

```
In [1]: # Author: Abiral Chalise  
# Project: Final Year Project  
# Description: PTI Temporal and Statistical Analysis
```

Importing Required Libraries

```
In [2]: import os  
import glob  
from datetime import datetime, timedelta, time  
import numpy as np  
import pandas as pd  
import matplotlib.pyplot as plt  
import seaborn as sns  
from matplotlib.colors import LinearSegmentedColormap  
from scipy import stats
```

Reading GPS trajectory data and converting in proper format for GIS analysis

```
In [3]: # Input and output directories  
input_dir = r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\DATA"  
output_dir = r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\1.GISinputs  
  
# Make sure output directory exists  
os.makedirs(output_dir, exist_ok=True)  
  
# Walk through all subdirectories  
for root, dirs, files in os.walk(input_dir):  
    for file in files:  
        # Process only Excel files  
        if file.endswith(("xls", ".xlsx")):  
            file_path = os.path.join(root, file)  
            try:  
                # Read Excel file with header at row 7 (0-indexed, so header=7 reads row 8)  
                df = pd.read_excel(file_path, header=7)  
  
                # Create CSV file path  
                csv_filename = os.path.splitext(file)[0] + ".csv"  
                csv_path = os.path.join(output_dir, csv_filename)  
  
                # Save as CSV  
                df.to_csv(csv_path, index=False)  
            except Exception as e:  
                print(f"Error processing {file_path}: {e}")
```

Execution Requirement:

The following script is designed to run within the **QGIS Python environment**. Running it outside QGIS (e.g., in Jupyter Notebook or standard Python IDE) will result in missing module errors such as `qgis.core`.

GIS Analysis: Processing steps (for each CSV file):

1. Create point layer

- Uses Longitude & Latitude columns
- CRS: EPSG:4326 (WGS84)
- Saves points as a new layer in `day5.gpkg`

2. Join with route buffer (`Dissolvedbuffer`)

- Spatial join (intersect/contain)
- Adds field `Inside_Route` (1 = inside route, null/0 = outside)
- Output layer: `{filename}_insideroute`

3. Join with segment/stop buffers (`segment_buffer`)

- Spatial join (intersect/contain)
- Adds fields: `Description` (bus stop name) and `Segment_point` (segment ID)
- Final output: CSV file in `2.GIS result/{filename}_gis.csv`

Output files: Contains: original columns + `Inside_Route` + `Description` + `Segment_point`

```
In [ ]: directory = "C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\1.GISinputcsv"
files_name = [file for file in os.listdir(directory) if file.endswith('.csv')]

for file in files_name:
    file_withoutspace = file.replace(" ","")
    file_withoutcsv = file.replace(".csv","")

    # 3622 jan_result
    processing.run("native:createpointslayerfromtable", {'INPUT':f'C:/Users/ACER/Desktop/PROJECT-FINAL YEAR/Dataextraction/1.GISinputcsv/{file_withoutspace}'})
    processing.run("native:joinattributesbylocation", {'INPUT':f'C:/Users/ACER/Desktop/PROJECT-FINAL YEAR/Dataextraction/1.GISinputcsv/{file_withoutspace}'})
    processing.run("native:joinattributesbylocation", {'INPUT':f'C:/Users/ACER/Desktop/PROJECT-FINAL YEAR/Dataextraction/1.GISinputcsv/{file_withoutcsv}'})
    print(f"complete {file}")
```

Travel Time Calculation (Lagankhel → Budhanilkantha)

This section identifies **complete one-way trips** and calculates their **travel duration** in minutes.

Logic summary:

- **Forward** (Lagankhel → Budhanilkantha): starts near segment 1 → ends at segment 8
- **Backward** (Budhanilkantha → Lagankhel): starts near segment 8 → ends at segment 1
- Only daytime trips (05:00–22:00) are considered
- Only **complete** trips (terminal to terminal) are kept

Output:

- Separate Excel files for each direction
- Columns: `Departure Time`, `Arrival Time`, `Travel Time(min)`

```
In [4]: # -----
# INPUT & OUTPUT PATHS
# -----
input_folder = r'C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\2.GIS results'

# Correct folder names exactly as requested
output_Lagankhel_Budhanilkantha = r'C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\2.GIS results\output_Lagankhel_Budhanilkantha'
output_Budhanilkantha_Lagankhel = r'C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\2.GIS results\output_Budhanilkantha_Lagankhel'

# Create folders if they don't exist
os.makedirs(output_Lagankhel_Budhanilkantha, exist_ok=True)
os.makedirs(output_Budhanilkantha_Lagankhel, exist_ok=True)
```

```

# Get all CSV files
file_paths = glob.glob(os.path.join(input_folder, '*.csv'))

# -----
# PROCESS EACH FILE
# -----
for file in file_paths:

    # Read required columns only
    df = pd.read_csv(file, encoding='unicode_escape', usecols=["Time", "Inside_Route"])

    # Convert Time to datetime & sort
    df["Time"] = pd.to_datetime(df["Time"])
    # Filter rows between 5 AM and 10 PM
    df = df[(df['Time'].dt.time >= pd.to_datetime('05:00:00').time()) &
             (df['Time'].dt.time <= pd.to_datetime('22:00:00').time())]
    df = df.sort_values("Time").reset_index(drop=True)

    trips = []
    in_trip = False
    start_time = None
    start_point = None
    prev_segment = np.nan

    # -----
    # MAIN LOOP (state-based)
    # -----
    for _, row in df.iterrows():

        if row["Inside_Route"] == 0:
            prev_segment = row["Segment_point"]
            continue

        current_segment = row["Segment_point"]

        # START CONDITION
        if not in_trip:
            if prev_segment in [1, 8] and pd.isna(current_segment):
                in_trip = True
                start_time = row["Time"]
                start_point = prev_segment

        # END CONDITION
        else:
            if start_point == 1 and current_segment == 8:
                trips.append([start_time, row["Time"], "Lagankhel-Budhanilkantha"])
                in_trip = False

            elif start_point == 8 and current_segment == 1:
                trips.append([start_time, row["Time"], "Budhanilkantha-Lagankhel"])
                in_trip = False

        prev_segment = current_segment

    # -----
    # CREATE OUTPUT DATAFRAME
    # -----
    trips_df = pd.DataFrame(
        trips,
        columns=["Departure Time", "Arrival Time", "Direction"]
    )

    if trips_df.empty:
        continue

```

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    trips_df["Travel Time(min)"] = (
        trips_df["Arrival Time"] - trips_df["Departure Time"]
    ).dt.total_seconds() / 60

    # -----
    # SPLIT BY DIRECTION
    #
    df_LB = trips_df[trips_df["Direction"] == "Lagankhel-Budhanilkantha"].drop(columns=[ "Segment_point"])
    df_BL = trips_df[trips_df["Direction"] == "Budhanilkantha-Lagankhel"].drop(columns=[ "Segment_point"])

    base_name = os.path.splitext(os.path.basename(file))[0]

    #
    # SAVE OUTPUT FILES
    #
    if not df_LB.empty:
        df_LB.to_excel(
            os.path.join(output_Lagankhel_Budhanilkantha, f"{base_name}.xlsx"),
            index=False
        )

    if not df_BL.empty:
        df_BL.to_excel(
            os.path.join(output_Budhanilkantha_Lagankhel, f"{base_name}.xlsx"),
            index=False
        )

```

C:\Users\ACER\AppData\Local\Temp\ipykernel_2988\3153259368.py:23: DtypeWarning: Columns (10) have mixed types. Specify dtype option on import or set low_memory=False.

df = pd.read_csv(file, encoding='unicode_escape', usecols=["Time", "Inside_Route", "Description", "Segment_point"])

Segment-level Travel Time Extraction

(Adjacent Segments Only – Forward & Reverse)

This section detects **short trips between adjacent segments** only and calculates their travel duration.

Key segments (in order): 1 → Lagankhel

- 3 → Kupondole
- 5 → Lazimpat
- 7 → Gangalal
- 8 → Budhanilkantha

Detected segment pairs (only adjacent):

- Forward: 1→3, 3→5, 5→7, 7→8
- Reverse: 3→1, 5→3, 7→5, 8→7

Output structure:

Each folder contains `.xlsx` files with columns:

Departure Time	•	Arrival Time	•	Travel Time(min)
----------------	---	--------------	---	------------------

In [5]:

PATHS

```

# -----
input_folder = r'C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\2.GIS results'
forward_base = r'C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\3.Duration'
reverse_base = r'C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\3.Duration'

# Segment order and mapping
segment_order = [1, 3, 5, 7, 8]
segment_map = {
    1: "Lagankhel",
    3: "Kupondole",
    5: "Lazimpat",
    7: "Gangalal",
    8: "Budhanilkantha"
}

# Create output folders for adjacent segments only (with names)
for i in range(len(segment_order) - 1):
    forward_name = f'{segment_map[segment_order[i]]}-{segment_map[segment_order[i+1]]}'
    reverse_name = f'{segment_map[segment_order[i+1]]}-{segment_map[segment_order[i]]}'
    os.makedirs(os.path.join(forward_base, forward_name), exist_ok=True)
    os.makedirs(os.path.join(reverse_base, reverse_name), exist_ok=True)

# Create allowed segment pairs (adjacent only)
allowed_pairs = set()
for i in range(len(segment_order)-1):
    # forward
    allowed_pairs.add((segment_order[i], segment_order[i+1]))
    # reverse
    allowed_pairs.add((segment_order[i+1], segment_order[i]))

# -----
# PROCESS FILES
# -----
file_paths = glob.glob(os.path.join(input_folder, '*.csv'))

for file in file_paths:

    # Read required columns only
    df = pd.read_csv(file, encoding='unicode_escape',
                     usecols=['Time', "Inside_Route", "Description", "Segment_point"])

    # Convert Time to datetime & sort
    df['Time'] = pd.to_datetime(df['Time'])
    # Filter rows between 5 AM and 10 PM
    df = df[(df['Time'].dt.time >= pd.to_datetime('05:00:00').time()) &
             (df['Time'].dt.time <= pd.to_datetime('22:00:00').time())]
    df = df.sort_values("Time").reset_index(drop=True)

    trips = []
    in_trip = False
    start_time = None
    start_segment = None
    prev_segment = np.nan

    for _, row in df.iterrows():

        if row["Inside_Route"] == 0:
            prev_segment = np.nan
            in_trip = False
            continue

        current_segment = row["Segment_point"]

```

```

# START
if not in_trip:
    if prev_segment in segment_order and pd.isna(current_segment):
        in_trip = True
        start_time = row["Time"]
        start_segment = prev_segment

# END
else:
    if current_segment in segment_order and current_segment != start_segment:
        # Only allow adjacent pairs
        if (start_segment, current_segment) in allowed_pairs:
            trips.append([start_time, row["Time"], start_segment, current_segment])
        in_trip = False

prev_segment = current_segment

# -----
# CREATE OUTPUT
# -----
trips_df = pd.DataFrame(
    trips,
    columns=["Departure Time", "Arrival Time", "Start", "End"]
)

if trips_df.empty:
    continue

trips_df["Travel Time(min)"] = (
    trips_df["Arrival Time"] - trips_df["Departure Time"]
).dt.total_seconds() / 60

base_name = os.path.splitext(os.path.basename(file))[0]

# -----
# SAVE FILES
# -----
for _, r in trips_df.iterrows():

    # Map segment numbers to names
    start_name = segment_map[int(r['Start'])]
    end_name = segment_map[int(r['End'])]
    seg_name = f"{start_name}-{end_name}"

    # Forward adjacent segment
    if (r['Start'], r['End']) in allowed_pairs and r['Start'] < r['End']:
        out_dir = os.path.join(forward_base, seg_name)

    # Reverse adjacent segment
    elif (r['Start'], r['End']) in allowed_pairs and r['Start'] > r['End']:
        out_dir = os.path.join(reverse_base, seg_name)

    else:
        # Skip non-adjacent segments
        continue

    os.makedirs(out_dir, exist_ok=True)
    out_path = os.path.join(out_dir, f"{base_name}.xlsx")

    # Append if file exists
    if os.path.exists(out_path):
        existing = pd.read_excel(out_path)
        combined = pd.concat([existing, pd.DataFrame([r.drop(['Start', 'End'])])])

```

```

    else:
        combined = pd.DataFrame([r.drop(['Start', 'End'])])

    combined.to_excel(out_path, index=False)

```

Half-Hourly Sorting of Travel Times

This section takes all travel time records from each segment/direction and **groups them into half-hourly intervals** based on **Departure Time**.

Purpose:

Organize trip data into separate worksheets inside one Excel file per segment, making it easier to analyze patterns by time of day.

Time range: 06:00 – 20:00

Intervals: 30-minute bins

Examples of sheets: 06_00-06_30 , 06_30-07_00 , 07_00-07_30 , ..., 19_30-20_00

Input:

All .xlsx files from each segment folder (e.g. Lagankhel-Kupondole/ , Kupondole-Lazimpal/ , etc.)

Output structure: Each Excel file contains multiple sheets — one for each half-hour interval (with trips sorted by departure time)

```

In [6]: # -----
# PATHS
# -----
input_base = r'C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\3.Duration_etc'
output_base = r'C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\4.half_hour

# Top-Level folders renamed to your desired style
forward_out = os.path.join(output_base, 'Lagankhel-Budhanilkantha')
reverse_out = os.path.join(output_base, 'Budhanilkantha-Lagankhel')

os.makedirs(forward_out, exist_ok=True)
os.makedirs(reverse_out, exist_ok=True)

# -----
# SEGMENTS (using names)
# -----
# Mapping: 1=Lagankhel, 3=Kupondole, 5=Lazimpal, 7=Gangalal, 8=Budhanilkantha
forward_segments = [
    'Lagankhel-Kupondole',
    'Kupondole-Lazimpal',
    'Lazimpal-Gangalal',
    'Gangalal-Budhanilkantha',
    'Lagankhel-Budhanilkantha'
]

reverse_segments = [
    'Kupondole-Lagankhel',
    'Lazimpal-Kupondole',
    'Gangalal-Lazimpal',
    'Budhanilkantha-Gangalal',
    'Budhanilkantha-Lagankhel'
]

```

```

# -----
# HALF-HOUR BINS
# -----
def generate_half_hour_bins(start=time(6,0), end=time(20,0)):
    bins = []
    h, m = start.hour, start.minute

    while (h < end.hour) or (h == end.hour and m < end.minute):
        start_t = time(h, m)
        if m == 0:
            end_t = time(h, 30)
            m = 30
        else:
            end_t = time(h + 1, 0)
            h += 1
            m = 0
        bins.append((start_t, end_t))
    return bins

time_bins = generate_half_hour_bins()

# -----
# PROCESS FUNCTION
# -----
def process_segments(segment_list, source_root, output_root):

    for seg in segment_list:

        source_folder = os.path.join(source_root, seg)
        files = glob.glob(os.path.join(source_folder, '*.xlsx'))
        if not files:
            continue

        all_data = []
        for f in files:
            df = pd.read_excel(f)
            df['Departure Time'] = pd.to_datetime(df['Departure Time'])
            all_data.append(df)

        data = pd.concat(all_data, ignore_index=True)

        out_path = os.path.join(output_root, f'{seg}.xlsx')

        with pd.ExcelWriter(out_path, engine='openpyxl') as writer:
            for start_t, end_t in time_bins:

                mask = (
                    (data['Departure Time'].dt.time >= start_t) &
                    (data['Departure Time'].dt.time < end_t)
                )

                chunk = data.loc[mask].sort_values('Departure Time')

                sheet = f"{start_t.strftime('%H_%M')}-{end_t.strftime('%H_%M')}"
                if not chunk.empty:
                    chunk.to_excel(writer, sheet_name=sheet, index=False)

    # print(f"Saved: {out_path}")

# -----
# RUN
# -----
process_segments(forward_segments,
                 source_root=os.path.join(input_base, 'Lagankhel-Budhanilkantha'),

```

```

        output_root=forward_out)

process_segments(reverse_segments,
                 source_root=os.path.join(input_base, 'Budhanilkantha-Lagankhel'),
                 output_root=reverse_out)

print("Half-hour sorting completed.")

Half-hour sorting completed.

```

Holiday & Outlier Removal

This section cleans the half-hourly sorted travel time data by removing:

- All trips that occurred on **Saturdays** (weekend in Nepal)
- Any trips with unrealistic duration (> **5 hours**)

Purpose:

Exclude non-working days (Saturdays) and obvious data errors/outliers to improve analysis quality for typical weekday patterns.

Input:

Excel files from half-hourly sorted folders (each containing multiple time-bin sheets)

Output structure: Half-hourly Excel files → Same structure, but filtered

```
In [7]: # -----
# PATHS
# -----
input_base = r'C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\4.half_hour'
output_base = r'C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\5.holiday_r

# Directions using place names
directions = ['Lagankhel-Budhanilkantha', 'Budhanilkantha-Lagankhel']

# Create output folders
for d in directions:
    os.makedirs(os.path.join(output_base, d), exist_ok=True)

# -----
# PROCESS FILES
# -----
for direction in directions:

    in_dir = os.path.join(input_base, direction)
    out_dir = os.path.join(output_base, direction)

    files = glob.glob(os.path.join(in_dir, '*.xlsx'))

    for file in files:

        xls = pd.ExcelFile(file)
        output_path = os.path.join(out_dir, os.path.basename(file))

        with pd.ExcelWriter(output_path, engine='openpyxl') as writer:

            for sheet in xls.sheet_names:
                df = pd.read_excel(xls, sheet_name=sheet)

                # Ensure datetime
```

```

        df['Departure Time'] = pd.to_datetime(df['Departure Time'])

        # Remove Saturday (Monday=0, Saturday=5)
        df = df[df['Departure Time'].dt.dayofweek != 5]
        # Remove trips Longer than 5 hours
        df = df[(df['Travel Time(min)'] <= 5 * 60)]

        # Write back (even if empty, to preserve structure)
        df.to_excel(writer, sheet_name=sheet, index=False)

    # print(f"Processed (Saturday removed): {output_path}")

print("Holiday and outlier removal completed.")

```

Holiday and outlier removal completed.

Distribution Fitting & Goodness-of-Fit Analysis

(Travel Time Distributions per Time Interval)

Purpose

This section evaluates which probability distribution best describes the **travel time data** in each 30-minute time bin, for every segment and direction.

Travel times in urban traffic are typically **right-skewed** (long tail of unusually long trips due to congestion, incidents, signals, etc.).

Therefore, common skewed distributions are tested instead of assuming normality.

Distributions compared:	Distribution Parameters fitted Typical use in traffic Shape flexibility
	----- ----- ----- -----
	--- ----- Log-Normal shape, scale (loc=0) Most widely used for travel times
	High Gamma shape, scale (loc=0) Flexible, often good for moderate skewness High
	Weibull shape, scale (loc=0) Used in reliability engineering & some traffic Medium-High
	Exponential scale (loc=0) Memoryless — assumes no learning/improvement Low (only one shape)

Key statistical test used:

Anderson–Darling (A-D) goodness-of-fit test

- Sensitive to deviations in both tails (especially important for right-skewed data)
- Lower A-D statistic = better fit
- Critical value at $\alpha = 0.05$ level used for decision
 - If A-D \leq critical value → **Pass** (distribution is acceptable at 5% significance)
 - Otherwise → **Fail**

Critical values used (approximate for large samples):

- Log-Normal : 0.795
- Gamma : 0.752
- Weibull : 0.474
- Exponential: 1.321

What is calculated for each distribution & each time interval:

- Mean & Standard Deviation (empirical)
- Fitted parameters (shape & scale)
- Percentiles: 15th, 50th (median), 95th
- Anderson–Darling test statistic
- Pass/Fail result at 5% significance level

Visual output:

For each time interval → Histogram of actual travel times + overlaid PDF curves of all four fitted distributions
 → Helps visually judge which distribution follows the data most closely

Output structure: For each segment and direction, a dedicated folder is created containing:

- `distribution_fitting_results.xlsx`
 → One sheet per distribution (Log-Normal, Weibull, Gamma, Exponential) with fitted parameters, percentiles, A-D statistics, and pass/fail results.
- `Histograms/` subfolder
 → One PNG file per time interval (e.g. `06_00-06_30.png`, `06_30-07_00.png`, ...)
 showing the histogram of travel times overlaid with the fitted PDF curves of all four distributions.

Interpretation guide:

- If **Log-Normal** consistently passes and has the lowest A-D value → confirms it is usually the best theoretical model for travel times (very common finding in literature)
- If **Weibull** or **Gamma** performs better in some intervals → indicates different skewness or tail behavior (possible presence of multimodal effects or incidents)
- **Exponential** almost never fits well (too light-tailed) — used mainly as a baseline
- Visual inspection of histograms is very important — numerical test alone can be misleading with small sample sizes

```
In [8]: import scipy.stats as stats
# Main input and output directories
input_base = r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\5.holiday_re
output_base = r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Distribution_fitting"

distributions = ['Log-Normal', 'Exponential', 'Gamma', 'Weibull']

CRITICAL_VALUES = {
    'Log-Normal': {0.05: 0.795},
    'Exponential': {0.05: 1.321},
    'Gamma': {0.05: 0.752},
    'Weibull': {0.05: 0.474}
}

def compute_ad_stat(data, cdf_func, *params):
    n = len(data)
    sorted_data = np.sort(data)
    cdf_vals = cdf_func(sorted_data, *params)
    epsilon = 1e-10
    cdf_vals = np.clip(cdf_vals, epsilon, 1 - epsilon)
    ad_stat = -n - np.sum((2 * np.arange(1, n + 1) - 1) *
                          (np.log(cdf_vals) + np.log(1 - cdf_vals[:-1]))) / n
```

```

    return ad_stat

def check_ad_test(ad_stat, distribution):
    crit_5 = CRITICAL_VALUES[distribution][0.05]
    return "Pass (5%)" if ad_stat <= crit_5 else "Fail"

# Loop through all Excel files in subfolders
for root, dirs, files in os.walk(input_base):
    for file in files:
        if file.endswith('.xlsx') or file.endswith('.xls'):
            input_file = os.path.join(root, file)

            # Determine parent folder name and file name without extension
            parent_folder = os.path.basename(root)
            file_name_no_ext = os.path.splitext(file)[0]

            # Output folder: Distribution_fitting\ParentFolder\FileName
            output_folder = os.path.join(output_base, parent_folder, file_name_no_ext)
            os.makedirs(output_folder, exist_ok=True)

            # Histogram folder inside output folder
            hist_folder = os.path.join(output_folder, 'Histograms')
            os.makedirs(hist_folder, exist_ok=True)

            # Read Excel file
            xls = pd.ExcelFile(input_file)
            sheet_names = xls.sheet_names
            results = {dist: [] for dist in distributions}

            for sheet in sheet_names:
                df = pd.read_excel(xls, sheet_name=sheet)
                travel_times = df.iloc[:, 2].dropna().values
                travel_times = travel_times[travel_times > 0]
                if len(travel_times) < 2:
                    continue

                # Fit distributions
                shape_ln, loc_ln, scale_ln = stats.lognorm.fit(travel_times, floc=0)
                shape_wb, loc_wb, scale_wb = stats.weibull_min.fit(travel_times, floc=0)
                shape_gm, loc_gm, scale_gm = stats.gamma.fit(travel_times, floc=0)
                scale_exp = stats.expon.fit(travel_times, floc=0)[1]

                # Percentiles
                percentiles = [15, 50, 95]
                ln_perc = stats.lognorm.ppf(np.array(percentiles) / 100, shape_ln, loc=loc_ln)
                wb_perc = stats.weibull_min.ppf(np.array(percentiles) / 100, shape_wb, loc=loc_wb)
                gm_perc = stats.gamma.ppf(np.array(percentiles) / 100, shape_gm, loc=loc_gm)
                exp_perc = stats.expon.ppf(np.array(percentiles) / 100, loc=0, scale=scale_exp)

                # A-D stats
                ad_ln = compute_ad_stat(travel_times, stats.lognorm.cdf, shape_ln, loc_ln, scale_ln)
                ad_wb = compute_ad_stat(travel_times, stats.weibull_min.cdf, shape_wb, loc_wb, scale_wb)
                ad_gm = compute_ad_stat(travel_times, stats.gamma.cdf, shape_gm, loc_gm, scale_gm)
                ad_exp = compute_ad_stat(travel_times, stats.expon.cdf, 0, scale_exp)

                # Append results
                results['Log-Normal'].append([sheet, np.mean(travel_times), np.std(travel_times), ad_ln, shape_ln, scale_ln, *ln_perc, ad_ln, check])
                results['Weibull'].append([sheet, np.mean(travel_times), np.std(travel_times), ad_wb, shape_wb, scale_wb, *wb_perc, ad_wb, check])
                results['Gamma'].append([sheet, np.mean(travel_times), np.std(travel_times), ad_gm, shape_gm, scale_gm, *gm_perc, ad_gm, check])
                results['Exponential'].append([sheet, np.mean(travel_times), np.std(travel_times), ad_exp, None, scale_exp, *exp_perc, ad_exp, check])

```

```

# Plot histogram
x = np.linspace(min(travel_times), max(travel_times), 100)
plt.hist(travel_times, bins=20, density=True, alpha=0.6, color='gray')
plt.plot(x, stats.lognorm.pdf(x, shape_ln, loc_ln, scale_ln), label='Log-Normal')
plt.plot(x, stats.expon.pdf(x, 0, scale_exp), label='Exponential')
plt.plot(x, stats.gamma.pdf(x, shape_gm, loc_gm, scale_gm), label='Gamma')
plt.plot(x, stats.weibull_min.pdf(x, shape_wb, loc_wb, scale_wb), label='Weibull')
plt.xlabel('Travel Time (min)')
plt.ylabel('Density')
plt.title(f'Distribution Fit - {sheet}')
plt.legend()
plt.savefig(os.path.join(hist_folder, f'{sheet}.png'))
plt.close()

# Save results to Excel
output_file = os.path.join(output_folder, 'distribution_fitting_results.xlsx')
with pd.ExcelWriter(output_file) as writer:
    for dist in distributions:
        columns = ['Time Interval', 'Mean', 'Std Dev', 'Shape', 'Scale',
                   '15th Perc', '50th Perc', '95th Perc', 'A-D Stat', 'P-Value']
        df_out = pd.DataFrame(results[dist], columns=columns)
        df_out.to_excel(writer, sheet_name=dist, index=False)

print("All files saved")

```

All files saved

Final Distribution Comparison Summary

(Best-Fitting Distribution Across All Time Intervals)

This section aggregates results from all `distribution_fitting_results.xlsx` files and answers two key questions for each segment:

1. Cases Pass (%)

→ What percentage of time intervals (30-min bins) does the distribution **pass the Anderson–Darling test at 5% significance?**
 (i.e., can be considered an acceptable fit)

2. Cases 1st (%)

→ In what percentage of time intervals does the distribution have the **lowest A-D statistic** (best numerical fit) compared to the other three?

Distributions evaluated:

- Log-Normal
- Exponential
- Gamma
- Weibull

Output

A new file `distribution_analysis.xlsx` is created in each segment folder containing one simple table:

Distribution	Cases Pass (%)	Cases 1st (%)
Log-Normal	e.g. 96.4%	e.g. 78.6% (most often best)
Gamma
Weibull
Exponential

Purpose & Interpretation

- **Highest "Cases 1st (%)"** → the most frequently best-fitting distribution (winner overall)
- **Highest "Cases Pass (%)"** → the most consistently acceptable model

```
In [9]: # Base folder where all distribution_fitting results are stored
base_folder = r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Distribution_fitting"

# Sheet names
distributions = ["Log-Normal", "Exponential", "Gamma", "Weibull"]

# Walk through all subfolders
for root, dirs, files in os.walk(base_folder):
    if "distribution_fitting_results.xlsx" in files:
        input_file = os.path.join(root, "distribution_fitting_results.xlsx")

        # Read all sheets
        data = {sheet: pd.read_excel(input_file, sheet_name=sheet) for sheet in distributions}
        total_cases = len(data[distributions[0]]) # assuming all sheets have same number of rows

        results = []

        # Compute Cases Pass (%)
        for sheet, df in data.items():
            pass_cases = df[df.iloc[:, 9] == "Pass (5%)"].shape[0] # Column J: Pass (5%)
            pass_percentage = (pass_cases / total_cases) * 100 if total_cases > 0 else 0
            results.append([sheet, pass_percentage, 0]) # Placeholder for Cases 1st (%)

        # Compute Cases 1st (%)
        first_case_counts = [0] * len(distributions)
        for i in range(total_cases):
            row_values = {sheet: data[sheet].iloc[i, 8] for sheet in distributions}
            min_dist = min(row_values, key=row_values.get)
            index = distributions.index(min_dist)
            first_case_counts[index] += 1

        # Update Cases 1st (%)
        for i, sheet in enumerate(distributions):
            first_percentage = (first_case_counts[i] / total_cases) * 100 if total_cases > 0 else 0
            results[i][2] = first_percentage

        # Create final DataFrame
        output_df = pd.DataFrame(results, columns=["Distribution", "Cases Pass (%)", "Cases 1st (%)"])

        # Output file in the same folder
        output_file = os.path.join(root, "distribution_analysis.xlsx")
        output_df.to_excel(output_file, index=False)

print("Analysis saved successfully")
```

Analysis saved successfully

Final Conclusion

This analysis confirms that travel time data in the Lagankhel–Budhanilkantha corridor follows a **Log-Normal** distribution.

Travel Time Reliability Indices – Spatio-Temporal Analysis

This section performs **travel time reliability analysis** for each 30-minute time bin of every segment.

What it calculates (per half-hour interval):

- Mean travel time
- Standard deviation
- 15th & 95th percentiles (fitted using **Lognormal distribution**)
- Buffer Time = 95th percentile – Mean
- Buffer Time Index = Buffer Time / Mean
- Planning Time = 95th percentile
- Planning Time Index = Planning Time / 15th percentile

Purpose:

Quantify travel time reliability and variability over the day

→ Useful for identifying peak congestion periods and planning time buffers

Input: Cleaned half-hourly Excel files (from step 5)

Method: Lognormal distribution fitting (common for travel time data)

Output structure: Columns in each output file:

- Time (e.g. 06_00-06_30)
- Mean
- Standard Dev
- 15th Perc
- 95th Perc
- Buffer Time
- Buffer Time Index
- Planning Time
- Planning Time Index

All numeric values rounded to 3 decimal places.

```
In [10]: # -----
# PATHS
# -----
input_base = r'C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\5.holiday_re
output_base = r'C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_tempo

# Directions using place names
directions = ['Lagankhel-Budhanilkantha', 'Budhanilkantha-Lagankhel']

# Create output folder if not exists
os.makedirs(output_base, exist_ok=True)

# -----
# PROCESS FILES
```

```

# -----
for direction in directions:
    in_dir = os.path.join(input_base, direction)
    out_dir = os.path.join(output_base, direction)
    os.makedirs(out_dir, exist_ok=True)

    files = glob.glob(os.path.join(in_dir, '*.xlsx'))

    for file in files:
        xls = pd.ExcelFile(file)
        segment_name = os.path.splitext(os.path.basename(file))[0]

        results = []

        for sheet in xls.sheet_names:
            df = pd.read_excel(xls, sheet_name=sheet)

            # Ensure Travel Time column exists
            if 'Travel Time(min)' not in df.columns:
                continue

            travel_times = df['Travel Time(min)'].dropna().values
            if len(travel_times) == 0:
                continue

            # Convert time format: 7_30-8_00 → 7:30-8:00
            time_label = sheet.replace('_', ':')

            # Fit lognormal distribution
            shape_ln, loc_ln, scale_ln = stats.lognorm.fit(travel_times, floc=0)

            # Percentiles
            p15, p95 = stats.lognorm.ppf(
                np.array([0.15, 0.95]),
                shape_ln, loc=loc_ln, scale=scale_ln
            )

            # Statistics
            mean_time = np.mean(travel_times)
            std_time = np.std(travel_times)

            buffer_time = p95 - mean_time
            buffer_time_index = buffer_time / mean_time
            planning_time = p95
            planning_time_index = planning_time / p15

            results.append({
                'Time': time_label,
                'Mean': mean_time,
                'Standard Dev': std_time,
                '15th Perc': p15,
                '95th Perc': p95,
                'Buffer Time': buffer_time,
                'Buffer Time Index': buffer_time_index,
                'Planning Time': planning_time,
                'Planning Time Index': planning_time_index
            })

        if results:
            results_df = pd.DataFrame(results)

            numeric_cols = [
                'Mean', 'Standard Dev', '15th Perc', '95th Perc',
                'Buffer Time', 'Buffer Time Index',

```

```

        'Planning Time', 'Planning Time Index'
    ]
results_df[numeric_cols] = results_df[numeric_cols].round(3)

out_path = os.path.join(out_dir, f"{segment_name}.xlsx")

# -----
# WRITE EXCEL (TITLE + TABLE)
# -----
with pd.ExcelWriter(out_path, engine='openpyxl') as writer:
    # Row 1: file name (title)
    pd.DataFrame([[segment_name]]).to_excel(
        writer,
        index=False,
        header=False,
        startrow=0
    )

    # Row 2 onwards: column names + data
    results_df.to_excel(
        writer,
        index=False,
        startrow=1
    )

```

print("PTI temporal analysis completed.")

PTI temporal analysis completed.

Overall Performance Travel Time Indices (PTI) – Entire Dataset

This section computes **overall (whole-day) travel time reliability metrics** for each segment by combining **all time bins** together.

What it calculates (per segment, across all hours):

- Mean travel time
- Standard deviation
- 15th & 95th percentiles (fitted using **Lognormal distribution**)
- Buffer Time = 95th percentile – Mean
- Buffer Time Index = Buffer Time / Mean
- Planning Time = 95th percentile
- Planning Time Index = Planning Time / 15th percentile

Purpose:

Provide a **single summary view** of travel time performance and reliability for each segment/direction

→ Ideal for comparing segments, directions, or overall route characteristics

Input: Cleaned half-hourly Excel files (from step 5)

Method: Lognormal distribution fitted to **all travel times** of the segment (ignoring time-of-day)

Output structure: One Excel file per direction containing overall metrics for all segments All numeric values rounded to 3 decimal places.

This completes the full PTI analysis pipeline!

In [11]:

```
# -----
# PATHS
# -----
input_base = r'C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\5.holiday_re
output_base = r'C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\7.PTI_overa

# Directions using place names
directions = ['Lagankhel-Budhanilkantha', 'Budhanilkantha-Lagankhel']

# Create output folder if not exists
os.makedirs(output_base, exist_ok=True)

# -----
# PROCESS FILES
# -----
for direction in directions:
    in_dir = os.path.join(input_base, direction)
    files = glob.glob(os.path.join(in_dir, '*.xlsx'))

    # Store overall results for this direction
    overall_results = []

    for file in files:
        xls = pd.ExcelFile(file)
        segment_name = os.path.splitext(os.path.basename(file))[0]

        # Merge all sheets for this segment
        all_data = []
        for sheet in xls.sheet_names:
            df = pd.read_excel(xls, sheet_name=sheet)
            if 'Travel Time(min)' in df.columns:
                all_data.append(df['Travel Time(min)').dropna()

        if not all_data:
            continue

        travel_times = pd.concat(all_data).values

        # Fit lognormal distribution
        shape_ln, loc_ln, scale_ln = stats.lognorm.fit(travel_times, floc=0)

        # Compute percentiles
        percentiles = [15, 95]
        ln_perc = stats.lognorm.ppf(np.array(percentiles)/100, shape_ln, loc=loc_ln)
        p15, p95 = ln_perc

        # Mean and standard deviation
        mean_time = np.mean(travel_times)
        std_time = np.std(travel_times)

        # Additional metrics
        buffer_time = p95 - mean_time
        buffer_time_index = buffer_time / mean_time
        planning_time = p95
        planning_time_index = p95 / p15

        # Append to overall results
        overall_results.append({
            'Segment': segment_name,
            'Mean': mean_time,
            'Standard Dev': std_time,
            '15th Perc': p15,
            '95th Perc': p95,
```

```

        'Buffer Time': buffer_time,
        'Buffer Time Index': buffer_time_index,
        'Planning Time': planning_time,
        'Planning Time Index': planning_time_index
    })

# Save results to one Excel file per direction
if overall_results:
    results_df = pd.DataFrame(overall_results)
    numeric_cols = ['Mean', 'Standard Dev', '15th Perc', '95th Perc',
                    'Buffer Time', 'Buffer Time Index', 'Planning Time', 'Planr
    results_df[numeric_cols] = results_df[numeric_cols].round(3)

    # Save using place-name direction
    out_path = os.path.join(output_base, f"{direction}.xlsx")
    results_df.to_excel(out_path, index=False)
    print(f"Saved overall PTI analysis: {out_path}")

print("Overall PTI analysis completed.")

```

C:\Users\ACER\AppData\Local\Temp\ipykernel_2988\2987661786.py:37: FutureWarning: The behavior of array concatenation with empty entries is deprecated. In a future version, this will no longer exclude empty items when determining the result dtype. To retain the old behavior, exclude the empty entries before the concat operation.
travel_times = pd.concat(all_data).values
C:\Users\ACER\AppData\Local\Temp\ipykernel_2988\2987661786.py:37: FutureWarning: The behavior of array concatenation with empty entries is deprecated. In a future version, this will no longer exclude empty items when determining the result dtype. To retain the old behavior, exclude the empty entries before the concat operation.
travel_times = pd.concat(all_data).values
Saved overall PTI analysis: C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\7.PTI_overall\Lagankhel-Budhanilkantha.xlsx
Saved overall PTI analysis: C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\7.PTI_overall\Budhanilkantha-Lagankhel.xlsx
Overall PTI analysis completed.

Data Visualization

Budhanilkantha → Lagankhel(Route 2)

Travel Time Variation by Time of Day

Budhanilkantha → Lagankhel

Mean travel time (blue) vs 95th percentile / Planning Time (red)
30-minute intervals starting from 06:30

```
In [12]: # File path
file_path = r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_tempor
output_path = r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Datavisualization\Budhanil
os.makedirs(output_path, exist_ok=True)

# Read Excel file (skip header rows if necessary)
df = pd.read_excel(file_path, header=None)

# Extract Mean Travel Time (column B, index 1) and 95th Percentile (column E, index
# Data starts from row 3, which is index 2 in 0-based indexing
mean_travel_time = pd.to_numeric(df.iloc[2:, 1], errors='coerce')
```

```

percentile_95 = pd.to_numeric(df.iloc[2:, 4], errors='coerce')

# Create time intervals starting from 6:30 in 30-min intervals
start_time = datetime.strptime("06:30", "%H:%M")
time_labels = [(start_time + timedelta(minutes=30*i)).strftime('%H:%M') for i in range(24)]

# Plot
plt.figure(figsize=(12, 5))
plt.plot(time_labels, mean_travel_time, marker='o', color='blue', label='Mean Travel Time')
plt.plot(time_labels, percentile_95, marker='o', color='red', label='95th Percentile (Planning Time)')

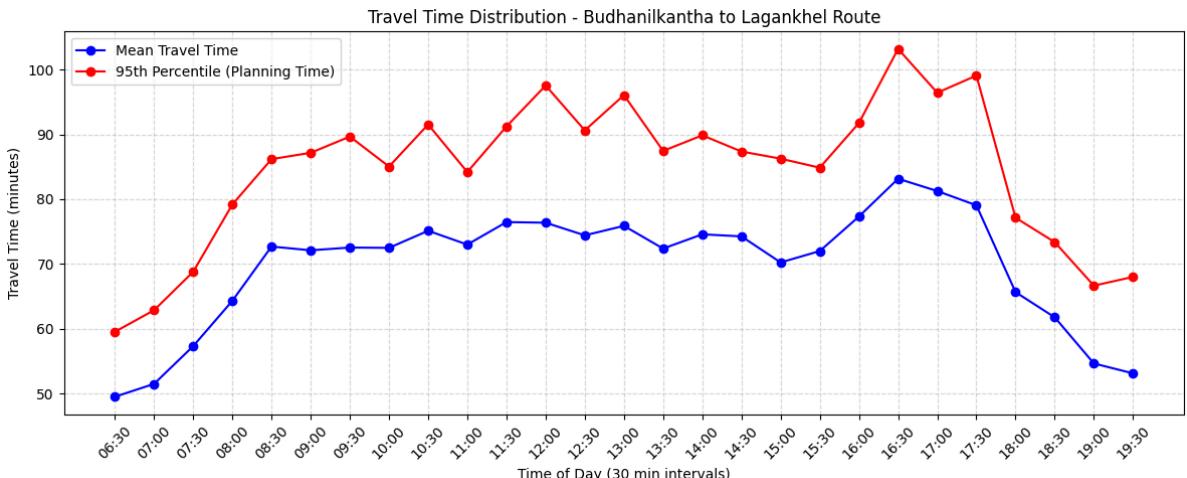
# Customize
plt.xticks(rotation=45)
plt.xlabel("Time of Day (30 min intervals)")
plt.ylabel("Travel Time (minutes)")
plt.title("Travel Time Distribution - Budhanilkantha to Lagankhel Route")
plt.grid(True, linestyle='--', alpha=0.5)
plt.legend()

plt.tight_layout()

# Save figure
output_file = os.path.join(output_path, "PT and MTT vs Time of day.png")
plt.savefig(output_file, dpi=300)
plt.show()

print("✓ Line graph saved at:", output_file)

```



✓ Line graph saved at: C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Datavisualization\Budhanilkantha-Lagankhel\PT and MTT vs Time of day.png

PTI Heatmap – Full Route

Budhanilkantha → Lagankhel

Planning Time Index by time of day (start of each 30-min interval)

Higher values (darker colors) = greater travel time variability

```

In [13]: # File paths
file_path = r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal.xlsx"
output_path = r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Datavisualization\Budhanilkantha-Lagankhel"
os.makedirs(output_path, exist_ok=True)

# Read Excel file
df = pd.read_excel(file_path, header=None)

# Segment name

```

```

segment_name = str(df.iloc[0, 0]).strip()

# Extract and clean PTI values from I2 to I29
pti_values = df.iloc[2:29, 8].replace(r'^0-9.?', '', regex=True)
pti_values = pd.to_numeric(pti_values, errors='coerce').fillna(0).tolist()

# Use only start time of each interval as the label (e.g., '06:00' instead of '06:00:00')
start_time = datetime.strptime("06:30", "%H:%M")
interval_labels = [
    (start_time + timedelta(minutes=30 * i)).strftime('%H:%M')
    for i in range(len(pti_values))
]

# Create a DataFrame with one row and all correct PTI values
pti_df = pd.DataFrame(
    [pti_values],
    index=["Budhanilkantha-Lagankhel Route"],
    columns=interval_labels
)

# Define custom colormap
color_map = LinearSegmentedColormap.from_list(
    "white_lightgreen_blue_darkerpink_red",
    ["#FFFFFF", "#D0F0C0", "#4C99B1", "#F28D8D", "#D40000"]
)

# Dynamic color scale range
vmin = 1
vmax = round(max(pti_values) + 0.03, 2) if max(pti_values) <= 2 else round(max(pti_values) + 0.05, 2)
vmax = max(vmax + 0.05, vmin)

# Plot with reduced horizontal scaling
plt.figure(figsize=(10, 3.5))
ax = sns.heatmap(pti_df, cmap=color_map, annot=True, fmt='.{2}f', linewidths=0.5,
                  vmin=vmin, vmax=vmax, annot_kws={"size": 9}, cbar_kws={'label': 'PTI Value'})

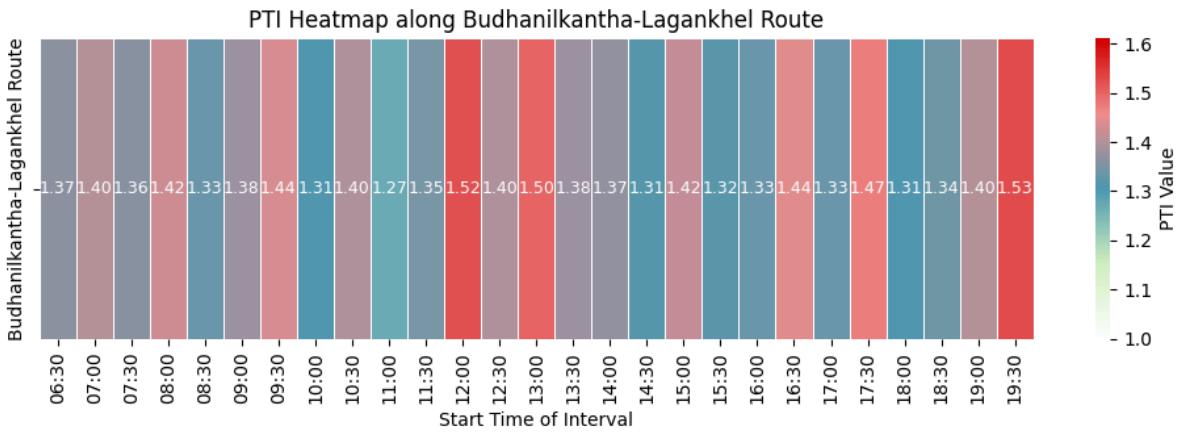
# Adjust ticks
ax.set_xticks([i + 0.5 for i in range(len(interval_labels))])
ax.set_xticklabels(interval_labels, rotation=90)
ax.set_yticklabels(["Budhanilkantha-Lagankhel Route"], rotation=90)

# Titles and Layout
plt.xlabel("Start Time of Interval")
# plt.ylabel("Route", rotation=90)
plt.title("PTI Heatmap along Budhanilkantha-Lagankhel Route")
plt.tight_layout()

# Save
output_file = os.path.join(output_path, "PTI_Heatmap_Budhanilkantha-Lagankhel Route")
plt.savefig(output_file, dpi=300)
plt.show()

print("✅ PTI heatmap with start-time labels (e.g., 06:30) saved at:", output_file)

```



PTI heatmap with start-time labels (e.g., 06:30) saved at: C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Datavisualization\Budhanilkantha-Lagankhel\PTI_Heatmap_Budhanilkantha-Lagankhel Route_2.png

Mean Travel Time & Planning Time Index vs Time of Day

Budhanilkantha → Lagankhel Route

All segments compared:

- Mean Travel Time (minutes)
 - Planning Time Index (PTI)
- across 30-minute intervals starting from 07:00

```
In [14]: # List of Excel file paths
file_paths = [
    r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal_analysis",
    r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal_analysis",
    r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal_analysis",
    r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal_analysis"
]

# Output directory
output_dir = r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Datavisualization\Budhanilkantha"
os.makedirs(output_dir, exist_ok=True)

# Dictionary to hold data
mean_travel_dict = {}
pti_dict = {}

# Define time intervals: 6:00 to 19:30 → 28 intervals at 30-min gap
start_time = datetime.strptime("07:00", "%H:%M")
intervals = [(start_time + timedelta(minutes=30 * i)).strftime('%H:%M') for i in range(28)]

# Read each file
for file_path in file_paths:
    df = pd.read_excel(file_path, header=None)

    segment_name = str(df.iloc[0, 0]).strip()

    # Mean Travel Time from B3:B30 (column 1, rows 2 to 29)
    mean_times = df.iloc[2:27, 1].replace(r'^0-9.', '', regex=True)
    mean_times = pd.to_numeric(mean_times, errors='coerce').fillna(0).tolist()
    mean_travel_dict[segment_name] = mean_times

    # PTI from H3:H30 (column 7, rows 2 to 29)
    pti_values = df.iloc[2:27, 7].replace(r'^0-9.', '', regex=True)
```

```

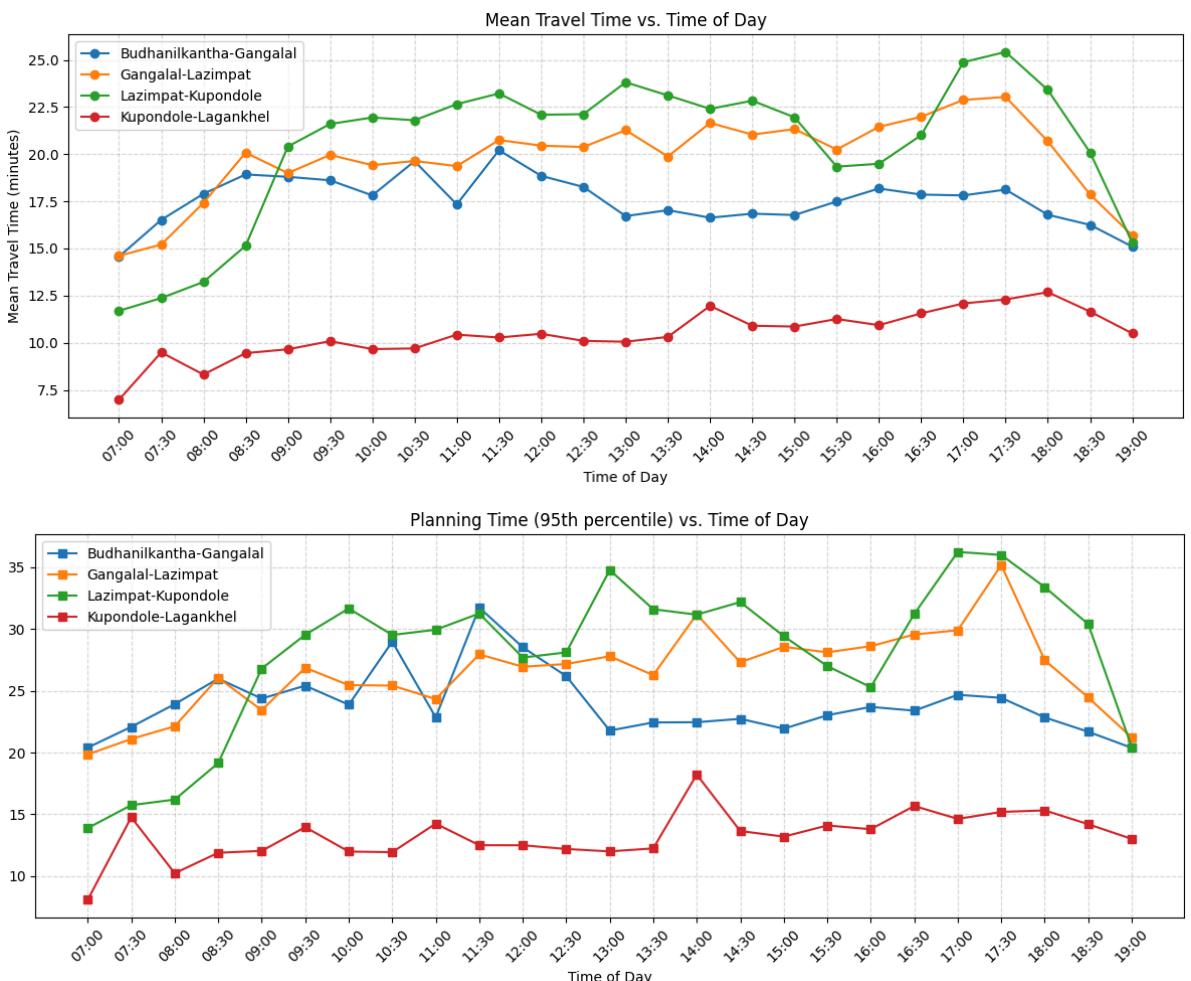
pti_values = pd.to_numeric(pti_values, errors='coerce').fillna(0).tolist()
pti_dict[segment_name] = pti_values

# Plot Mean Travel Time
plt.figure(figsize=(12, 5))
for segment, values in mean_travel_dict.items():
    plt.plot(intervals, values, marker='o', label=segment)
plt.title("Mean Travel Time vs. Time of Day")
plt.xlabel("Time of Day")
plt.ylabel("Mean Travel Time (minutes)")
plt.xticks(rotation=45)
plt.grid(True, linestyle='--', alpha=0.5)
plt.legend()
plt.tight_layout()
plt.savefig(os.path.join(output_dir, "Mean_Travel_Time_vs_Time_of_Day.png"), dpi=300)
plt.show()

# Plot PTI
plt.figure(figsize=(12, 5))
for segment, values in pti_dict.items():
    plt.plot(intervals, values, marker='s', label=segment)
plt.title("Planning Time (95th percentile) vs. Time of Day")
plt.xlabel("Time of Day")
# plt.ylabel("PTI")
plt.xticks(rotation=45)
plt.grid(True, linestyle='--', alpha=0.5)
plt.legend()
plt.tight_layout()
plt.savefig(os.path.join(output_dir, "PTI_vs_Time_of_Day.png"), dpi=300)
plt.show()

print("✅ Graphs saved successfully in:", output_dir)

```



Graphs saved successfully in: C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Datavisu
alization\Budhanilkantha-Lagankhel\Combined Graphs

Planning Time Index (PTI) Heatmap by Segment & Time of Day

Budhanilkantha → Lagankhel Route

PTI values across all segments (rows) and 30-minute intervals (columns)

Higher values (darker red) = greater travel time variability

```
In [15]: # List of Excel file paths
file_paths = [
    r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal_analys",
    r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal_analys",
    r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal_analys",
    r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal_analys"
]

# Initialize an empty dictionary to store PTI values
pti_data = {}

# Read data from each file
for file in file_paths:
    df = pd.read_excel(file, header=None)
    segment_name = str(df.iloc[0, 0]).strip()
    pti_values = df.iloc[2:28, 8]
    pti_values_cleaned = pti_values.replace(r'^[0-9.]', '', regex=True)
    pti_values = pd.to_numeric(pti_values_cleaned, errors='coerce')
    pti_data[segment_name] = pti_values

# Convert to DataFrame and assign time intervals
pti_df = pd.DataFrame(pti_data)
time_intervals = [f"{hour}:{minute:02d}" for hour in range(7, 21) for minute in [0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330, 360, 390, 420, 450, 480, 510, 540, 570, 600, 630, 660, 690, 720, 750, 780, 810, 840, 870, 900, 930, 960, 990, 1020, 1050, 1080, 1110, 1140, 1170, 1200, 1230, 1260, 1290, 1320, 1350, 1380, 1410, 1440, 1470, 1500, 1530, 1560, 1590, 1620, 1650, 1680, 1710, 1740, 1770, 1800, 1830, 1860, 1890, 1920, 1950, 1980, 2010, 2040, 2070, 2100, 2130, 2160, 2190, 2220, 2250, 2280, 2310, 2340, 2370, 2400, 2430, 2460, 2490, 2520, 2550, 2580, 2610, 2640, 2670, 2700, 2730, 2760, 2790, 2820, 2850, 2880, 2910, 2940, 2970, 3000, 3030, 3060, 3090, 3120, 3150, 3180, 3210, 3240, 3270, 3300, 3330, 3360, 3390, 3420, 3450, 3480, 3510, 3540, 3570, 3600, 3630, 3660, 3690, 3720, 3750, 3780, 3810, 3840, 3870, 3900, 3930, 3960, 3990, 4020, 4050, 4080, 4110, 4140, 4170, 4200, 4230, 4260, 4290, 4320, 4350, 4380, 4410, 4440, 4470, 4500, 4530, 4560, 4590, 4620, 4650, 4680, 4710, 4740, 4770, 4800, 4830, 4860, 4890, 4920, 4950, 4980, 5010, 5040, 5070, 5100, 5130, 5160, 5190, 5220, 5250, 5280, 5310, 5340, 5370, 5400, 5430, 5460, 5490, 5520, 5550, 5580, 5610, 5640, 5670, 5700, 5730, 5760, 5790, 5820, 5850, 5880, 5910, 5940, 5970, 5990, 6020, 6050, 6080, 6110, 6140, 6170, 6200, 6230, 6260, 6290, 6320, 6350, 6380, 6410, 6440, 6470, 6500, 6530, 6560, 6590, 6620, 6650, 6680, 6710, 6740, 6770, 6800, 6830, 6860, 6890, 6920, 6950, 6980, 7010, 7040, 7070, 7100, 7130, 7160, 7190, 7220, 7250, 7280, 7310, 7340, 7370, 7400, 7430, 7460, 7490, 7520, 7550, 7580, 7610, 7640, 7670, 7700, 7730, 7760, 7790, 7820, 7850, 7880, 7910, 7940, 7970, 7990, 8020, 8050, 8080, 8110, 8140, 8170, 8200, 8230, 8260, 8290, 8320, 8350, 8380, 8410, 8440, 8470, 8500, 8530, 8560, 8590, 8620, 8650, 8680, 8710, 8740, 8770, 8800, 8830, 8860, 8890, 8920, 8950, 8980, 9010, 9040, 9070, 9100, 9130, 9160, 9190, 9220, 9250, 9280, 9310, 9340, 9370, 9400, 9430, 9460, 9490, 9520, 9550, 9580, 9610, 9640, 9670, 9700, 9730, 9760, 9790, 9820, 9850, 9880, 9910, 9940, 9970, 10000, 10030, 10060, 10090, 10120, 10150, 10180, 10210, 10240, 10270, 10300, 10330, 10360, 10390, 10420, 10450, 10480, 10510, 10540, 10570, 10600, 10630, 10660, 10690, 10720, 10750, 10780, 10810, 10840, 10870, 10900, 10930, 10960, 10990, 11020, 11050, 11080, 11110, 11140, 11170, 11200, 11230, 11260, 11290, 11320, 11350, 11380, 11410, 11440, 11470, 11500, 11530, 11560, 11590, 11620, 11650, 11680, 11710, 11740, 11770, 11800, 11830, 11860, 11890, 11920, 11950, 11980, 12010, 12040, 12070, 12100, 12130, 12160, 12190, 12220, 12250, 12280, 12310, 12340, 12370, 12400, 12430, 12460, 12490, 12520, 12550, 12580, 12610, 12640, 12670, 12700, 12730, 12760, 12790, 12820, 12850, 12880, 12910, 12940, 12970, 12990, 13020, 13050, 13080, 13110, 13140, 13170, 13200, 13230, 13260, 13290, 13320, 13350, 13380, 13410, 13440, 13470, 13500, 13530, 13560, 13590, 13620, 13650, 13680, 13710, 13740, 13770, 13800, 13830, 13860, 13890, 13920, 13950, 13980, 14010, 14040, 14070, 14100, 14130, 14160, 14190, 14220, 14250, 14280, 14310, 14340, 14370, 14400, 14430, 14460, 14490, 14520, 14550, 14580, 14610, 14640, 14670, 14700, 14730, 14760, 14790, 14820, 14850, 14880, 14910, 14940, 14970, 14990, 15020, 15050, 15080, 15110, 15140, 15170, 15200, 15230, 15260, 15290, 15320, 15350, 15380, 15410, 15440, 15470, 15500, 15530, 15560, 15590, 15620, 15650, 15680, 15710, 15740, 15770, 15800, 15830, 15860, 15890, 15920, 15950, 15980, 16010, 16040, 16070, 16100, 16130, 16160, 16190, 16220, 16250, 16280, 16310, 16340, 16370, 16400, 16430, 16460, 16490, 16520, 16550, 16580, 16610, 16640, 16670, 16700, 16730, 16760, 16790, 16820, 16850, 16880, 16910, 16940, 16970, 16990, 17020, 17050, 17080, 17110, 17140, 17170, 17200, 17230, 17260, 17290, 17320, 17350, 17380, 17410, 17440, 17470, 17500, 17530, 17560, 17590, 17620, 17650, 17680, 17710, 17740, 17770, 17800, 17830, 17860, 17890, 17920, 17950, 17980, 18010, 18040, 18070, 18100, 18130, 18160, 18190, 18220, 18250, 18280, 18310, 18340, 18370, 18400, 18430, 18460, 18490, 18520, 18550, 18580, 18610, 18640, 18670, 18700, 18730, 18760, 18790, 18820, 18850, 18880, 18910, 18940, 18970, 18990, 19020, 19050, 19080, 19110, 19140, 19170, 19200, 19230, 19260, 19290, 19320, 19350, 19380, 19410, 19440, 19470, 19500, 19530, 19560, 19590, 19620, 19650, 19680, 19710, 19740, 19770, 19800, 19830, 19860, 19890, 19920, 19950, 19980, 20010, 20040, 20070, 20100, 20130, 20160, 20190, 20220, 20250, 20280, 20310, 20340, 20370, 20400, 20430, 20460, 20490, 20520, 20550, 20580, 20610, 20640, 20670, 20700, 20730, 20760, 20790, 20820, 20850, 20880, 20910, 20940, 20970, 20990, 21020, 21050, 21080, 21110, 21140, 21170, 21200, 21230, 21260, 21290, 21320, 21350, 21380, 21410, 21440, 21470, 21500, 21530, 21560, 21590, 21620, 21650, 21680, 21710, 21740, 21770, 21800, 21830, 21860, 21890, 21920, 21950, 21980, 22010, 22040, 22070, 22100, 22130, 22160, 22190, 22220, 22250, 22280, 22310, 22340, 22370, 22400, 22430, 22460, 22490, 22520, 22550, 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31110, 31140, 31170, 31200, 31230, 31260, 31290, 31320, 31350, 31380, 31410, 31440, 31470, 31500, 31530, 31560, 31590, 31620, 31650, 31680, 31710, 31740, 31770, 31800, 31830, 31860, 31890, 31920, 31950, 31980, 32010, 32040, 32070, 32100, 32130, 32160, 32190, 32220, 32250, 32280, 32310, 32340, 32370, 32400, 32430, 32460, 32490, 32520, 32550, 32580, 32610, 32640, 32670, 32700, 32730, 32760, 32790, 32820, 32850, 32880, 32910, 32940, 32970, 32990, 33020, 33050, 33080, 33110, 33140, 33170, 33200, 33230, 33260, 33290, 33320, 33350, 33380, 33410, 33440, 33470, 33500, 33530, 33560, 33590, 33620, 33650, 33680, 33710, 33740, 33770, 33800, 33830, 33860, 33890, 33920, 33950, 33980, 34010, 34040, 34070, 34100, 34130, 34160, 34190, 34220, 34250, 34280, 34310, 34340, 34370, 34400, 34430, 34460, 34490, 34520, 34550, 34580, 34610, 34640, 34670, 34700, 34730, 34760, 34790, 34820, 34850, 34880, 34910, 34940, 34970, 34990, 35020, 35050, 35080, 35110, 35140, 35170, 35200, 35230, 35260, 35290, 35320, 35350, 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43920, 43950, 43980, 44010, 44040, 44070, 44100, 44130, 44160, 44190, 44220, 44250, 44280, 44310, 44340, 44370, 44400, 44430, 44460, 44490, 44520, 44550, 44580, 44610, 44640, 44670, 44700, 44730, 44760, 44790, 44820, 44850, 44880, 44910, 44940, 44970, 44990, 45020, 45050, 45080, 45110, 45140, 45170, 45200, 45230, 45260, 45290, 45320, 45350, 45380, 45410, 45440, 45470, 45500, 45530, 45560, 45590, 45620, 45650, 45680, 45710, 45740, 45770, 45800, 45830, 45860, 45890, 45920, 45950, 45980, 46010, 46040, 46070, 46100, 46130, 46160, 46190, 46220, 46250, 46280, 46310, 46340, 46370, 46400, 46430, 46460, 46490, 46520, 46550, 46580, 46610, 46640, 46670, 46700, 46730, 46760,
```

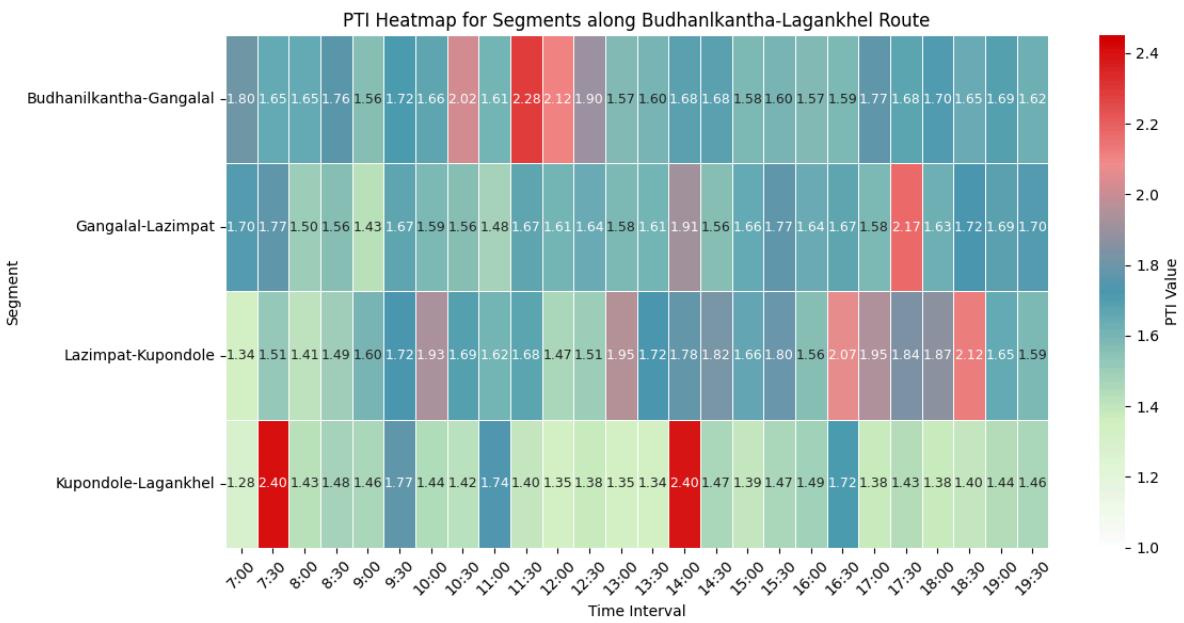
```

plt.ylabel("Segment")
plt.title("PTI Heatmap for Segments along Budhanikantha-Lagankhel Route")
plt.xticks(rotation=45)
plt.yticks(rotation=0)
plt.tight_layout()

#  Save the figure as PNG
output_path = r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Datavisualization\Budhanil
plt.savefig(output_path, dpi=300)

plt.show()

```



Lagankhel → Budhanikantha (Route 1)

Travel Time Variation by Time of Day

Lagankhel → Budhanikantha

Mean travel time (blue) vs 95th percentile / Planning Time (red)
30-minute intervals starting from 06:30

```

In [16]: # File path
file_path = r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_tempora
output_path = r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Datavisualization\Lagankhe
os.makedirs(output_path, exist_ok=True)

# Read Excel file (skip header rows if necessary)
df = pd.read_excel(file_path, header=None)

# Extract Mean Travel Time (column B, index 1) and 95th Percentile (column E, index
# Data starts from row 3, which is index 2 in 0-based indexing
mean_travel_time = pd.to_numeric(df.iloc[2:, 1], errors='coerce')
percentile_95 = pd.to_numeric(df.iloc[2:, 4], errors='coerce')

# Create time intervals starting from 6:30 in 30-min intervals
start_time = datetime.strptime("06:30", "%H:%M")
time_labels = [(start_time + timedelta(minutes=30*i)).strftime('%H:%M') for i in ra
# Plot
plt.figure(figsize=(12, 5))

```

```

plt.plot(time_labels, mean_travel_time, marker='o', color='blue', label='Mean Travel Time')
plt.plot(time_labels, percentile_95, marker='o', color='red', label='95th Percentile')

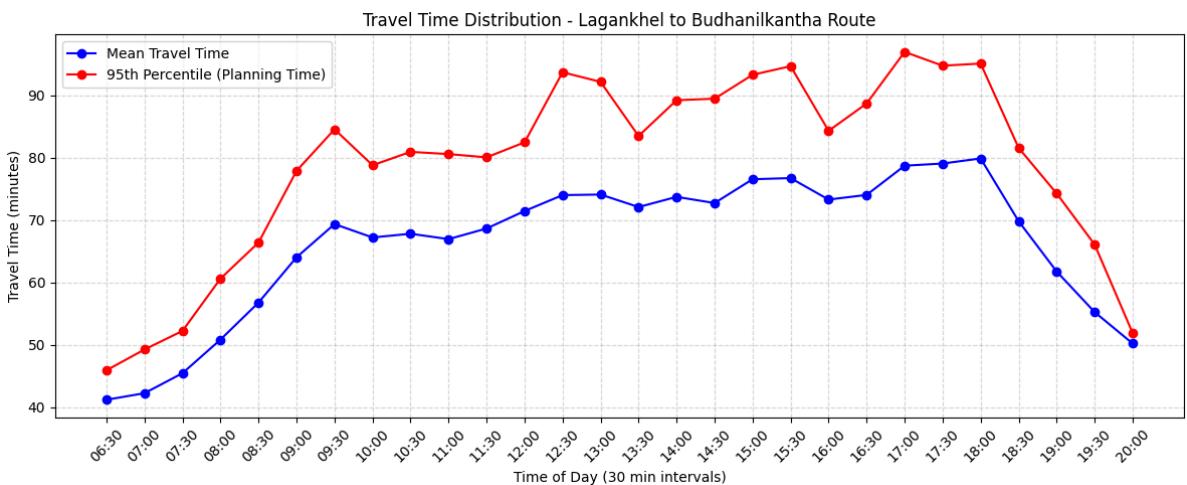
# Customize
plt.xticks(rotation=45)
plt.xlabel("Time of Day (30 min intervals)")
plt.ylabel("Travel Time (minutes)")
plt.title("Travel Time Distribution - Lagankhel to Budhanilkantha Route")
plt.grid(True, linestyle='--', alpha=0.5)
plt.legend()

plt.tight_layout()

# Save figure
output_file = os.path.join(output_path, "PT and MTT vs Time of day.png")
plt.savefig(output_file, dpi=300)
plt.show()

print("✅ Line graph saved at:", output_file)

```



✅ Line graph saved at: C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Datavisualization\Lagankhel-Budhanilkantha\PT and MTT vs Time of day.png

PTI Heatmap – Full Route

Lagankhel → Budhanilkantha

Planning Time Index by time of day (start of each 30-min interval)

Higher values (darker colors) = greater travel time variability

```

In [17]: # File paths
file_path = r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal.xlsx"
output_path = r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Datavisualization\Lagankhel-Budhanilkantha"
os.makedirs(output_path, exist_ok=True)

# Read Excel file
df = pd.read_excel(file_path, header=None)

# Segment name
segment_name = str(df.iloc[0, 0]).strip()

# Extract and clean PTI values from I2 to I29
pti_values = df.iloc[2:29, 8].replace(r'^0-9. ]', '', regex=True)
pti_values = pd.to_numeric(pti_values, errors='coerce').fillna(0).tolist()

# Use only start time of each interval as the label (e.g., '06:00' instead of '06:00:00')
start_time = datetime.strptime("06:00", "%H:%M")

```

```

interval_labels = [
    (start_time + timedelta(minutes=30 * i)).strftime('%H:%M')
    for i in range(len(pti_values))
]

# Create a DataFrame with one row and all correct PTI values
pti_df = pd.DataFrame(
    [pti_values],
    index=["Lagankhel-Budhanilkantha Route"],
    columns=interval_labels
)

# Define custom colormap
color_map = LinearSegmentedColormap.from_list(
    "white_lightgreen_blue_darkerpink_red",
    ["#FFFFFF", "#D0F0C0", "#4C99B1", "#F28D8D", "#D40000"]
)

# Dynamic color scale range
vmin = 1
vmax = round(max(pti_values) + 0.03, 2) if max(pti_values) <= 2 else round(max(pti_values) + 0.05, vmin)

# Plot with reduced horizontal scaling
plt.figure(figsize=(10, 3.5))
ax = sns.heatmap(pti_df, cmap=color_map, annot=True, fmt='%.2f', linewidths=0.5,
                  vmin=vmin, vmax=vmax, annot_kws={"size": 9}, cbar_kws={'label': 'PTI Value'})

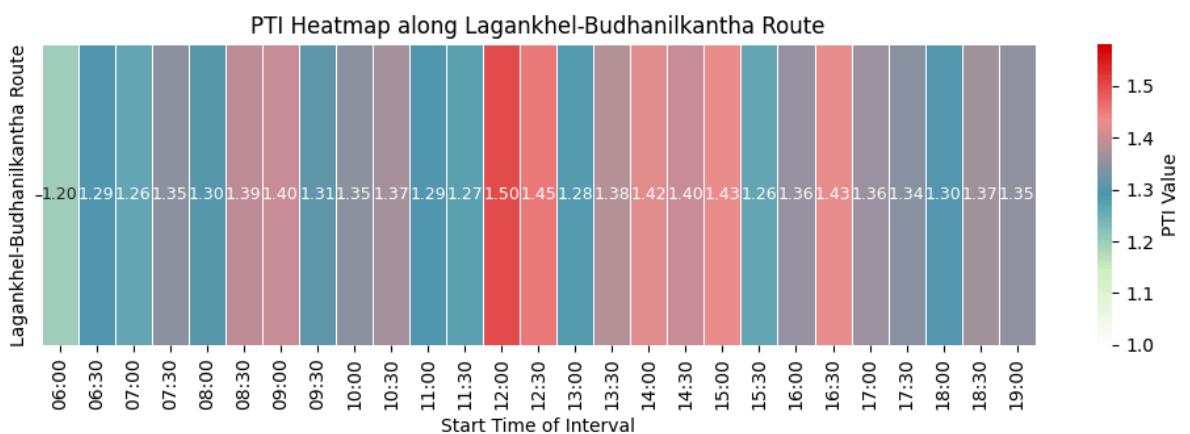
# Adjust ticks
ax.set_xticks([i + 0.5 for i in range(len(interval_labels))])
ax.set_xticklabels(interval_labels, rotation=90)
ax.set_yticklabels(["Lagankhel-Budhanilkantha Route"], rotation=90)

# Titles and layout
plt.xlabel("Start Time of Interval")
# plt.ylabel("Route", rotation=90)
plt.title("PTI Heatmap along Lagankhel-Budhanilkantha Route")
plt.tight_layout()

# Save
output_file = os.path.join(output_path, "PTI_Heatmap_Lagankhel-Budhanilkantha Route")
plt.savefig(output_file, dpi=300)
plt.show()

print("✓ PTI heatmap with start-time labels (e.g., 06:30) saved at:", output_file)

```



✓ PTI heatmap with start-time labels (e.g., 06:30) saved at: C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Datavisualization\Lagankhel-Budhanilkantha\PTI_Heatmap_Lagankhel-Budhanilkantha Route 1.png

Mean Travel Time & Planning Time Index vs Time of Day

Lagankhel → Budhanilkantha Route

All segments compared:

- Mean Travel Time (minutes)
 - Planning Time Index (PTI)
- across 30-minute intervals starting from 06:00

```
In [18]: # List of Excel file paths
file_paths = [
    r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal_analys",
    r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal_analys",
    r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal_analys",
    r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal_analys"
]

# Output directory
output_dir = r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Datavisualization\Lagankhel"
os.makedirs(output_dir, exist_ok=True)

# Dictionary to hold data
mean_travel_dict = {}
pti_dict = {}

# Define time intervals: 6:00 to 19:30 → 28 intervals at 30-min gap
start_time = datetime.strptime("06:00", "%H:%M")
intervals = [(start_time + timedelta(minutes=30 * i)).strftime('%H:%M') for i in range(28)]

# Read each file
for file_path in file_paths:
    df = pd.read_excel(file_path, header=None)

    segment_name = str(df.iloc[0, 0]).strip()

    # Mean Travel Time from B3:B30 (column 1, rows 2 to 29)
    mean_times = df.iloc[2:30, 1].replace(r'^[0-9.]', '', regex=True)
    mean_times = pd.to_numeric(mean_times, errors='coerce').fillna(0).tolist()
    mean_travel_dict[segment_name] = mean_times

    # PTI from H3:H30 (column 7, rows 2 to 29)
    pti_values = df.iloc[2:30, 7].replace(r'^[0-9.]', '', regex=True)
    pti_values = pd.to_numeric(pti_values, errors='coerce').fillna(0).tolist()
    pti_dict[segment_name] = pti_values

# Plot Mean Travel Time
plt.figure(figsize=(12, 5))
for segment, values in mean_travel_dict.items():
    plt.plot(intervals, values, marker='o', label=segment)
plt.title("Mean Travel Time vs. Time of Day")
plt.xlabel("Time of Day")
plt.ylabel("Mean Travel Time (minutes)")
plt.xticks(rotation=45)
plt.grid(True, linestyle='--', alpha=0.5)
plt.legend()
plt.tight_layout()
plt.savefig(os.path.join(output_dir, "Mean_Travel_Time_vs_Time_of_Day.png"), dpi=300)
plt.show()

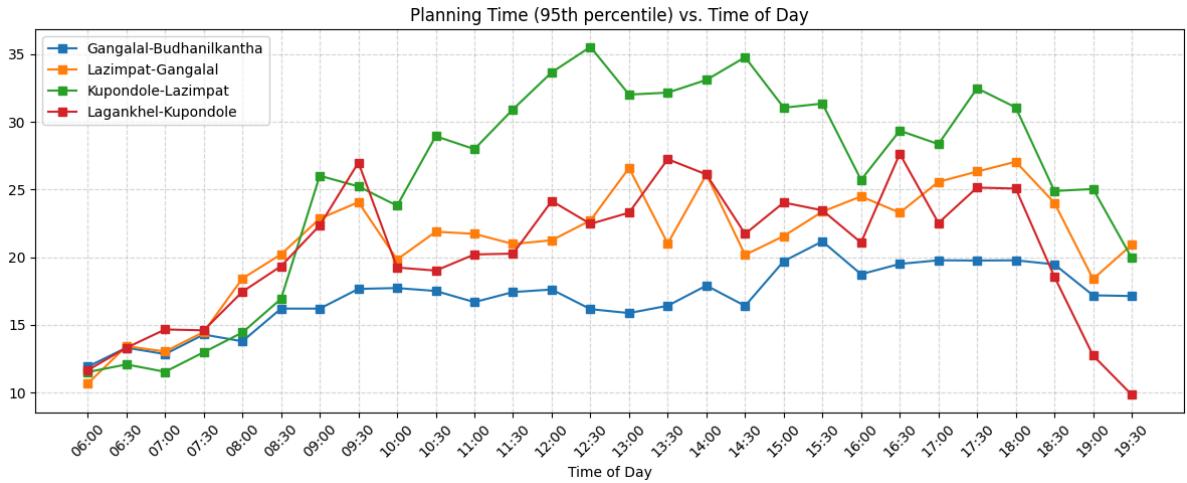
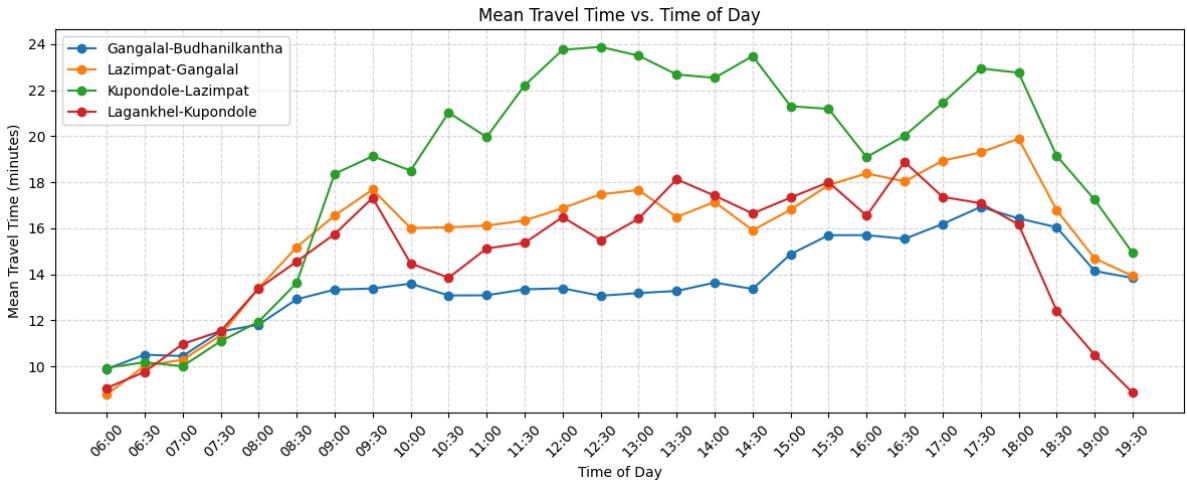
# Plot PTI
```

```

plt.figure(figsize=(12, 5))
for segment, values in pti_dict.items():
    plt.plot(intervals, values, marker='s', label=segment)
plt.title("Planning Time (95th percentile) vs. Time of Day")
plt.xlabel("Time of Day")
# plt.ylabel("PTI")
plt.xticks(rotation=45)
plt.grid(True, linestyle='--', alpha=0.5)
plt.legend()
plt.tight_layout()
plt.savefig(os.path.join(output_dir, "PTI_vs_Time.png"), dpi=300)
plt.show()

print("✅ Graphs saved successfully in:", output_dir)

```



✅ Graphs saved successfully in: C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Data visualization\Lagankhel-Budhanilkantha\Combined Graphs

Planning Time Index (PTI) Heatmap by Segment & Time of Day

Lagankhel → Budhanilkantha Route

PTI values across all segments (rows) and 30-minute intervals (columns)

Higher values (darker red) = greater travel time variability

```

In [19]: # List of Excel file paths
# List of Excel file paths
file_paths = [
    r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal_analys
    r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal_analys

```

```

r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal_analys
r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Dataextraction\6.PTI_temporal_analys
]

# Initialize an empty dictionary to store PTI values
pti_data = {}

# Read data from each file
for file in file_paths:
    df = pd.read_excel(file, header=None)
    segment_name = str(df.iloc[0, 0]).strip()
    pti_values = df.iloc[2:30, 8]
    pti_values_cleaned = pti_values.replace(r'^[0-9.]', '', regex=True)
    pti_values = pd.to_numeric(pti_values_cleaned, errors='coerce')
    pti_data[segment_name] = pti_values

# Convert to DataFrame and assign time intervals
pti_df = pd.DataFrame(pti_data)
time_intervals = [f"{hour}:{minute:02d}" for hour in range(7, 21) for minute in [0,
pti_df.index = time_intervals
pti_df = pti_df.fillna(0)

#  Custom colormap: white → Light green → blue → dark pink → dark red
custom_cmap = LinearSegmentedColormap.from_list(
    "white_lightgreen_blue_darkerpink_red",
    ["#FFFFFF", "#D0F0C0", "#4C99B1", "#F28D8D", "#D40000"]
)

# Define vmin/vmax for consistency in color scale
vmin = 1
vmax = round(np.nanmax(pti_df.values) + 0.05, 2) if np.nanmax(pti_df.values) <= 2 else
vmax = max(vmax + 0.05, vmin)

# Plot heatmap with consistent color scale and colorbar ticks like 1.1, 1.2, ...
plt.figure(figsize=(12, 6))
ax = sns.heatmap(pti_df.T, cmap=custom_cmap, annot=True, fmt='.2f', linewidths=0.5,
                  vmin=vmin, vmax=vmax, annot_kws={"size": 9}, cbar_kws={'label': 'PTI Value'})

# Set manual ticks for colorbar
tick_interval = 0.2
ticks = np.round(np.arange(vmin, vmax, tick_interval), 1)
colorbar = ax.collections[0].colorbar
colorbar.set_ticks(ticks)
colorbar.set_ticklabels([f"{tick:.1f}" for tick in ticks])

# Labels and titles
plt.xlabel("Time Interval")
plt.ylabel("Segment")
plt.title("PTI Heatmap for Segments along Lagankhel-Budhanlkantha Route")
plt.xticks(rotation=45)
plt.yticks(rotation=0)
plt.tight_layout()

#  Save the figure as PNG
output_path = r"C:\Users\ACER\Desktop\PROJECT-FINAL YEAR\Datavisualization\Lagankhel-Budhanlkantha Route\Heatmap.png"
plt.savefig(output_path, dpi=300)

plt.show()

```

