - 11s 4ms/step - loss: 1543747796992.0000
Epoch 10/200
2774/2774 [==============================] - 11s 4ms/step - loss: 1871928229888.0000
Epoch 11/200
2774/2774 [==============================] - 11s 4ms/step - loss: 1533951213568.0000
Epoch 12/200
2774/2774 [==============================] - 12s 4ms/step - loss: 1392954179584.0000
Epoch 13/200
2774/2774 [==============================] - 20s 7ms/step - loss: 1111712858112.0000
Epoch 14/200
2774/2774 [==============================] - 27s 10ms/step - loss: 1078364340224.0000
Epoch 15/200
2774/2774 [==============================] - 23s 8ms/step - loss: 1062859964416.0000
Epoch 16/200
2774/2774 [==============================] - 25s 9ms/step - loss: 913377787904.0000
Epoch 17/200
2774/2774 [==============================] - 24s 9ms/step - loss: 969691758592.0000
Epoch 18/200
2774/2774 [==============================] - 24s 9ms/step - loss: 899877896192.0000
Epoch 19/200
2774/2774 [==============================] - 25s 9ms/step - loss: 880695115776.0000
Epoch 20/200
2774/2774 [==============================] - 24s 9ms/step - loss: 811646255104.0000
Epoch 21/200
2774/2774 [==============================] - 26s 9ms/step - loss: 834768601088.0000
Epoch 22/200
2774/2774 [==============================] - 28s 10ms/step - loss: 847597666304.0000
Epoch 23/200
2774/2774 [==============================] - 21s 8ms/step - loss: 834325053440.0000
Epoch 24/200
2774/2774 [==============================] - 26s 10ms/step - loss: 812631654400.0000
Epoch 25/200
2774/2774 [==============================] - 27s 10ms/step - loss: 754191106048.0000
Epoch 26/200
2774/2774 [==============================] - 30s 11ms/step - loss: 906597236736.0000
Epoch 27/200
2774/2774 [==============================] - 30s 11ms/step - loss: 791592173568.0000
Epoch 28/200
2774/2774 [==============================] - 27s 10ms/step - loss: 867282452480.0000
Epoch 29/200
2774/2774 [==============================] - 26s 9ms/step - loss: 757165457408.0000
Epoch 30/200
2774/2774 [==============================] - 27s 10ms/step - loss: 761216761856.0000
Epoch 31/200
2774/2774 [==============================] - 29s 10ms/step - loss: 807524892672.0000
Epoch 32/200
2774/2774 [==============================] - 27s 10ms/step - loss: 685213220864.0000
Epoch 33/200
2774/2774 [==============================] - 30s 11ms/step - loss: 848152297472.0000
Epoch 34/200
2774/2774 [==============================] - 28s 10ms/step - loss: 718005796864.0000
Epoch 35/200
2774/2774 [==============================] - 28s 10ms/step - loss: 773660868608.0000
Epoch 36/200
2774/2774 [==============================] - 27s 10ms/step - loss: 696069521408.0000
Epoch 37/200
2774/2774 [==============================] - 30s 11ms/step - loss: 639792513024.0000
Epoch 38/200
2774/2774 [==============================] - 31s 11ms/step - loss: 656524771328.0000
Epoch 39/200
2774/2774 [==============================] - 34s 12ms/step - loss: 675342057472.0000
Epoch 40/200
2774/2774 [==============================] - 31s 11ms/step - loss: 749900595200.0000
Epoch 41/200
2774/2774 [==============================] - 31s 11ms/step - loss: 665440747520.0000
Epoch 42/200
2774/2774 [==============================] - 33s 12ms/step - loss: 598591668224.0000
Epoch 43/200
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2774/2774 [==============================] - 32s 12ms/step - loss: 614677479424.0000
Epoch 44/200
2774/2774 [==============================] - 23s 8ms/step - loss: 583556464640.0000
Epoch 45/200
2774/2774 [==============================] - 22s 8ms/step - loss: 599565533184.0000
Epoch 46/200
2774/2774 [==============================] - 23s 8ms/step - loss: 566696738816.0000
Epoch 47/200
2774/2774 [==============================] - 21s 8ms/step - loss: 531952959488.0000
Epoch 48/200
2774/2774 [==============================] - 22s 8ms/step - loss: 582381207552.0000
Epoch 49/200
2774/2774 [==============================] - 23s 8ms/step - loss: 511823052800.0000
Epoch 50/200
2774/2774 [==============================] - 20s 7ms/step - loss: 459484889088.0000
Epoch 51/200
2774/2774 [==============================] - 20s 7ms/step - loss: 694397173760.0000
Epoch 52/200
2774/2774 [==============================] - 16s 6ms/step - loss: 492908249088.0000
Epoch 53/200
2774/2774 [==============================] - 12s 4ms/step - loss: 501951201280.0000
Epoch 54/200
2774/2774 [==============================] - 14s 5ms/step - loss: 499984072704.0000
Epoch 55/200
2774/2774 [==============================] - 11s 4ms/step - loss: 559160360960.0000
Epoch 56/200
2774/2774 [==============================] - 12s 4ms/step - loss: 529933729792.0000
Epoch 57/200
2774/2774 [==============================] - 14s 5ms/step - loss: 540411363328.0000
Epoch 58/200
2774/2774 [==============================] - 3s 1ms/step - loss: 464101736448.0000
Epoch 59/200
2774/2774 [==============================] - 3s 1ms/step - loss: 403907543040.0000
Epoch 60/200
2774/2774 [==============================] - 3s 1ms/step - loss: 373112930304.0000
Epoch 61/200
2774/2774 [==============================] - 3s 945us/step - loss: 392152088576.0000
Epoch 62/200
2774/2774 [==============================] - 3s 955us/step - loss: 281001754624.0000
Epoch 63/200
2774/2774 [==============================] - 3s 959us/step - loss: 257343389696.0000
Epoch 64/200
2774/2774 [==============================] - 2s 861us/step - loss: 178874580992.0000
Epoch 65/200
2774/2774 [==============================] - 2s 878us/step - loss: 140436094976.0000
Epoch 66/200
2774/2774 [==============================] - 3s 931us/step - loss: 123514929152.0000
Epoch 67/200
2774/2774 [==============================] - 3s 937us/step - loss: 112464199680.0000
Epoch 68/200
2774/2774 [==============================] - 2s 845us/step - loss: 109270581248.0000
Epoch 69/200
2774/2774 [==============================] - 3s 911us/step - loss: 108336922624.0000
Epoch 70/200
2774/2774 [==============================] - 3s 1ms/step - loss: 101452259328.0000
Epoch 71/200
2774/2774 [==============================] - 2s 863us/step - loss: 101290688512.0000
Epoch 72/200
2774/2774 [==============================] - 3s 911us/step - loss: 99421839360.0000
Epoch 73/200
2774/2774 [==============================] - 3s 1ms/step - loss: 96500793344.0000
Epoch 74/200
2774/2774 [==============================] - 3s 920us/step - loss: 95675981824.0000
Epoch 75/200
2774/2774 [==============================] - 2s 869us/step - loss: 98910109696.0000
Epoch 76/200
2774/2774 [==============================] - 3s 912us/step - loss: 113375141888.0000
Epoch 77/200
2774/2774 [==============================] - 3s 945us/step - loss: 93208854528.0000
Epoch 78/200
2774/2774 [==============================] - 3s 924us/step - loss: 93370564608.0000
Epoch 79/200
2774/2774 [==============================] - 3s 936us/step - loss: 91950956544.0000
Epoch 80/200
2774/2774 [==============================] - 3s 947us/step - loss: 91876663296.0000
Epoch 81/200
2774/2774 [==============================] - 3s 961us/step - loss: 90371964928.0000
Epoch 82/200
2774/2774 [==============================] - 2s 834us/step - loss: 89848324096.0000
Epoch 83/200
2774/2774 [==============================] - 2s 861us/step - loss: 90039681024.0000
Epoch 84/200
2774/2774 [==============================] - 2s 829us/step - loss: 88182685696.0000
Epoch 85/200
2774/2774 [==============================] - 3s 937us/step - loss: 90209853440.0000
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Epoch 86/200
2774/2774 [==============================] - 2s 891us/step - loss: 86918275072.0000
Epoch 87/200
2774/2774 [==============================] - 2s 861us/step - loss: 87135297536.0000
Epoch 88/200
2774/2774 [==============================] - 2s 838us/step - loss: 87869521920.0000
Epoch 89/200
2774/2774 [==============================] - 2s 864us/step - loss: 85014847488.0000
Epoch 90/200
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Epoch 91/200
2774/2774 [==============================] - 2s 833us/step - loss: 85382078464.0000
Epoch 92/200
2774/2774 [==============================] - 2s 867us/step - loss: 86586417152.0000
Epoch 93/200
2774/2774 [==============================] - 2s 879us/step - loss: 84979105792.0000
Epoch 94/200
2774/2774 [==============================] - 2s 829us/step - loss: 82931040256.0000
Epoch 95/200
2774/2774 [==============================] - 2s 883us/step - loss: 86038478848.0000
Epoch 96/200
2774/2774 [==============================] - 3s 929us/step - loss: 81965572096.0000
Epoch 97/200
2774/2774 [==============================] - 3s 932us/step - loss: 81666007040.0000
Epoch 98/200
2774/2774 [==============================] - 3s 998us/step - loss: 89013911552.0000
Epoch 99/200
2774/2774 [==============================] - 3s 967us/step - loss: 81439072256.0000
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Epoch 101/200
2774/2774 [==============================] - 3s 986us/step - loss: 81465311232.0000
Epoch 102/200
2774/2774 [==============================] - 3s 967us/step - loss: 80316825600.0000
Epoch 103/200
2774/2774 [==============================] - 3s 979us/step - loss: 81724186624.0000
Epoch 104/200
2774/2774 [==============================] - 3s 1ms/step - loss: 79138652160.0000
Epoch 105/200
2774/2774 [==============================] - 3s 997us/step - loss: 80187219968.0000
Epoch 106/200
2774/2774 [==============================] - 3s 1ms/step - loss: 79358820352.0000
Epoch 107/200
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Epoch 108/200
2774/2774 [==============================] - 3s 1ms/step - loss: 86744236032.0000
Epoch 109/200
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Epoch 110/200
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Epoch 111/200
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Epoch 115/200
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Epoch 116/200
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Epoch 124/200
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Epoch 125/200
2774/2774 [==============================] - 3s 1ms/step - loss: 74882031616.0000
Epoch 126/200
2774/2774 [==============================] - 3s 1ms/step - loss: 74850205696.0000
Epoch 127/200
2774/2774 [==============================] - 3s 1ms/step - loss: 72227102720.0000
Epoch 128/200
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2774/2774 [==============================] - 3s 1ms/step - loss: 72320679936.0000
Epoch 129/200
2774/2774 [==============================] - 3s 1ms/step - loss: 71961878528.0000
Epoch 130/200
2774/2774 [==============================] - 3s 1ms/step - loss: 73217556480.0000
Epoch 131/200
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Epoch 132/200
2774/2774 [==============================] - 3s 1ms/step - loss: 71934099456.0000
Epoch 133/200
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Epoch 134/200
2774/2774 [==============================] - 3s 1ms/step - loss: 70033817600.0000
Epoch 135/200
2774/2774 [==============================] - 3s 1ms/step - loss: 70891520000.0000
Epoch 136/200
2774/2774 [==============================] - 3s 1ms/step - loss: 69724602368.0000
Epoch 137/200
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Epoch 138/200
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Epoch 141/200
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Epoch 142/200
2774/2774 [==============================] - 3s 1ms/step - loss: 71197220864.0000
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Epoch 149/200
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Epoch 151/200
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Epoch 152/200
2774/2774 [==============================] - 5s 2ms/step - loss: 66899124224.0000
Epoch 153/200
2774/2774 [==============================] - 5s 2ms/step - loss: 83813318656.0000
Epoch 154/200
2774/2774 [==============================] - 5s 2ms/step - loss: 77018267648.0000
Epoch 155/200
2774/2774 [==============================] - 5s 2ms/step - loss: 68481941504.0000
Epoch 156/200
2774/2774 [==============================] - 4s 1ms/step - loss: 67904364544.0000
Epoch 157/200
2774/2774 [==============================] - 4s 1ms/step - loss: 65510150144.0000
Epoch 158/200
2774/2774 [==============================] - 5s 2ms/step - loss: 67099860992.0000
Epoch 159/200
2774/2774 [==============================] - 6s 2ms/step - loss: 65322582016.0000
Epoch 160/200
2774/2774 [==============================] - 6s 2ms/step - loss: 65654599680.0000
Epoch 161/200
2774/2774 [==============================] - 4s 1ms/step - loss: 65832701952.0000
Epoch 162/200
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Epoch 163/200
2774/2774 [==============================] - 4s 1ms/step - loss: 80956301312.0000
Epoch 164/200
2774/2774 [==============================] - 4s 1ms/step - loss: 64624746496.0000
Epoch 165/200
2774/2774 [==============================] - 4s 2ms/step - loss: 65020084224.0000
Epoch 166/200
2774/2774 [==============================] - 6s 2ms/step - loss: 64681324544.0000
Epoch 167/200
2774/2774 [==============================] - 4s 1ms/step - loss: 64768339968.0000
Epoch 168/200
2774/2774 [==============================] - 3s 1ms/step - loss: 65313095680.0000
Epoch 169/200
2774/2774 [==============================] - 3s 1ms/step - loss: 64387411968.0000
Epoch 170/200
2774/2774 [==============================] - 3s 1ms/step - loss: 68502523904.0000
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Epoch 171/200
2774/2774 [==============================] - 3s 1ms/step - loss: 67726401536.0000
Epoch 172/200
2774/2774 [==============================] - 3s 1ms/step - loss: 64087711744.0000
Epoch 173/200
2774/2774 [==============================] - 3s 1ms/step - loss: 63319158784.0000
Epoch 174/200
2774/2774 [==============================] - 3s 1ms/step - loss: 63415431168.0000
Epoch 175/200
2774/2774 [==============================] - 3s 1ms/step - loss: 66163216384.0000
Epoch 176/200
2774/2774 [==============================] - 3s 1ms/step - loss: 63833214976.0000
Epoch 177/200
2774/2774 [==============================] - 3s 1ms/step - loss: 63053008896.0000
Epoch 178/200
2774/2774 [==============================] - 3s 1ms/step - loss: 63650988032.0000
Epoch 179/200
2774/2774 [==============================] - 3s 1ms/step - loss: 62971072512.0000
Epoch 180/200
2774/2774 [==============================] - 3s 1ms/step - loss: 62928986112.0000
Epoch 181/200
2774/2774 [==============================] - 3s 1ms/step - loss: 64751808512.0000
Epoch 182/200
2774/2774 [==============================] - 3s 1ms/step - loss: 62252748800.0000
Epoch 183/200
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Epoch 184/200
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Feature importances (descending):

Aggregated Feature Importances:

Area (SQFT): 1.261851
Sale Month-Year: 0.384004
Lease: 0.326418
Type of Sale: 0.296333
Property Type: 0.189708
Postal District: 0.168648
Floor Level: 0.064866
Distance to MRT (km): 0.058170
```
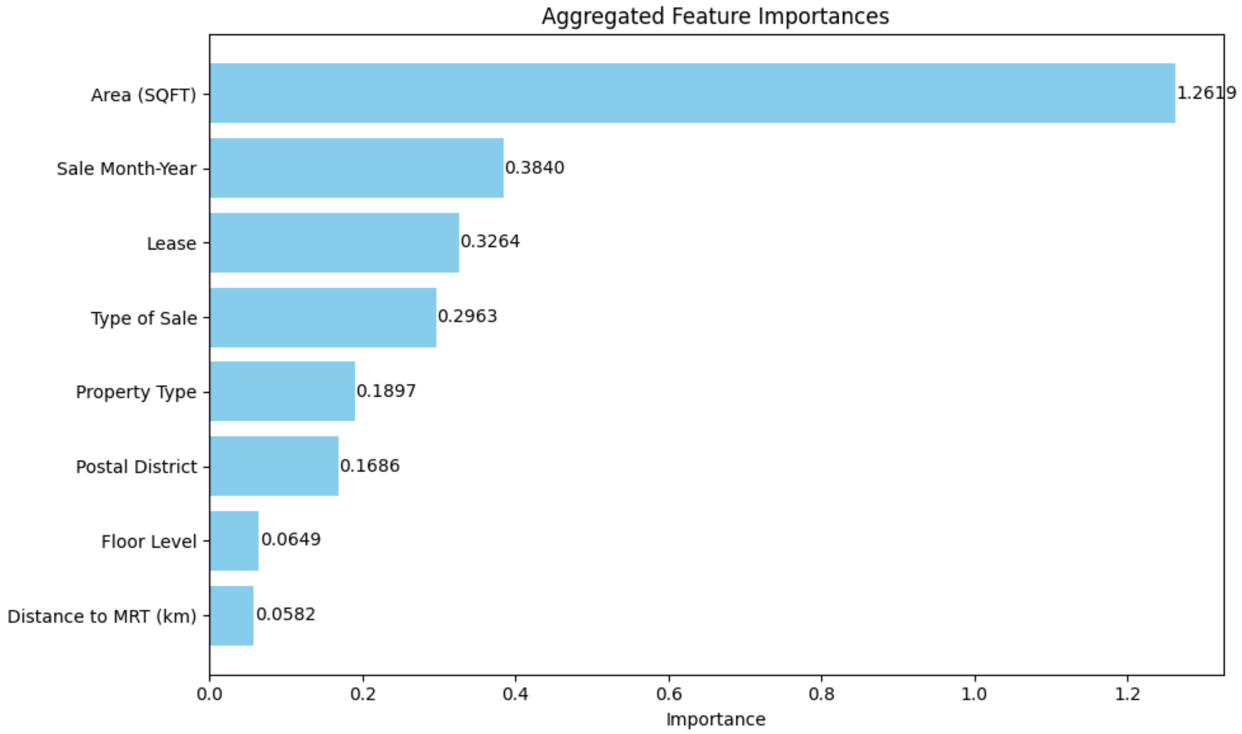
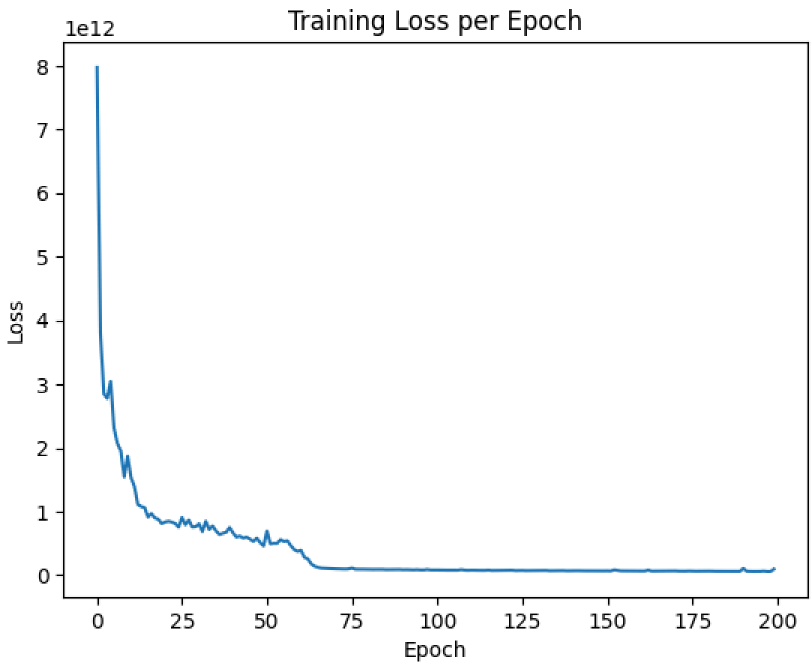



In [ ]:
```python
# training loss
loss = model_result.history['loss']
sns.lineplot(x=range(len(loss)),y=loss)
plt.title("Training Loss per Epoch")
plt.xlabel("Epoch")
plt.ylabel("Loss")
plt.show()
```



In [17]:
```python
test_predictions = wrapped_model.predict(x_test)
df_pred=pd.DataFrame({'test_actual': y_test})
df_pred['test_pred']=test_predictions
df_pred.head()
```

```
925/925 [==============================] - 1s 607us/step
```

Out[17]:

	test_actual	test_pred
0	3675000.0	3.333120e+06
1	1447300.0	1.330068e+06
2	960000.0	1.014468e+06
3	1060000.0	1.261895e+06
4	1206000.0	1.267639e+06

In [19]:
```python
# Predict using the ANN model
y_pred = model.predict(x_test).flatten()

# Scatter Plot: Actual vs Predicted Prices
plt.figure(figsize=(8, 6))
plt.scatter(y_test, y_pred, alpha=0.5, color='royalblue')
plt.plot([y_test.min(), y_test.max()], [y_test.min(), y_test.max()], 'r--')  # perfect prediction line
plt.xlabel('Actual Price')
plt.ylabel('Predicted Price')
plt.title('Actual vs Predicted Prices (ANN)')
plt.grid(True)
plt.tight_layout()
plt.show()
```

```
925/925 [==============================] - 1s 610us/step
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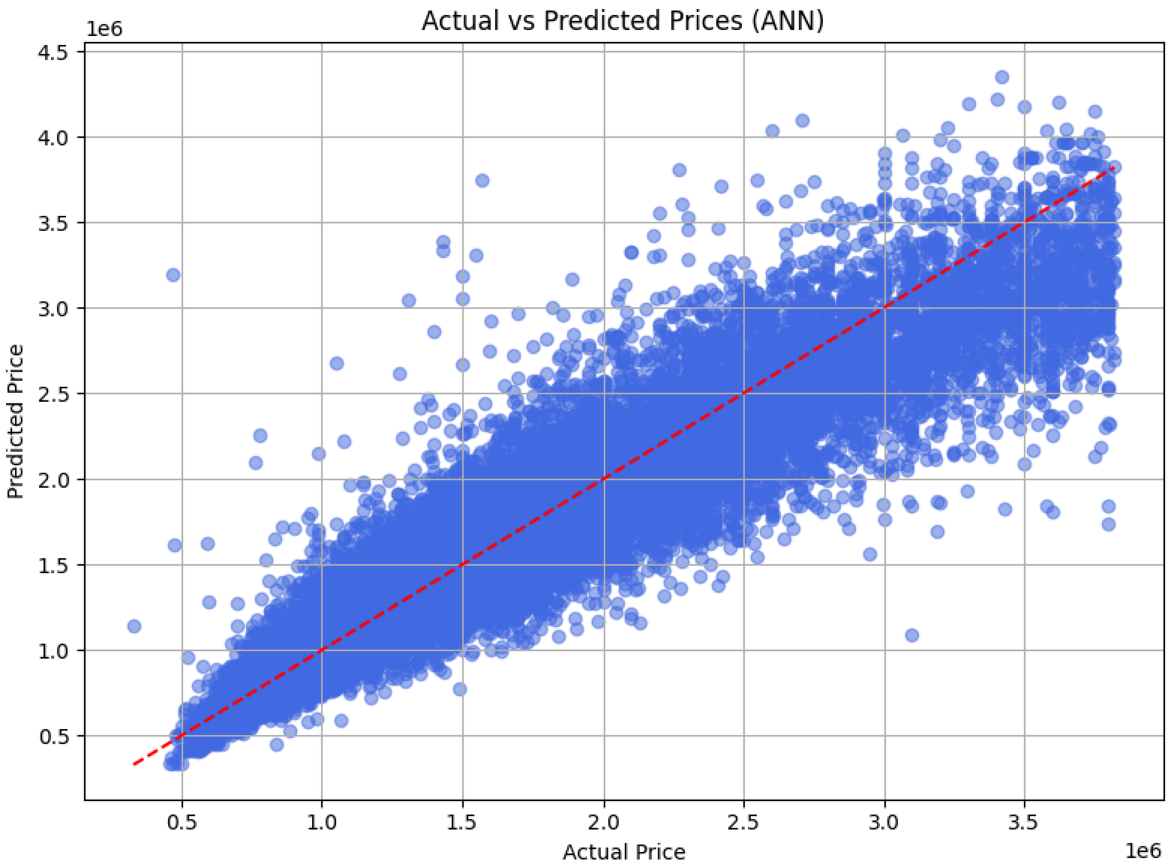

In [18]:
```python
#find rmse score
mse = mean_squared_error(df_pred['test_actual'], df_pred['test_pred'])
rmse = math.sqrt(mse)
print(f"RMSE: {rmse}")

mse = mean_squared_error(df_pred['test_actual'], df_pred['test_pred'])
mae = mean_absolute_error(df_pred['test_actual'], df_pred['test_pred'])
r2 = r2_score(df_pred['test_actual'], df_pred['test_pred'])

print(f"Mean Squared Error (MSE): {mse:.2f}")
print(f"Mean Absolute Error (MAE): {mae:.2f}")
print(f"R^2 Score: {r2:.4f}")
```

```
RMSE: 249481.61294973223
Mean Squared Error (MSE): 62241075200.00
Mean Absolute Error (MAE): 173008.09
R^2 Score: 0.8737
```

In [ ]: