Information Analysis and Visualisation(COMP1844)

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Task 1

Code

The code was explained in detail by comments

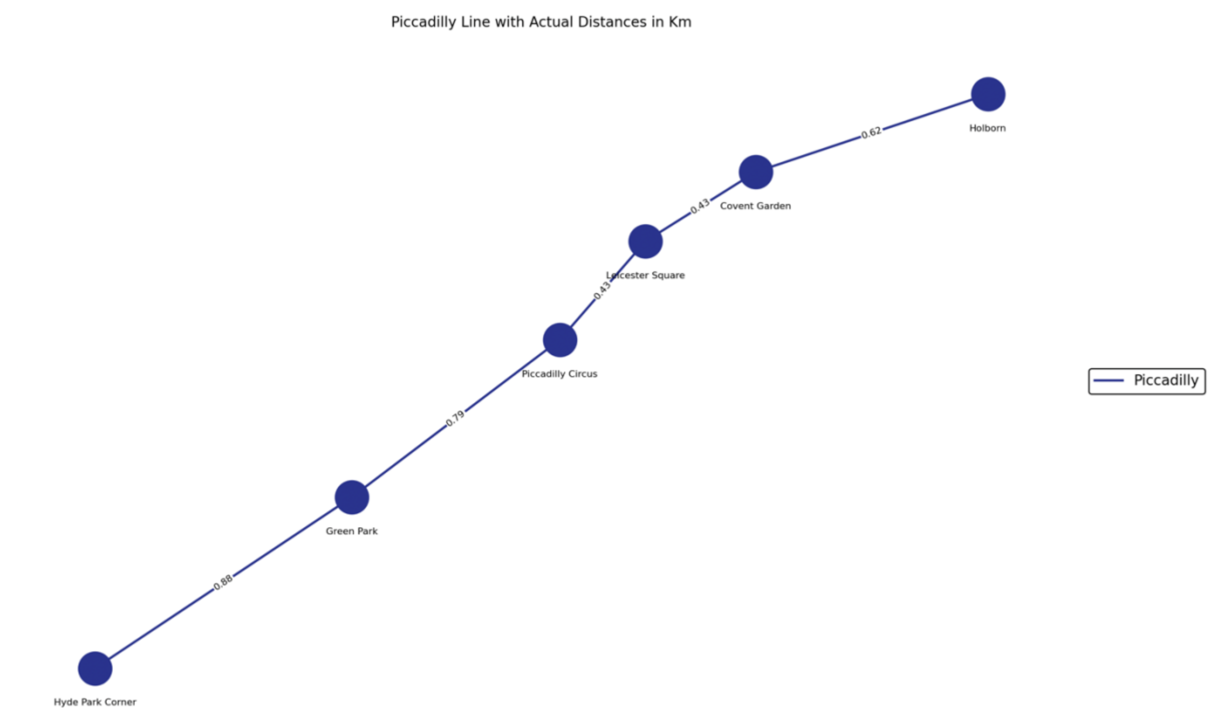
```
import pandas as pd  # Importing pandas library for data manipulation and analysis
import networkx as nx  # Importing NetworkX library for creating and manipulating complex networks
import matplotlib.pyplot as plt  # Importing Matplotlib library for plotting graphs
from matplotlib.lines import Line2D  # Importing Line2D class from Matplotlib for creating custom legend
elements
import requests  # Importing requests library for making HTTP requests

# Function to get distance between two locations using GraphHopper
def get_distance(from_place, to_place, api_key):
    """
    Fetch distance between two coordinates using the GraphHopper API.

    Args:
    - from_place (str): Coordinates of the starting point as "lat,lon".
    - to_place (str): Coordinates of the destination as "lat,lon".
    - api_key (str): Your GraphHopper API key.

    Returns:
    - float: Distance in kilometers, rounded to two decimal places.
    """
    # Constructing the URL for the GraphHopper API request
    url =
f"https://graphhopper.com/api/1/route?point={from_place}&point={to_place}&vehicle=foot&locale=en&key={api_k
ey}"
    try:
        # Making the API request
        response = requests.get(url)
        # Raising an exception if the request was unsuccessful
        response.raise_for_status()
        # Parsing the JSON response
        data = response.json()
        # Checking if the response contains the 'paths' key and if it has at least one path
        if 'paths' in data and len(data['paths']) > 0:
```

```
        # Extracting the distance from the response and converting it from meters to kilometers
        distance = data['paths'][0]['distance'] / 1000
        # Returning the distance rounded to two decimal places
        return round(distance, 2)
    except requests.exceptions.RequestException as e:
        # Printing an error message if there was a request exception
        print(f"Request error: {e}")
    except KeyError:
        # Printing an error message if the response format was unexpected
        print(f"Unexpected API response format: {response.json()}")
    # Returning None if there was an error
    return None

# Define stations and their positions (latitude, longitude)
stations = {
    'Hyde Park Corner': (51.5025, -0.1527),  # Coordinates for Hyde Park Corner
    'Green Park': (51.5067, -0.1428),  # Coordinates for Green Park
    'Piccadilly Circus': (51.5101, -0.1337),  # Coordinates for Piccadilly Circus
    'Leicester Square': (51.5115, -0.1280),  # Coordinates for Leicester Square
    'Covent Garden': (51.5133, -0.1240),  # Coordinates for Covent Garden
    'Holborn': (51.5171, -0.1195)  # Coordinates for Holborn
}

# Define connections (edges)
connections = [
    ('Hyde Park Corner', 'Green Park'),  # Connection between Hyde Park Corner and Green Park
    ('Green Park', 'Piccadilly Circus'),  # Connection between Green Park and Piccadilly Circus
    ('Piccadilly Circus', 'Leicester Square'),  # Connection between Piccadilly Circus and Leicester Square
    ('Leicester Square', 'Covent Garden'),  # Connection between Leicester Square and Covent Garden
    ('Covent Garden', 'Holborn')  # Connection between Covent Garden and Holborn
]

api_key = 'Your-GraphHopper-API-key'  # API key for GraphHopper

# Calculate distances and store them
distances = {}  # Initializing an empty dictionary to store distances
for u, v in connections:
    # Getting the distance between two stations
    distance = get_distance(f"{stations[u][0]},{stations[u][1]}", f"{stations[v][0]},{stations[v][1]}", api_key)
    if distance is not None:
```

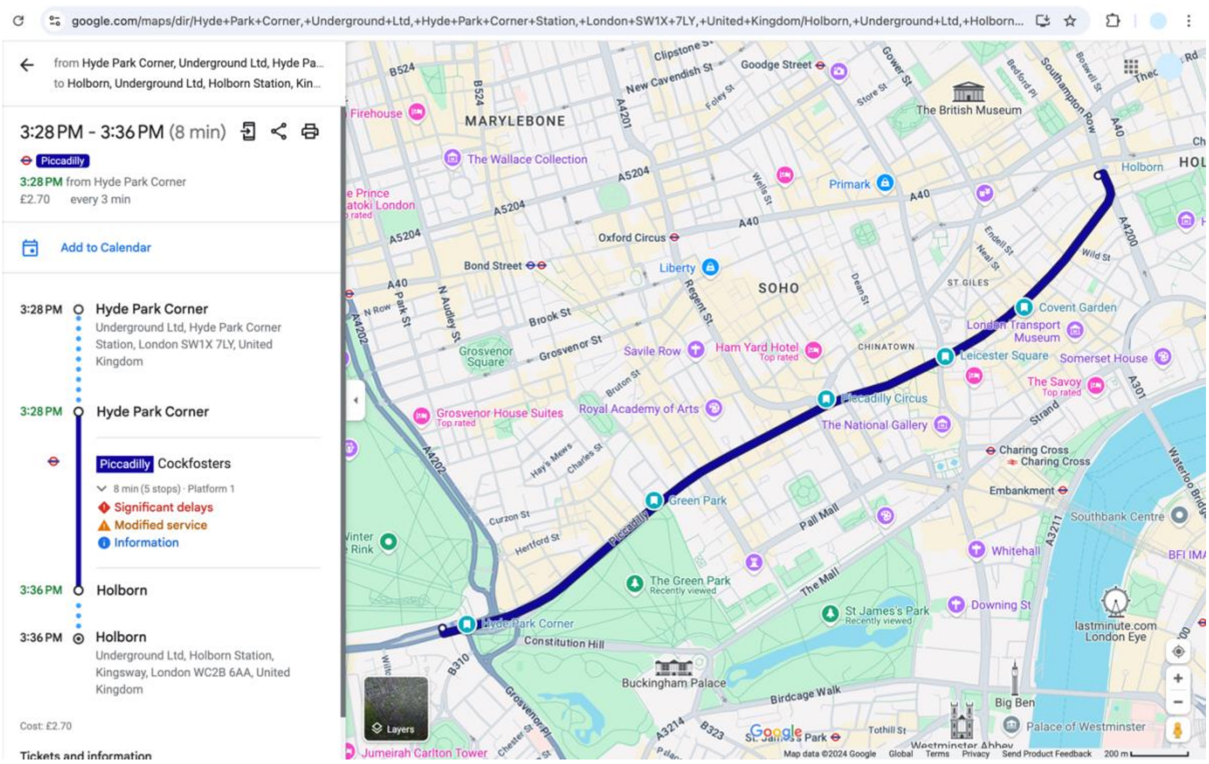
```
        # Storing the distance in the dictionary if it was successfully fetched
        distances[(u, v)] = distance
    else:
        # Printing an error message if the distance could not be fetched
        print(f"Failed to fetch distance for: {u} -> {v}")

# Create the network graph
def create_piccadilly_segment():
    # Create a new directed graph
    G = nx.Graph()  # Initialize an empty undirected graph using NetworkX

    # Add nodes (stations) with their geographical coordinates
    for station, pos in stations.items():
        G.add_node(station, pos=pos)  # Add each station as a node with its coordinates as attributes

    # Define connections with distances from the API or hardcoded values
    connections_with_distances = [
        (u, v, distances.get((u, v), "N/A"))
        for u, v in connections  # Create a list of connections with their distances
    ]

    # Add edges (connections)
    for u, v, distance in connections_with_distances:
        if distance != "N/A":
            G.add_edge(u, v, weight=distance)  # Add an edge with the distance as weight if available
        else:
            print(f"Skipping edge: {u} -> {v} due to missing data")  # Print a message if distance data is missing

    # Create the plot
    plt.figure(figsize=(12, 6))  # Create a new figure with specified size

    # Get positions of the nodes
    pos = nx.get_node_attributes(G, 'pos')  # Get the positions of the nodes from the graph attributes

    # Draw edges
    nx.draw_networkx_edges(G, pos, edge_color='#29338D', width=2)  # Draw the edges with specified color and
width

    # Draw nodes
```

```
    nx.draw_networkx_nodes(G, pos, node_color='#29338D', node_size=800)  # Draw the nodes with specified color and size

    # Add station names below each node
    for node, (x, y) in pos.items():
        plt.text(
            x, y - 0.002, node, ha='center', va='center', fontsize=8,
            color="black", bbox=dict(facecolor="none", edgecolor="none", boxstyle="round,pad=0.1")
        )  # Add text labels for each node with specified formatting

    # Add edge labels (distances)
    edge_labels = nx.get_edge_attributes(G, 'weight')  # Get the edge weights (distances) from the graph attributes
    formatted_labels = {k: f"{v}" for k, v in edge_labels.items() if v != "N/A"}  # Format the labels for display
    nx.draw_networkx_edge_labels(G, pos, edge_labels=formatted_labels, font_size=8,
                                 bbox=dict(facecolor="white", edgecolor="none", boxstyle="round,pad=0.1"))  # Draw the edge labels

    # Add key/legend
    legend_elements = [Line2D([0], [0], color="#29338D", lw=2, label="Piccadilly")]  # Create a legend element

    plt.legend(handles=legend_elements, loc='center left', bbox_to_anchor=(1, 0.5), fontsize=12,
               frameon=True, framealpha=1, facecolor='white', edgecolor='black')  # Add the legend to the plot

    # Set plot title
    plt.title("Piccadilly Line with Actual Distances in Km")  # Set the title of the plot
    plt.axis("off")  # Hide axes

    return plt  # Return the plot object

# Create and show the plot
plt = create_piccadilly_segment()  # Call the function to create the plot
plt.tight_layout()  # Adjust the layout to fit everything nicely
plt.show()  # Display the plot
```

Plot



The plot was drawed by using actual positions so the route looks like on Google Maps



Task 2

Code

The code was explained in detail by comments.

```
import pandas as pd  # Importing pandas for data manipulation and analysis
import networkx as nx  # Importing NetworkX for creating and manipulating complex networks
import matplotlib.pyplot as plt  # Importing Matplotlib for plotting graphs
import requests  # Importing requests for making HTTP requests to APIs
from matplotlib.lines import Line2D  # Importing Line2D for custom legend creation in Matplotlib
import numpy as np  # Importing NumPy for numerical operations

# Function to get distance between two locations using GraphHopper API
def get_distance(from_place, to_place, api_key):
    # Constructing the URL for the API request
    url =
f"https://graphhopper.com/api/1/route?point={from_place}&point={to_place}&vehicle=foot&locale=en&key={api_k
ey}"
    try:
        # Making the GET request to the API
        response = requests.get(url)
        # Raise an exception if the request was unsuccessful
        response.raise_for_status()
        # Parsing the JSON response
        data = response.json()
        # Check if 'paths' key exists and has at least one path
        if 'paths' in data and len(data['paths']) > 0:
            # Extracting the distance and converting from meters to kilometers
            distance = data['paths'][0]['distance'] / 1000
            # Returning the distance rounded to two decimal places
            return round(distance, 2)
    except requests.exceptions.RequestException as e:
        # Print the error if the request fails
        print(f"Request error: {e}")
    except KeyError:
        # Print an error if the response format is unexpected
        print(f"Unexpected API response format: {response.json()}")
    return None

# Define stations and their positions (latitude, longitude)
stations = {
    'St Paul\'s': (51.5143, -0.0978),
```

```
    'Chancery Lane': (51.5186, -0.1114),
    'Holborn': (51.5171, -0.1195),
    'Oxford Circus': (51.5154, -0.1419),
    'Marble Arch': (51.5144, -0.1589),
    'Notting Hill Gate': (51.5099, -0.1966),
    'South Kensington': (51.4943, -0.1748),
    'Sloane Square': (51.4926, -0.1569),
    'St James\'s Park': (51.4994, -0.1337),
    'Embankment': (51.5074, -0.1223),
    'Temple': (51.5112, -0.1140),
    'Warren Street': (51.5247, -0.1384),
    'Green Park': (51.5067, -0.1428),
    'Victoria': (51.4966, -0.1443),
    'Pimlico': (51.4892, -0.1334),
    'Vauxhall': (51.4856, -0.1231),
    'Hyde Park Corner': (51.5025, -0.1527),
    'Piccadilly Circus': (51.5101, -0.1337),
    'Leicester Square': (51.5115, -0.1280),
    'Covent Garden': (51.5133, -0.1240),
    'Swiss Cottage': (51.5431, -0.1746),
    'Bond Street': (51.5142, -0.1440),
    'Westminster': (51.5010, -0.1246),
    'Southwark': (51.5055, -0.1044),
    'London Bridge': (51.5055, -0.0865),
}

# Define connections (edges) for different lines
# Each connection is a tuple of two station names
# The connections are defined for the red, yellow, light blue, dark blue, and grey lines
# "Central" line
connections_red = [
    ('St Paul\'s', 'Chancery Lane'),
    ('Chancery Lane', 'Holborn'),
    ('Holborn', 'Oxford Circus'),
    ('Oxford Circus', 'Marble Arch'),
    ('Marble Arch', 'Notting Hill Gate'),
]

# "Circle" line
connections_yellow = [
```

```
    ('South Kensington', 'Sloane Square'),
    ('Sloane Square', 'St James\'s Park'),
    ('St James\'s Park', 'Embankment'),
    ('Embankment', 'Temple')
]

# "Victoria" line
connections_light_blue = [
    ('Warren Street', 'Oxford Circus'),
    ('Oxford Circus', 'Green Park'),
    ('Green Park', 'Victoria'),
    ('Victoria', 'Pimlico'),
    ('Pimlico', 'Vauxhall')
]

# "Piccadilly" line
connections_dark_blue = [
    ('Hyde Park Corner', 'Green Park'),
    ('Green Park', 'Piccadilly Circus'),
    ('Piccadilly Circus', 'Leicester Square'),
    ('Leicester Square', 'Covent Garden'),
    ('Covent Garden', 'Holborn')
]

# "Jubilee" line
connections_grey = [
    ('Swiss Cottage', 'Bond Street'),
    ('Bond Street', 'Green Park'),
    ('Green Park', 'Westminster'),
    ('Westminster', 'Southwark'),
    ('Southwark', 'London Bridge'),
]

# API key for GraphHopper
api_key = 'Your-GraphHopper-API-key'

# Calculate distances and store them in a dictionary
distances = {}
for u, v in connections_red + connections_yellow + connections_light_blue + connections_dark_blue +
connections_grey:
```

```
    # Get the distance between two stations
    distance = get_distance(f"{stations[u][0]},{stations[u][1]}", f"{stations[v][0]},{stations[v][1]}", api_key)
    if distance is not None:
        # Store the distance in the dictionary
        distances[(u, v)] = distance
    else:
        # Print a message if the distance could not be fetched
        print(f"Failed to fetch distance for: {u} -> {v}")
```

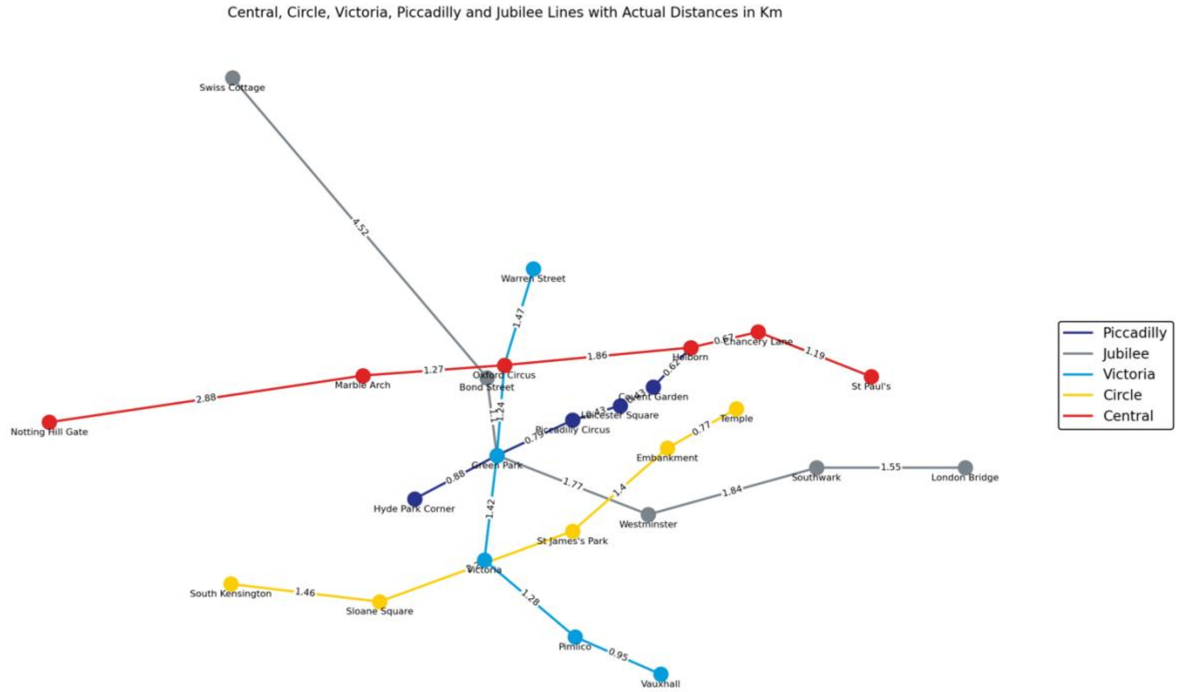
```
# Create the network graph
def create_combined_segment():
    G = nx.Graph()  # Initialize an empty graph using NetworkX

    # Define line colors
    line_colors = {
        'Piccadilly': '#29338D',  # Dark Blue
        'Jubilee': '#7B848A',     # Grey
        'Victoria': '#039DDC',    # Light Blue
        'Circle': '#FDCE04',      # Yellow
        'Central': '#E02425',     # Red
    }

    # Add nodes (stations) with their geographical coordinates
    # Iterate over each station and its coordinates (latitude, longitude) in the stations dictionary
    for station, pos in stations.items():
        # Add each station as a node to the graph G
        # The node is labeled with the station name and its position is set to the coordinates (latitude, longitude)
        # The add_node method is a function provided by the NetworkX library to add nodes to a graph
        G.add_node(station, pos=pos)

    # Define connections with distances from the API or hardcoded values
    # Create a dictionary connections_with_distances to store connections for each line
    connections_with_distances = {
        # For the 'Central' line, create a list of tuples (u, v, distance)
        # Iterate over each connection (u, v) in connections_red
        # Use the distances dictionary to get the distance for each connection (u, v)
        # If the distance is not found, use "N/A" as the default value
        'Central': [(u, v, distances.get((u, v), "N/A")) for u, v in connections_red],
        'Circle': [(u, v, distances.get((u, v), "N/A")) for u, v in connections_yellow],
        'Victoria': [(u, v, distances.get((u, v), "N/A")) for u, v in connections_light_blue],
```

```
    'Piccadilly': [(u, v, distances.get((u, v), "N/A")) for u, v in connections_dark_blue],
    'Jubilee': [(u, v, distances.get((u, v), "N/A")) for u, v in connections_grey],
}

# Add edges (connections)
# Iterate over each line and its connections in the connections_with_distances dictionary
for line, connections in connections_with_distances.items():
    # Get the color for the current line from the line_colors dictionary
    color = line_colors[line]
    # Iterate over each connection (u, v) and its distance in the current line's connections
    for u, v, distance in connections:
        if distance != "N/A":
            # Add an edge to the graph G with the specified distance as the weight and the line color
            G.add_edge(u, v, weight=distance, color=color)
        else:
            # Print a message if the distance is missing
            print(f"Skipping edge: {u} -> {v} due to missing data")

# Use the geographical coordinates for node positions
# Create a dictionary pos that maps each station to its coordinates (longitude, latitude)
# Iterate over each station and its coordinates (latitude, longitude) in the stations dictionary
# For each station, create a key-value pair in the pos dictionary
# The key is the station name, and the value is a tuple of its coordinates in the format (longitude, latitude)
# This format is used because plotting libraries often expect coordinates in (longitude, latitude) order
pos = {station: (lon, lat) for station, (lat, lon) in stations.items()}

# Create the plot
# Create a new figure for the plot with a specified size of 14x8 inches
plt.figure(figsize=(14, 8))

# Draw edges with different colors
# Iterate over each line and its corresponding color in the line_colors dictionary
for line, color in line_colors.items():
    # Get edges for the current line
    # This list comprehension iterates over all edges in the graph G,
    # and selects the edges that have the same color as the current line.
    edges = [(u, v) for u, v, d in G.edges(data=True) if d['color'] == color]

    # Draw edges
    # Use NetworkX's draw_networkx_edges function to draw the selected edges on the plot.
```

```
    # The edges are drawn with the specified color and a width of 2.
    nx.draw_networkx_edges(G, pos, edgelist=edges, edge_color=color, width=2)

# Draw nodes with different colors
for line, color in line_colors.items():
    nodes = {station for station, pos in stations.items() if any(
        # Get nodes for the current line
        station in edge for edge in connections_with_distances[line])}
    nx.draw_networkx_nodes(G, pos, nodelist=nodes, node_color=color, node_size=150)  # Draw nodes

# Add station names near each node
# Iterate over each node and its coordinates (x, y) in the pos dictionary
for node, (x, y) in pos.items():
    # Add text labels for each node
    # Use Matplotlib's plt.text function to place text on the plot
    # x, y - 0.001: Position the text slightly below the node's coordinates
    # node: The text to be displayed, which is the station name
    # ha='center': Horizontally align the text to the center
    # va='center': Vertically align the text to the center
    # Create a bounding box around the text with no face color and no edge color,
    # and a rounded box style with a padding of 0.1
    plt.text(
        x, y - 0.001, node, ha='center', va='center', fontsize=8,
        color="black", bbox=dict(facecolor="none", edgecolor="none", boxstyle="round,pad=0.1")
    )  # Add text labels for each node

# Add edge labels (distances)
# Get edge attributes (distances)
# Use NetworkX's get_edge_attributes function to retrieve the 'weight' attribute for all edges in the graph G
# This returns a dictionary where the keys are edge tuples (u, v) and the values are the weights (distances)
edge_labels = nx.get_edge_attributes(G, 'weight')

# Format labels
# Create a new dictionary formatted_labels to store the formatted edge labels
# Iterate over each key-value pair (k, v) in the edge_labels dictionary
# If the value (distance) is not "N/A", add the key-value pair to the formatted_labels dictionary
# The value is formatted as a string using an f-string
formatted_labels = {k: f"{v}" for k, v in edge_labels.items() if v != "N/A"}

# Draw edge labels
```

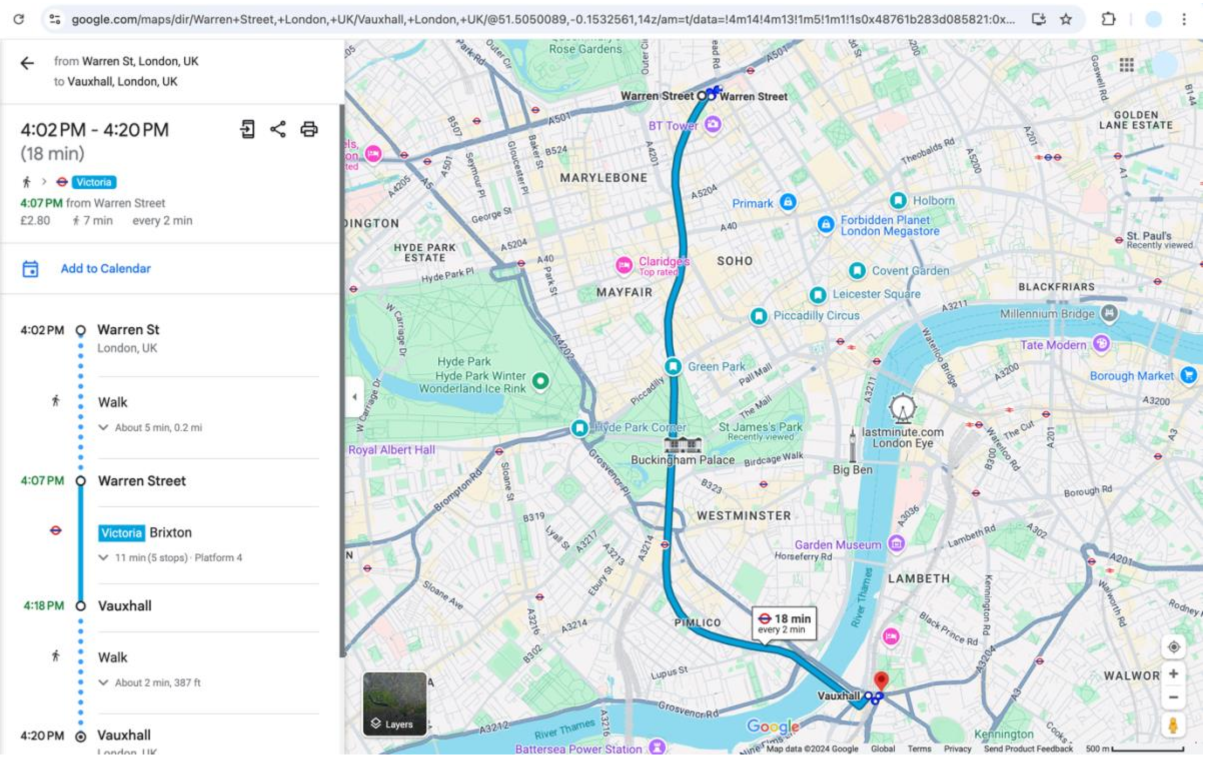
```
# Use NetworkX's draw_networkx_edge_labels function to draw the edge labels on the plot
# pos: The positions of the nodes
# edge_labels: The dictionary of formatted edge labels
# Create a bounding box around the labels with a white face color, no edge color,
# and a rounded box style with a padding of 0.1
nx.draw_networkx_edge_labels(G, pos, edge_labels=formatted_labels, font_size=8,
                             bbox=dict(facecolor="white", edgecolor="none", boxstyle="round,pad=0.1"))

# Add key/legend
# Use a list comprehension to create a list of Line2D objects for the legend
# Iterate over each line and its corresponding color in the line_colors dictionary
# Line2D is a class from Matplotlib used to create line objects.
# [0], [0]: These are dummy data points for the line (not used in the legend).
# color=color: Set the color of the line to the corresponding color from the line_colors dictionary.
# lw=2: Set the line width to 2.
# label=line: Set the label of the line to the name of the line (used in the legend).
legend_elements = [Line2D([0], [0], color=color, lw=2, label=line)
                   for line, color in line_colors.items()]

# Add legend
# Use Matplotlib's plt.legend function to add the legend to the plot
# handles=legend_elements: Use the list of Line2D objects created above as the legend handles
# loc='center left': Position the legend at the center left of the plot
# bbox_to_anchor=(1, 0.5): Adjust the legend's position using a bounding box anchor
# frameon=True: Draw a frame around the legend
# framealpha=1: Set the transparency of the legend frame to fully opaque
# facecolor='white': Set the background color of the legend frame to white
# edgecolor='black': Set the edge color of the legend frame to black
plt.legend(handles=legend_elements, loc='center left', bbox_to_anchor=(1, 0.5), fontsize=12,
           frameon=True, framealpha=1, facecolor='white', edgecolor='black')

# Set plot title
plt.title("Central, Circle, Victoria, Piccadilly and Jubilee Lines with Actual Distances in Km")
plt.axis("off")  # Hide axes

return G, plt  # Return the graph and plot
```

Plot

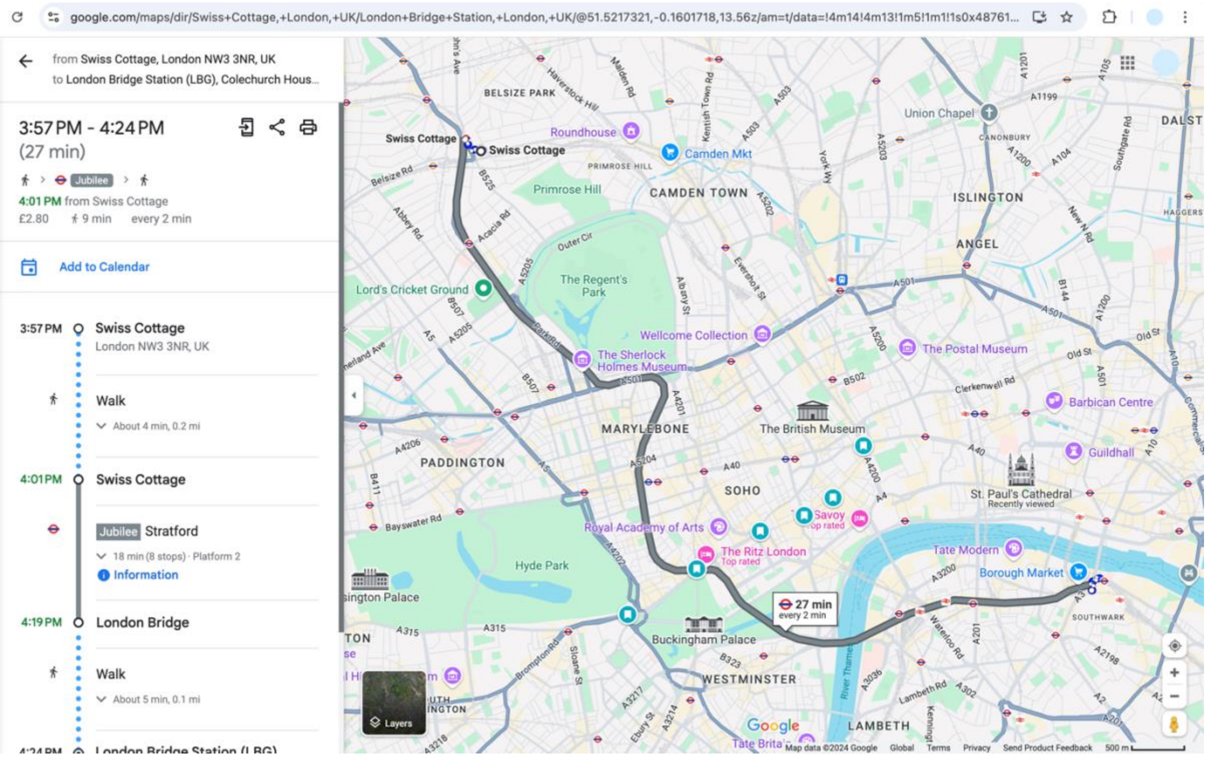


The plot was drawed by using actual positions so the routes looks like on Google Maps

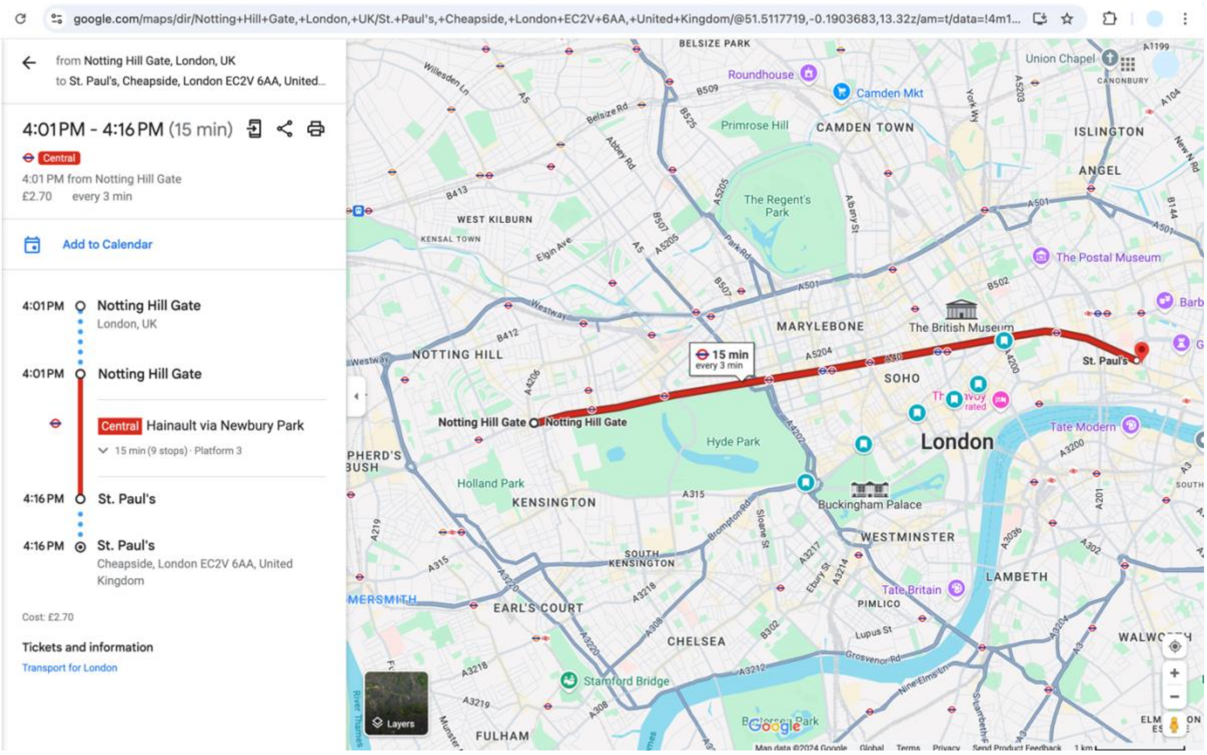
Victoria line



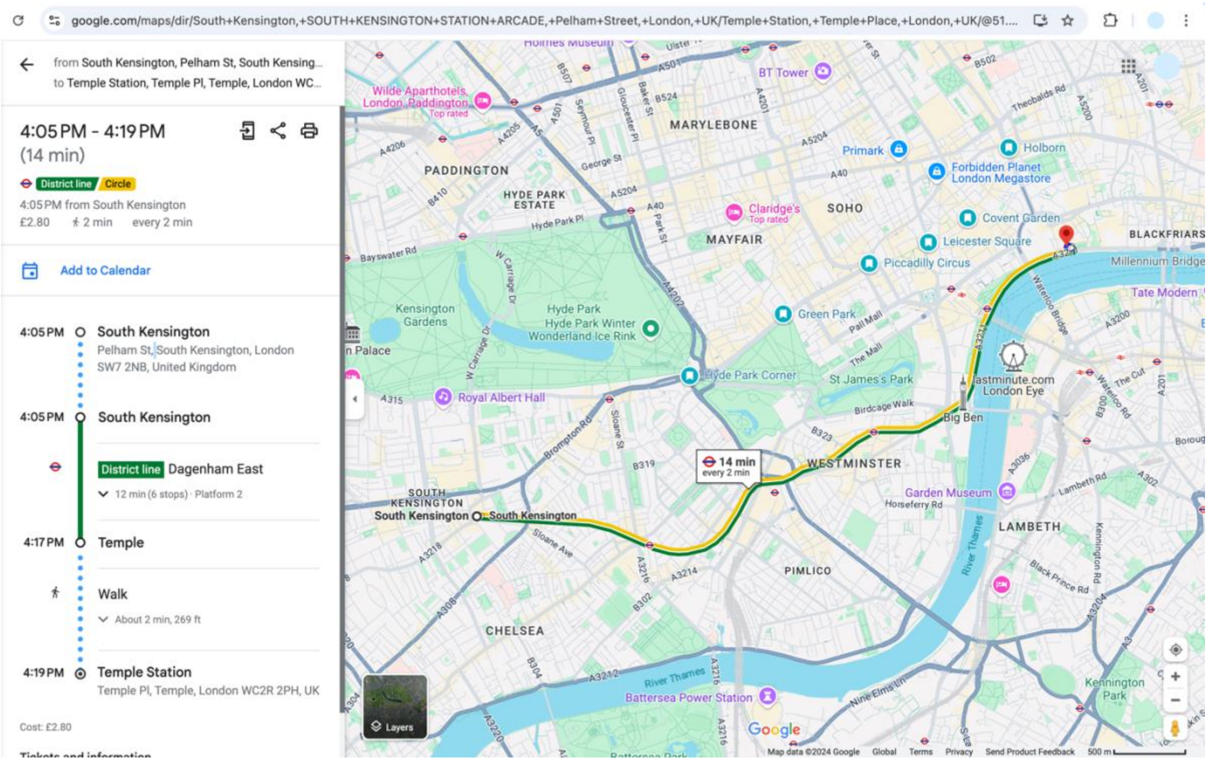
Jubilee line



Central line



Circle line (District line also has this route)



Task 3

Code

```
def calculate_network_statistics(G):
    # Extract distances from the graph
    # This list comprehension iterates over all edges in the graph G,
    # extracting the 'weight' attribute (which represents distance) for each edge,
    # and includes it in the distances list only if the weight is not "N/A".
    distances = [d['weight'] for u, v, d in G.edges(data=True) if d['weight'] != "N/A"]

    # Calculate total length of the transport network
    # The total length is calculated by summing up all the distances in the distances list.
    total_length = sum(distances)

    # Calculate the average distance between the stations
    # The average distance is calculated using NumPy's mean function on the distances list.
    average_distance = np.mean(distances)

    # Calculate the standard deviation of the distances between the stations
```

```python
    # The standard deviation is calculated using NumPy's std function on the distances list.
    std_deviation = np.std(distances)

    # Return the calculated statistics as a tuple
    return total_length, average_distance, std_deviation
```

```python
# Create the graph and plot
G, plt = create_combined_segment()  # Call the function to create the graph and plot

# Calculate and print the network statistics
total_length, average_distance, std_deviation = calculate_network_statistics(G)  # Calculate statistics
print(f"Total length of the transport network: {total_length:.2f} km")  # Print total length
print(f"Average distance between the stations: {average_distance:.2f} km")  # Print average distance
print(f"Standard deviation of the distances between the stations: {std_deviation:.2f} km")  # Print standard
deviation

# Adjust the margins and show the plot
plt.subplots_adjust(left=0.1, right=0.9, top=0.9, bottom=0.1)  # Adjust plot margins
plt.tight_layout()  # Automatically adjust subplot parameters to give specified padding
plt.show()  # Display the plot
```

```python
print("Distances:" , distances)
```

```
Distances: {("St Paul's", 'Chancery Lane'): 1.19, ('Chancery Lane', 'Holborn'): 0.67, ('Holborn', 'Oxford Circus'): 1.86,
('Oxford Circus', 'Marble Arch'): 1.27, ('Marble Arch', 'Notting Hill Gate'): 2.88, ('South Kensington', 'Sloane Square'): 1.46,
('Sloane Square', "St James's Park"): 2.25, ("St James's Park", 'Embankment'): 1.4, ('Embankment', 'Temple'): 0.77, ('Warren
Street', 'Oxford Circus'): 1.47, ('Oxford Circus', 'Green Park'): 1.24, ('Green Park', 'Victoria'): 1.42, ('Victoria',
'Pimlico'): 1.28, ('Pimlico', 'Vauxhall'): 0.95, ('Hyde Park Corner', 'Green Park'): 0.88, ('Green Park', 'Piccadilly Circus'):
0.79, ('Piccadilly Circus', 'Leicester Square'): 0.43, ('Leicester Square', 'Covent Garden'): 0.43, ('Covent Garden',
'Holborn'): 0.62, ('Swiss Cottage', 'Bond Street'): 4.52, ('Bond Street', 'Green Park'): 1.1, ('Green Park', 'Westminster'):
1.77, ('Westminster', 'Southwark'): 1.84, ('Southwark', 'London Bridge'): 1.55}
```

Explain the math

1. Total Length of the Transport Network

- **Formula:**

$$L_{\text{total}} = \sum_{(i,j)\in E} d(i,j)$$

- **Explanation:**
  The total length is the sum of all edge weights (distances) in the graph G, where E represents the set of edges, and $d(i,j)$ is the weight (distance) of the edge connecting nodes i and j.

2. Average Distance Between Stations

- **Formula**:

$$\text{Average Distance} = \frac{1}{|E|} \sum_{(i,j)\in E} d(i,j)$$

- **Explanation**:
  The average distance is calculated by dividing the total length (L_{total}) by the number of edges ($|E|$). It gives the mean value of all distances in the network.

3. Standard Deviation of Distances

- **Formula**:

$$\sigma = \sqrt{\frac{1}{|E|} \sum_{(i,j)\in E} (d(i,j) - \text{Average Distance})^2}$$

- **Explanation**:
  The standard deviation measures the spread of the distances around the mean (average distance). It is the square root of the average squared differences between each distance $d(i,j)$ and the average distance.

Result

```
Total length of the transport network: 34.04 km
Average distance between the stations: 1.42 km
Standard deviation of the distances between the stations: 0.86 km
```