1: Import Libraries

In [2]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

from statsmodels.tsa.arima.model import ARIMA
from statsmodels.tsa.stattools import adfuller
from statsmodels.graphics.tsaplots import plot_acf, plot_pacf

from sklearn.model_selection import train_test_split
from sklearn.preprocessing import MinMaxScaler
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_sco
re

from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import LSTM, Dense, Dropout
from tensorflow.keras.callbacks import EarlyStopping
from tcn import TCN


import math
import sys
print(sys.executable)
```

```
b:\Dublin City University\Practicum\Proj\venv_311\Scripts\python.exe
```

2: Load and Explore Dataset

In [3]:
```
multimodal = pd.read_csv("B:/Dublin City University/Practicum/Proj/Dataset/
main/processed/multimodal_dataset_final_v4_1.csv", parse_dates=["Date"])
multimodal.head()
```

Out[3]:

	Date	Open	High	Low	Close	Volume	Adj Close
0	2016-07-01	17924.240234	18002.380859	17916.910156	17949.369141	82160000	17949.369141
1	2016-06-30	17712.759766	17930.609375	17711.800781	17929.990234	133030000	17929.990234
2	2016-06-29	17456.019531	17704.509766	17456.019531	17694.679688	106380000	17694.679688
3	2016-06-28	17190.509766	17409.720703	17190.509766	17409.720703	112190000	17409.720703
4	2016-06-27	17355.210938	17355.210938	17063.080078	17140.240234	138740000	17140.240234

5 rows × 56 columns

In [4]:
```
missing_values = multimodal.isnull().sum()
print("\nMissing values per column:")
missing_values[missing_values > 0]
```

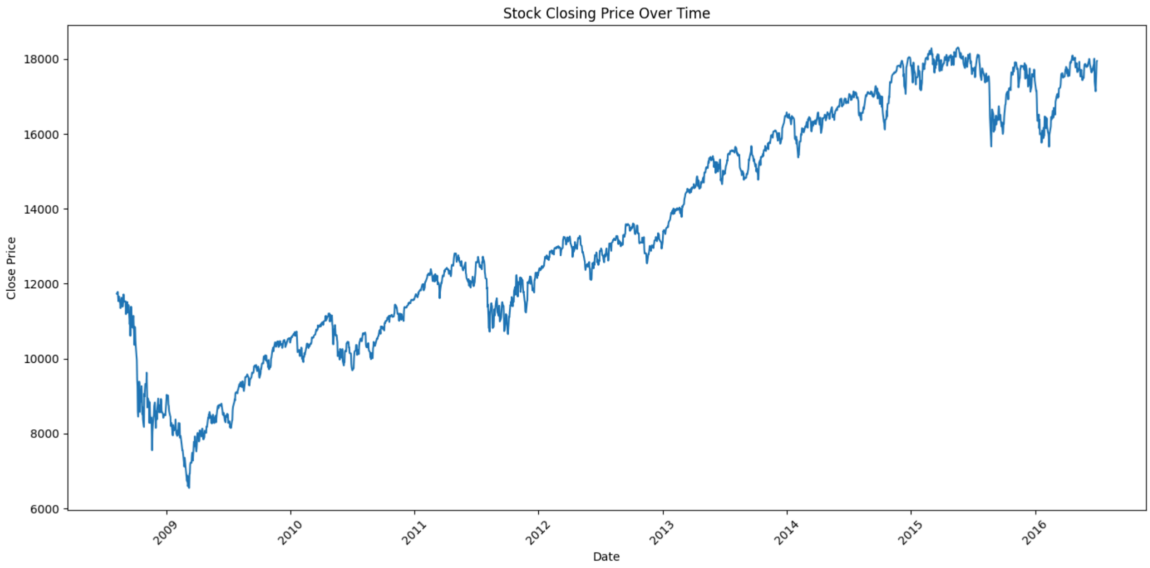
```
Missing values per column:
```

Out[4]:
```
Log_Returns          1
Volatility_Log_10   10
pct_change           1
Next_3_Close         3
Next_7_Close         7
Next_Close           1
dtype: int64
```

In [5]:
```
multimodal.describe()
multimodal.dtypes
```

Out[5]:
```
Date                               datetime64[ns]
Open                                      float64
High                                      float64
Low                                       float64
Close                                     float64
Volume                                      int64
Adj Close                                 float64
Log_Returns                               float64
Volatility_Log_10                         float64
cl-op                                     float64
hi-lo                                     float64
Label                                       int64
vader_news_sentiment                      float64
FinBERT_news_sentiment                    float64
Smart_news_sentiment                      float64
news_buying_intent                        float64
news_selling_intent                       float64
news_uncertainty_intent                   float64
news_urgency_intent                       float64
news_prediction_intent                    float64
news_fear_intent                          float64
news_greed_intent                         float64
news_question_intent                      float64
news_action_intent                        float64
vader_reddit_sentiment                    float64
FinBERT_reddit_sentiment                  float64
Smart_reddit_sentiment                    float64
reddit_buying_intent                      float64
reddit_selling_intent                     float64
reddit_uncertainty_intent                 float64
reddit_urgency_intent                     float64
reddit_prediction_intent                  float64
reddit_fear_intent                        float64
reddit_greed_intent                       float64
reddit_question_intent                    float64
reddit_action_intent                      float64
Target                                      int64
pct_change                                float64
finbert_final_sentiment                   float64
total_buying_intent                       float64
total_selling_intent                      float64
total_uncertainty_intent                  float64
total_urgency_intent                      float64
total_prediction_intent                   float64
total_fear_intent                         float64
total_greed_intent                        float64
total_question_intent                     float64
total_action_intent                       float64
sentiment_minus_uncertainty               float64
sentiment_minus_fear                      float64
sentiment_minus_action                    float64
sentiment_minus_urgency                   float64
sentiment_minus_prediction                float64
Next_3_Close                              float64
Next_7_Close                              float64
Next_Close                                float64
dtype: object
```

In [6]:
```
plt.figure(figsize=(14, 7))
plt.plot(pd.to_datetime(multimodal['Date']), multimodal['Close'])
plt.title('Stock Closing Price Over Time')
plt.xlabel('Date')
plt.ylabel('Close Price')
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```



3: Data Preprocessing

In [7]:
```
# Drop top 10 (rolling NaNs) and bottom 7 (from shift(-7))
multimodal_modelling = multimodal.iloc[10:-7].copy()

# Optional: reset index
# multimodal_modelling.reset_index(drop=True, inplace=True)

# Sanity check
print(f"Shape: {multimodal_modelling.shape}")
print(multimodal_modelling.isnull().sum())
```

```
Shape: (1972, 56)
Date                          0
Open                          0
High                          0
Low                           0
Close                         0
Volume                        0
Adj Close                     0
Log_Returns                   0
Volatility_Log_10             0
cl-op                         0
hi-lo                         0
Label                         0
vader_news_sentiment          0
FinBERT_news_sentiment        0
Smart_news_sentiment          0
news_buying_intent            0
news_selling_intent           0
news_uncertainty_intent       0
news_urgency_intent           0
news_prediction_intent        0
news_fear_intent              0
news_greed_intent             0
news_question_intent          0
news_action_intent            0
vader_reddit_sentiment        0
FinBERT_reddit_sentiment      0
Smart_reddit_sentiment        0
reddit_buying_intent          0
reddit_selling_intent         0
reddit_uncertainty_intent     0
reddit_urgency_intent         0
reddit_prediction_intent      0
reddit_fear_intent            0
reddit_greed_intent           0
reddit_question_intent        0
reddit_action_intent          0
Target                        0
pct_change                    0
finbert_final_sentiment       0
total_buying_intent           0
total_selling_intent          0
total_uncertainty_intent      0
total_urgency_intent          0
total_prediction_intent       0
total_fear_intent             0
total_greed_intent            0
total_question_intent         0
total_action_intent           0
sentiment_minus_uncertainty   0
sentiment_minus_fear          0
sentiment_minus_action        0
sentiment_minus_urgency       0
sentiment_minus_prediction    0
Next_3_Close                  0
Next_7_Close                  0
Next_Close                    0
dtype: int64
```

In [8]:
```
df_targets = multimodal_modelling[["Date", "Target", "Label", "Next_Close",
"Next_3_Close", "Next_7_Close"]].copy()

df_arima = multimodal_modelling[["Date", "Close", "Next_Close"]].copy()
df_arima.set_index("Date", inplace=True)

drop_cols_lstm = ["Date", "Label", "Target", "Next_Close", "Next_3_Close",
"Next_7_Close"]
df_lstm = multimodal_modelling.drop(columns=drop_cols_lstm).copy()

drop_cols_tcn = ["Date", "Label", "Target", "Next_Close", "Next_3_Close",
"Next_7_Close"]
df_tcn = multimodal_modelling.drop(columns=drop_cols_tcn).copy()
```

4: Time Series Stationarity Analysis for ARIMA

In [9]:
```
df_arima.head()
```

Out[9]:

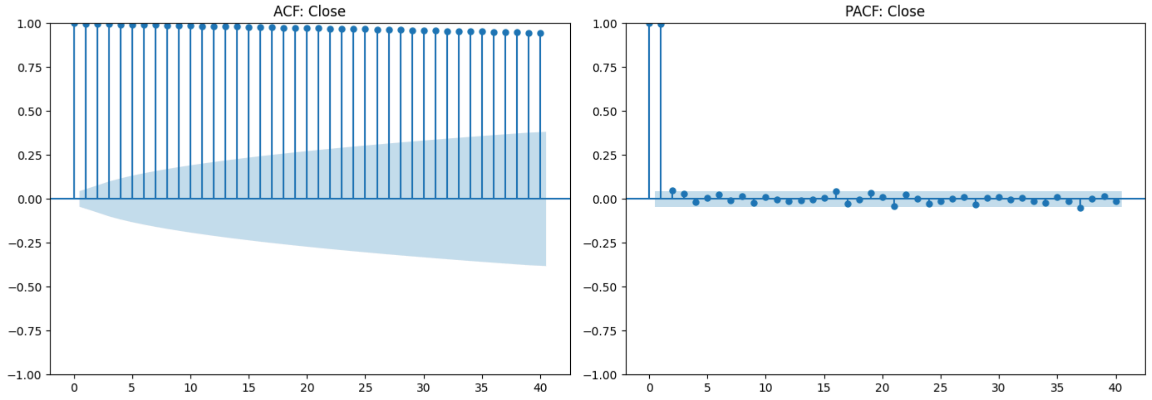
Date	Close	Next_Close
2016-06-17	17675.160156	17733.099609
2016-06-16	17733.099609	17640.169922
2016-06-15	17640.169922	17674.820312
2016-06-14	17674.820312	17732.480469
2016-06-13	17732.480469	17865.339844

In [10]:
```
result = adfuller(df_arima["Close"])
print(f"ADF Statistic: {result[0]}")
print(f"p-value: {result[1]}")
```

```
ADF Statistic: -1.210171226984291
p-value: 0.6692050737972017
```

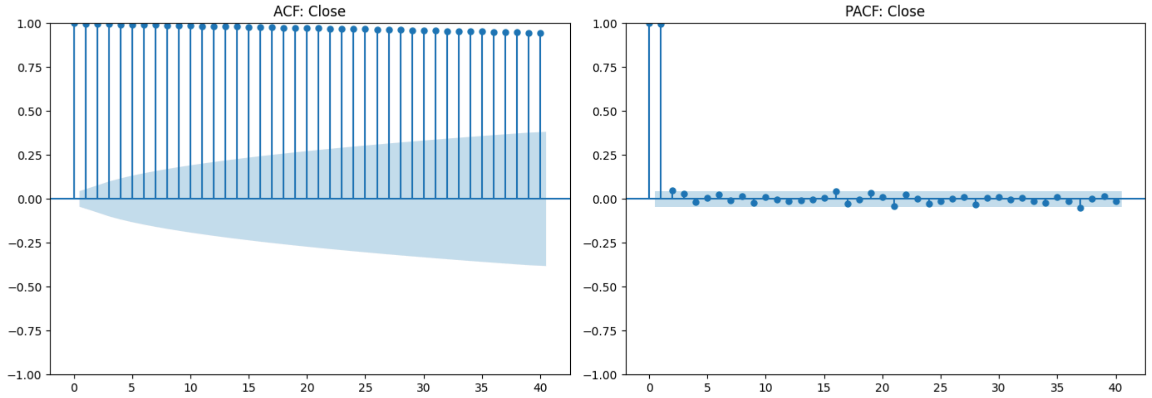
In [11]:

```
plt.figure(figsize=(14, 5))
plt.subplot(1, 2, 1)
plot_acf(multimodal_modelling["Close"], lags=40, ax=plt.gca())
plt.title("ACF: Close")

plt.subplot(1, 2, 2)
plot_pacf(multimodal_modelling["Close"], lags=40, ax=plt.gca(), method='yw
m')
plt.title("PACF: Close")

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



In [12]:

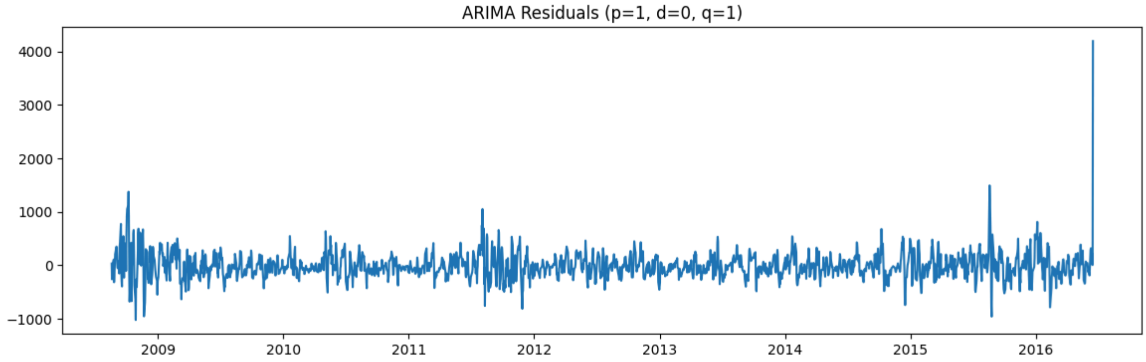
```
plt.figure(figsize=(14, 5))
plt.subplot(1, 2, 1)
plot_acf(df_arima["Close"], lags=40, ax=plt.gca())
plt.title("ACF: Close")

plt.subplot(1, 2, 2)
plot_pacf(df_arima["Close"], lags=40, ax=plt.gca(), method='ywm')
plt.title("PACF: Close")

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



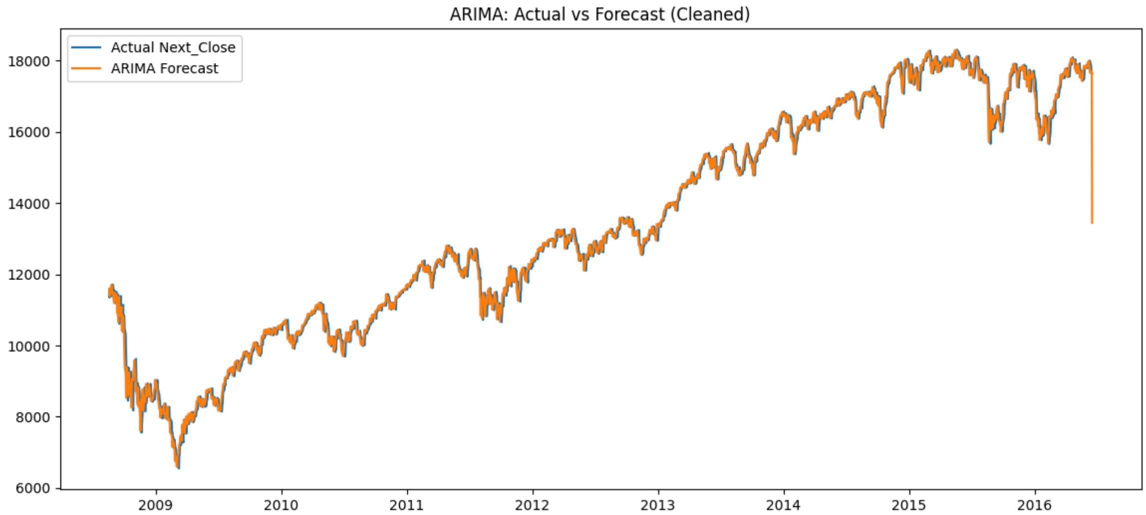
In [13]:
```
# Fit ARIMA model (you can ADF test and gridsearch later)
model = ARIMA(df_arima["Close"], order=(1,0,1))
model_fit = model.fit()

# Forecast next day
forecast = model_fit.predict(start=0, end=len(df_arima)-1)
true = df_arima["Next_Close"]

# Shift Close forward to align with Next_Close
forecast = forecast.shift(1)  # now forecast[i] ≈ Close[i+1]
forecast = forecast[:len(true)]

# Align forecast and true by dropping NaNs introduced by shift
mask = forecast.notna()
forecast_clean = forecast[mask]
true_clean = true[mask]

# Evaluation
print("R²:", r2_score(true_clean, forecast_clean))
print("MSE:", mean_squared_error(true_clean, forecast_clean))
```

```
R²: 0.9937197053841297
MSE: 61862.3376472596

b:\Dublin City University\Practicum\Proj\venv_311\Lib\site-packages\statsm
odels\tsa\base\tsa_model.py:473: ValueWarning: A date index has been provi
ded, but it has no associated frequency information and so will be ignored
when e.g. forecasting.
  self._init_dates(dates, freq)
b:\Dublin City University\Practicum\Proj\venv_311\Lib\site-packages\statsm
odels\tsa\base\tsa_model.py:473: ValueWarning: A date index has been provi
ded, but it is not monotonic and so will be ignored when e.g. forecasting.
  self._init_dates(dates, freq)
b:\Dublin City University\Practicum\Proj\venv_311\Lib\site-packages\statsm
odels\tsa\base\tsa_model.py:473: ValueWarning: A date index has been provi
ded, but it has no associated frequency information and so will be ignored
when e.g. forecasting.
  self._init_dates(dates, freq)
b:\Dublin City University\Practicum\Proj\venv_311\Lib\site-packages\statsm
odels\tsa\base\tsa_model.py:473: ValueWarning: A date index has been provi
ded, but it is not monotonic and so will be ignored when e.g. forecasting.
  self._init_dates(dates, freq)
b:\Dublin City University\Practicum\Proj\venv_311\Lib\site-packages\statsm
odels\tsa\base\tsa_model.py:473: ValueWarning: A date index has been provi
ded, but it has no associated frequency information and so will be ignored
when e.g. forecasting.
  self._init_dates(dates, freq)
b:\Dublin City University\Practicum\Proj\venv_311\Lib\site-packages\statsm
odels\tsa\base\tsa_model.py:473: ValueWarning: A date index has been provi
ded, but it is not monotonic and so will be ignored when e.g. forecasting.
  self._init_dates(dates, freq)
```

In [14]:
```
residuals = true_clean - forecast_clean
plt.figure(figsize=(14,4))
plt.plot(residuals)
plt.title("ARIMA Residuals (p=1, d=0, q=1)")
plt.show()
```



In [15]:
```
plt.figure(figsize=(14,6))
plt.plot(forecast_clean.index, true_clean, label="Actual Next_Close")
plt.plot(forecast_clean.index, forecast_clean, label="ARIMA Forecast")
plt.title("ARIMA: Actual vs Forecast (Cleaned)")
plt.legend()
plt.show()
```



LSTM Model

In [16]:
```
df_lstm.columns
```

Out[16]:
```
Index(['Open', 'High', 'Low', 'Close', 'Volume', 'Adj Close', 'Log_Return
s',
       'Volatility_Log_10', 'cl-op', 'hi-lo', 'vader_news_sentiment',
       'FinBERT_news_sentiment', 'Smart_news_sentiment', 'news_buying_inte
nt',
       'news_selling_intent', 'news_uncertainty_intent', 'news_urgency_int
ent',
       'news_prediction_intent', 'news_fear_intent', 'news_greed_intent',
       'news_question_intent', 'news_action_intent', 'vader_reddit_sentime
nt',
       'FinBERT_reddit_sentiment', 'Smart_reddit_sentiment',
       'reddit_buying_intent', 'reddit_selling_intent',
       'reddit_uncertainty_intent', 'reddit_urgency_intent',
       'reddit_prediction_intent', 'reddit_fear_intent', 'reddit_greed_int
ent',
       'reddit_question_intent', 'reddit_action_intent', 'pct_change',
       'finbert_final_sentiment', 'total_buying_intent',
       'total_selling_intent', 'total_uncertainty_intent',
       'total_urgency_intent', 'total_prediction_intent', 'total_fear_inte
nt',
       'total_greed_intent', 'total_question_intent', 'total_action_inten
t',
       'sentiment_minus_uncertainty', 'sentiment_minus_fear',
       'sentiment_minus_action', 'sentiment_minus_urgency',
       'sentiment_minus_prediction'],
      dtype='object')
```

In [17]:
```
# Separate features and target
X = df_lstm
y = df_targets["Next_Close"]

# Scale features and target
X_scaler = MinMaxScaler()
y_scaler = MinMaxScaler()

X_scaled = X_scaler.fit_transform(X)
y_scaled = y_scaler.fit_transform(y.values.reshape(-1, 1))

# Create sequences
def create_sequences(X, y, window_size=60):
    Xs, ys = [], []
    for i in range(window_size, len(X)):
        Xs.append(X[i-window_size:i])
        ys.append(y[i])
    return np.array(Xs), np.array(ys)

X_seq, y_seq = create_sequences(X_scaled, y_scaled)

# Return final sequence shapes
X_seq.shape, y_seq.shape
```

Out[17]:
```
((1912, 60, 50), (1912, 1))
```

In [18]:
```
# simple lstm model
X_train, X_test, y_train, y_test = train_test_split(X_seq, y_seq, test_size
=0.2, shuffle=False)

model = Sequential()
model.add(LSTM(64, input_shape=(X_train.shape[1], X_train.shape[2])))
model.add(Dense(1))

model.compile(optimizer='adam', loss='mse')

history = model.fit(
    X_train, y_train,
    epochs=20,
    batch_size=32,
    validation_split=0.1,
    verbose=1
)

y_pred_scaled = model.predict(X_test)

y_pred = y_scaler.inverse_transform(y_pred_scaled)
y_true = y_scaler.inverse_transform(y_test)

y_pred[:5], y_true[:5]
```

```
WARNING:tensorflow:From b:\Dublin City University\Practicum\Proj\venv_311
\Lib\site-packages\keras\src\backend.py:873: The name tf.get_default_graph
is deprecated. Please use tf.compat.v1.get_default_graph instead.

WARNING:tensorflow:From b:\Dublin City University\Practicum\Proj\venv_311
\Lib\site-packages\keras\src\optimizers\__init__.py:309: The name tf.trai
n.Optimizer is deprecated. Please use tf.compat.v1.train.Optimizer instea
d.

Epoch 1/20
WARNING:tensorflow:From b:\Dublin City University\Practicum\Proj\venv_311
\Lib\site-packages\keras\src\utils\tf_utils.py:492: The name tf.ragged.Rag
gedTensorValue is deprecated. Please use tf.compat.v1.ragged.RaggedTensorV
alue instead.

43/43 [==============================] - 2s 21ms/step - loss: 0.0191 - val
_loss: 0.0033
Epoch 2/20
43/43 [==============================] - 1s 12ms/step - loss: 0.0014 - val
_loss: 0.0019
Epoch 3/20
43/43 [==============================] - 1s 13ms/step - loss: 8.9126e-04 -
val_loss: 9.6582e-04
Epoch 4/20
43/43 [==============================] - 1s 12ms/step - loss: 6.9453e-04 -
val_loss: 7.9687e-04
Epoch 5/20
43/43 [==============================] - 1s 13ms/step - loss: 5.7693e-04 -
val_loss: 6.7365e-04
Epoch 6/20
43/43 [==============================] - 1s 13ms/step - loss: 4.4752e-04 -
val_loss: 5.2529e-04
Epoch 7/20
43/43 [==============================] - 1s 12ms/step - loss: 4.0316e-04 -
val_loss: 4.3235e-04
Epoch 8/20
43/43 [==============================] - 1s 12ms/step - loss: 3.5750e-04 -
val_loss: 4.3866e-04
Epoch 9/20
43/43 [==============================] - 1s 12ms/step - loss: 3.2052e-04 -
val_loss: 4.3915e-04
Epoch 10/20
43/43 [==============================] - 1s 13ms/step - loss: 3.7284e-04 -
val_loss: 3.4279e-04
Epoch 11/20
43/43 [==============================] - 1s 12ms/step - loss: 2.8154e-04 -
val_loss: 3.8910e-04
Epoch 12/20
43/43 [==============================] - 1s 14ms/step - loss: 3.0392e-04 -
val_loss: 4.2350e-04
Epoch 13/20
43/43 [==============================] - 1s 13ms/step - loss: 2.7841e-04 -
val_loss: 4.8148e-04
Epoch 14/20
43/43 [==============================] - 1s 12ms/step - loss: 2.4175e-04 -
val_loss: 2.6846e-04
Epoch 15/20
43/43 [==============================] - 0s 12ms/step - loss: 2.5177e-04 -
val_loss: 3.0993e-04
Epoch 16/20
43/43 [==============================] - 1s 13ms/step - loss: 2.1522e-04 -
```

```
val_loss: 2.5791e-04
Epoch 17/20
43/43 [==============================] - 1s 13ms/step - loss: 2.1244e-04 -
val_loss: 3.1360e-04
Epoch 18/20
43/43 [==============================] - 1s 13ms/step - loss: 1.9313e-04 -
val_loss: 2.8534e-04
Epoch 19/20
43/43 [==============================] - 1s 12ms/step - loss: 1.9394e-04 -
val_loss: 2.8639e-04
Epoch 20/20
43/43 [==============================] - 1s 12ms/step - loss: 2.1770e-04 -
val_loss: 5.7899e-04
12/12 [==============================] - 0s 5ms/step
```

Out[18]:

```
(array([[10657.491],
        [10429.721],
        [10492.446],
        [10471.94 ],
        [10583.363]], dtype=float32),
 array([[10374.160156],
        [10282.410156],
        [10383.379883],
        [10402.349609],
        [10392.900391]]))
```

In [19]:
```
# two Stacked layers LSTM Model
model = Sequential()
model.add(LSTM(64, return_sequences=True, input_shape=(X_train.shape[1], X_
train.shape[2])))
model.add(Dropout(0.2))
model.add(LSTM(32))
model.add(Dropout(0.2))
model.add(Dense(1))

model.compile(optimizer='adam', loss='mse')

early_stop = EarlyStopping(monitor='val_loss', patience=5, restore_best_wei
ghts=True)

history = model.fit(
    X_train, y_train,
    epochs=100,
    batch_size=32,
    validation_split=0.1,
    callbacks=[early_stop],
    verbose=1
)

y_pred_scaled = model.predict(X_test)

y_pred = y_scaler.inverse_transform(y_pred_scaled)
y_true = y_scaler.inverse_transform(y_test)

rmse = np.sqrt(mean_squared_error(y_true, y_pred))
r2 = r2_score(y_true, y_pred)

print(f"RMSE: {rmse:.2f}")
print(f"R²: {r2:.4f}")
```

```
Epoch 1/100
43/43 [==============================] - 4s 35ms/step - loss: 0.0587 - val
_loss: 0.0070
Epoch 2/100
43/43 [==============================] - 1s 22ms/step - loss: 0.0096 - val
_loss: 0.0011
Epoch 3/100
43/43 [==============================] - 1s 22ms/step - loss: 0.0080 - val
_loss: 0.0011
Epoch 4/100
43/43 [==============================] - 1s 21ms/step - loss: 0.0073 - val
_loss: 8.4096e-04
Epoch 5/100
43/43 [==============================] - 1s 22ms/step - loss: 0.0074 - val
_loss: 9.1441e-04
Epoch 6/100
43/43 [==============================] - 1s 22ms/step - loss: 0.0066 - val
_loss: 9.4233e-04
Epoch 7/100
43/43 [==============================] - 1s 23ms/step - loss: 0.0060 - val
_loss: 6.5717e-04
Epoch 8/100
43/43 [==============================] - 1s 22ms/step - loss: 0.0062 - val
_loss: 6.4488e-04
Epoch 9/100
43/43 [==============================] - 1s 22ms/step - loss: 0.0055 - val
_loss: 7.8311e-04
Epoch 10/100
43/43 [==============================] - 1s 22ms/step - loss: 0.0054 - val
_loss: 6.2761e-04
Epoch 11/100
43/43 [==============================] - 1s 22ms/step - loss: 0.0052 - val
_loss: 0.0013
Epoch 12/100
43/43 [==============================] - 1s 22ms/step - loss: 0.0056 - val
_loss: 6.4265e-04
Epoch 13/100
43/43 [==============================] - 1s 21ms/step - loss: 0.0052 - val
_loss: 9.2899e-04
Epoch 14/100
43/43 [==============================] - 1s 21ms/step - loss: 0.0048 - val
_loss: 5.6294e-04
Epoch 15/100
43/43 [==============================] - 1s 21ms/step - loss: 0.0042 - val
_loss: 6.0678e-04
Epoch 16/100
43/43 [==============================] - 1s 22ms/step - loss: 0.0046 - val
_loss: 5.9768e-04
Epoch 17/100
43/43 [==============================] - 1s 22ms/step - loss: 0.0045 - val
_loss: 7.4557e-04
Epoch 18/100
43/43 [==============================] - 1s 22ms/step - loss: 0.0046 - val
_loss: 5.0253e-04
Epoch 19/100
43/43 [==============================] - 1s 24ms/step - loss: 0.0048 - val
_loss: 6.1953e-04
Epoch 20/100
43/43 [==============================] - 1s 23ms/step - loss: 0.0047 - val
_loss: 6.1856e-04
Epoch 21/100
```

```
43/43 [==============================] - 1s 25ms/step - loss: 0.0045 - val
_loss: 5.3388e-04
Epoch 22/100
43/43 [==============================] - 1s 26ms/step - loss: 0.0042 - val
_loss: 6.0353e-04
Epoch 23/100
43/43 [==============================] - 1s 24ms/step - loss: 0.0043 - val
_loss: 5.7590e-04
12/12 [==============================] - 1s 9ms/step
RMSE: 488.87
R²: 0.8144
```

Temporal Convolutional Networks

In [20]:

```
X = df_tcn.values
y = df_targets['Next_Close'].values.reshape(-1, 1)

# Scale features and target
X_scaler = MinMaxScaler()
y_scaler = MinMaxScaler()

X_scaled = X_scaler.fit_transform(X)
y_scaled = y_scaler.fit_transform(y)
```

In [21]:

```
def create_sequences(X, y, window_size=60):
    X_seq, y_seq = [], []
    for i in range(window_size, len(X)):
        X_seq.append(X[i-window_size:i])
        y_seq.append(y[i])
    return np.array(X_seq), np.array(y_seq)

X_seq, y_seq = create_sequences(X_scaled, y_scaled)
print(f"X_seq shape: {X_seq.shape}, y_seq shape: {y_seq.shape}")
```

```
X_seq shape: (1912, 60, 50), y_seq shape: (1912, 1)
```

In [22]:

```
split = int(0.8 * len(X_seq))
X_train, X_test = X_seq[:split], X_seq[split:]
y_train, y_test = y_seq[:split], y_seq[split:]
```

In [23]:
```
model = Sequential([
    TCN(
        input_shape=(X_train.shape[1], X_train.shape[2]),
        nb_filters=64,
        kernel_size=3,
        dilations=[1, 2, 4, 8],
        return_sequences=False,
        activation='relu',
        dropout_rate=0.2
    ),
    Dense(1)
])

model.compile(optimizer='adam', loss='mse')
model.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 tcn (TCN)                   (None, 64)                99392     
                                                                 
 dense_2 (Dense)             (None, 1)                 65        
                                                                 
=================================================================
Total params: 99457 (388.50 KB)
Trainable params: 99457 (388.50 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

In [24]:
```
early_stop = EarlyStopping(
    monitor='val_loss',
    patience=5,
    restore_best_weights=True
)

history = model.fit(
    X_train, y_train,
    validation_split=0.1,
    epochs=100,
    batch_size=32,
    callbacks=[early_stop],
    verbose=1
)
```

```
Epoch 1/100
43/43 [==============================] - 3s 20ms/step - loss: 1.3935 - val
_loss: 0.0819
Epoch 2/100
43/43 [==============================] - 1s 15ms/step - loss: 0.1271 - val
_loss: 0.0450
Epoch 3/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0899 - val
_loss: 0.0290
Epoch 4/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0604 - val
_loss: 0.0224
Epoch 5/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0402 - val
_loss: 0.0187
Epoch 6/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0375 - val
_loss: 0.0126
Epoch 7/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0302 - val
_loss: 0.0138
Epoch 8/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0268 - val
_loss: 0.0098
Epoch 9/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0234 - val
_loss: 0.0094
Epoch 10/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0211 - val
_loss: 0.0080
Epoch 11/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0189 - val
_loss: 0.0057
Epoch 12/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0162 - val
_loss: 0.0061
Epoch 13/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0161 - val
_loss: 0.0049
Epoch 14/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0152 - val
_loss: 0.0045
Epoch 15/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0148 - val
_loss: 0.0043
Epoch 16/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0131 - val
_loss: 0.0044
Epoch 17/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0113 - val
_loss: 0.0037
Epoch 18/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0102 - val
_loss: 0.0036
Epoch 19/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0101 - val
_loss: 0.0031
Epoch 20/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0093 - val
_loss: 0.0034
Epoch 21/100
```

```
43/43 [==============================] - 1s 14ms/step - loss: 0.0090 - val
_loss: 0.0035
Epoch 22/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0083 - val
_loss: 0.0030
Epoch 23/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0087 - val
_loss: 0.0025
Epoch 24/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0080 - val
_loss: 0.0030
Epoch 25/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0079 - val
_loss: 0.0031
Epoch 26/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0067 - val
_loss: 0.0035
Epoch 27/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0068 - val
_loss: 0.0025
Epoch 28/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0061 - val
_loss: 0.0022
Epoch 29/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0061 - val
_loss: 0.0020
Epoch 30/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0057 - val
_loss: 0.0020
Epoch 31/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0056 - val
_loss: 0.0023
Epoch 32/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0054 - val
_loss: 0.0017
Epoch 33/100
43/43 [==============================] - 1s 16ms/step - loss: 0.0050 - val
_loss: 0.0021
Epoch 34/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0048 - val
_loss: 0.0017
Epoch 35/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0046 - val
_loss: 0.0017
Epoch 36/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0047 - val
_loss: 0.0015
Epoch 37/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0042 - val
_loss: 0.0013
Epoch 38/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0046 - val
_loss: 0.0018
Epoch 39/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0042 - val
_loss: 0.0017
Epoch 40/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0040 - val
_loss: 0.0016
Epoch 41/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0040 - val
```

```
_loss: 0.0011
Epoch 42/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0039 - val
_loss: 0.0014
Epoch 43/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0038 - val
_loss: 0.0012
Epoch 44/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0033 - val
_loss: 0.0012
Epoch 45/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0029 - val
_loss: 0.0012
Epoch 46/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0033 - val
_loss: 0.0010
Epoch 47/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0028 - val
_loss: 0.0010
Epoch 48/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0031 - val
_loss: 0.0012
Epoch 49/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0029 - val
_loss: 9.9372e-04
Epoch 50/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0027 - val
_loss: 0.0011
Epoch 51/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0028 - val
_loss: 0.0010
Epoch 52/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0027 - val
_loss: 0.0010
Epoch 53/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0027 - val
_loss: 9.1456e-04
Epoch 54/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0025 - val
_loss: 9.2352e-04
Epoch 55/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0027 - val
_loss: 8.1137e-04
Epoch 56/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0025 - val
_loss: 8.0810e-04
Epoch 57/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0023 - val
_loss: 8.7996e-04
Epoch 58/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0023 - val
_loss: 8.2694e-04
Epoch 59/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0023 - val
_loss: 9.2751e-04
Epoch 60/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0023 - val
_loss: 8.3767e-04
Epoch 61/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0021 - val
_loss: 7.7993e-04
```

```
Epoch 62/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0022 - val
_loss: 6.8478e-04
Epoch 63/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0021 - val
_loss: 7.8318e-04
Epoch 64/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0018 - val
_loss: 6.3919e-04
Epoch 65/100
43/43 [==============================] - 1s 16ms/step - loss: 0.0019 - val
_loss: 6.6885e-04
Epoch 66/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0017 - val
_loss: 7.0671e-04
Epoch 67/100
43/43 [==============================] - 1s 14ms/step - loss: 0.0019 - val
_loss: 6.1753e-04
Epoch 68/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0017 - val
_loss: 5.9483e-04
Epoch 69/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0018 - val
_loss: 6.0356e-04
Epoch 70/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0017 - val
_loss: 5.6949e-04
Epoch 71/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0018 - val
_loss: 5.4879e-04
Epoch 72/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0017 - val
_loss: 6.7285e-04
Epoch 73/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0016 - val
_loss: 6.6422e-04
Epoch 74/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0016 - val
_loss: 5.6020e-04
Epoch 75/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0016 - val
_loss: 6.0786e-04
Epoch 76/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0015 - val
_loss: 5.0926e-04
Epoch 77/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0015 - val
_loss: 6.1035e-04
Epoch 78/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0016 - val
_loss: 5.5441e-04
Epoch 79/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0015 - val
_loss: 5.5164e-04
Epoch 80/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0015 - val
_loss: 5.5822e-04
Epoch 81/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0014 - val
_loss: 4.8048e-04
Epoch 82/100
```

```
43/43 [==============================] - 1s 15ms/step - loss: 0.0013 - val
_loss: 5.1199e-04
Epoch 83/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0014 - val
_loss: 5.1879e-04
Epoch 84/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0014 - val
_loss: 5.6091e-04
Epoch 85/100
43/43 [==============================] - 1s 16ms/step - loss: 0.0012 - val
_loss: 4.9482e-04
Epoch 86/100
43/43 [==============================] - 1s 15ms/step - loss: 0.0013 - val
_loss: 4.8312e-04
```

In [25]:

```
y_pred_scaled = model.predict(X_test)
y_pred = y_scaler.inverse_transform(y_pred_scaled)
y_true = y_scaler.inverse_transform(y_test)

mse = mean_squared_error(y_true, y_pred)
r2 = r2_score(y_true, y_pred)

print(f"✅ MSE: {mse:.4f}")
print(f"✅ R²: {r2:.4f}")
```

```
12/12 [==============================] - 0s 5ms/step
✅ MSE: 895016.4955
✅ R²: 0.3049
```

In [26]:
```
plt.figure(figsize=(14,6))
plt.plot(y_true, label='Actual')
plt.plot(y_pred, label='TCN Prediction')
plt.title("TCN: Actual vs Predicted Next_Close")
plt.legend()
plt.show()

# Residuals
residuals = y_true - y_pred
plt.figure(figsize=(14,4))
plt.plot(residuals)
plt.axhline(0, color='gray', linestyle='--')
plt.title("Residuals")
plt.show()
```