# Shade-Optimized Pedestrian Routing to Transit

University, City
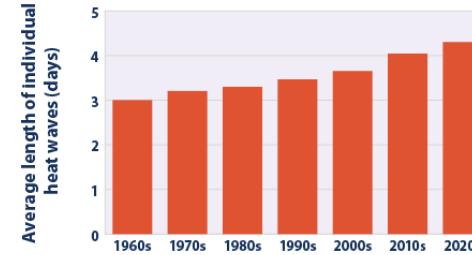
Kavana Raju

Heat Wave Characteristics in the United States by Decade, 1961–2023
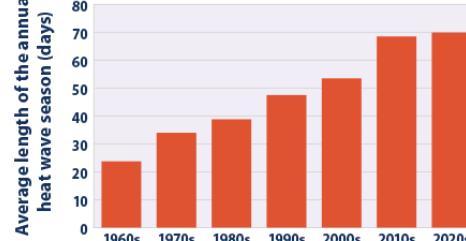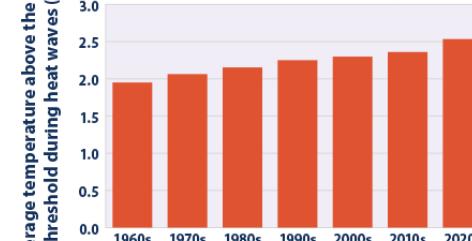
Source: United States Environmental Protection Agency
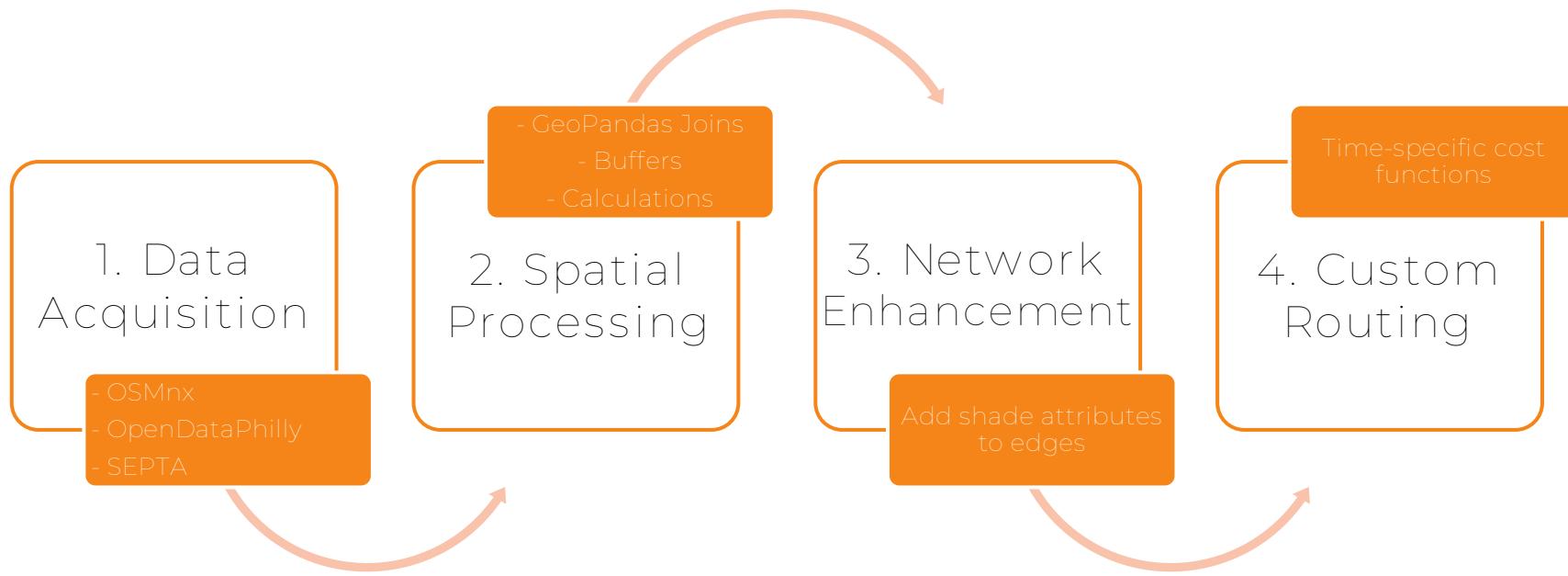
Would you walk 5 minutes longer for shade?

Research Questions

1. How much longer are people willing to walk for shade?

2. How do optimal routes change by time of day?

3. How do seasonal patterns affect route recommendations?

Methodology

1. Data Acquisition
- OSMnx
- OpenDataPhilly
- SEPTA

2. Spatial Processing
- GeoPandas Joins
- Buffers
- Calculations

3. Network Enhancement
Add shade attributes to edges

4. Custom Routing
Time-specific cost functions

Result : Dynamic network with time-varying attributes
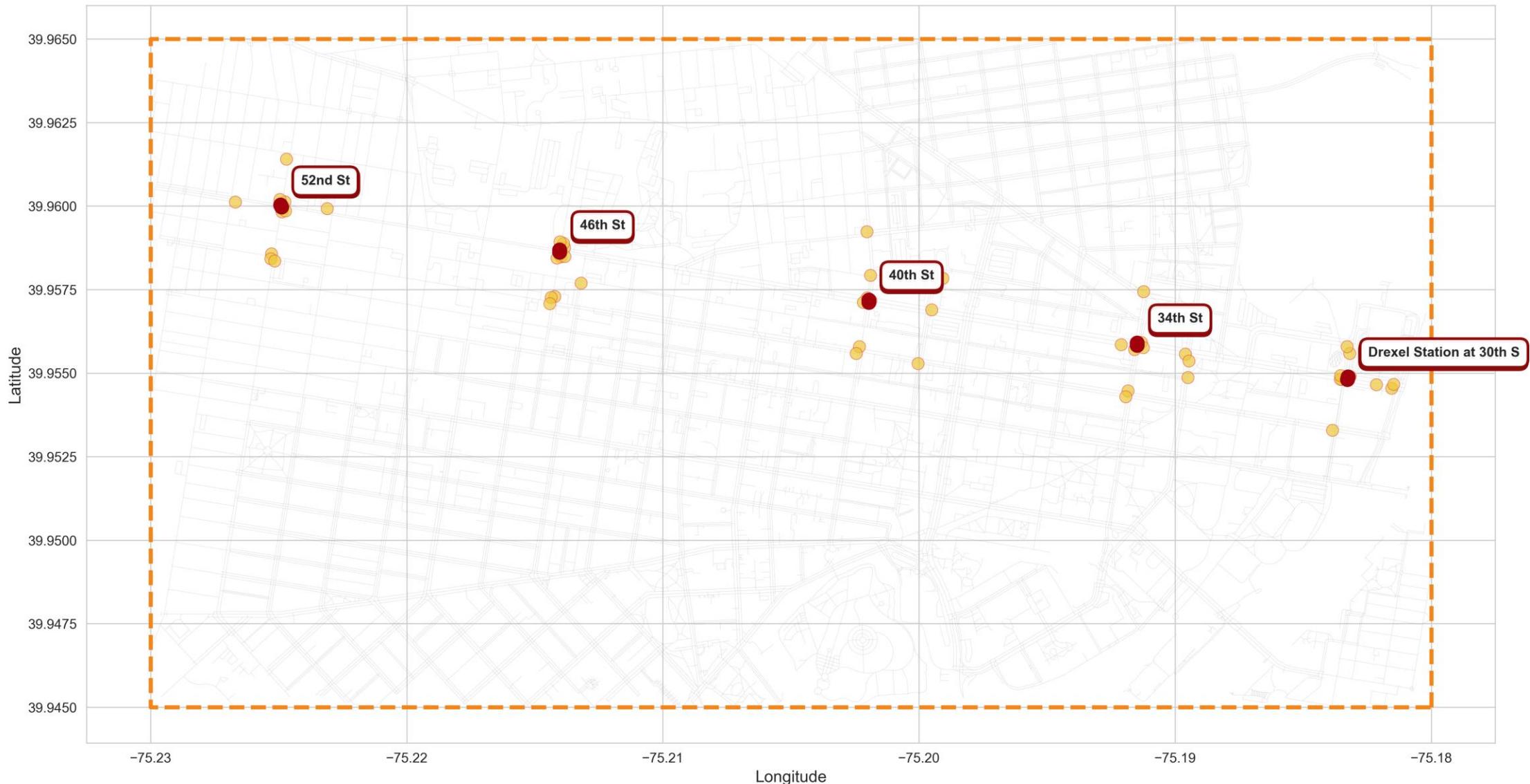
Data Sources

Data	Source	Details
Building Heights	OpenDataPhilly	LiDAR-derived
Tree Canopy	OpenDataPhilly	0.5m resolution
Street Network	OpenStreetMap	Walk-accessible paths
Transit Stops	SEPTA	Locations

Study Area

SEPTA Transit Stops - University City
Major Stations + Connecting Bus Stops (60 total)

Legend:
- Study Area
- Major Transit (10)
- Connecting Bus (50)

Labels on map: 52nd St, 46th St, 40th St, 34th St, Drexel Station at 30th S

Longitude axis: −75.23, −75.22, −75.21, −75.20, −75.19, −75.18
Latitude axis: 39.9450, 39.9475, 39.9500, 39.9525, 39.9550, 39.9575, 39.9600, 39.9625, 39.9650
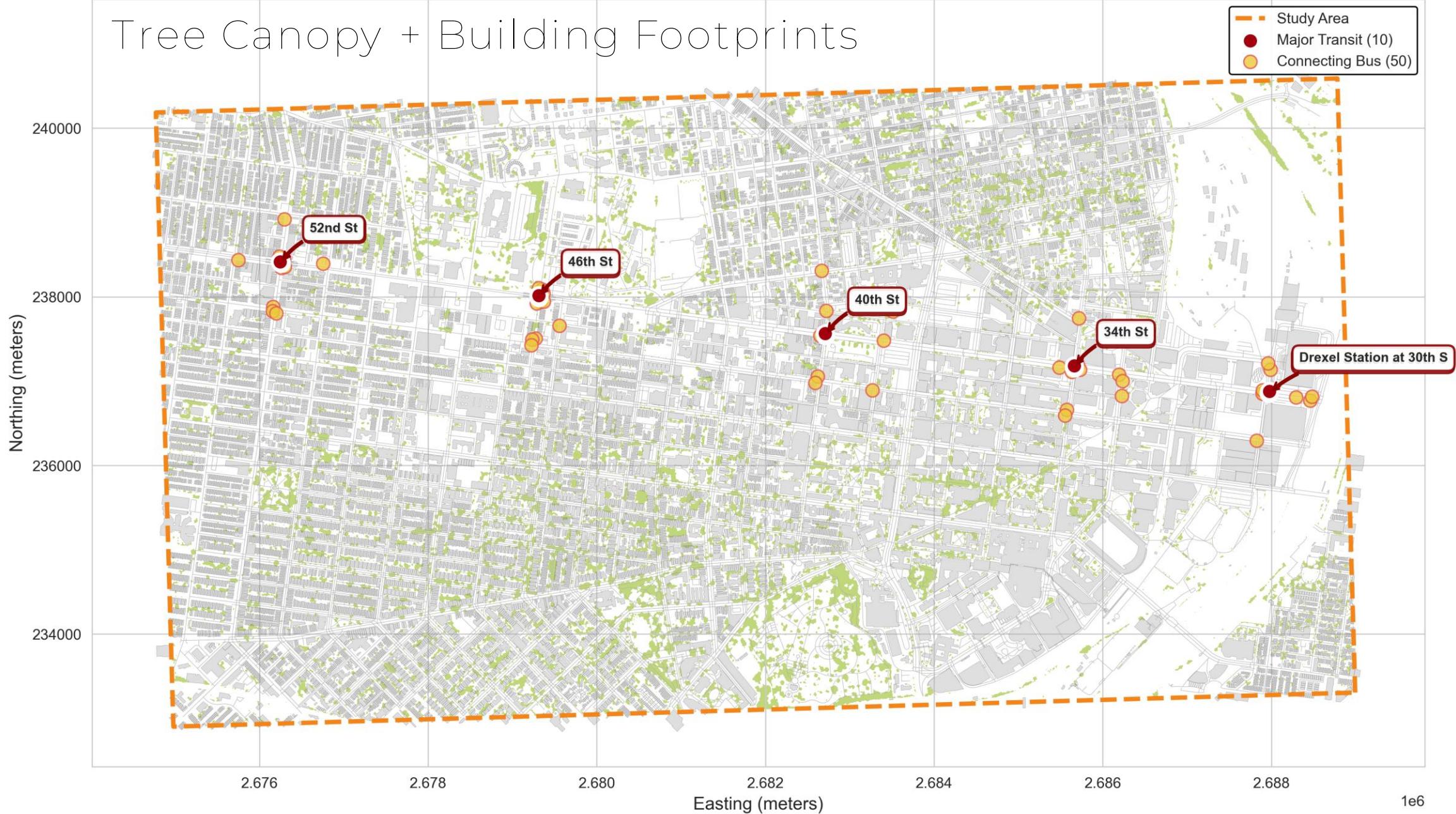
Area : 3.2 sq km   23,486 Street Segments   16,635 Buildings   5 major SEPTA stations

Tree Canopy + Building Footprints

Multi-Scenario Analysis

	Morning	Midday	Evening
Summer	8 am	12pm	5 pm
Winter	8 am	12pm	5 pm
Spring	-	12pm	-
Fall	-	12pm	-

8 sets of network attributes
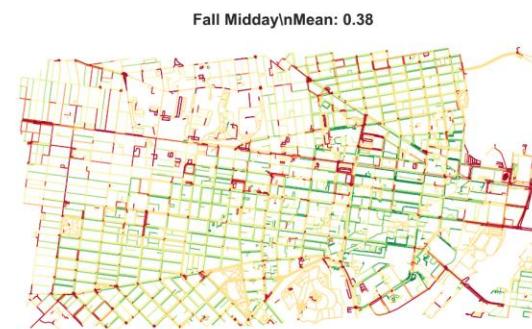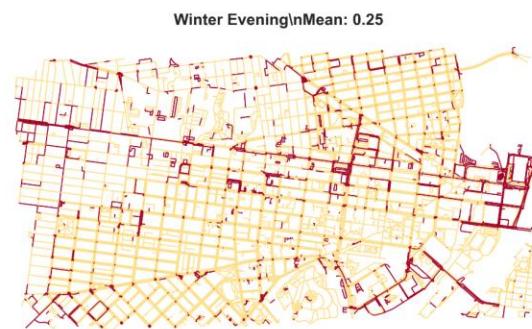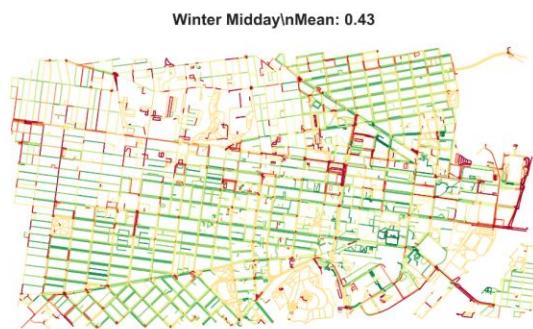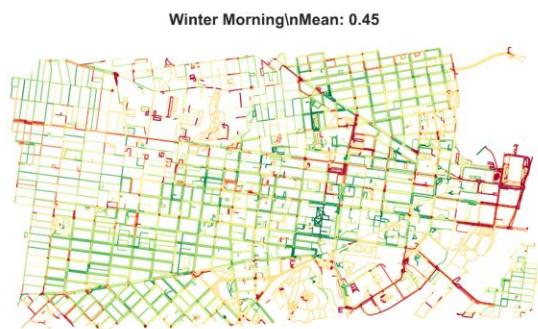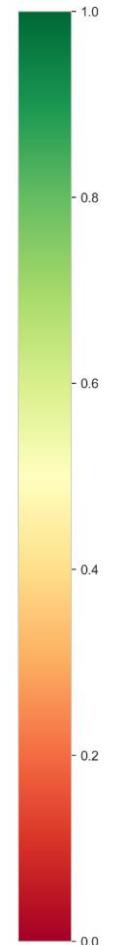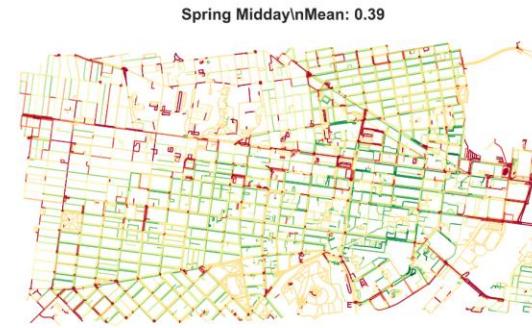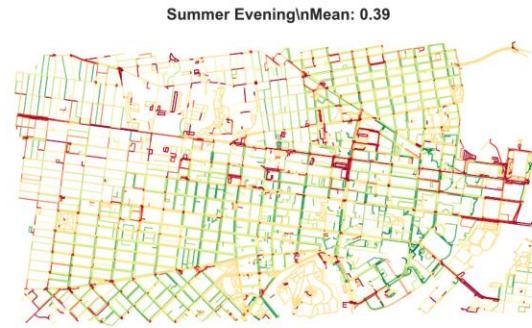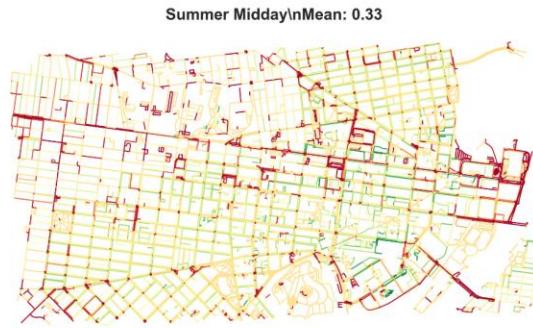
Purpose: Capture time-of-day and seasonal variation

Spatial Integration and Cost Function
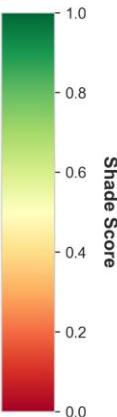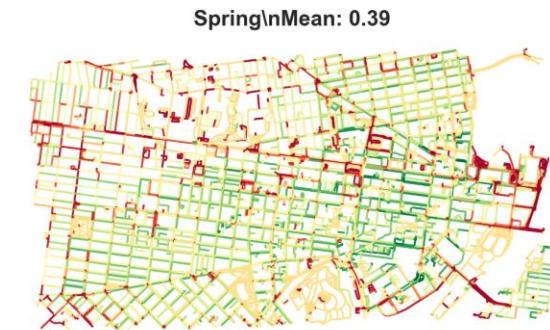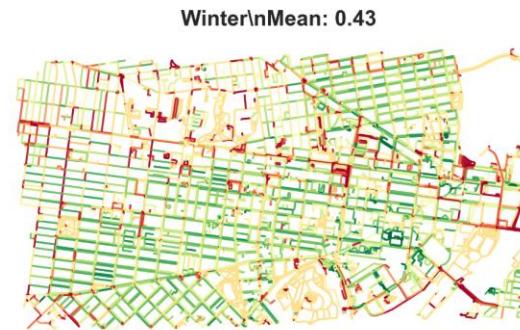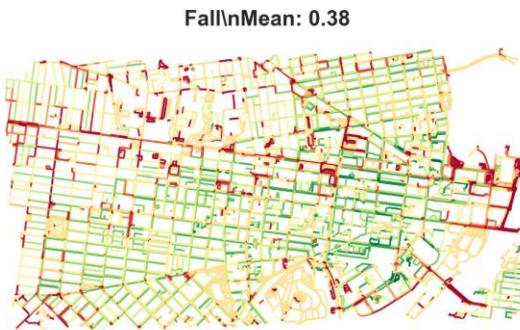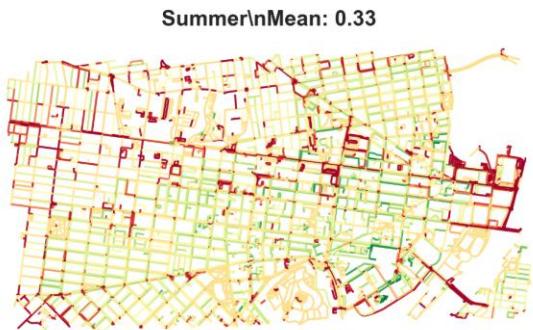
Combined Shade Score = 0.4 × Tree + 0.6 × Building Shadow
Walking Cost = Length × (1 - 0.3 × Shade)
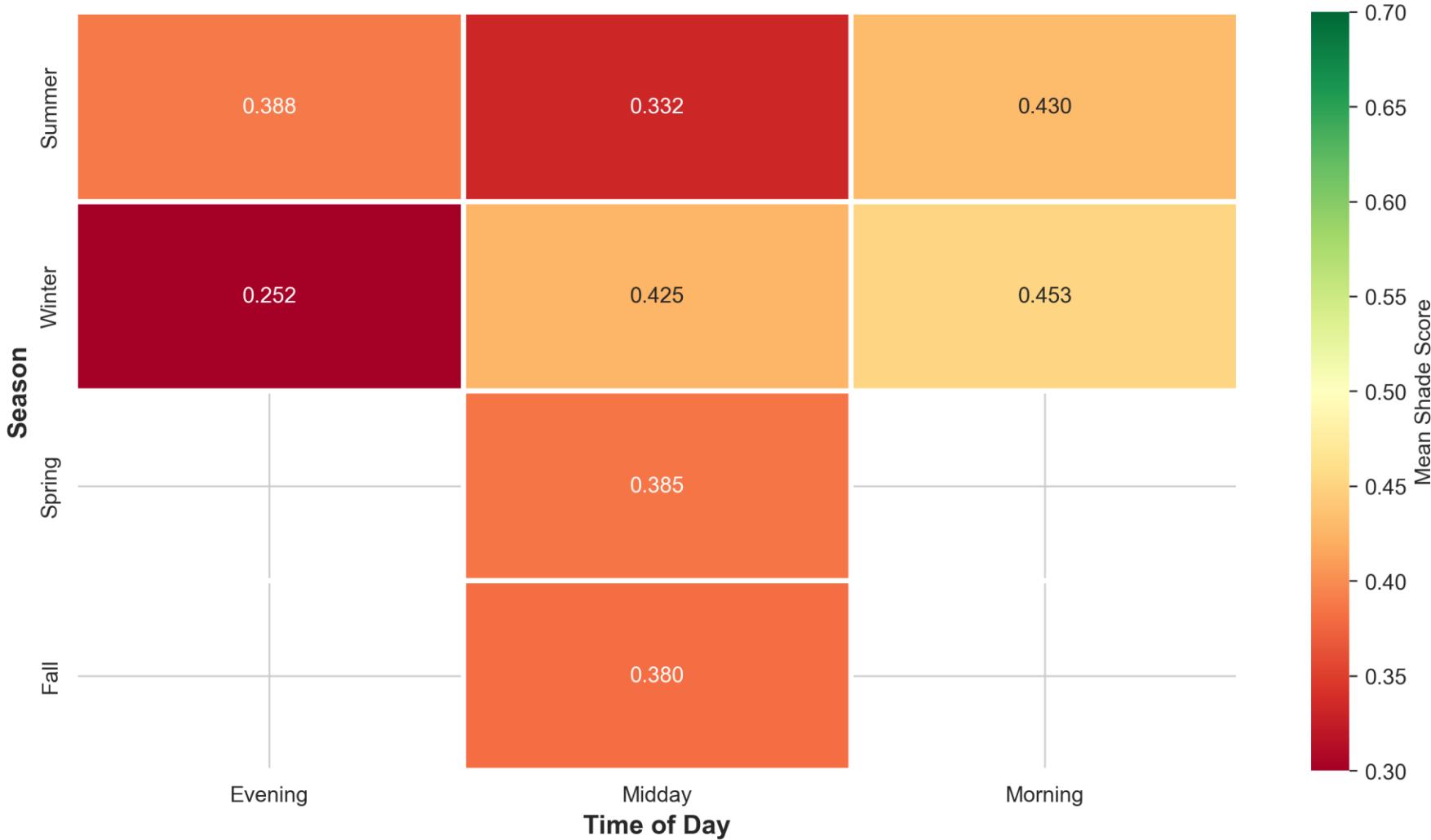
Network Coverage – All Scenarios

Seasonal Comparison - Midday

Summer\nMean: 0.33

Fall\nMean: 0.38

Winter\nMean: 0.43

Spring\nMean: 0.39

Shade Score

Shade Score Heatmap

	Evening	Midday	Morning
Summer	0.388	0.332	0.430
Winter	0.252	0.425	0.453
Spring		0.385	
Fall		0.380	

Time of Day

Season

Mean Shade Score

Shade Statistics

Scenario	Mean	Median	Std Dev	High Shade %
Summer Morning	0.43	0.433	0.262	16.00%
Summer Midday	0.332	0.4	0.226	3.00%
Summer Evening	0.388	0.405	0.246	9.30%
Winter Morning	0.453	0.453	0.268	18.50%
Winter Midday	0.425	0.428	0.262	15.40%
Winter Evening	0.252	0.4	0.193	0.00%
Spring Midday	0.385	0.408	0.251	9.60%
Fall Midday	0.38	0.405	0.249	9.20%

Results: Trade-Off Analysis

Three example routes:
Penn to 40th St
- Detour: +95m (12%)
- Shade: +38%
- Efficiency: **3.2 HIGH**

Drexel to 34th St
- Detour: +45m (8%)
- Shade: +28%
- Efficiency: **3.5 HIGH**
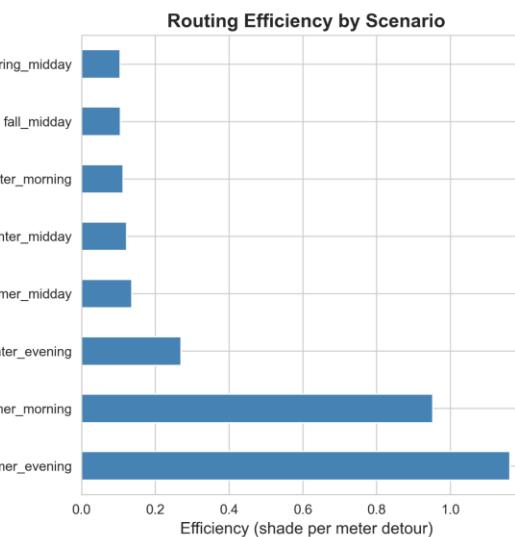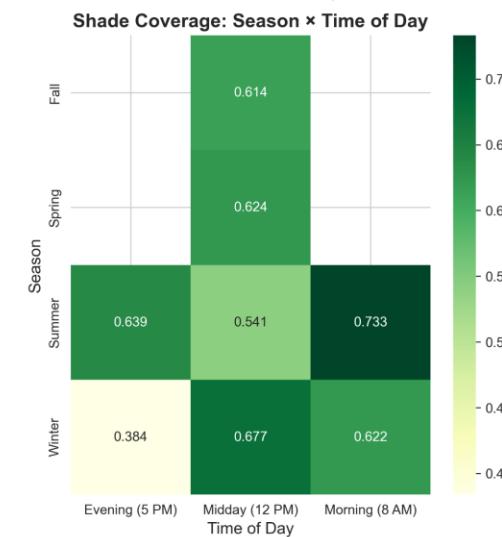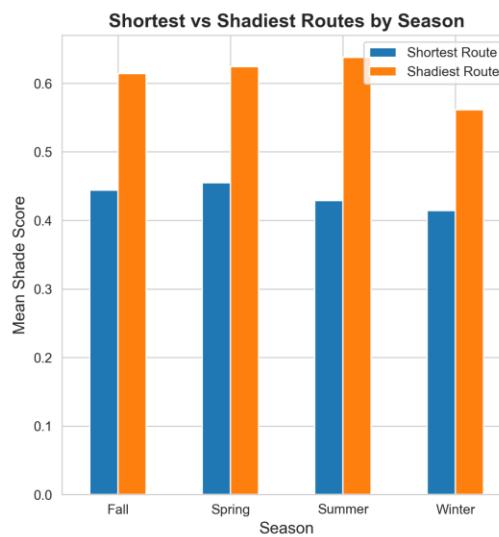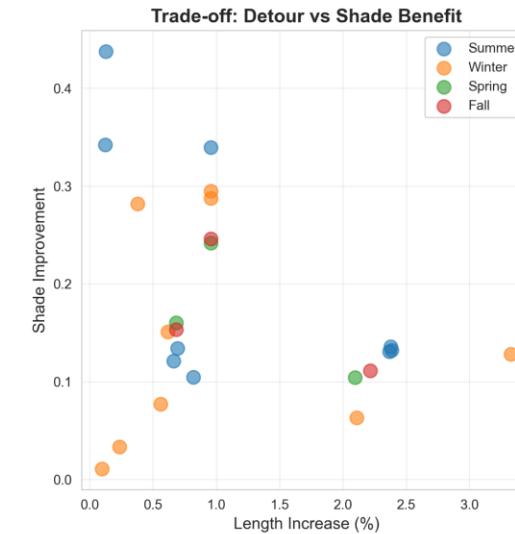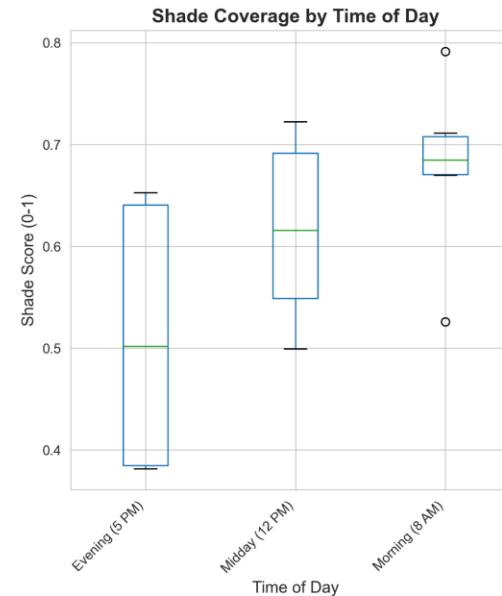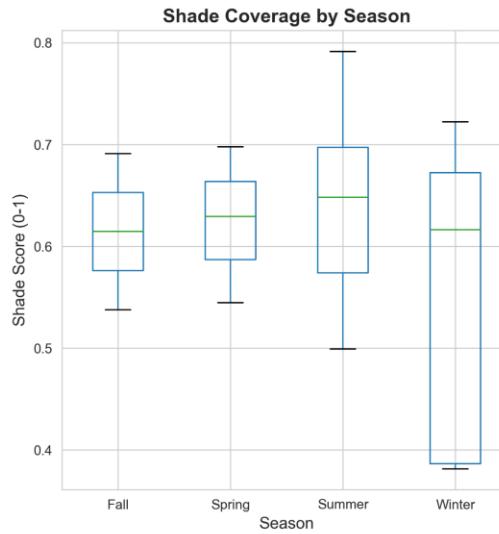
Clark Park to 46th St
- Detour: +185m (15%)
- Shade: +42%
- Efficiency: **2.8 MODERATE**

**Key Insight:** Most routes offer 25-40% shade gain for 8-15% detour
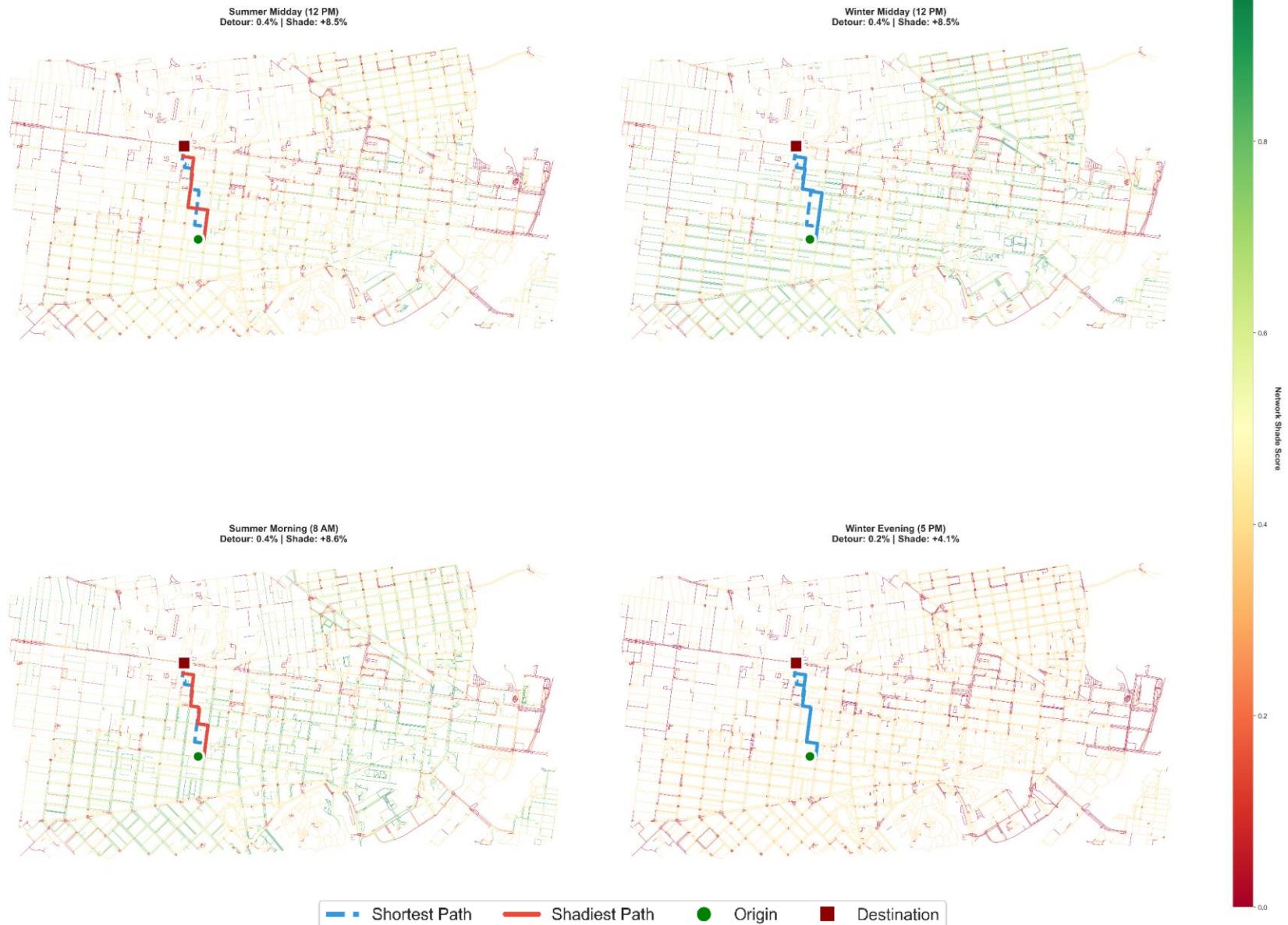
Best and Worst Scenarios

| Type	Route	Scenario	Shade Score	Shade Gain	Detour %
BEST	Drexel to 34th St	summer_evening	0.652383757	0.437485294	0.12795336
BEST	Drexel to 34th St	summer_morning	0.791394018	0.3419060	0.122737036
BEST	Drexel to 34th St	summer_midday	0.498926086	0.339188094	0.958269408
BEST	Drexel to 34th St	winter_midday	0.692427031	0.294503159	0.958269408
BEST	Drexel to 34th St	winter_morning	0.52564398	0.28733227	0.958269408
WORST	Penn to 40th St	winter_evening	0.386324375	0.010785089	0.096902299
WORST	Clark Park to 46th St	winter_evening	0.381281128	0.033394776	0.235378999
WORST	Penn to 40th St	winter_morning	0.672236878	0.063008448	2.10946062
WORST	Clark Park to 46th St	winter_morning	0.669605999	0.076871612	0.559754358
WORST	Penn to 40th St	spring_midday	0.697681947	0.104093457	2.096044773
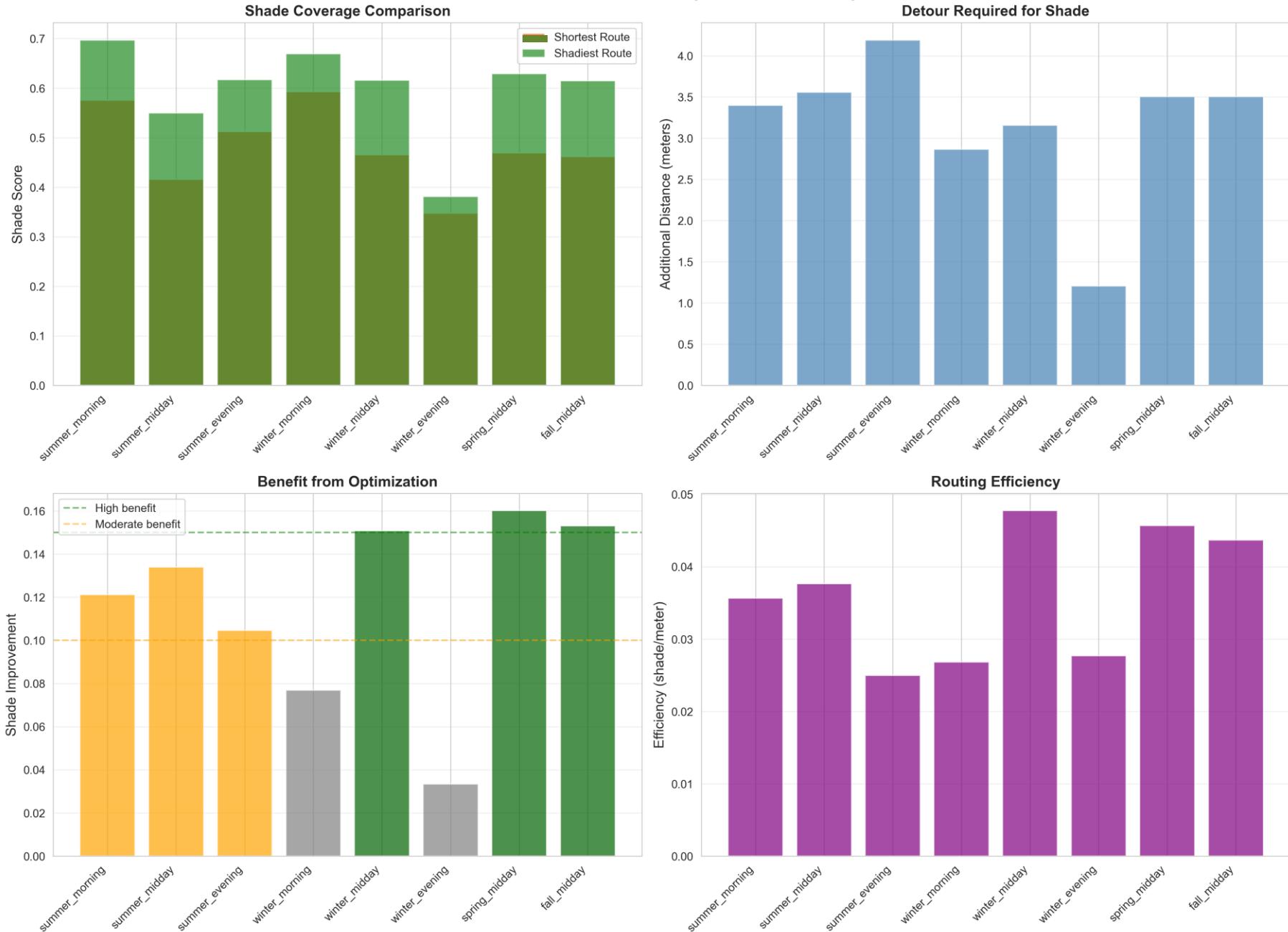
Time of Day: Comparative Analysis

Clark Park to 46th St Station

Summer Midday (12 PM)
Detour: 0.4% | Shade: +8.5%

Winter Midday (12 PM)
Detour: 0.4% | Shade: +8.5%

Summer Morning (8 AM)
Detour: 0.4% | Shade: +8.6%

Winter Evening (5 PM)
Detour: 0.2% | Shade: +4.1%

Network Shade Score

- - - Shortest Path —— Shadiest Path ● Origin ■ Destination

Clark Park to 46th St: Time-of-Day & Seasonal Analysis

Shade Coverage Comparison

Detour Required for Shade

Benefit from Optimization

Routing Efficiency

Limitations and Next Steps

- Binary tree canopy data
- Computational intensity
- Single comfort factor focus

Future Enhancements
- Additional environmental factors
- Real-time API development
- Mobile interface
- Seasonal tree modeling
- User preference controls

Thank you!