Advancing Transportation Performance Management and Metrics with Census Data

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Outline

- Research objectives and collaborative approaches
- Background on CTPP and performance metrics
- Performance measurement process
  - Safety evaluation
  - Mobility evaluation
  - Accessibility evaluation
- Summary of findings and final recommendations
- Discussion and future research efforts

CTPP Program

- Journey-to-work traveler behavior dynamics
- Data sampling issues and improving the data structure
- The implications for new travel demand models

Research Objective

Demonstrate the application of CTPP for the purpose of advancing Transportation Performance Management (TPM)

Performance Measurements

- Improving safety
- Maintaining infrastructure condition
- Reducing traffic congestion
- Improving efficiency of the system and freight movement
- Protecting the environment
- Reducing delays in project delivery

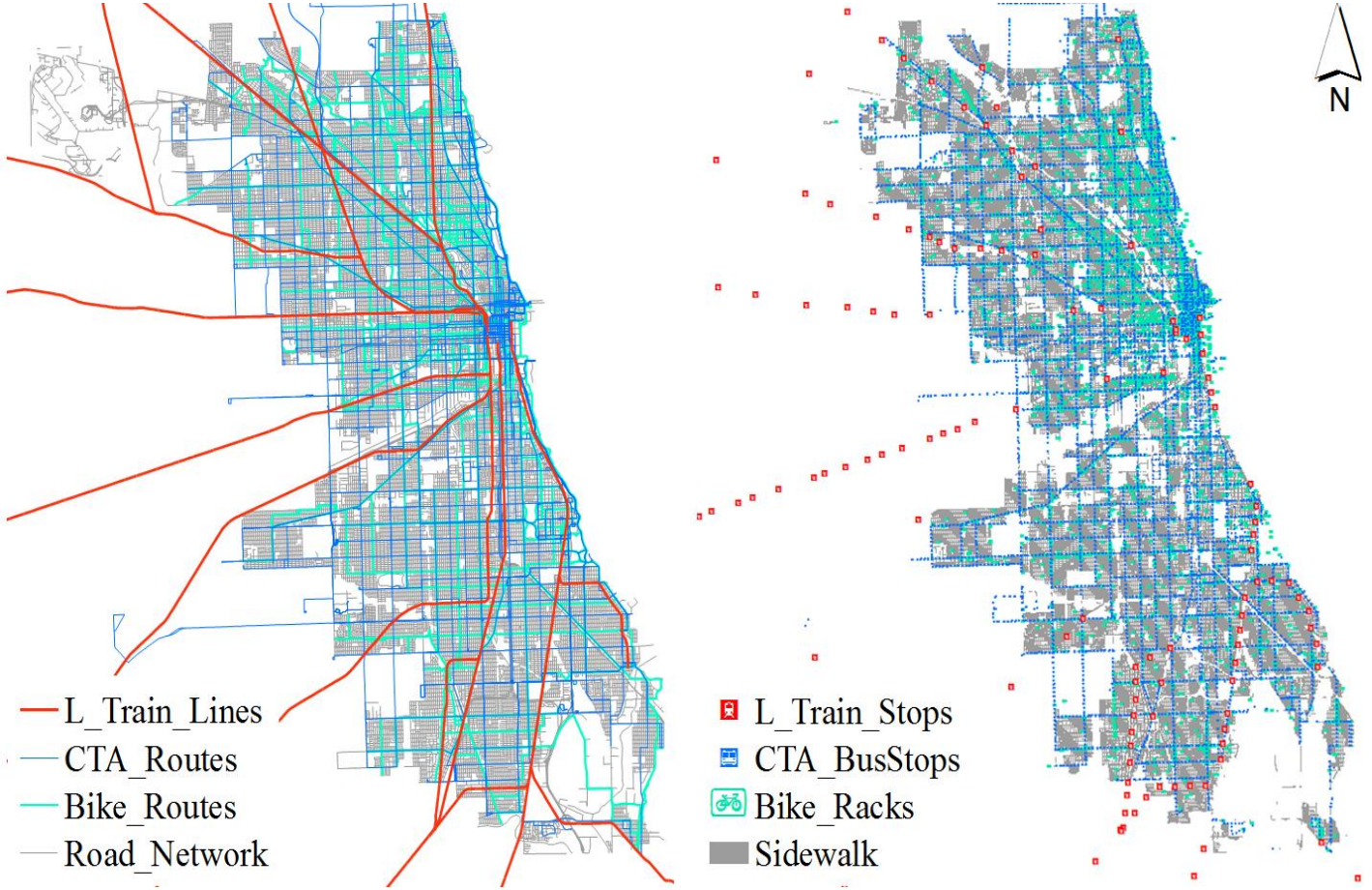
Transportation Performance Metrics

✓Safety

✓Mobility

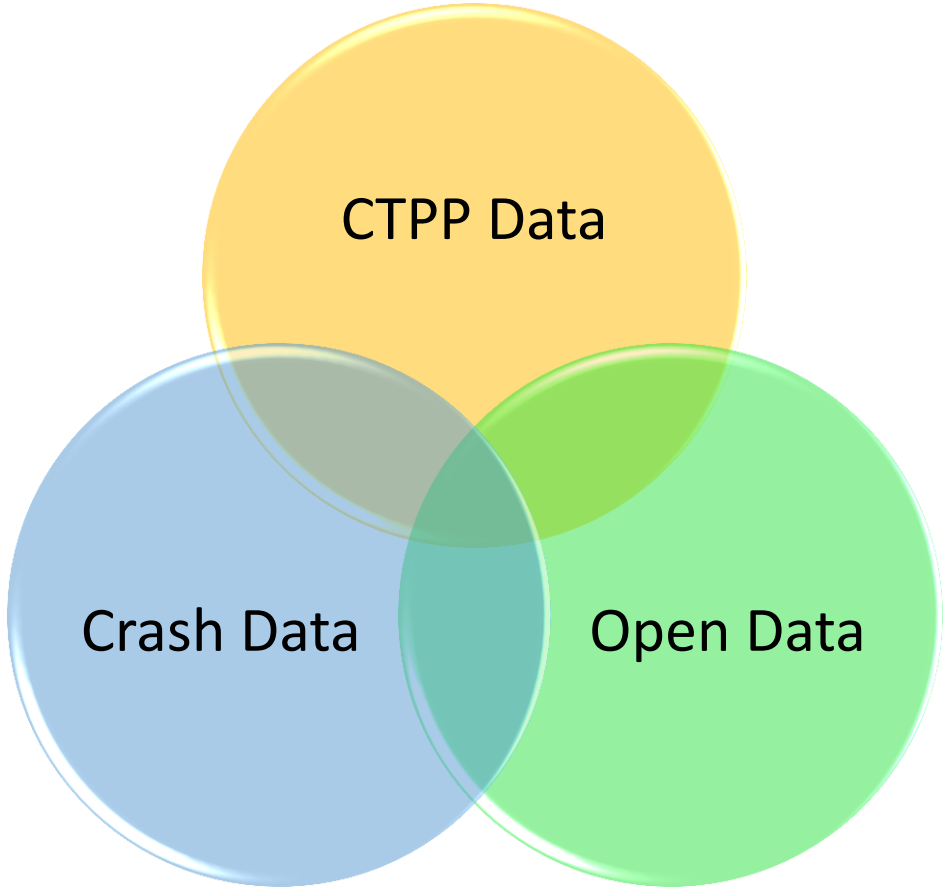
✓Accessibility

Case Study


L_Train_Lines
CTA_Routes
Bike_Routes
Road_Network
L_Train_Stops
CTA_BusStops
Bike_Racks
Sidewalk
N

Data Collection

- DOT Crash Data
  - Vehicle-only crashes, pedestrian crashes, bicyclist crashes
- CTPP Data
  - Population, employment, income, vehicle ownership, work commute trips
- Open City Data
  - Multimodal infrastructure, vehicle miles traveled, trips by mode



Safety

- Safety Performance Function (SPF):

$$\theta_i = e^{\left(\beta_0 + \beta_1 \ln(\mathrm{Exp1}_i) + \beta_2 \ln(\mathrm{Exp2}_i) + \sum_j \beta_j x_{ij} + \varepsilon_i\right)}$$

θ_i - expected number of crashes for census tract "i"

β_0- intercept

β_i - coefficients quantifying the effect of the "j" explanatory variables characterizing census tract "i" on θ_i

$\mathrm{Exp1}$ and $\mathrm{Exp2}$ – measures of exposure in census tract "i"

x_i - a set of "j" explanatory variables that characterize census tract "i" and influence θ_i

ε_i - disturbance term corresponding to census tract "i"

Safety Evaluation Methods

- SPFs for vehicle-only, pedestrian and bike crashes:
  - CTPP data (exposure from ACS commute trips)
  - CTPP data + Open data (exposure from ACS commute trips)
  - CTPP data (exposure from regional travel demand models)
  - CTPP data + Open data (exposure from regional travel demand models)
- Total of 12 statistical safety models developed
- Used bootstrapping for model validation and AIC for comparison

Safety Evaluation Results:
Vehicle-only crashes

- SPF based on CTPP data, exposure from ACS:

$$Vehicular\ crashes_i = e^{(5.55+3.64\times10^{-4}\times\text{Workers Driving}+4.00\times10^{-6}\times\text{Income}-2.99\times10^{-3}\times\text{Median Age})}$$

- SPF based on CTPP data, exposure from CMAP:

$$Vehicular\ crashes_i = e^{(0.23+0.54\times\ln(\text{DVMT})+1.00\times10^{-6}\times\text{Income}-1.33\times10^{-3}\times\text{Median Age})}$$

- SPFs based on CTPP + Open Data:

CTPP Data + Open Data					
Coefficients:	Estimate	Std. Error	Z value	P value	
Intercept	4.726000	0.121800	38.790	0.000	***
Workers Driving	0.000255	0.000033	7.848	0.000	***
Income per Capita	0.000004	0.000001	3.807	0.000	***
Median Age	-0.005388	0.003269	-1.648	0.099	.
Arterial Network	0.249600	0.021620	11.547	0.000	***
Intersection Density	0.001062	0.000338	3.143	0.002	**
Bus Stops	0.032590	0.002651	12.297	0.000	***
AIC	10363.79				

CTPP Data + Open Data with CMAP Exposure					
Coefficients:	Estimate	Std. Error	Z value	P value	
Intercept	1.215000	0.227300	5.348	0.000	***
ln(DVMT)	0.403200	0.022540	17.886	0.000	***
Income per Capita	0.000000	0.000001	0.472	0.637	
Median Age	-0.001696	0.002899	-0.585	0.559	
Arterial Network	0.033860	0.022240	1.523	0.128	
Intersection Density	0.000907	0.000302	3.006	0.003	**
Bus Stops	0.025420	0.002394	10.618	0.000	***
AIC	10167.14				

*** - 99.9% statistical significance; ** - 99% statistical significance; * - 95% statistical significance; . – 90% statistical significance

Safety Evaluation Results:
Vehicle-pedestrian crashes

- SPF based on CTPP data, exposure from ACS:

$$Pedestrian\ crashes_i = e^{(3.42+1.47\times10^{-4}\times\text{Workers Driving}+1.76\times10^{-3}\times\text{Workers Walking}+\cdots)}$$

- SPF based on CTPP data, exposure from CMAP:

$$Pedestrian\ crashes_i = e^{(0.98+0.17\times\ln(\text{DVMT})+0.41\times\ln(\text{Ped.Trips})+\cdots)}$$

- SPFs based on CTPP + Open Data:

CTPP Data + Open Data					
Coefficients:	Estimate	Std. Error	Z value	P value	
Intercept	3.130000	0.268100	11.672	0.000	***
Workers Driving	0.000052	0.000043	1.206	0.228	
Workers Walking	0.001080	0.000134	8.075	0.000	***
Income per Capita	-0.000003	0.000001	-1.876	0.061	.
Male Population	-0.011200	0.005093	-2.198	0.028	*
Median Age	-0.016850	0.004265	-3.951	0.000	***
Intersection Density	0.000890	0.000435	2.048	0.041	*
L Train Stops	-0.165000	0.072360	-2.280	0.023	*
Bus Stops	0.040490	0.002942	13.763	0.000	***
AIC	5854.43				

CTPP Data + Open Data with CMAP Exposure					
Coefficients:	Estimate	Std. Error	Z value	P value	
Intercept	1.976000	0.340600	5.803	0.000	***
ln(DVMT)	0.068300	0.028060	2.435	0.015	*
ln(Pedestrian Trips)	0.418600	0.035870	11.670	0.000	***
Income per Capita	-0.000006	0.000001	-4.329	0.000	***
Male Population	-0.025210	0.004999	-5.044	0.000	***
Median Age	-0.014870	0.004028	-3.691	0.000	***
Intersection Density	0.001190	0.000416	2.858	0.004	**
L Train Stops	-0.229600	0.070390	-3.262	0.001	**
Bus Stops	0.029360	0.003189	9.208	0.000	***
AIC	5773.997				

*** - 99.9% statistical significance; ** - 99% statistical significance; * - 95% statistical significance; . – 90% statistical significance

Safety Evaluation Results:
Vehicle-bicyclist crashes

- SPF based on CTPP data, exposure from ACS:

$$Bicyclist\ crashes_i = e^{(-0.02+4.36\times10^{-4}\times\text{Workers Driving}+5.26\times10^{-2}\times\text{Workers Biking}+\cdots)}$$

- SPF based on CTPP data, exposure from CMAP:

$$Bicyclist\ crashes_i = e^{(-2.77+0.27\times\ln(\text{DVMT})+0.50\times\ln(\text{Bike Trips})+\cdots)}$$

- SPFs based on CTPP + Open Data:

CTPP Data + Open Data					
Coefficients:	Estimate	Std. Error	Z value	P value	
Intercept	-0.535500	0.364800	-1.468	0.142	
Workers Driving	0.000312	0.000045	7.013	0.000	***
Workers Biking	0.045400	0.009210	4.929	0.000	***
Income per Capita	0.000015	0.000001	11.176	0.000	***
Male Population	0.044540	0.006474	6.880	0.000	***
Median Age	-0.037880	0.004829	-7.843	0.000	***
Intersection Density	0.002053	0.000440	4.666	0.000	***
Bus Stops	0.028030	0.003338	8.397	0.000	***
Bike Lanes	0.230700	0.041410	5.571	0.000	***
AIC	4712.349				

CTPP Data + Open Data with CMAP Exposure					
Coefficients:	Estimate	Std. Error	Z value	P value	
Intercept	-2.200000	0.419800	-5.240	0.000	***
ln(DVMT)	0.177900	0.029970	5.937	0.000	***
ln(Bike Trips)	0.423600	0.043310	9.781	0.000	***
Income per Capita	0.000010	0.000001	6.894	0.000	***
Male Population	0.045690	0.006099	7.492	0.000	***
Median Age	-0.028440	0.004688	-6.066	0.000	***
Intersection Density	0.002344	0.000424	5.534	0.000	***
Bus Stops	0.011130	0.003662	3.039	0.002	**
Bike Lanes	0.201900	0.040200	5.021	0.000	***
AIC	4655.8				

*** - 99.9% statistical significance; ** - 99% statistical significance; * - 95% statistical significance; . – 90% statistical significance

Safety: Summary

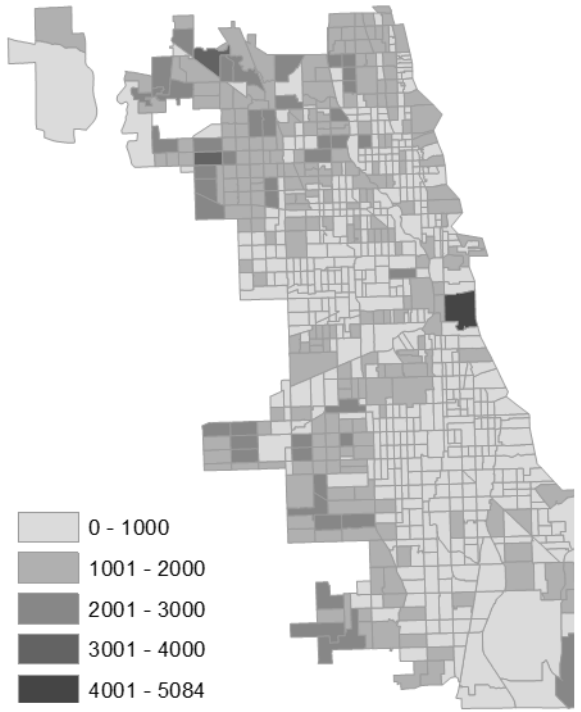
✓SPFs based on combined CTPP/Open data perform the best

✓Using CMAP exposure metrics improves the estimated SPFs

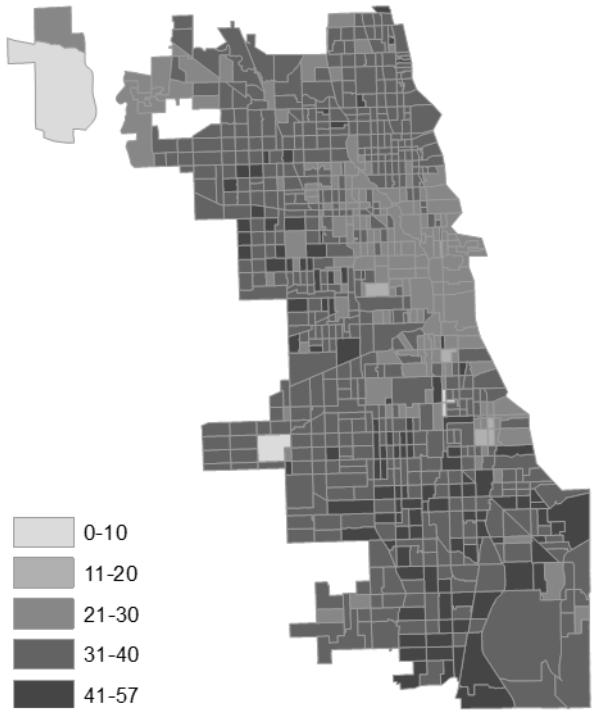
✓Open data enables capturing system-wide effects on safety

Mobility

- Efficiency of movement: How congested transportation system is?
- CTPP Data-based metrics:



Number of workers driving



Average travel time to work

Mobility Evaluation Methods

- Daily Vehicle Miles Traveled:

$$DVMT_i = \sum_{ij} AADT_{ij} \times L_{ij}$$

$DVMT_i$ - the total daily vehicle miles traveled in census tract "i"

$AADT_{ij}$ – the estimated AADT on road segment "j" within census tract "i"

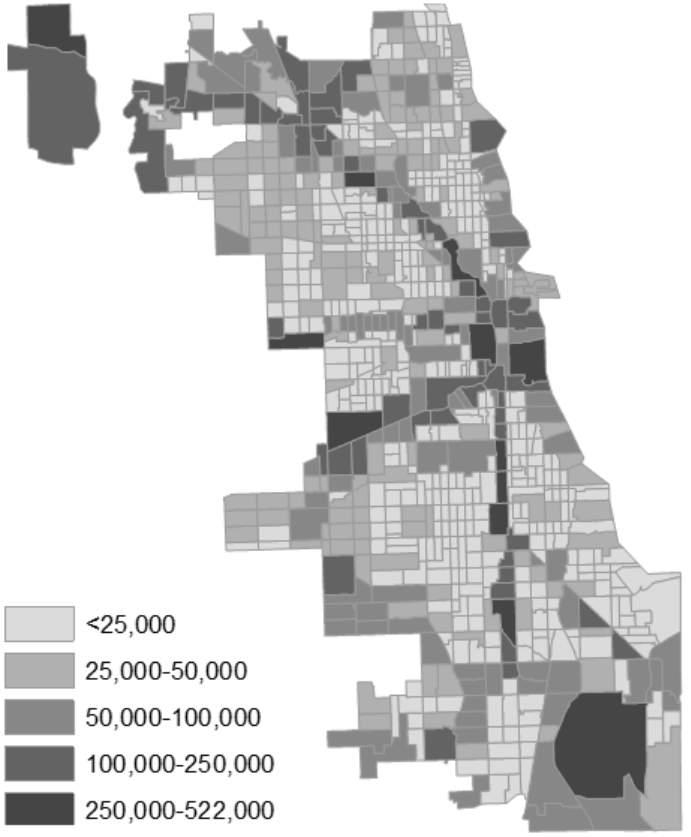
L_{ij} – the length of road segment "j" within census tract "i" in miles

- Commuter Travel Time Index:

$$CTTI_i = \frac{TTI_{ij}}{WTT_i}$$

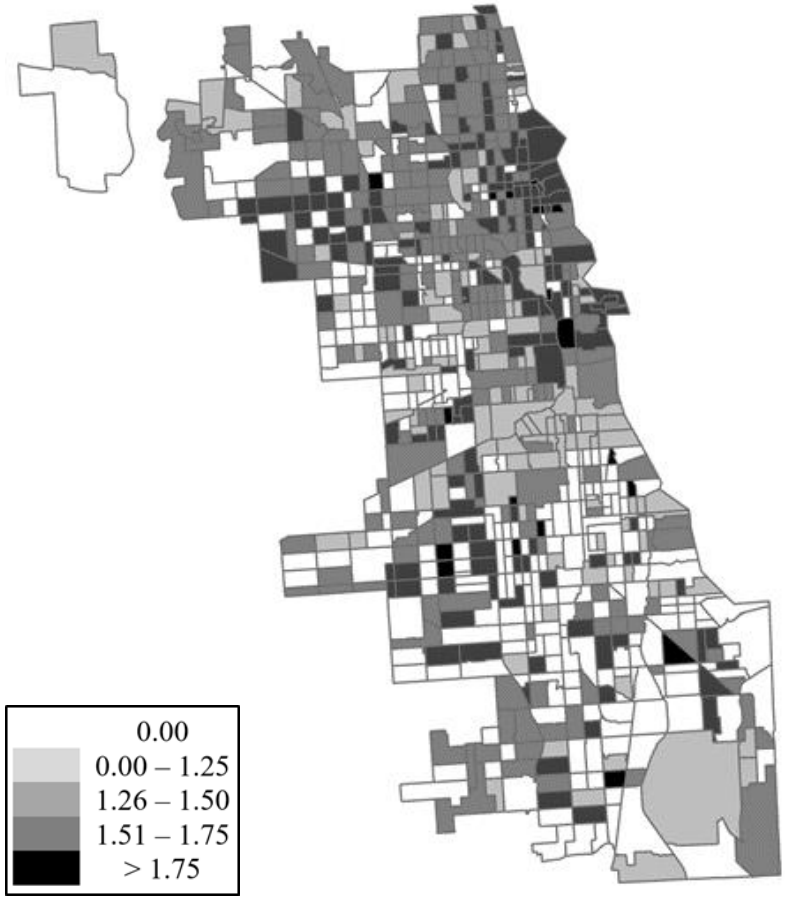
TTI_{ij} - the average travel time to work for census tract "i" and mode "j"

WTT_i – total average travel time to work in census tract "i"

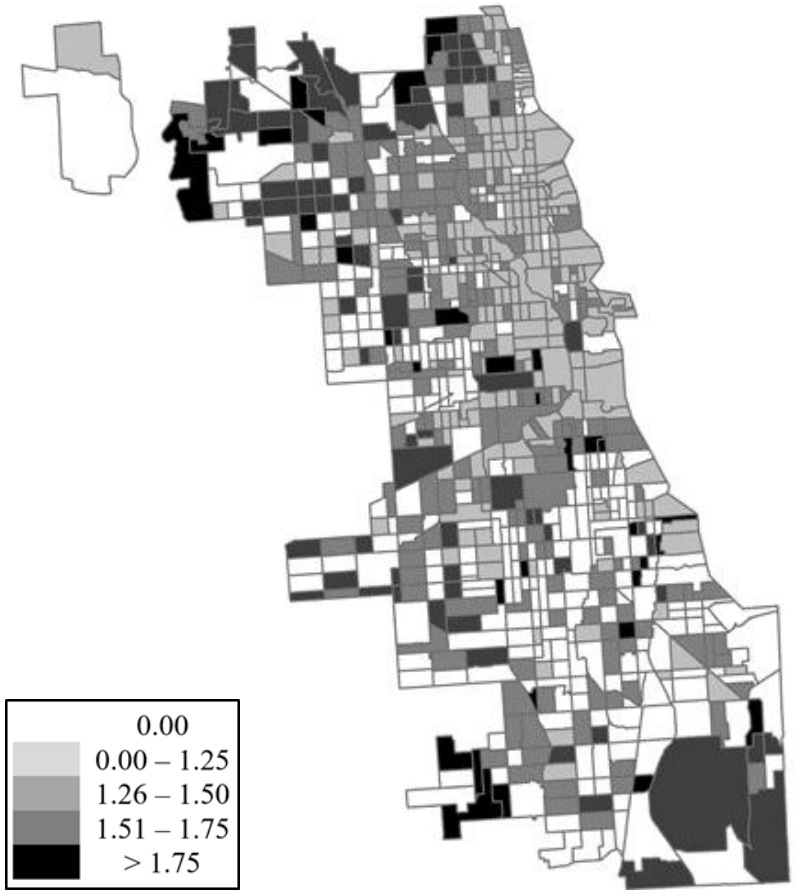


Daily Vehicle Miles Traveled

Mobility Evaluation Results



Travel time by car relative to the average travel time to work



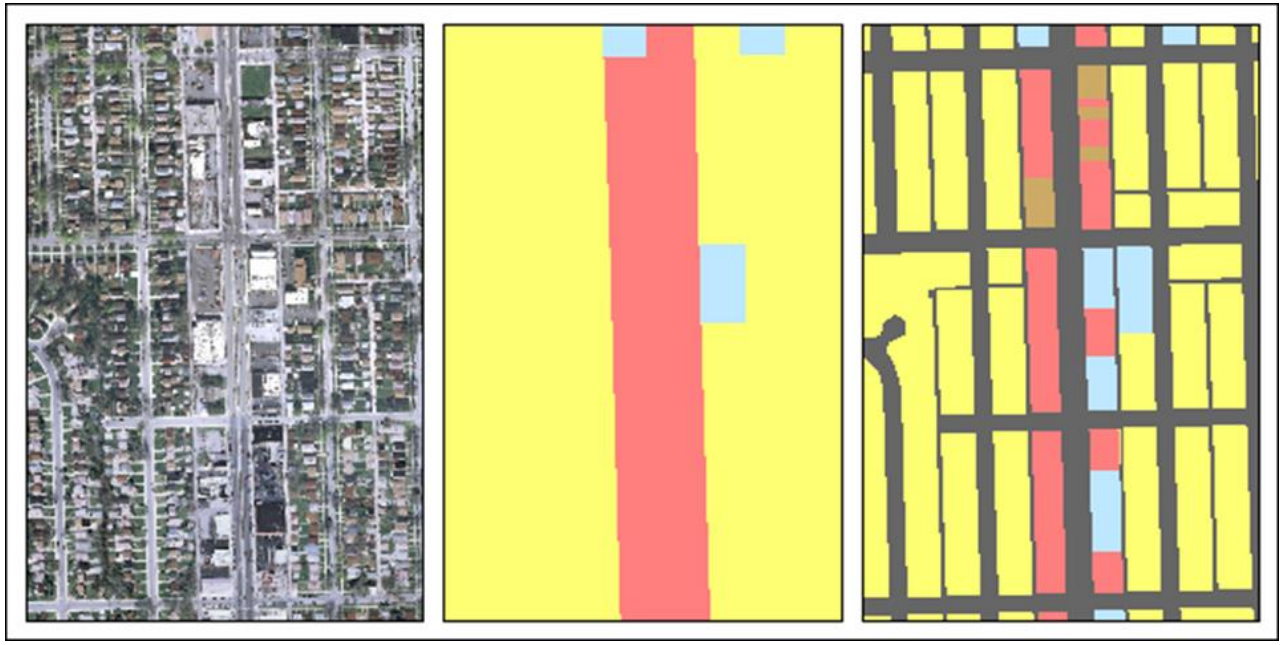
Travel time by public transit relative to the average travel time to work

Mobility: Summary

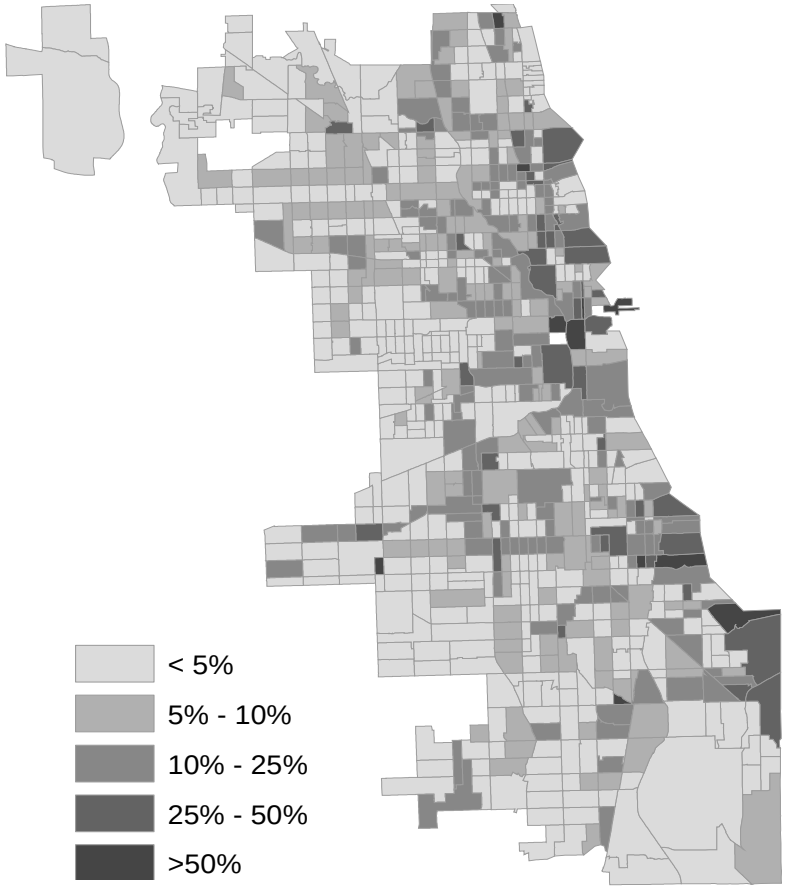
- ✓Macroscopic mobility more challenging and less accurate to measure
- ✓Missing travel time estimates present in current CTPP database
- ✓Possibilities to develop area-wide LOS should be explored

Accessibility

- The ability to reach desired destinations within the given spatial and temporal constraints



Polygon-based (center) versus parcel-based (right) land use inventory in Chicago (CMAP)



Percent of Fully Multimodal Street Network

Accessibility Evaluation Methods

$$A_{ik} = \sum_i \sum_j \{d_{ij} \in N | T_{ij} \leq T\}$$

Where:

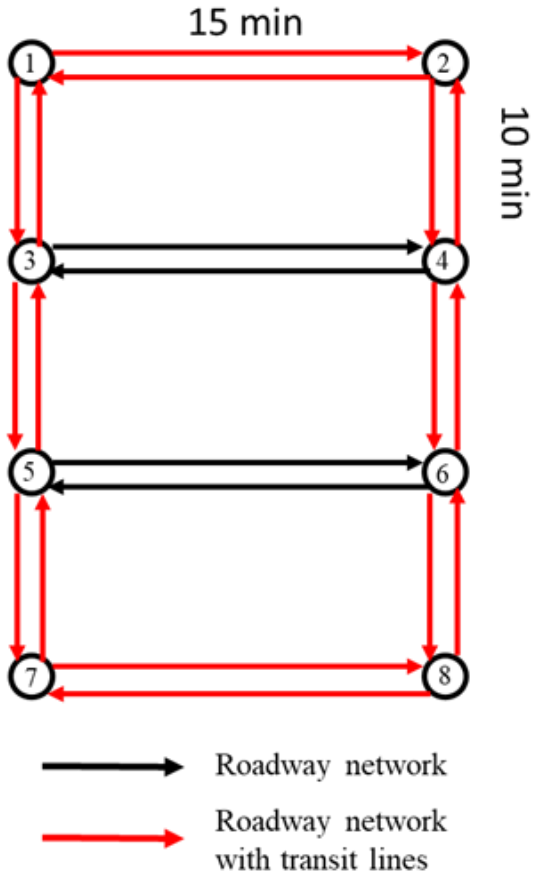
A_{ik} – total number of destinations accessible from origin i within time T, using mode k

d_{ij} – destination j accessible from origin i within time T_{ij}

N – total number of available destinations

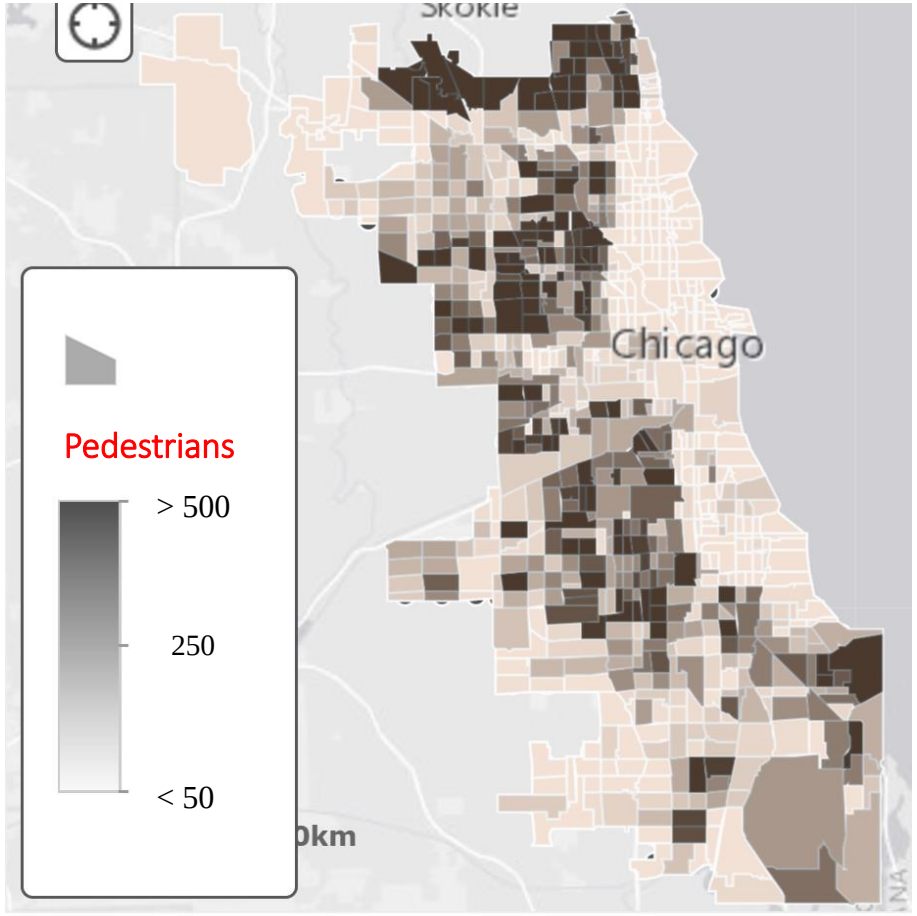
T_{ij} – time needed to reach destination j from origin i

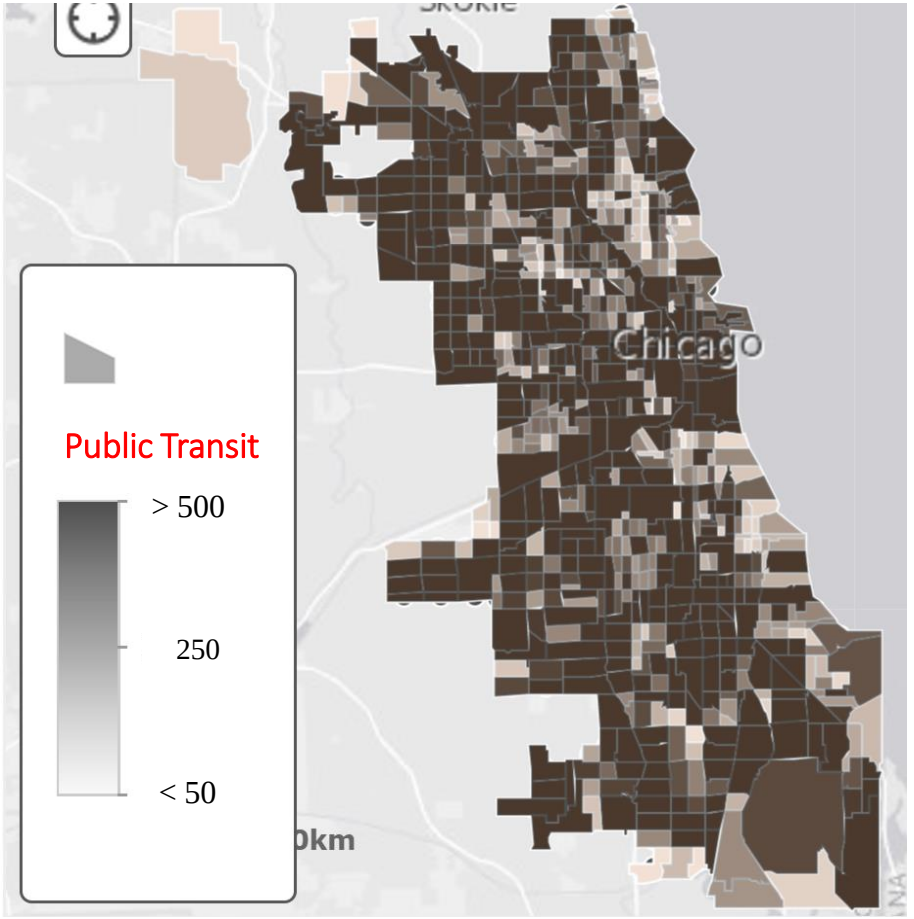
T – available time budget (5, 10, 15 … 120 minutes)



$$A_{1,transit} = d_{12} + d_{13} + d_{14} + d_{15} + d_{17}$$

Accessibility Evaluation Results





Accessibility: Summary

✓Accessibility should be prioritized in multimodal networks

✓Measuring accessibility is challenging based on CTPP data

✓Computational complexity increases with desired accuracy

Summary of Findings

- Safety performance measurement: the access to crash data is required in addition to CTPP data to develop the simplest form of SPFs. Further, the developed SPFs are improved if exposure metrics from sources other than CTPP are used.

- Mobility performance measurement: CTPP data can be used to derive conclusions about city-wide mobility, however, the metrics based on data combined from different sources are more informative when it comes to comparing different modes of transportation.

- Accessibility performance measurement: requires multimodal network infrastructure data and basic information about speeds for different modes to enable the computation of accessible opportunities available from CTPP datasets.

Summary of Findings

Performance Measurements	Required Data Input	Available from CTPP Database	Available from Other Data Sources
Safety	Crash data	No	Yes
	Exposure data	Yes	Yes
Mobility	Travel time by mode	Yes	Yes
	Travel demand by mode	Yes	Yes
Accessibility	Multimodal infrastructure	No	Yes
	Trip origins and destinations	Yes	Yes

Recommendations

- ✓Consider gaps in the existing CTPP data available to the public
- ✓Integrate CTPP data with other data sources whenever feasible
- ✓Develop TPM conscious of various transportation users/modes
- ✓Ensure that TPM is applicable in small towns and major cities
- ✓Continue to explore innovative data source capabilities

Acknowledgements

- TRB/AASHTO
- City of Chicago, Open Data Platform
- Chicago Crash Browser/Steven Vance
- Illinois Department of Transportation
- Chicago Metropolitan Planning Organization
- Chicago Public Transit Authority

Questions?


Commute
CTPP
Bike
Vehicles
Travel
Data
Transportation
Households
Access
Transit
TAZ
Time
Community
Microdata
Characteristics
Planning
MOE
Census
Trends
Synthesis
Walk

Facilitated Discussion

- Identify/share other innovative approaches
- Data concerns and issues
- User community needs

Discussion # 1: Innovative Approaches

- How are others using CTPP for Transportation Performance Management? Which performance areas and measures?
- Are practitioners combining other data with CTPP? How?
- What new, innovative data sources are being used?

Discussion # 2: Data Concerns and Issues

- What limits use of CTPP/Census Data for performance measures?
- What are the pitfalls or limitations to combining CTPP with other data sources?
- What impediments exist to implementing demonstrated measures immediately?

Discussion # 3: User Community Needs

- What tools, trainings, or other resources can be developed by the CTPP Program to facilitate use of CTPP data for performance measures?

- What additional research would help advance the use of CTPP data for performance measures?