Understanding Pedestrian Route Choices: Looking for the Path Forward

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ITE: Hawaii Section
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Speaker Information

- **Education**
  - Ph.D., University of Maryland, College Park
  - MS, BS, University of Texas at Austin

- **Research Interests**
  - Contexts
    - Travel Behavior Analysis and Demand Forecasting
    - Interactive Experiments (Lab/Field/Product Demonstrations/Virtual)
  - Methodologies
    - Econometric and Data Analysis
    - Network Modeling and Analysis
    - Simulation Approaches

- **Teaching**
  - CEE 490 – Senior Design Project
  - CEE 464 – Urban and Regional Transportation Planning
  - CEE 270 – Engineering Mechanics I: Statics
  - CEE 664 – Advanced Transportation Modeling and Statistics
  - CEE 696 – Smart Cities

Introduction and Context

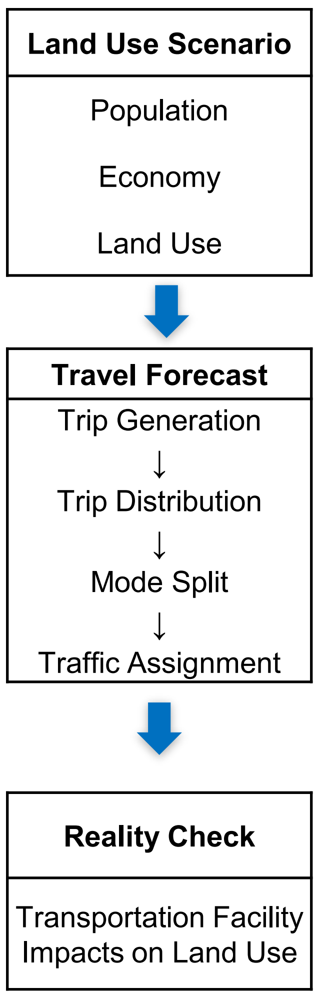
- Walking and Biking Infrastructure in the News
  - *Sensors to Count Pedestrians, Cyclists On Oahu Routes* – Star-Advertiser (12/9/2022)
  - *Protected Bicycle Lanes open on Ward Avenue* – Star Advertiser (8/31/2021)
  - *Work at Hawaii Kai intersection scheduled for bike improvements* – Star (4/3/2023)

- Recent Infrastructure Projects
  - Pensacola Bike Lane
  - Ala Pono Bridge
  - Skyline Transit Stations

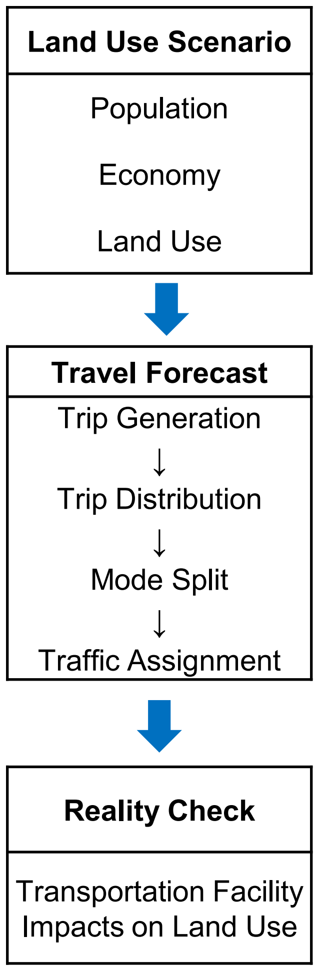
- Statewide Master Plans
  - Pedestrian
  - Bicycle

Transportation Scenario Planning and Analysis for emerging mobility contexts requires information on **who (household)** uses them, **when** they are used, **where** they go and **how** they are used

Travel Demand Analysis – Four Step Model for Forecasting



Travel Demand Analysis – Four Step Model for Forecasting



- Trip Generation - *How many trips will there be?*
- Trip Distribution – *Where will there be trips?*
- Mode Split – *What* ***travel modes*** *will be used?*
- Traffic Assignment – *What* ***routes*** *will be used (and at what time…)?*

Travel Demand Analysis – Four Step Model for Forecasting

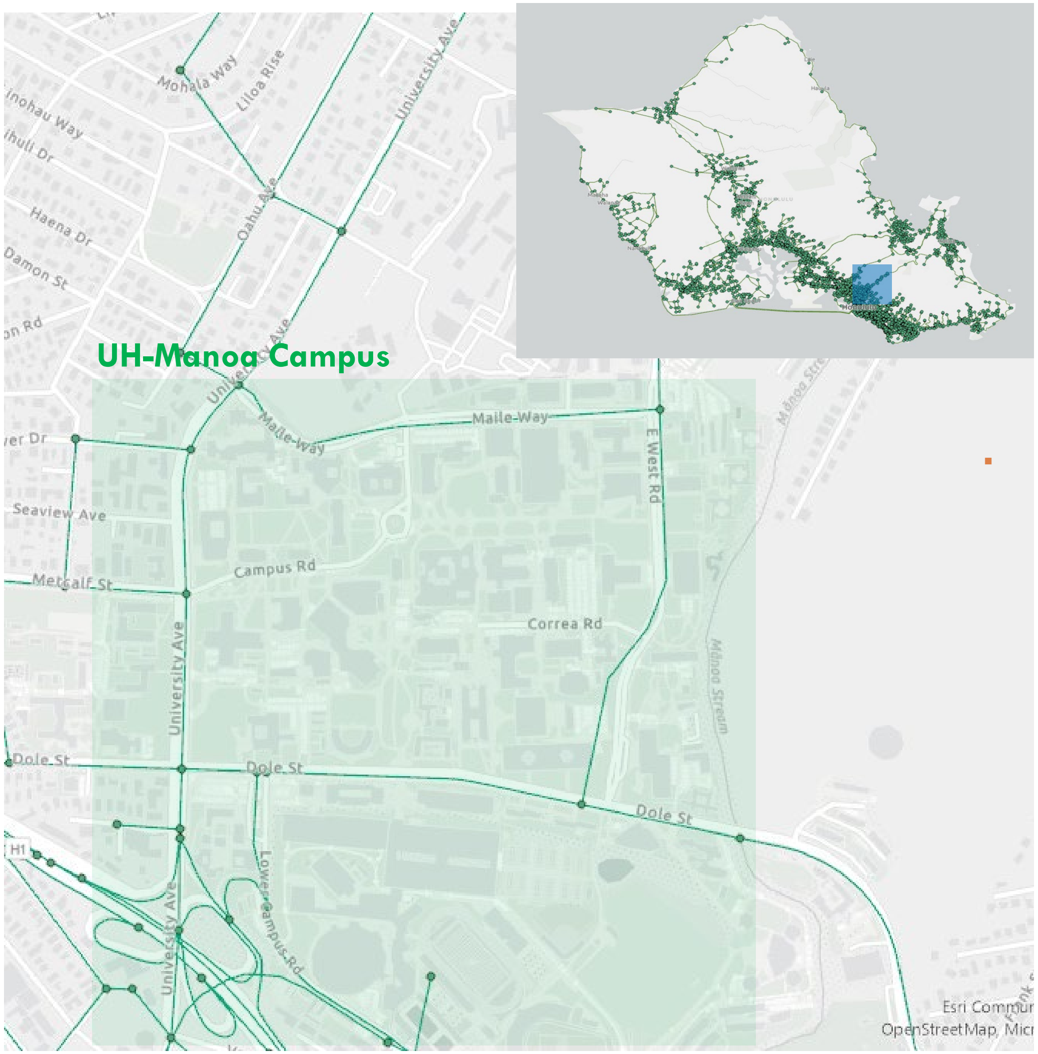
Oahu Network:
820 Nodes
5,000 Links

3,000 trips daily Chinatown/Downtown to UH

2,500 (auto); 400 (bus); **100 (Bike)**

80 (Route 1); 20 (Route 2)

TDFM Network for Active Travel Analysis



Oahu Travel Demand Forecasting Model (TDFM)

- Used by DTS, OMPO, HDOT:
  - **Evaluate Scenarios**
    - New Mobility Services
    - Demographic Shifts
  - **Measure Externalities:**
    - GHG Emissions/Fuel Consumption
    - Health Outcomes

Issues/Problems for Active Travel

- **Incomplete Representation**
  - Network Topology (**Multi-Resolution**)
  - Behavioral and Traffic Flow Modeling
- **Lack** of Consistent Traffic Data
- "Mixed Traffic Flow" **Poorly Understood**
- Multi-Modal Trips only **Implicitly Considered**

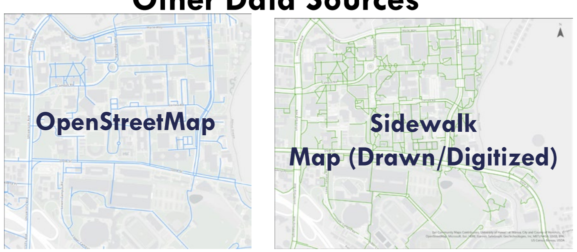
Analysis Framework

Community Contributions

Network Updating Process

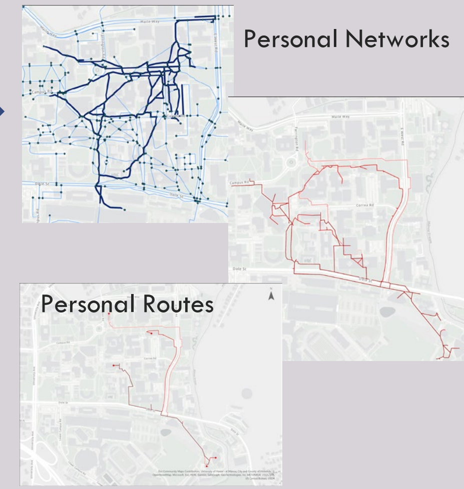
Community Contributions (**GPS Points, Drawings, Health Trackers –** *Strava/Garmin/Fitbit*, **etc.**) + Other Data (**OSM, etc.**)

Other Data Sources



Updated Estimated Network

Traveler **Routes (Paths)** and **Networks**: Behavioral Modeling

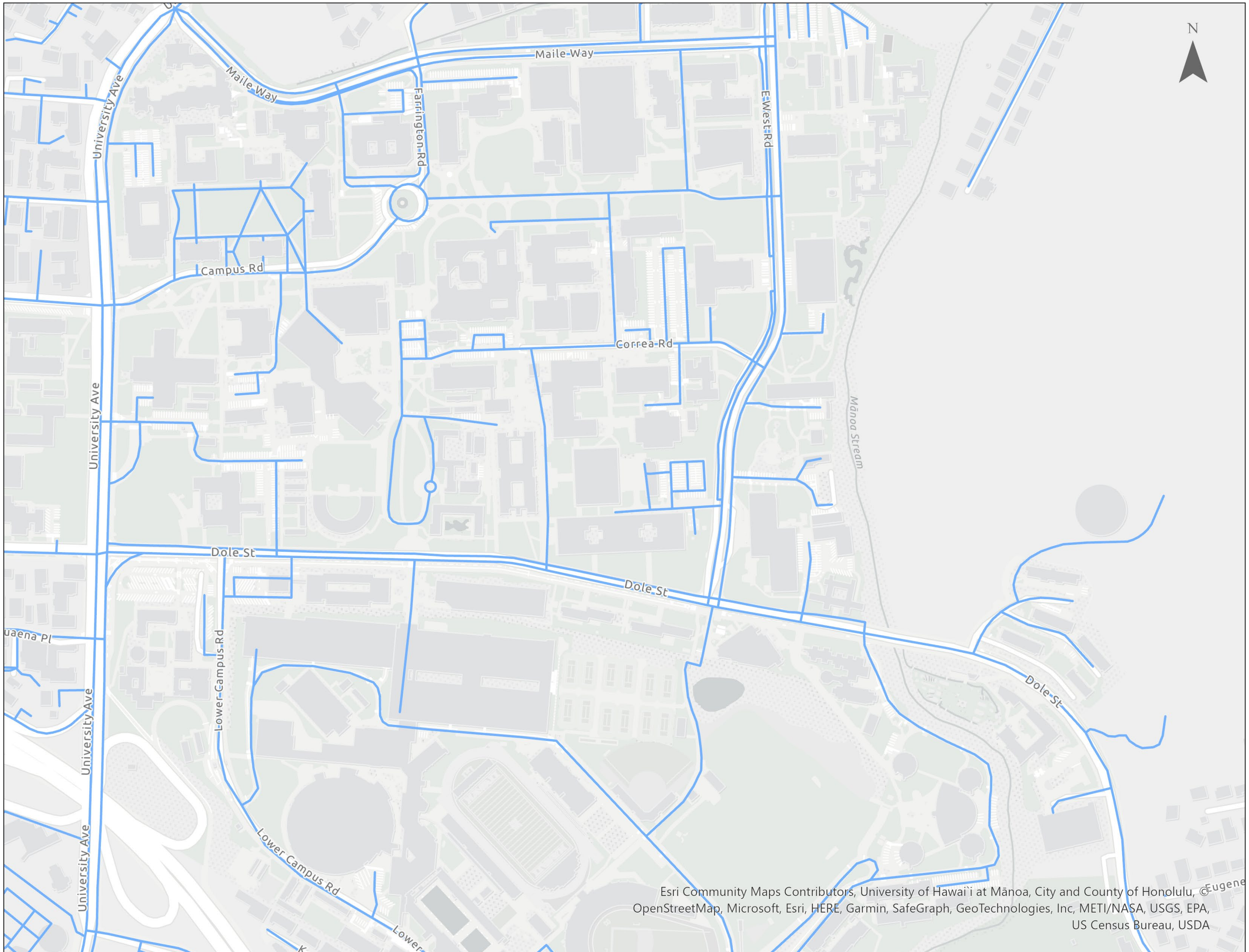


Web Interface (Open Routes):
https://manoa.hawaii.edu/openroutes/main.html

Scenario Analysis: **Network Modeling and Traffic Analysis**

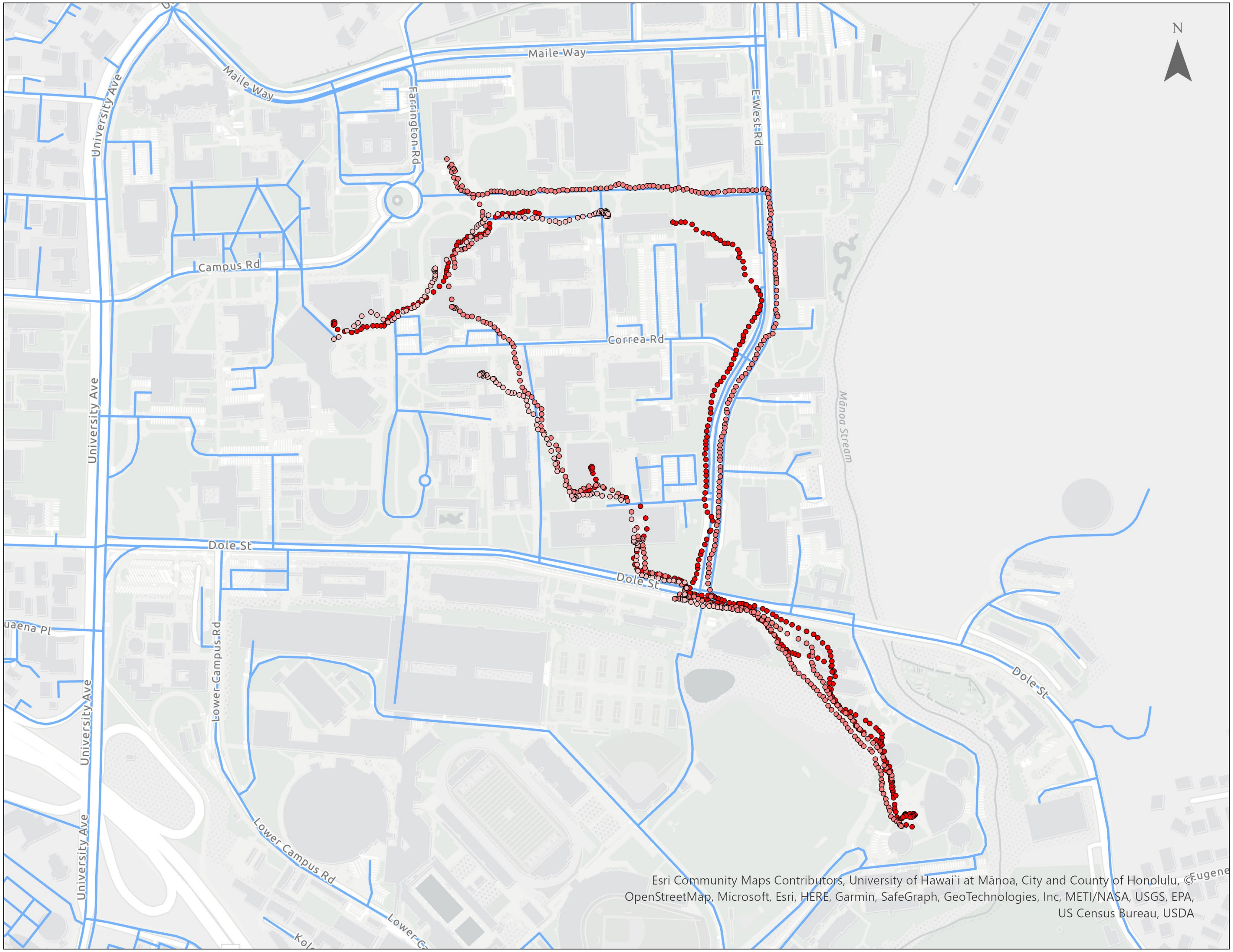
- Infrastructure Projects
- Operational Improvements
- Community Evacuations
- Planned Traffic Disruptions
- Other Scenarios

Open Street Maps (https://www.openstreetmap.org)



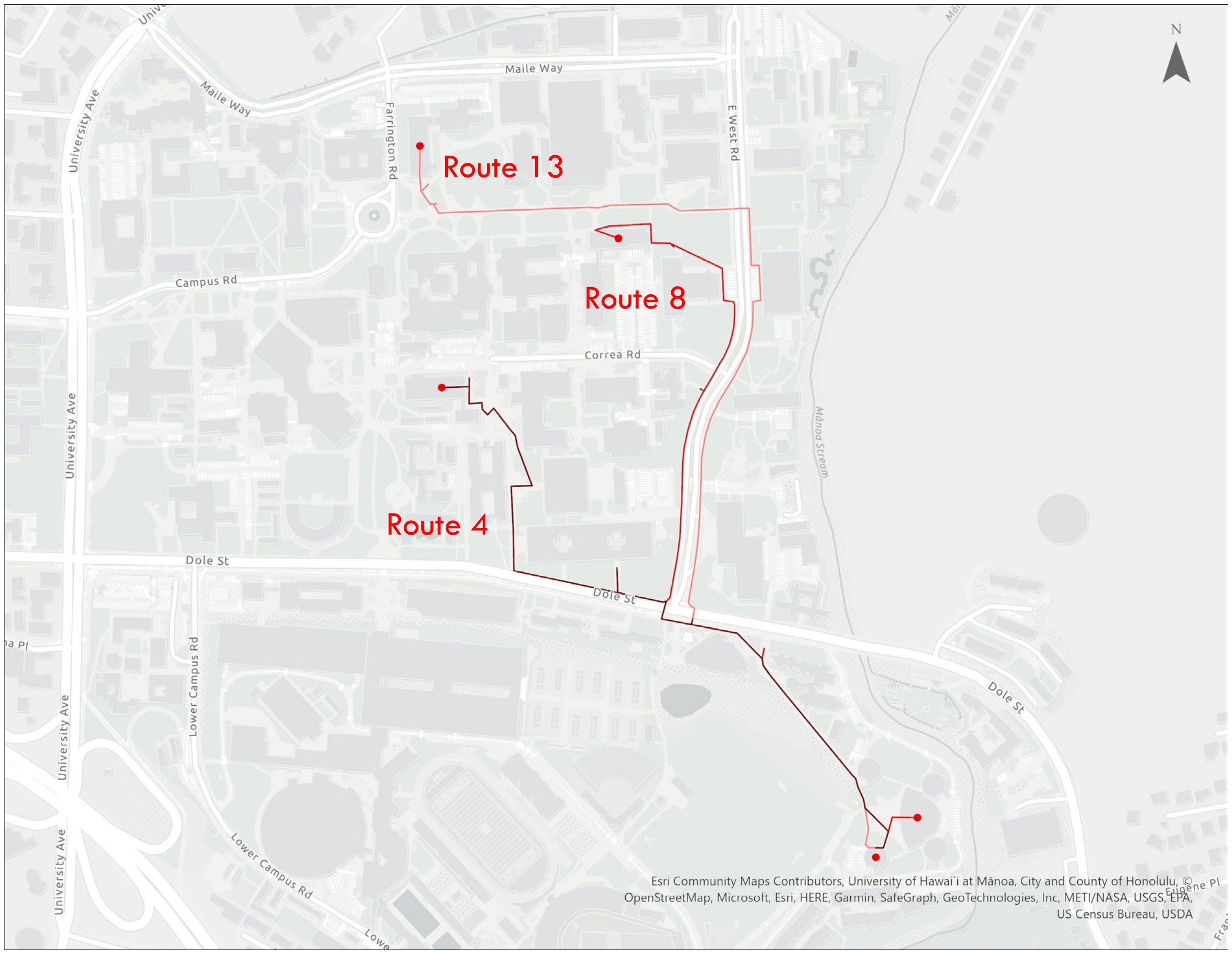
Person A - GPS Points: 1 Day

Person A - GPS Points: 3 Day



Person A - GPS Points: 5 Day

Person A - Route 4, Route 8 and Route 13



Timeframe: 10/12/22-10/18/22

Number of Points: **2,774**

Number of Walking Trips: **16**

Route 4: **Hale Aloha (Dorm)** to **Kuykendall Hall**

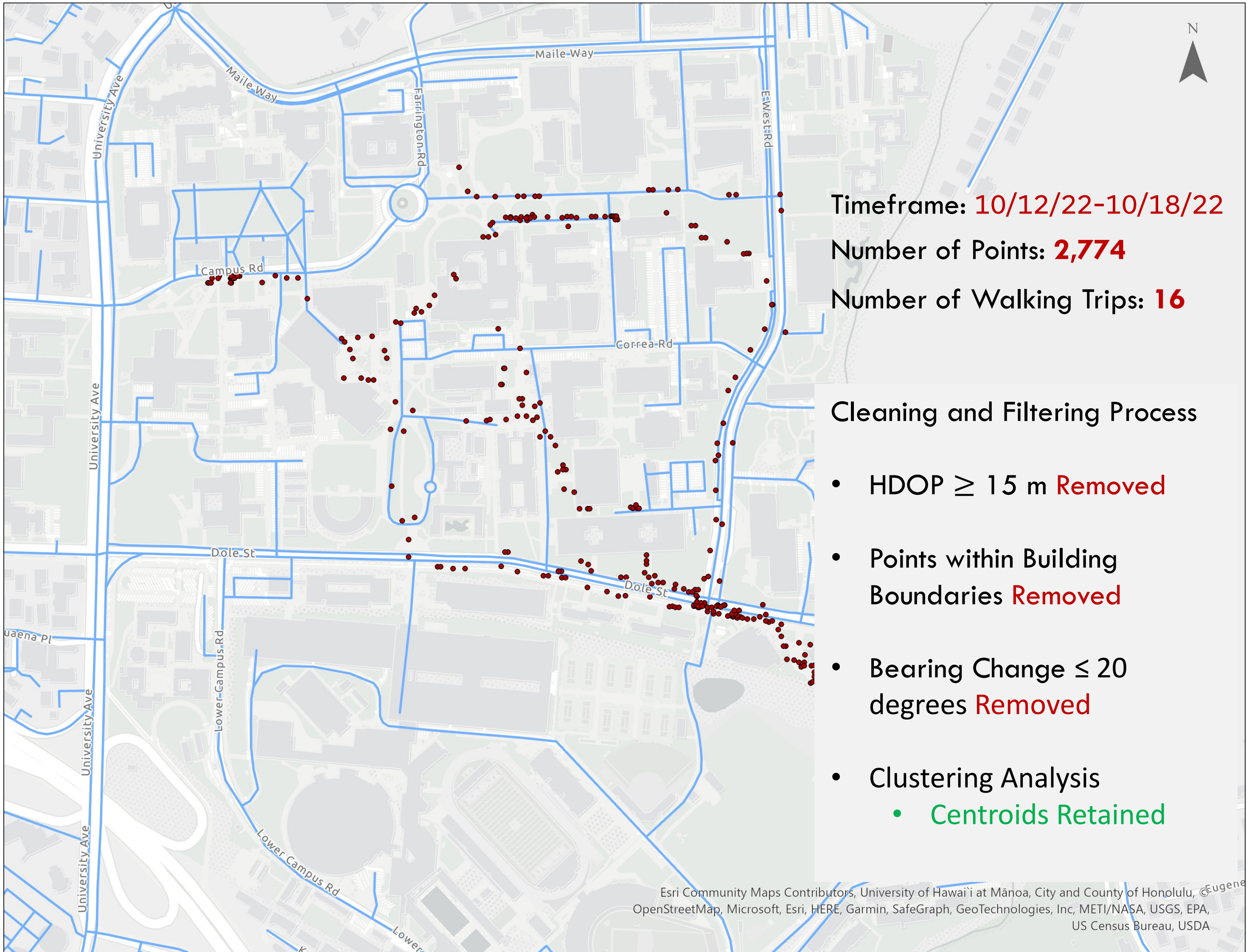
Route 8: **Keller Hall** to **Hale Aloha (Cafeteria)**

Route 13: **Webster Hall** to **Hale Aloha (Dorm)**

"I prefer direct paths…"

"I want to avoid people (in general)…"

Person A - GPS Points: 5 Day – Cleaned for Errors



Timeframe: 10/12/22-10/18/22

Number of Points: **2,774**

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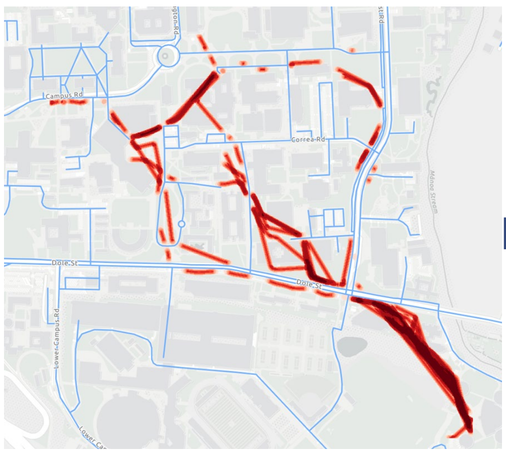
Cleaning and Filtering Process

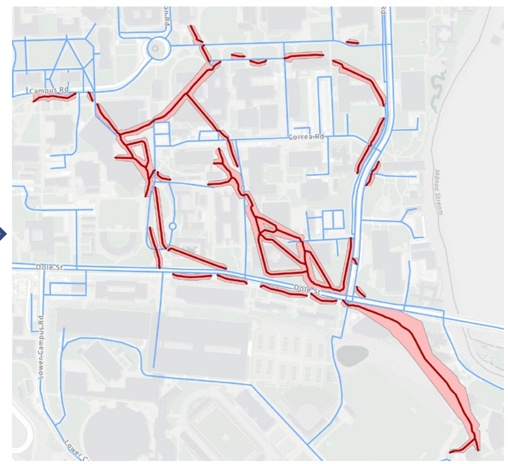
- HDOP ≥ 15 m Removed
- Points within Building Boundaries Removed
- Bearing Change ≤ 20 degrees Removed
- Clustering Analysis
  - Centroids Retained

Network Construction

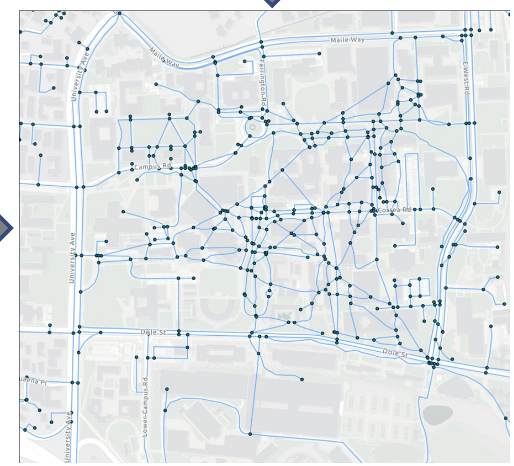
Geocoded POI's (Building Entrances, Outdoor Sitting Areas, etc…)



1) **Estimate Line Density**: Over Observed Trajectories from GPS



2) **Determine Threshold** and **Draw Centerlines** ("best" estimate of **routes/network**)



3) **Update Network** with NEW Observed Network

Data Collection

- Timeframe: **4/10/23-4/24/23 (only weekdays)**

- GPS Trace Data Collection
  - All Days
  - Smartphone App – GPS Point Logger (free)
  - Honolulu Metro Area (Kakaako, etc.)
  - **53** participants started data collection

- Final Analysis Sample Characteristics
  - N=**16**, Routes (Walking) = **298** (~2 trips per person per day)
  - Gender: Females **6;** Males **10**
  - Field: Engineering **13;** Kinesiology **2;** Public Health **1**
  - Class: Freshman: **5;** Sophomore **1;** Juniors **2;** Seniors **6;** Graduate **2**
  - Only Trips within the UH Campus Study Area

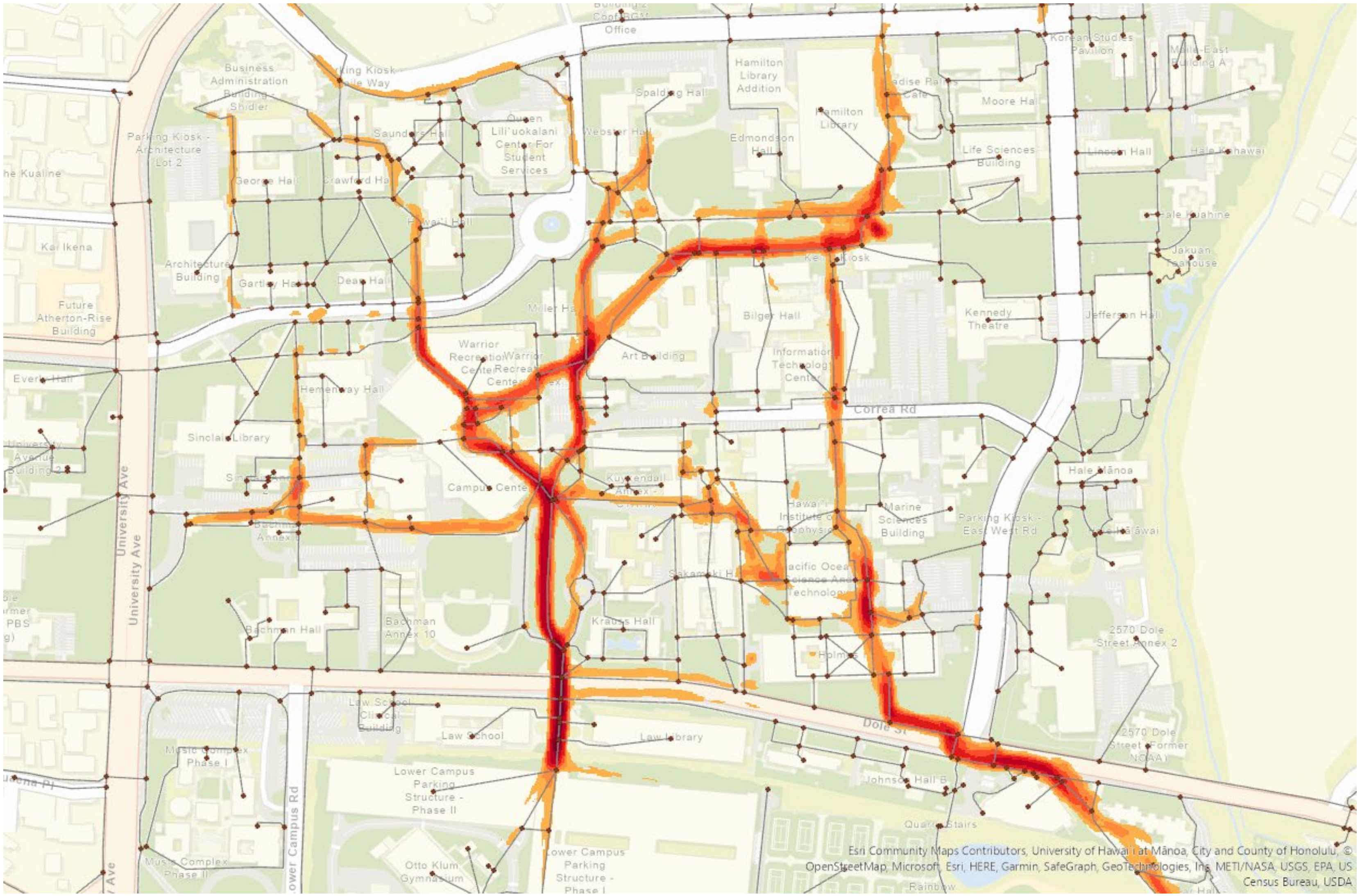
Link Attributes

- Travel Distance – distance of each link determined in GIS

- From Field Observation and a *Preliminary Walking Audit*
  - Sidewalk/Paved Walkway
  - Grass Surface
  - Parking Lot
  - Quadrangle: a space or a courtyard, usually rectangular in plan, the sides of which are entirely or mainly occupied by parts buildings (Fleming et al. 2000)

- From External Source
  - Grade/Slope – *U.S. Geological Survey (USGS) 10m DEM data*
  - Tree Canopy – *Raster Data from a partnership among*
    - *EarthDefine LLC, US Forest Service*
    - *National Oceanic and Atmospheric Administration, and*
    - *Hawaii Division of Forestry and Wildlife*

Final Estimated Pedestrian Network - Density Plot of All Routes Observed

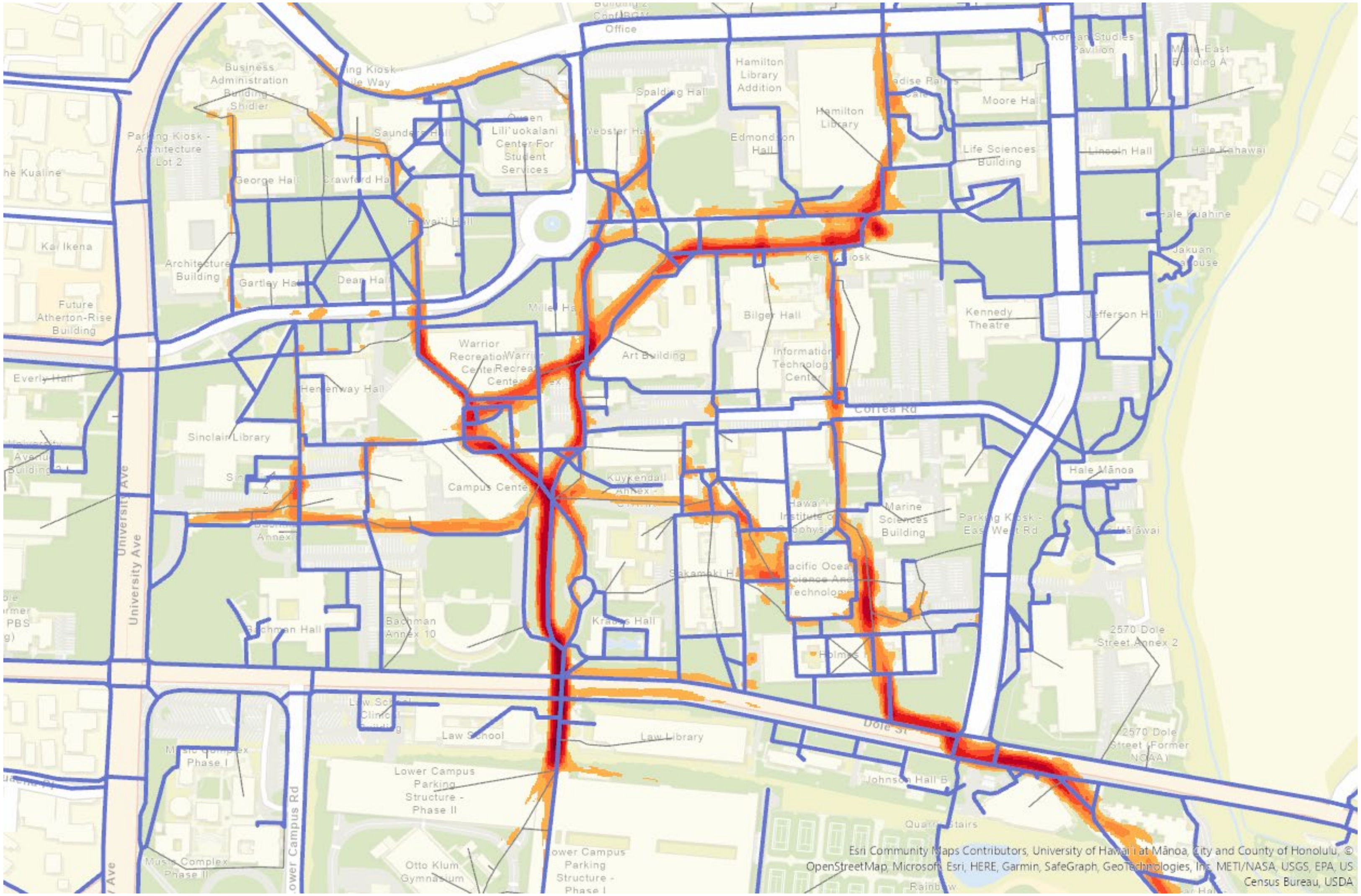


Network and Route Characteristics

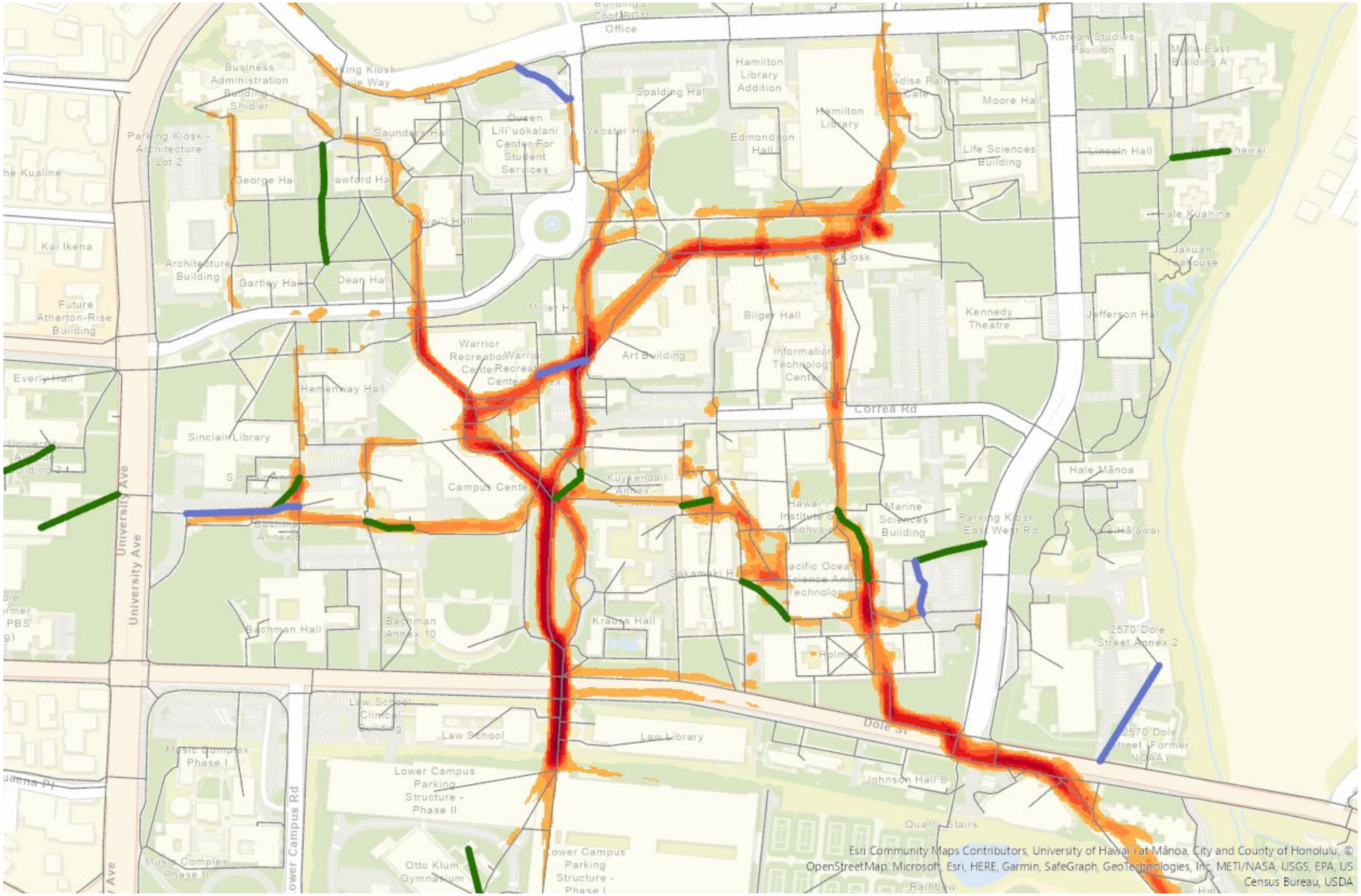
Network Characteristics	
Number of Links	1,354
Number of Nodes	1,084
Total Distance (meters)	61,851
Minimum Spanning Tree (meters)	39,395
Percentage of Network by Attribute (Distance)	
Sidewalk	79.3%
Grass Surface	1.9%
Quadrangle	17.3%
Tree Canopy	5.1%
Parking Lot	1.1%

Route Attributes	Observed Routes	Shortest Routes
Number of ODs	298	
Average Distance (meters)	532	474
Longest Distance (meters)	1,791	1,505
Shortest Distance (meters)	80	80
Average Percentage by Distance		
Sidewalk	74.5%	69.7%
Grass Surface	2.1%	2.1%
Quadrangle	22.2%	23.7%
Tree Canopy	17.8%	16.8%
Parking Lot	1.6%	1.0%

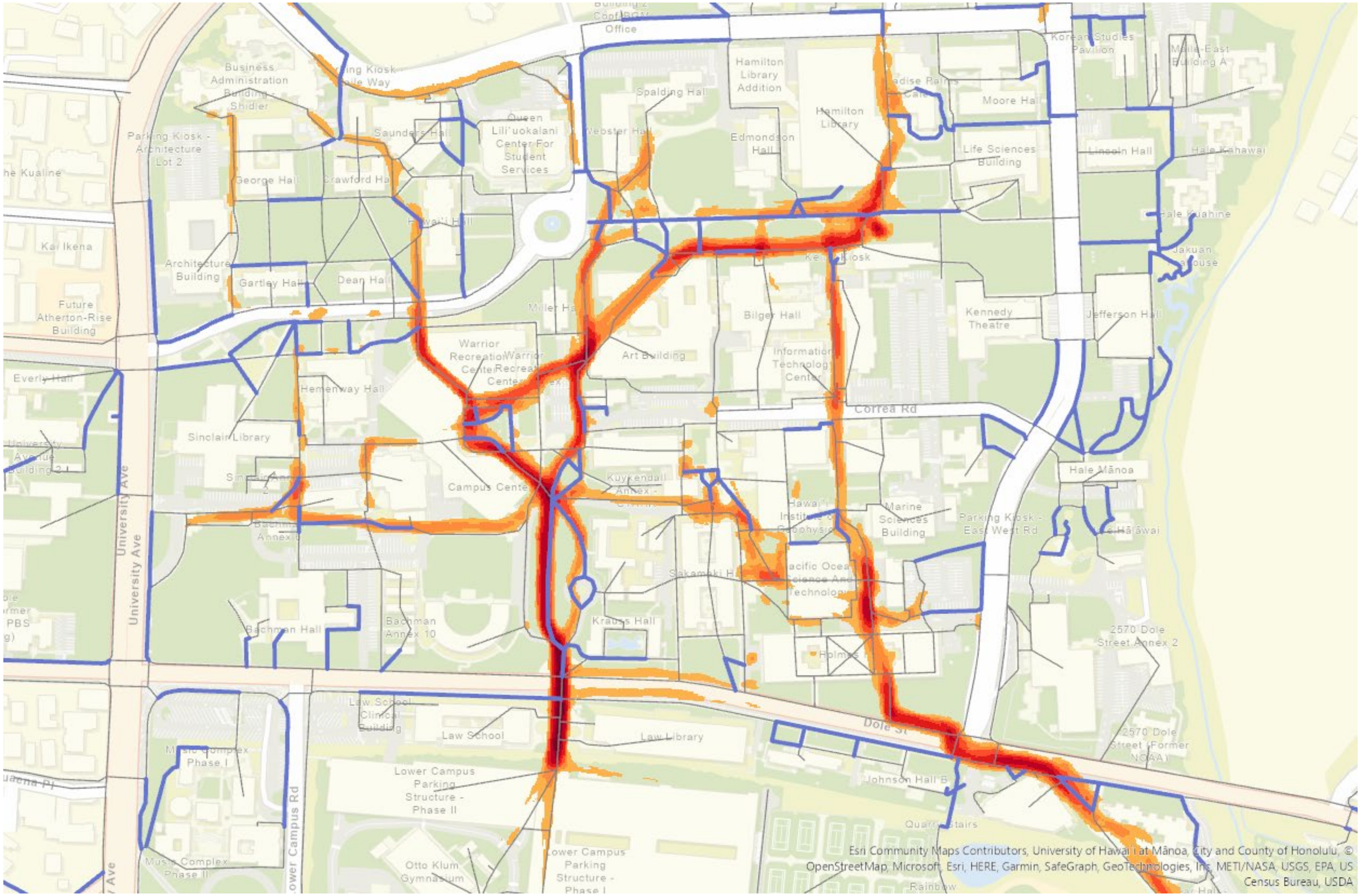
Link Attributes: **Sidewalk**



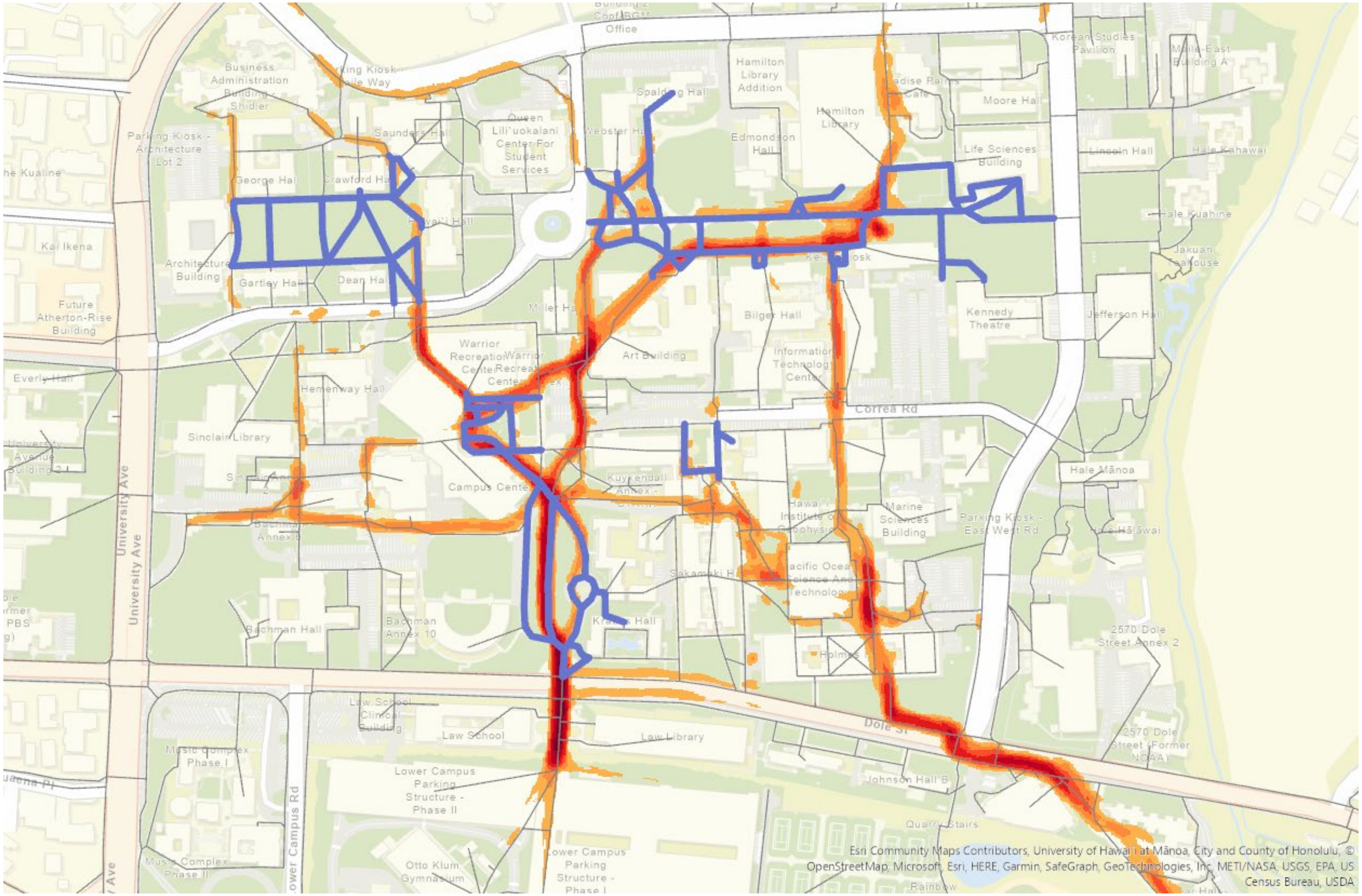
Link Attributes: Parking and Grass



Link Attributes: Tree Canopy

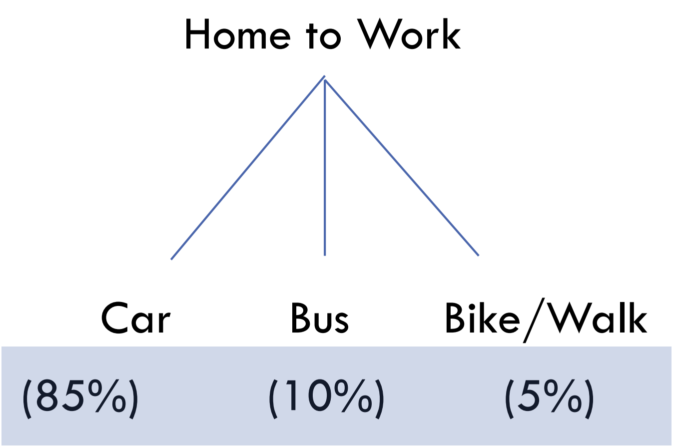


Link Attributes: Quadrangle



Analysis Framework

- Mode Choice Model for Trips

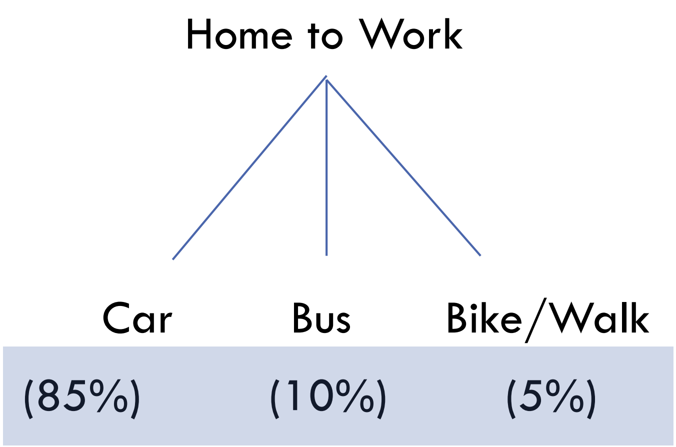


Choice Probabilities

= f(travel time, travel costs, transfers, income, etc.)

Analysis Framework

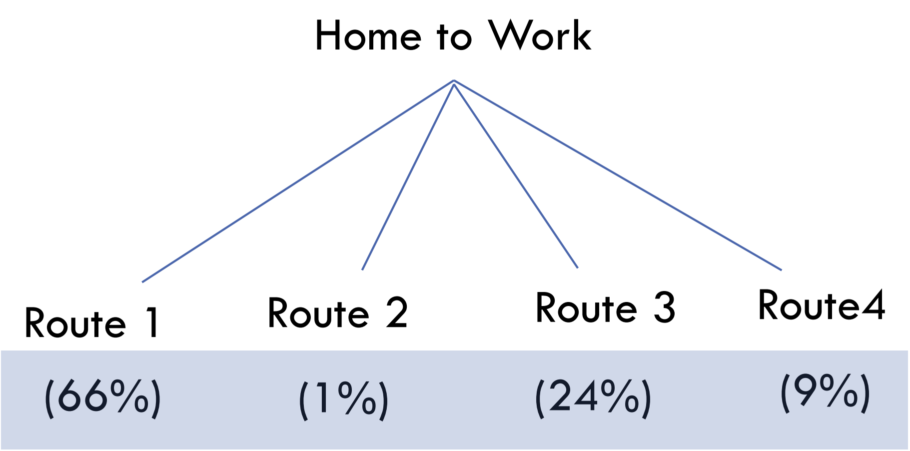
- Mode Choice Model for Trips



Choice Probabilities

= f(travel time, travel costs, transfers, income, etc.)

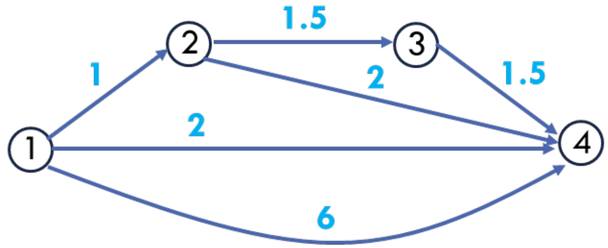
- Ped Route Choice Model for Trips



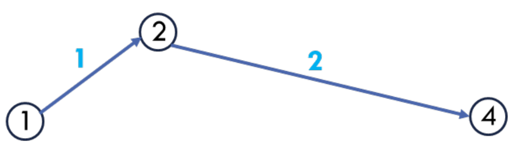
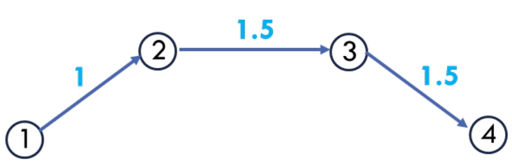
Choice Probabilities

= f(travel time, travel distance, shade, ADA accessibility, noise, congestion, etc.)

Conventional Route-Based Models



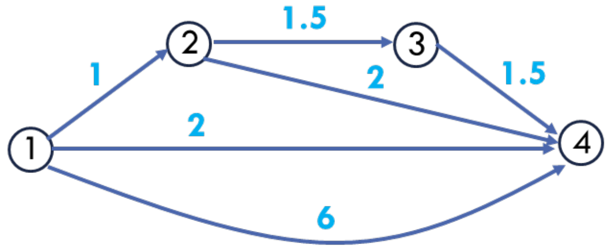
Node 1 → Node 4

Route	Length	Route Choice Probability
	2	0.6572
	6	0.0120
	3	0.2418
	4	0.0889

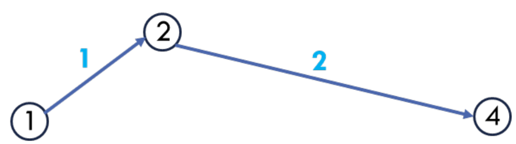
Shortest Length → Highest Probability

Longest Length → Lowest Probability

Recursive Link-Based Models



Node 1 ⟶ Node 4

Route	Link Attributes (Length)	Route Choice Probability	Product of <u>Link Choice Probabilities</u> (**Recursive Model**)
	**2**	**0.6572**	**0.6572**
	**6**	**0.0120**	**0.0120**
	**1, 2**	**0.2418**	0.3307 · 0.7311 = **0.2418**
	**1, 1.5, 1.5**	**0.0889**	0.3307 · 0.2689 ·1.000 = **0.0889**

Results: Model Estimation

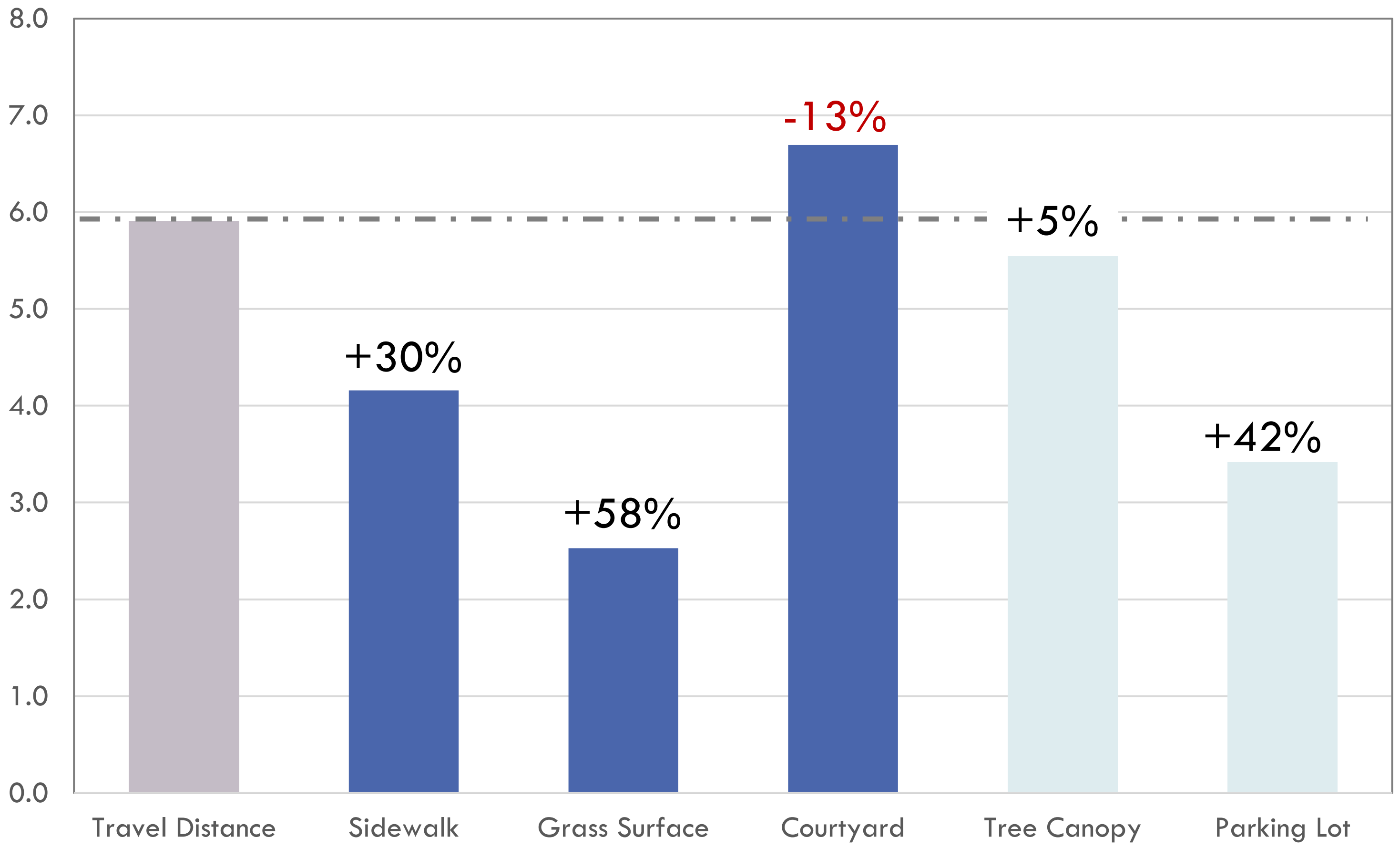
- **Coefficient Values**: Change in utility per attribute based on data
  - Positive (sign) indicates higher utility and likelihood of choice
  - Negative (sign) indicates lower utility and likelihood of choice
  - Units: Utility per Attribute Unit
    - Example (distance in meters): β_{DIST} (utility per meters)

- **t-statistic**: Indicates statistical significance of attribute based on data
  - 95% confidence → **t-statistic = ±1.96**

Results: Model Estimation

Coefficient	Value	Std. Error	t-statistic	Value	Std. Error	t-statistic
Travel Distance (100 meters)	-5.912	0.347	-17.030	-5.562	0.315	-17.663
Grade/Slope	0.004	0.006	0.674	---	---	---
Sidewalk (1/0)	-0.469	0.052	-8.935	-0.502	0.048	-10.384
Grass (1/0)	-1.754	0.584	-3.006	-1.793	0.586	-3.061
Quadrangle (1/0)	0.204	0.076	2.686	0.188	0.070	2.676
Tree Canopy (1/0)	-0.064	0.079	-0.811	---	---	---
Parking Lot (1/0)	0.144	0.497	0.290	---	---	---
Interaction Terms						
Travel Distance - Sidewalk	2.224	0.261	8.514	2.004	0.249	8.041
Travel Distance - Grass	5.139	1.385	3.710	4.911	1.360	3.612
Travel-Distance - Quadrangle	-0.985	0.364	-2.705	-0.811	0.336	-2.415
Travel Distance - Tree Canopy	0.350	0.280	1.249	---	---	---
Travel Distance - Parking Lot	2.351	1.623	1.449	---	---	---
Sample Size (Travelers)	16			16		
Sample Size (Routes)	298			298		
Sample Size (Links)	5,404			5,404		
LL(DIST)	-6.496			-6.496		
LL(β)	-5.950			-5.998		

Results: Marginal **Disutility** (per 100 meters)



Results: Summary

- Longer routes lead to greater **disutility** and were less likely to be chosen.

- Link attributes that will improve (offset) this disutility
  - Sidewalk – 30%
  - Grass Surface – 58%
  - Tree Canopy – 5%
  - Parking Lot – 42%

- Link attributes that lead to even greater disutility
  - Quadrangle – 13%

Conclusions and Future Work

- Distance is a disutility in route choice, but other link attributes can help compensate, such as the presence of a sidewalk and grass coverage

- Although the presence of tree canopies and parking lots also could compensate, based on the estimated model, these were statistically insignificant.

- Surprisingly, links that traversed quadrangles resulted in higher disutility, possibly due to greater sun exposure and a more crowded space.

Conclusions and Future Work

- Future Studies and Work
  - **More complete walking audit to collect and measure link attributes.**
  - Use of **estimated route choice model for forecasting** at other sites.
  - Extension to other travel modes.
  - Incorporation of latent variables into route choice will be incorporated
    - Ex. **Comfort, Reliability, Accessibility, Safety**
  - Greater coverage of traveler preferences and geographies (other areas of the city with heavy pedestrian traffic)
  - Link attributes may be highly correlated, requiring a different model besides the recursive logit.

THANK YOU