Modeling Urban Greenway Trail Use

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Modeling Urban Greenway Trail Use

- Primary aim
  - Explain variation in trail traffic
- Secondary aims
  - Develop model for forecasting trail traffic on proposed or existing trails
  - Measure traffic response to variations in correlates
  - Communicate relevant findings to policy makers and other practitioners
- Status
  - Trail monitoring network established, forecasting models estimated
  - Survey research scheduled for spring-summer 2005

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Methods

- Measure trail use[*]
  - Infrared counters: traffic counts
  - Field observations: traffic counts, mode/activity, some demographics, group use
  - Video monitoring: traffic counts, mode/activity, some demographics, group use
- Measure characteristics of physical environment[*]
  - Geographic information systems, satellite imagery
- Household and user surveys
  - Telephone survey of households
  - Mail questionnaire, trail intercepts for users
  - Collaboration with Marion County Health Department Obesity Needs Assessment
- Regression modeling[*]

[*]Results obtained

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Measuring Trail Use: Infrared Trail Monitors

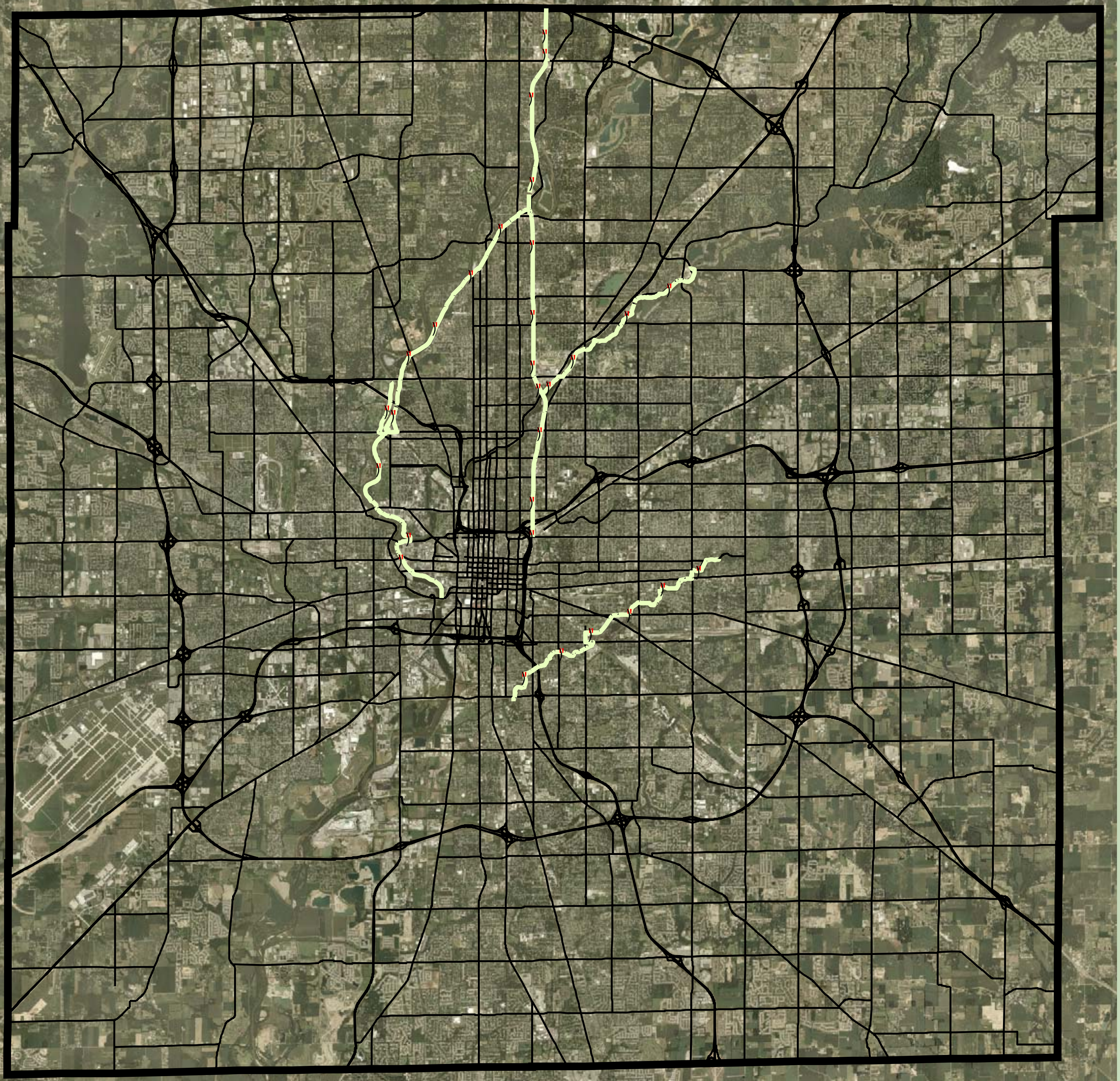
- Infrared counters: traffic counts (24/7)
  - Record time infrared beam broken
  - Measure bodies past a point, not individual users
  - Adjust for systematic error (users passing simultaneously)
- 30 locations on five trail, 40 mile network
  - 4 locations: November 2000 – present
  - 2 locations: September 2002 - present
  - 24 locations: May 2004 – present
- Examples of useful descriptive results
  - Hourly traffic (mean, peak hour, maximum)
  - Daily counts (11,254); Weekend vs. weekday

Monon Trail

Canal Towpath

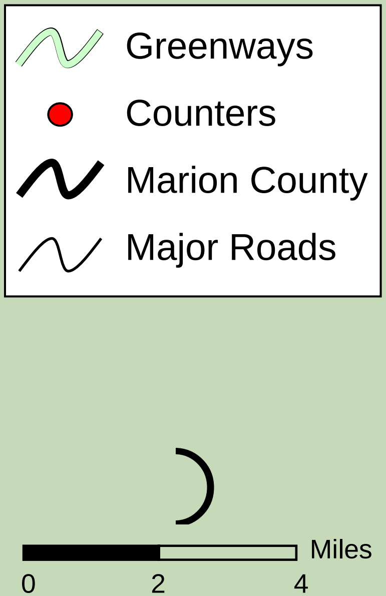
White River Trail

Pleasant Run



Indianapolis Greenway Monitoring Network

Greenways and monitor locations overlaid on 2003 aerial photograph of Indianapolis / Marion County, Indiana.



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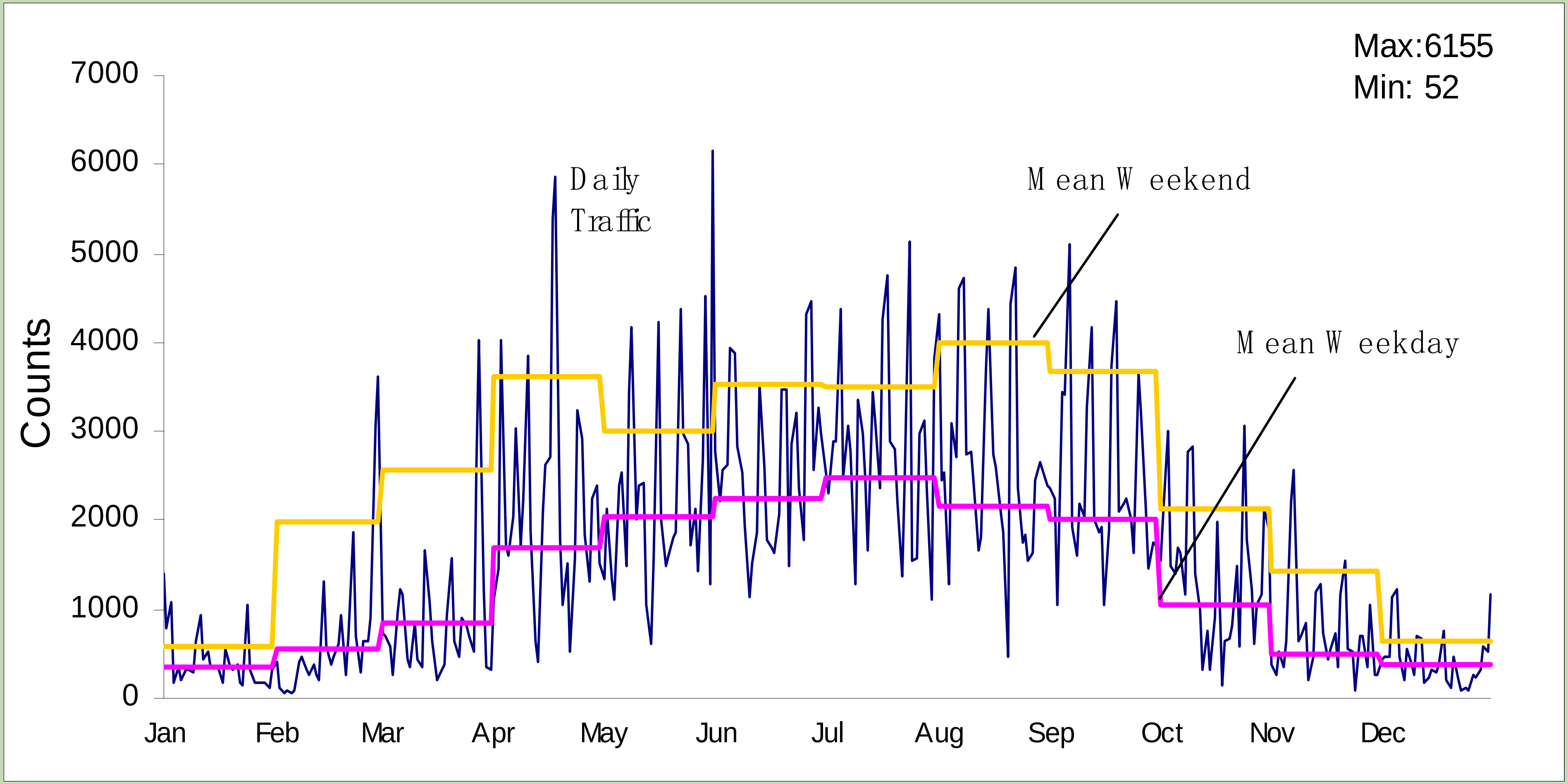
Daily Traffic Variation: Monon Trail, 67th Street, 2004



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Monitoring Trail Traffic

- Five trails, 33 miles network, in Indianapolis
- 30 locations
  - Four locations: 02/2001 – 11/2004
  - Two locations: 06/2002 – 11/2004
  - 24 locations: 05/2004 – 11/2004
- 24 hours/day,7 days/week
- Total daily traffic counts (N= 11,272)
- Traffic = users past point, not individual users or trips

Infrared Trail Monitor

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Correction Equations for Infrared Counters

- Estimated count =

$$(-0.0205 + X + 1.04563 * \text{Sqrt}(\text{Monitor}))^2$$

X = 0 if 0<Monitor Traffic<=60
X = 0.2287 if 60<Monitor Traffic<=110
X = 0.3938 if 110<Monitor Traffic<=200
X = 0.4551 if Monitor Traffic>200

$r^2 = .99$

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Validate Pedestrian Crosswalk Models

Davis, King, and Robertson (1991)			Lindsey and Lindsey (2004) (smaller sample size)		
Counting Intervals (minutes)	Expansion Equations	R^2	Counting Intervals (minutes)	Expansion Equations	R^2
Middle 5	$V_1=19.91*I_5^{.7862}$	0.77	Random 5	$V_1=23.196*I_5^{.6353}$	0.69
Middle 10	$V_1=9.82*I_{10}^{.8465}$	0.86	First 10 Middle 10	$V_1=11.472*I_{10}^{.7662}$ $V_1=12.543*I_{10}^{.7318}$	0.77
Middle 15	$V_1=5.75*I_{15}^{.8996}$	0.91	Last 15	$V_1=7.252*I_{15}^{.7918}$	0.87
Middle 30	$V_1=2.37*I_{30}^{.9625}$	0.96	Middle 30 Last 30 Random 30	$V_1=2.41*I_{30}^{.9517}$ $V_1=2.624*I_{30}^{.9196}$ $V_1=2.82*I_{30}^{.9128}$	0.94

Measuring Trail Use

– Video monitoring: traffic counts, mode/activity, some demographics, group use

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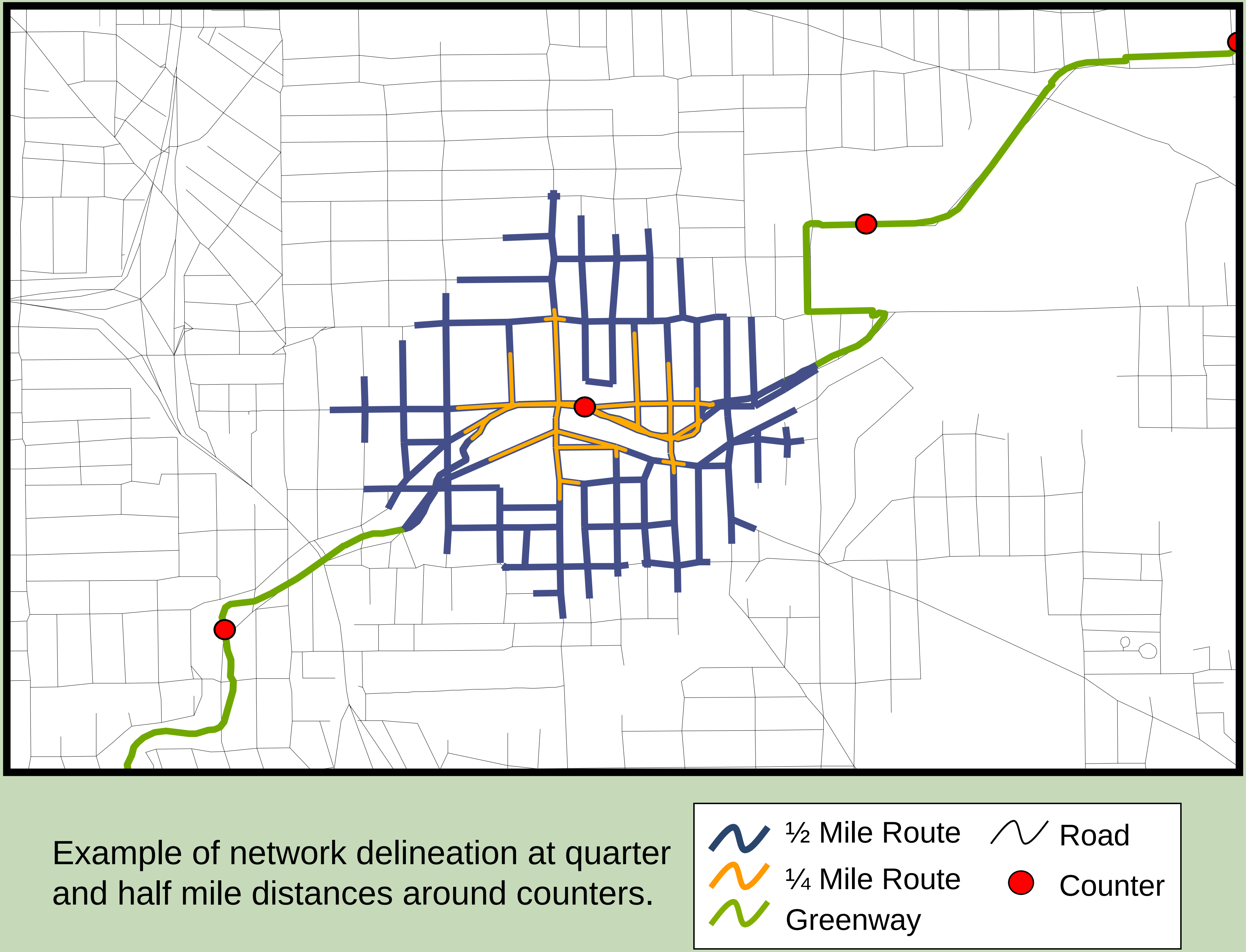
Measuring Characteristics of the Physical Environment

- Geographic information systems
  - Document variation in trail monitor neighborhoods (pedestrian access zones or catchment areas)
  - Network distance from counter (¼ mile, ½ mile)
- Satellite imagery:
  - NDVI
  - LIDAR



Example of network delineation at quarter and half mile distances around counters.


Monon Trail
Canal Towpath
Fall Creek
Monon Trail
White River Trail
Pleasant Run
Greenways
Counter Locations
Counter Neighborhoods
Road Network
Counter Networks (1/2 mile)
Marion County Boundary
Version 2
0 0.5 1 2
Miles

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Normalized Difference Vegetation Index (NDVI)

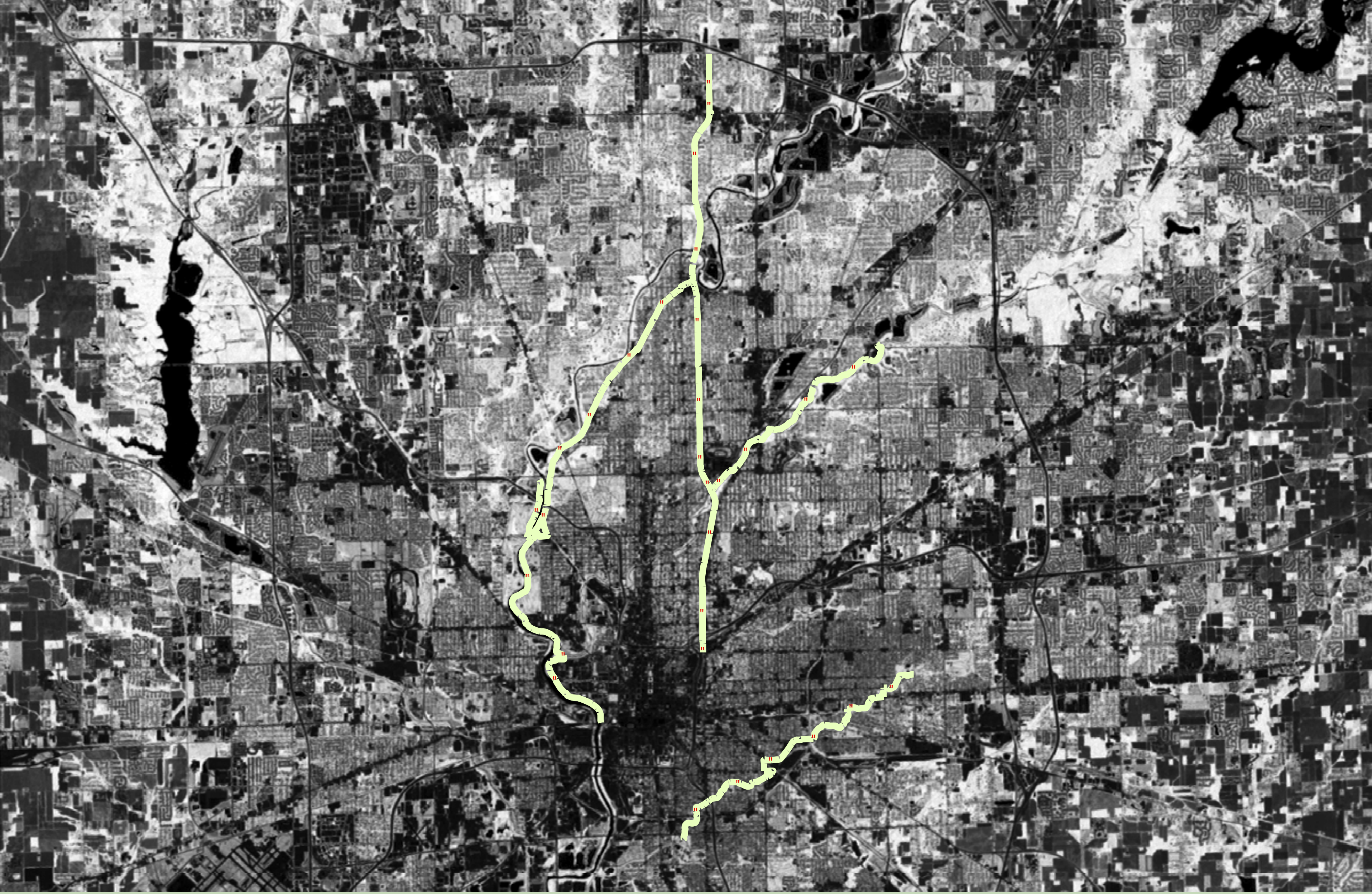
- **Common biophysical remote sensing algorithm for measuring vegetation**
- **Based on differences in red and NIR reflectance:**

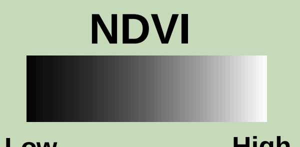
$$NDVI = (NIR - red) / (NIR + red)$$

- **Unitless index with possible range of -1 to +1**
- **Higher values indicative of dense green healthy vegetation**
- **Lower values indicative of stressed vegetation or bare ground**

- **NDVI correlates significantly with biophysical vegetation characteristics: green biomass, leaf area index, % vegetation ground cover**

- **30m resolution ETM+ imagery, four different dates (May, June, July, August)**
- **Mean NDVI values computed within trail neighborhoods for each date**





Example of ETM+ NDVI image (June 6) with greenways and counter locations overlaid.

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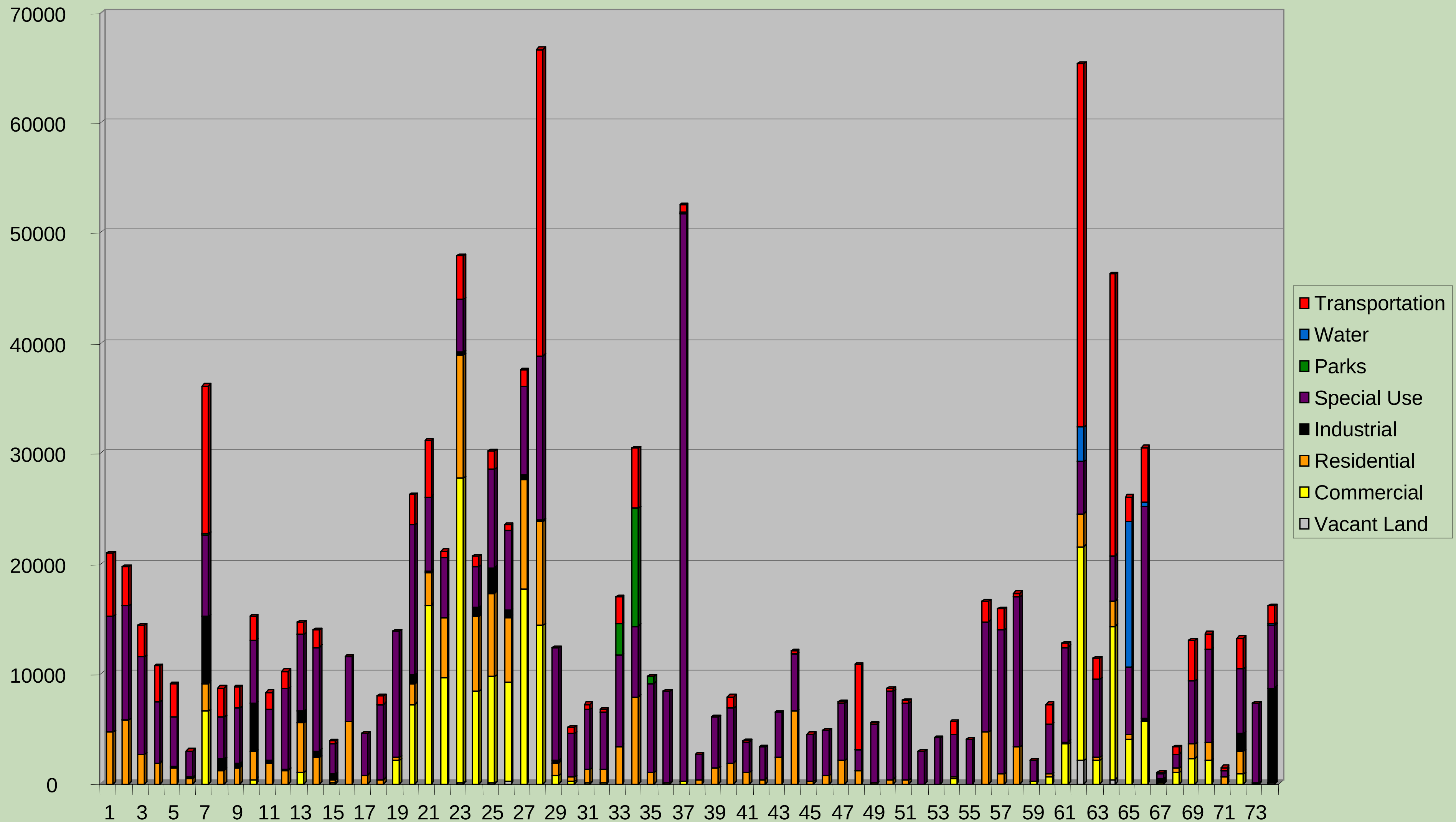
LIght Detection And Ranging (LIDAR)

- Optical equivalent of RADAR or SONAR
- Active laser sensors transmit pulse of light energy
- Some of this light energy is reflected back to the instrument
- Timing of laser pulse converted to X,Y,Z measurements
- Indianapolis airborne LIDAR data acquired Spring 2003
- >3 billion XYZ points, 145 GB of data collected for entire city
- Ongoing work focuses on developing 3D models from LIDAR data for visibility studies along greenways

Viewshed for point 10158 on Monon Trail overlaid on 2002 aerial photo (observer height 6', maximum distance 300').

Viewshed perspective (looking southeast) for point 10158 on Monon Trail overlaid on 2002 aerial photo (observer height 6’, maximum distance 300’).



Example of summarizing environmental variables on the basis of visibility. Here different types of land use for 75 locations spaced at 200 foot increments along a section of the Monon Trail are summarized on the basis of visibility from the trail.

Descriptive Results

Activity Patterns Generally Consistent across Five Trails*

- Cyclists: 46% - 61% of observed users
- Walkers: 19% - 37% of observed users
- Runners: 5% - 23% of observed users
- Skaters and other: 1% - 10% of observed users

*2004 data; 442 hours of observation

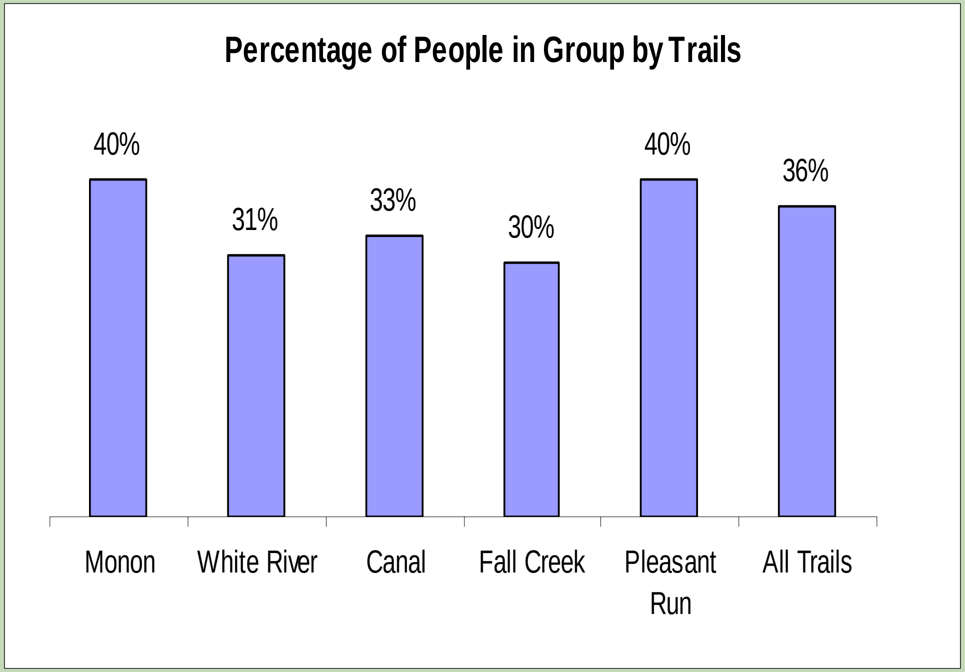
Variation in Observed User Demographics

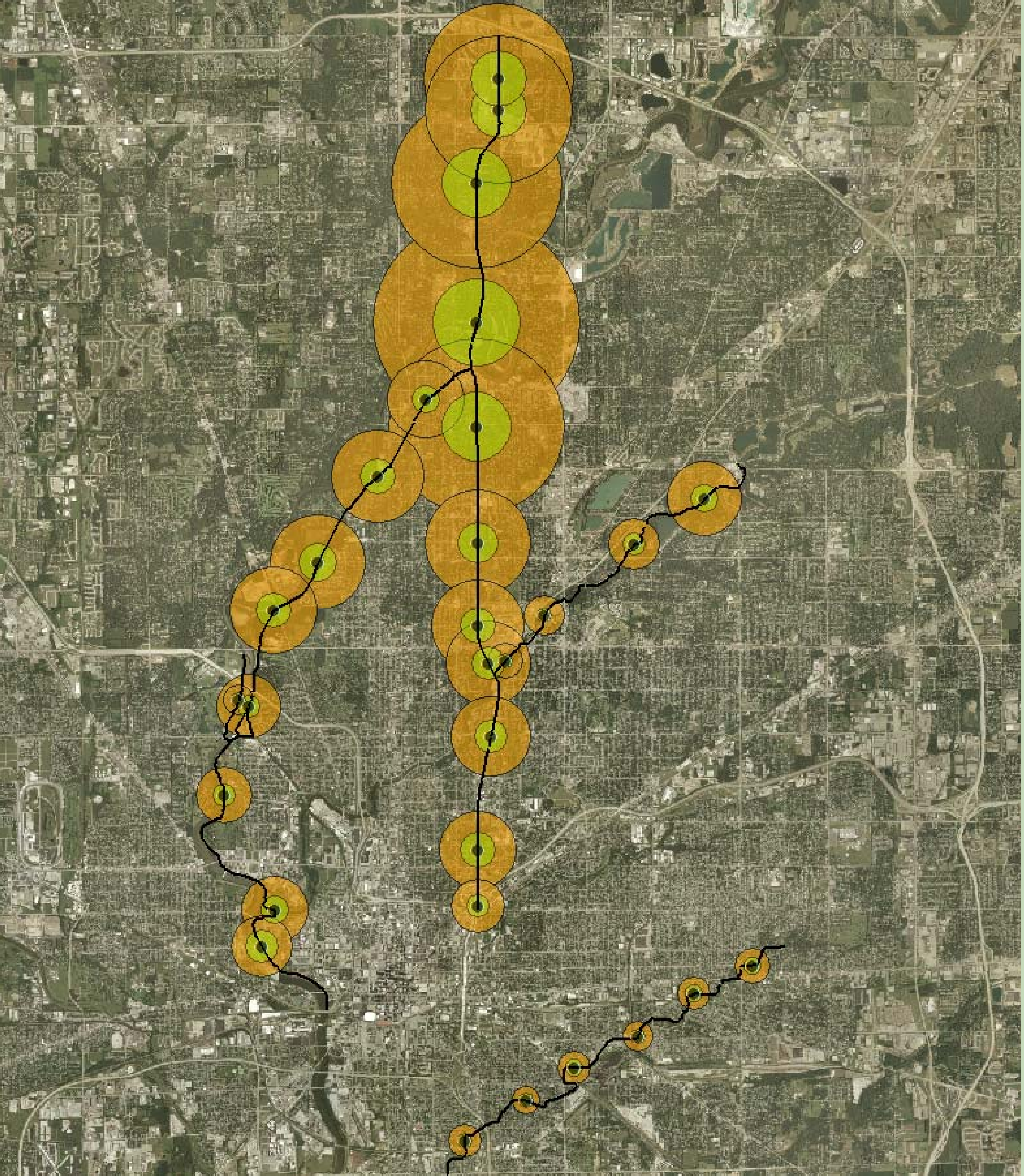
	Male	Female	White	Black	Other
Monon Trail	57%	43%	87%	11%	2%
White River	75%	25%	84%	12%	3%
Canal Towpath	56%	44%	93%	6%	2%
Fall Creek	59%	41%	58%	37%	5%
Pleasant Run	73%	27%	80%	15%	5%

People in groups (n ≥ 2) account for 30% - 40% of observed users.

Trail*	% People in Group (≥ 2)
Monon	40%
White River	31%
Canal	33%
Fall Creek	30%
Pleasant Run	40%
All Trails	36%

*2004 data; 442 hours of observation



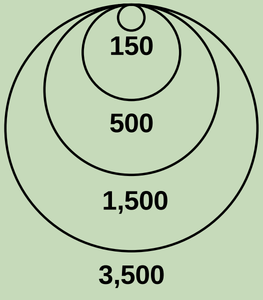


Spatial and Temporal Variation in Trail Use

Example of spatial and temporal variability in trail use depicting mean counts for week days and weekend days in September 2004.

	Min	Max	Mean
Week Days	79	2,017	436
Weekend Days	105	3,670	834

Mean Daily Count



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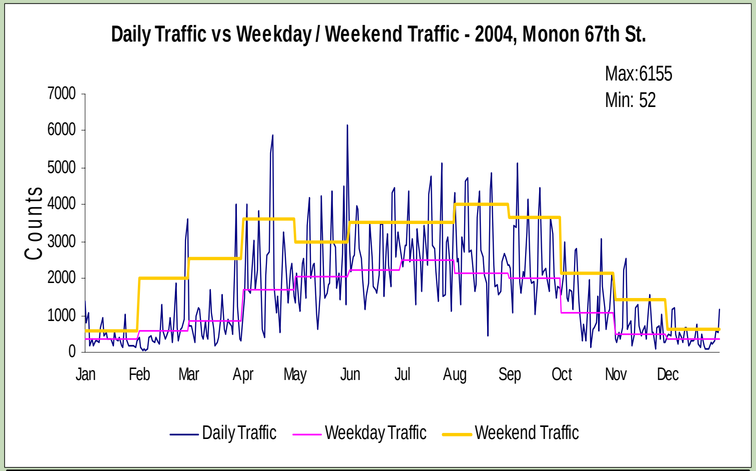
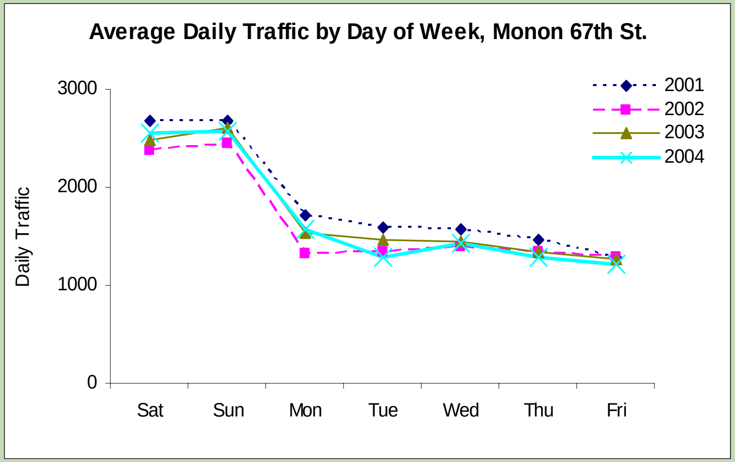
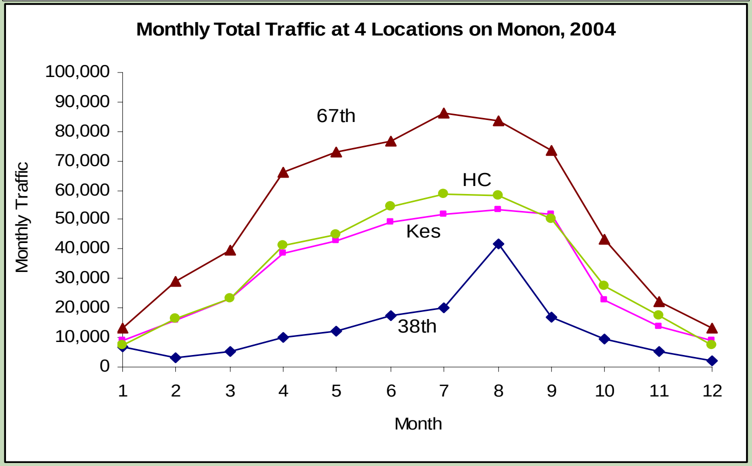
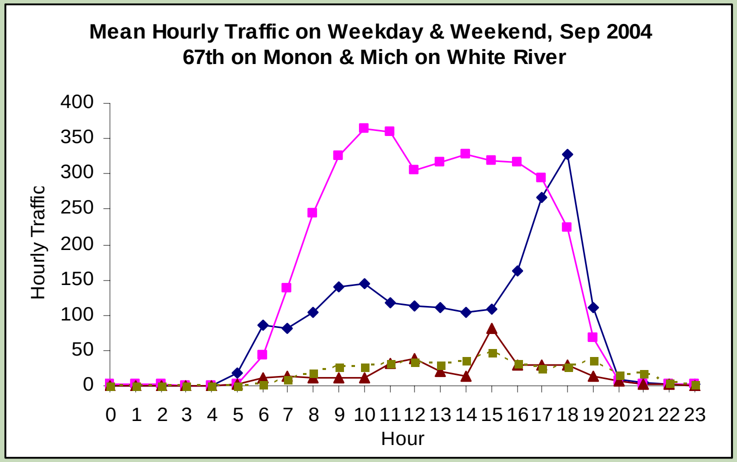
Spatial and Temporal Variation in Use

Traffic varied daily across seasons, locations, and days-of-week, but remained stable across years.









Modeling Approach

- Daily trail traffic estimated as function of:
  - Weather (control variables)
  - Time (control variables)
  - Neighborhood socio-demographic characteristics
  - Measures of neighborhood built form and physical environment
- Use standard multiple linear regression techniques

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Dependent and Control Variables

- Dependent variable
  - Log daily count
    - Add 1 count to days with zero measured trail use
- Control variables
  - Weather: deviation from long term daily mean
    - Temperature: degrees Fahrenheit
    - Squared temperature
    - Precipitation: inches
    - Snow: inches
    - Sunshine: percent
  - Time
    - Monthly dummy variables (relative to December)
    - Weekend dummy variable
    - StateFair dummy variable: interaction term for August and M38 location on days when Fair in session

Neighborhood Socio-demographic Measures

- Age (youngold)
  - Percent of residents less than 5 or greater than 64
- Ethnicity
  - Percent of black; other
- Education
  - Percent of residents older than 25 with college degree
- Income
  - Log of mean of median household income
  - Squared income term
- Measures estimated from Census data using GIS to identify block groups in trail monitor neighborhoods

Measures of Neighborhood Urban Form

- Population density
  - People/square kilometer
- Land use
  - Percent of trail neighborhood in commercial use
  - Log of area (square feet) in parking lot
- Accessibility
  - Log of average length of street network segments
- Vegetation density and condition
  - Mean NDVI in trail neighborhood (June 6, 2000; Landstat Thematic Mapper)
- Measures estimated from Census and other local databases using GIS for trail monitor neighborhoods

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A Trail Traffic Model

- Good statistical fit
  - Adjusted $R^2 = 0.80$
  - 27 of 29 variables are significant at 1% level
    - Snow and January are not significant

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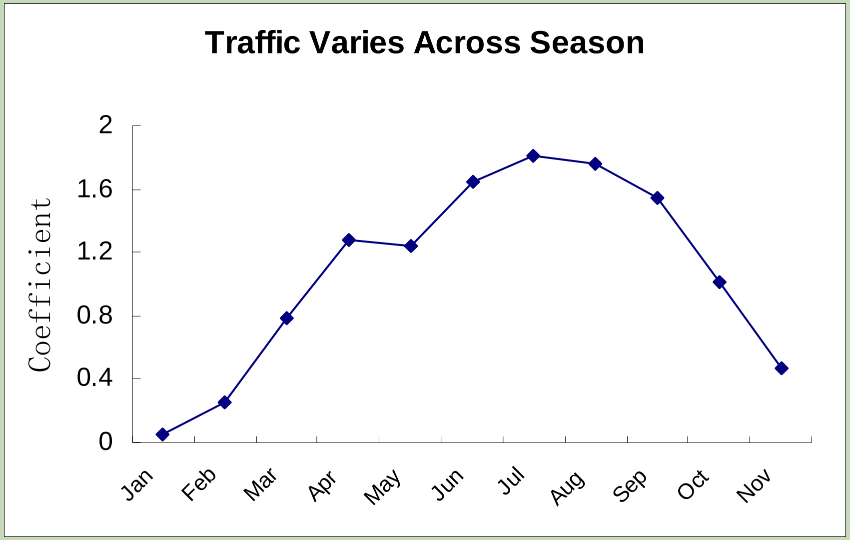
Temporal controls account for 18% of variation in daily trail traffic

- Weekend traffic is on average 1.5 times weekday traffic
- July has the largest effect, Dec. has lowest traffic
- StateFair is highly significant



Variables	Coefficient
Weekend	**0.435**
Jan	0.0492
Feb	0.2576
Mar	0.7853
Apr	1.2732
May	1.2466
Jun	1.6411
Jul	**1.8107**
Aug	1.7637
Sep	1.5522
Oct	1.0199
Nov	0.4772

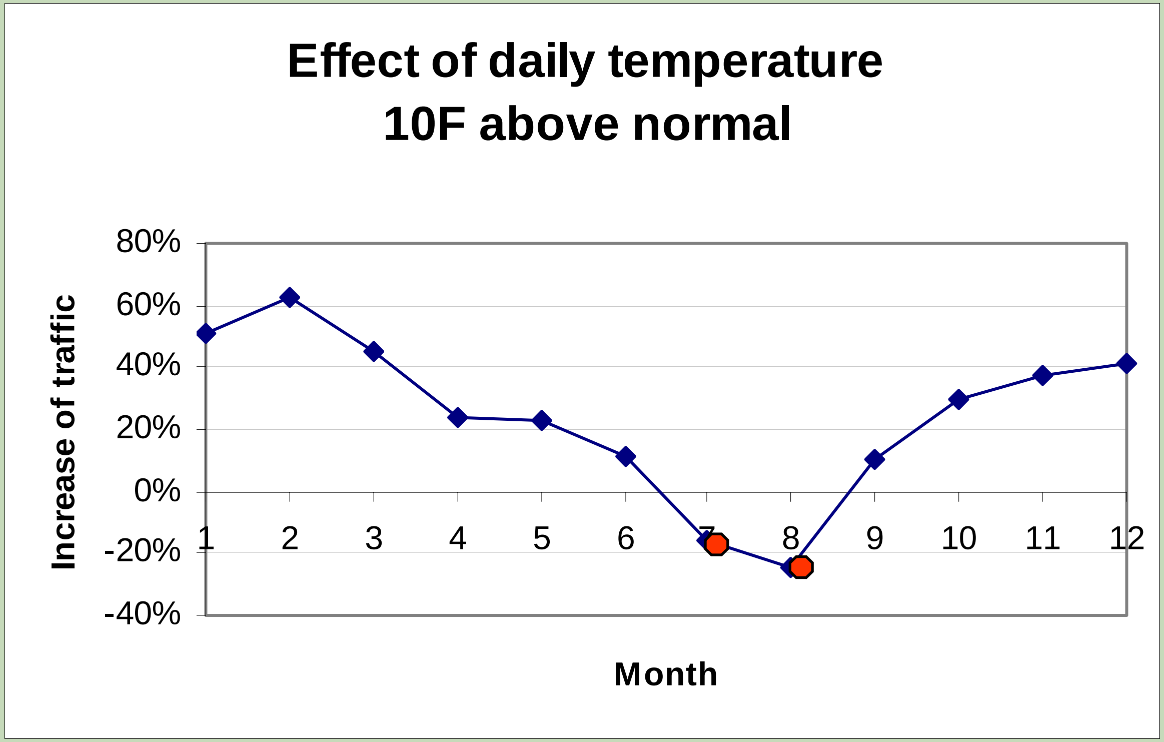
Weather controls account for 7% of variation in daily trail traffic

- Precipitation reduces traffic: one inch above average reduces traffic by 29%
- Sunshine associated with increases in traffic: 10% increase above average increases traffic by 7%
- The effect of temperature diminish as the magnitude of the deviation increases (negative sign on squared temperature term)
- Snow is not significant

Variable	Coefficient
DevT	0.02289
sqDevt	-0.00016894
DevP	-0.34451
DevS (not sig.)	-0.01949
DevSH	0.00716

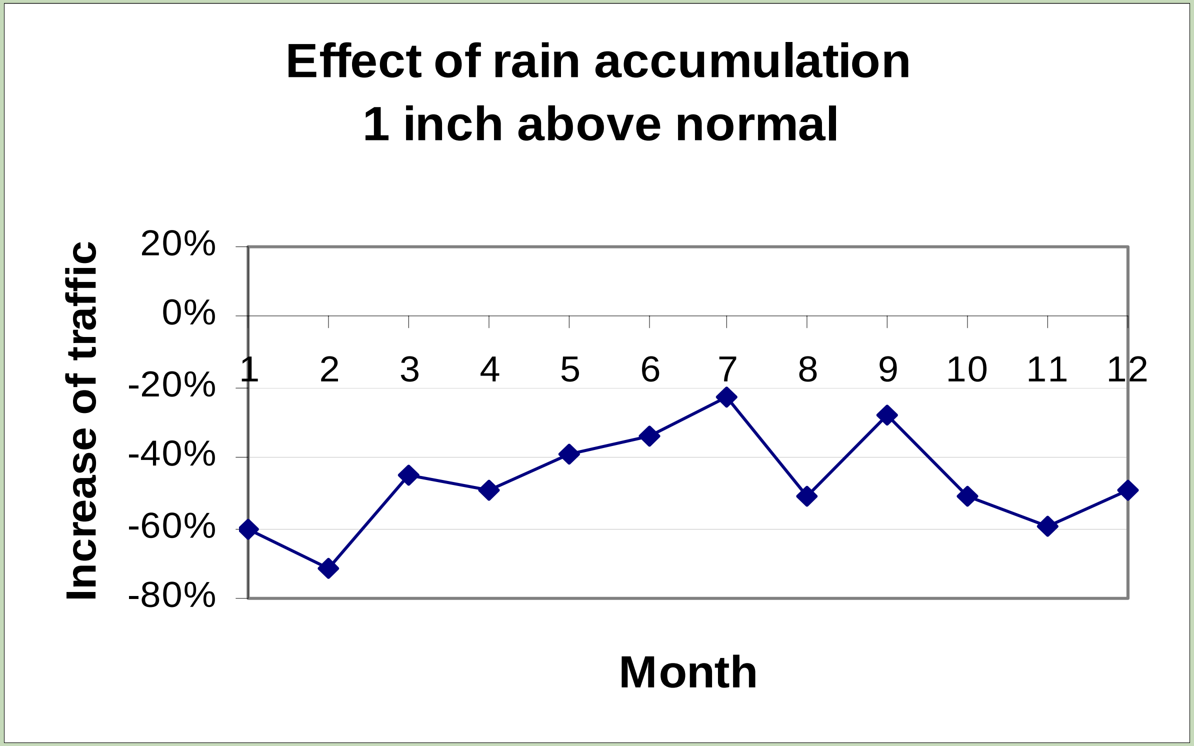
Temperature Effects

- *Negative* effect in July and August
- When temperature is 10F above daily average, traffic varies from 62% to -24%



Precipitation Effects

- *Negative* effect through the year
- When precipitation is 1 inch above daily average, traffic decreases from 22% to 72%



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Neighborhood socio-demographic variables account for 24% of variation in daily traffic

- Education: 1% increase percent college-educated population associated with 7% increase in traffic
- Age: 1% increase of young-old residents associated with 1.5% decrease in traffic
- Ethnicity: % black and %other ethnicity have positive and negative effects, respectively, relative to % white
- Income: has positive effect but effect diminishes as income increases.

Variable	Coefficient
Pct > 25 Col_Grad	0.07014
Log_Ave_ MHH Inc	24.89396
sqLog_Ave_ MHH_Inc	-1.26211
pctYoungOld	-0.0151
pctBlack	0.00764
pctOtherTtl	-0.00639

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Neighborhood urban form variables account for 31% of variation in daily traffic

- Mean-NDVI has positive effect
- Increase in density of 100 persons/km^2 associated with an increase in traffic of 1%
- 1% increase commercial land use associated with a 4.6% increase in traffic
- Increases in area of parking lots associated with statistically significant but practically small effect
- 1% increase in average segment length associated with very small decrease in traffic (0.088%)

Variable	Coefficient
mean_ndvi_ 06-06-00	1.5008
Pop_density	0.00009825
PctCom	0.04601
log_PrkLot	0.04256
log_NetSeg AvgLgth	-0.09287

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An Example

- Forecast traffic at M67 location on January 28, 2005
  - Mean temperature was 23F, 4 degrees below average
  - Sunshine was 14% below average
  - No precipitation, snowfall
- Estimated daily traffic with model: 274
- Adjusted monitor count: 263
- Model will be useful for estimating traffic on trail

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Observations and Conclusions

- Objective Measures of Trail Traffic
  - Activity patterns, modes of use generally appear to be consistent across trails
  - Trail users appear to be disproportionately male
  - Trail use may be social activity for large proportions of users
  - Traffic varies consistently by month, day of week, and hour of day

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Observations and Conclusions

- Covariates explain 80% of variation in trail traffic
- Trail traffic is highly correlated with:
  - Weather and temporal control variables
  - Socioeconomic status of trail neighborhoods
  - Percent of neighborhood population that is young and old (inverse relationship)
  - Dimensions of urban form hypothesized to increase pedestrian activity: population density, shorter block lengths, more vegetation, mixed (commercial) land use

Observations and Conclusions

- Implications for research, management, and policy
  - Take activity patterns into consideration in design of interventions to increase physical activity
  - Use model to estimate traffic for facility design, evaluations of project alternatives, or needs assessments for traffic safety improvements or maintenance
  - Design more efficient sampling strategies for trail user surveys
  - Evaluate policies and management actions (e.g., reductions in pedestrian activity on ozone action days)

Need for Additional Research

- Additional research can address limitations of study
  - Count data are limited; provide no insight into variation in mode of use
  - Model currently does not include measures for specific trail characteristics or areas outside trail monitor neighborhoods that might affect use
  - New measures for trail monitor neighborhoods can be developed (e.g., use LIDAR to develop measures of visual quality of trail segments)
  - Surveys of users will provide better understanding of preferences and patterns of use (spring-summer 2005) and permit new modeling approaches