Flexible Transit for Low-Density Communities

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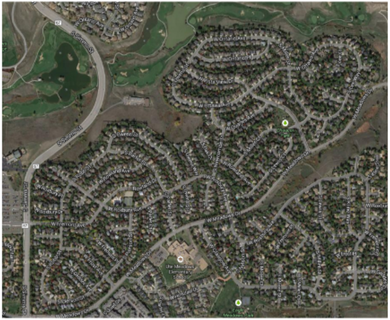
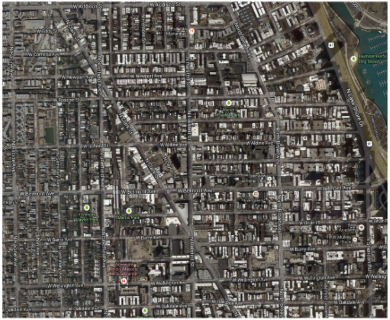
Outline

Public Transportation Provision in Low-Density Areas



Littleton, CO; Walk Score: 29 1000 ft 400 m



Chicago, IL; Walk Score: 94 Source: Google Maps

Figure: Comparison of Street Connectivity in urban vs. suburban setting

- Vicious and virtuous cycles of regional transit allocation
- High-cost of demand-responsive transit, taxis
- Demographics: youth travel, silver tsunami, suburbanization of poverty

Semi-Flexible Systems: Types

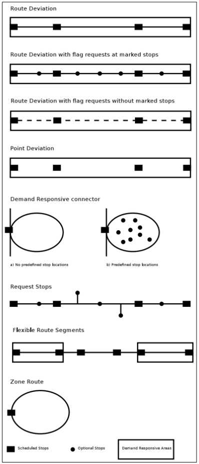


Figure: Flexible Service Types (From Errico et al. [4])

Demand-Responsive Transit Services

- Typically door-to-door unless some structure in place (as in previous slide)
- Sometimes a deadline (2 hours before, evening before), particularly for paratransit
- Most research focuses on different service combinations, meaningful objective functions, varying input parameters (time windows, vehicle types)

Transportation Network Companies (TNCs) and other emerging options

- Uber, Lyft and Sidecar currently operate in Chicago - and all are testing shared services
- Curb and other apps for hailing/paying for cabs
- Bridj (Boston) serves origins and destinations that are otherwise not connected, or require many transfers
- Chariot, Leap and Loup (San Francisco) offer more "dynamic" transit routes, primarily for commuters, but are not dynamic in the sense of DRT

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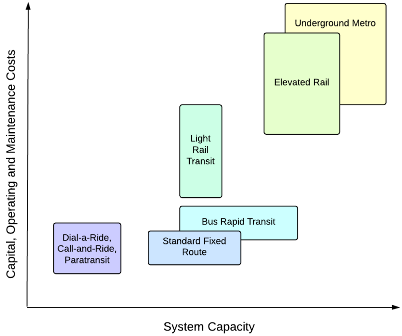
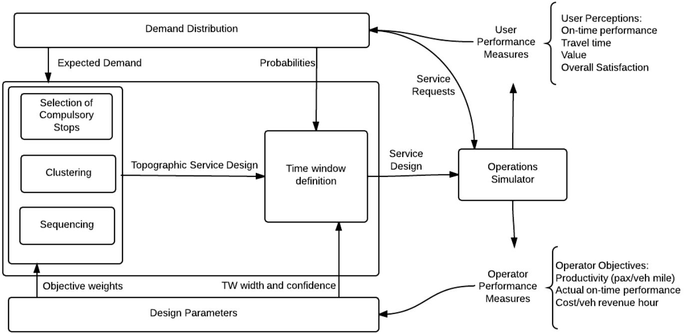
Research Questions



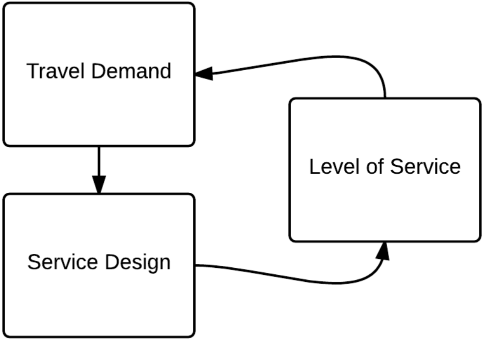
Adapted from Wright, 2004

- How much structure is needed at what level of demand?
- What level of structure offers benefits to both users and operators, as compared to DRT or fixed-route?

Conceptual Framework

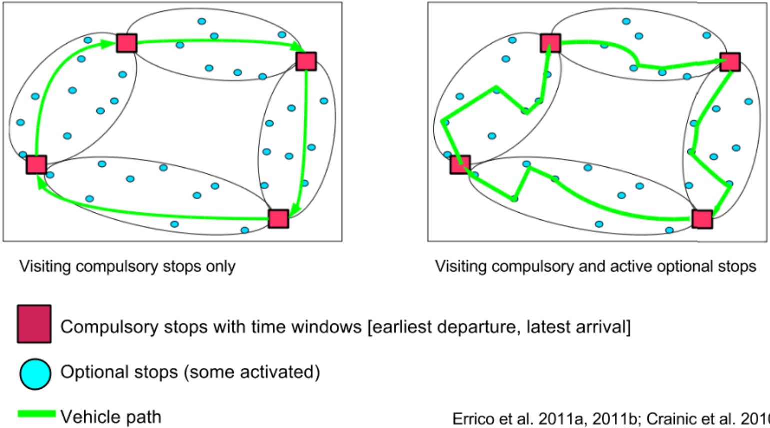


Simplified Concept



Existing Method: Single-Line DAS

- Crainic et al. - single line, single vehicle on networks with crow-fly distance
- Some interesting practical examples exist, e.g. Flexlinjen in Sweden and Kutsuplus in Finland, but little knowledge of supply-demand interactions
- Contribution: simulate on a real network with multiple vehicles and actual travel demand data

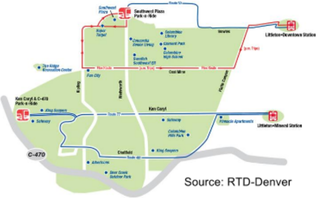


Errico et al. 2011a, 2011b; Crainic et al. 2010

Case Study Service Area Information

Census Fact Finder 2012 Estimates:

- Population: 42,000
- Current trip requests: ~5-10 per hour (off-peak/peak)
- Service Area: 16 square miles
- Median income: $57,330
- Employment:
    - 33,000 over age 16
    - ~22,000 in labor force
    - 7.4% unemployment
    - Lockheed Martin employs 14,000



Source: RTD-Denver

Applied to Existing Service Area

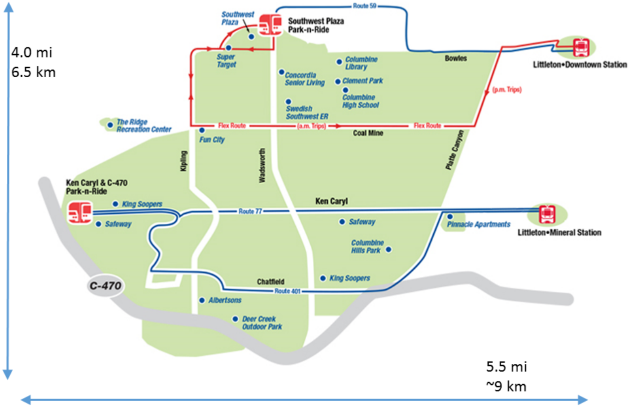


Figure: South Jefferson County Call-and-Ride Area

Clustering and Network Analysis

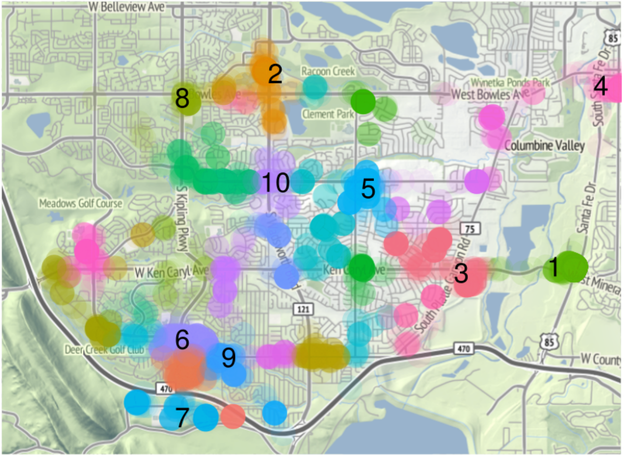


Figure: K-means Clustering with Clusters of highest degree labeled

Bird's Eye View of Location 6/7

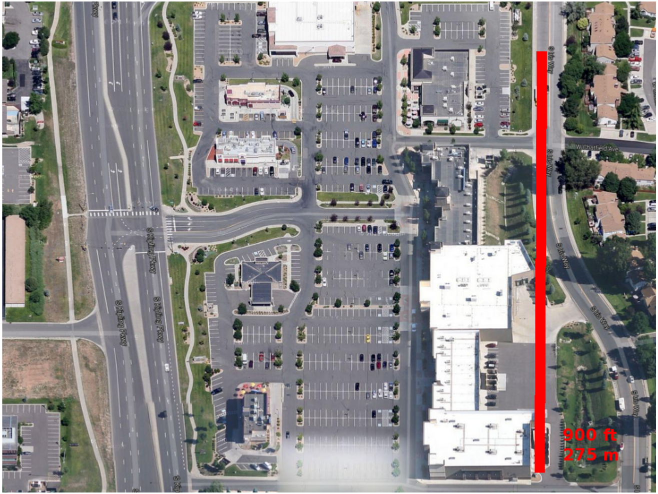
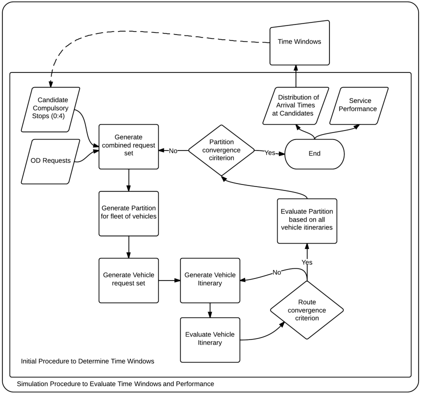


Figure: Bird's Eye View of Kipling Ave. & W Chatfield Ave.

Identifying Time Windows



- Simulate service without time windows (i.e. earliest arrival and latest departure from a “checkpoint”), but with compulsory stops, to determine ideal time for visiting.
- Then add time windows to simulation to assess performance.

Example: Joliet IL, 3 vehicles

Compulsory Stops	Stop	Mean Arrival	SD Arrival	75 %ile	90th %ile
1	1: Joliet Metra Station	6.07	9.99	12.27	18.70
2	1: Joliet Metra Station	11.27	11.31	14.97	25.66
2	2: Twin Oaks Shopping Place	14.42	12.37	22.98	27.31
3	1: Joliet Metra Station	8.62	11.99	15.53	25.80
3	2: Twin Oaks Shopping Place	15.69	12.66	23.93	32.03
3	3: Larkin Village Apartments	6.86	9.26	15.05	15.05
4	1: Joliet Metra Station	13.49	13.49	22.59	29.99
4	2: Twin Oaks Shopping Place	7.34	12.13	10.93	27.31
4	3: Larkin Village Apartments	6.58	8.29	15.05	15.05
4	4: Joliet Mall and Shopping Center	12.65	13.77	22.35	25.90

Service Objectives

- Typical DRT service objective function is to maximize slack time in the schedule.
- Here, minimize sum of operator and user cost and impose a large penalty for time window violations
- User travel time vs. operating time
  - Simple test showed including user costs does not increase operator cost much, but an objective minimizing only operator costs resulted in much high user costs.
  - Sensitivity analysis regarding weights for users, operators and violations

Candidates tested: 1, 2, 4 and 6

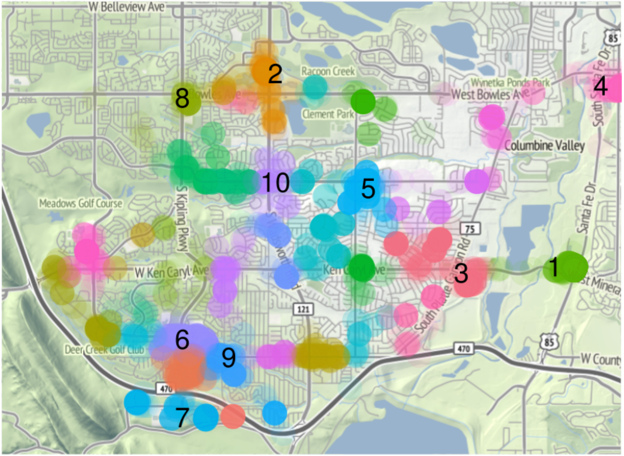


Figure: K-means Clustering with Clusters of highest degree labeled

Assessment of Appropriate Candidate "Checkpoints"

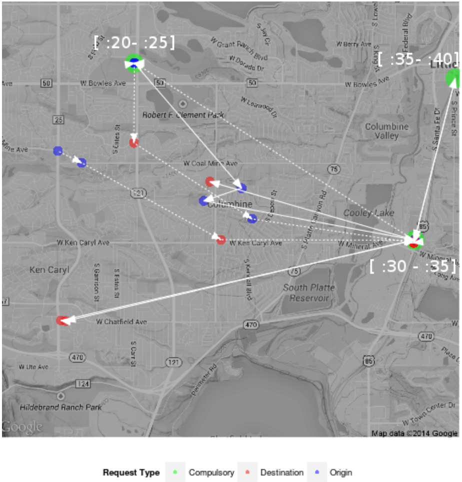
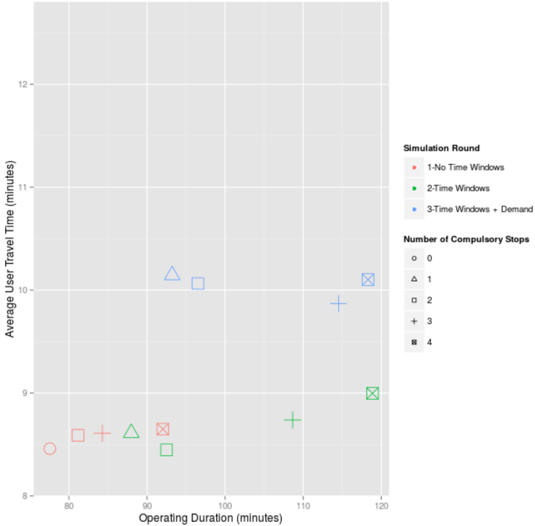


Figure: South Jefferson County, Colorado: Potential Last mile connector, 3 compulsory stops, 2 vehicles

User Travel Time vs. Operating Time for Fleet Size = 3



Improved Reliability (for some cases)

- As you add vehicles and compulsory stops, arrival times at any point in service area are more predictable
- For 3 vehicles, 3 compulsory stops: 1.5 minute reduction in standard deviation of arrival time, 0-1.2 minute increase in average travel time

Survey Design

- Convenience sample of Chicago area commuters, 120 responses in September 2014:
  - CMAP newsletter
  - NUTC Facebook and Twitter accounts
  - Personal Facebook and Twitter accounts
- Short-, medium- and long-commute markets to generate different attribute levels for efficient design
  - Maximizes information obtained from each respondent, and choices presented are more realistic
  - Gathered information about actual commute and revealed preference to classify respondents
- Will conduct a winter panel, Feb 1-28
  - 35 respondents from summer offered to take follow-up survey.

Stated Choice Survey

*

Scenario 1:

	Transit	Car	Flexible Transit
In-Vehicle Travel Time	13 min	46 min	68 min
Travel Costs	4 USD	14.57 USD**	1 USD
Walk Time	18 min	3 min	3 min
Wait Time	***		7 min
Frequency (Headway)	every 12 minutes		every 20 minutes
Number of Transfers	2		1

**Travel cost for car is a combination of fuel costs and parking costs at work

***Transit wait time is dependent on a number of things including: service reliability, frequency and when you decide to leave your house

Choose one of the following answers

○ Transit ○ Car ○ Flexible Transit ○ None

Figure: Sample Scenario from Stated Choice Survey

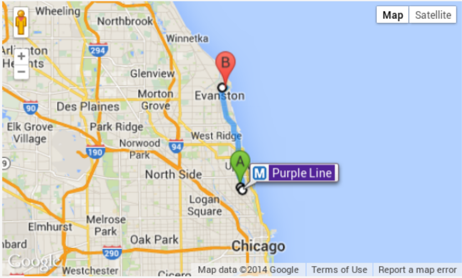
Reliability of current travel mode

Survey captured current reliability by asking the user to report their **actual** travel time (ATT) for transit and/or auto, compared to Google API generated result, and rate how confident they were in on-time arrival given their reported **allowed** time:

How many minutes does your transit work commute take?

For your given start and end location, Google Maps suggests the following time and distance:

Distance: 9.0 mi
Time: 39 mins



My transit commute typically takes: 45 minutes

Planning time index = Allowed/ Free flow; Buffer time index = (Allowed - Reported)/Reported

Preliminary results for flexible mode choice

- Value of...
  - Travel Time: $19/hour
  - Reliability: $10/hour
  - Wait Time: $27± 11/hour
  - Access Time: $29± 4 /hour
- Age ranged from 22 to 57 years old; 52% males in sample
- 57 of the 120 (48%) respondents have used a TNC such as Uber, Lyft, Sidecar:
  - These respondents were less likely to choose traditional transit in choice scenarios, all else equal, but neither more nor less likely to choose flexible transit over car

Preliminary results for flexible mode choice (continued)

- Other notable items
  - Divvy significant, car-sharing was not –> Early-adopters, low VOT, active travelers?
  - Whether a passenger conducts activities on-board (leisure reading, working on a laptop, relaxing) increased probability of choosing transit modes

- Respondents' revealed preference tended toward transit use, simple inertia parameter does not explain much variation [1]
  - Stated Choice: 31% Car, 13% flexible transit, 56% traditional transit

[1] 60% transit, 26% car, 11% walk, 3% bike in sample, versus 45/55 transit/auto split for trips to CBD for all Chicago commuters

Key Takeaways and Expected Findings

- Extract performance measures from user and operator objectives to determine appropriate service.
- Adding structure to a demand-responsive service may reduce (perceived) barriers to entry for people accustomed to a traditional transit service
  - Current transit users seem to prefer a timetable, had some wariness of (hypothetical) flexible mode
  - Structure can enhance reliability, but some flexibility will mean less walking in sparse areas
- Expect to identify thresholds for acceptable frequency of service in low-density areas
- **On-going** sensitivity analysis related to:
  - fleet size and capacity
  - objective function defined by user cost - trade-offs for operator and impact on demand
  - demand fluctuation: how robust is service design?

References

[1] Crainic, T. and et al. (2005). Meta-Heuristics for a class of demand responsive transit systems. *INFORMS Journal on Computing*, 17(1):10–24.

[2] Crainic, T. G., Errico, F., Malucelli, F., and Nonato, M. (2010). Designing the master schedule for demand-adaptive transit systems. *Annals of Operations Research*, 194(1):151–166.

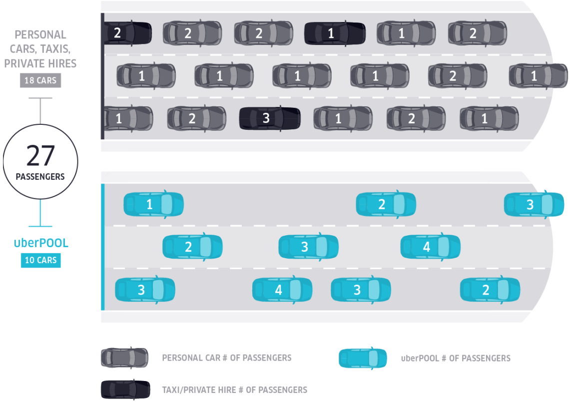
[3] Errico, F., Crainic, T. G., Malucelli, F., and Nonato, M. (2011a). The design problem for Single-Line demand- adaptive transit systems. Technical Report 2011-65.

[4] Errico, F., Crainic, T. G., Malucelli, F., and Nonato, M. (2011b). A unifying framework and review of Semi-Flexible transit systems. Technical Report 2011-64, CIRRELT.

[5] Errico, F., Crainic, T. G., Malucelli, F., and Nonato, M. (2012). A benders decomposition approach for the symmetric TSP with generalized latency. Technical Report 2012-78, CIRRELT.

[6] Errico, F., Crainic, T. G., Malucelli, F., and Nonato, M. (2013). A survey on planning semi-flexible transit systems: Methodological issues and a unifying framework. *Transportation Research Part C: Emerging Technologies*, 36:324–338.

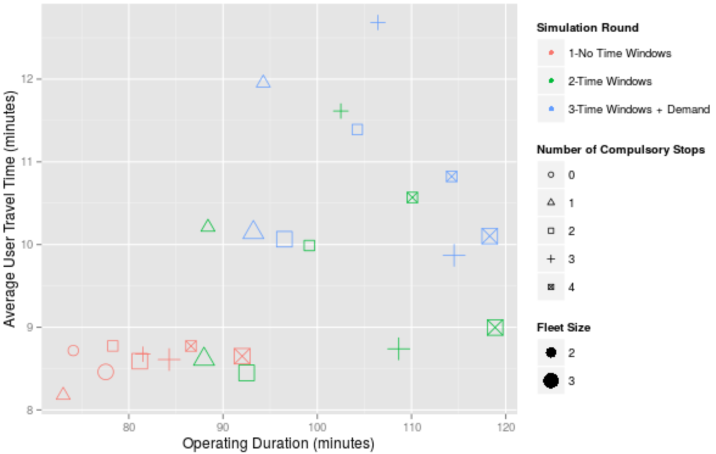
A Comment on Emerging and Existing Flexible Modes



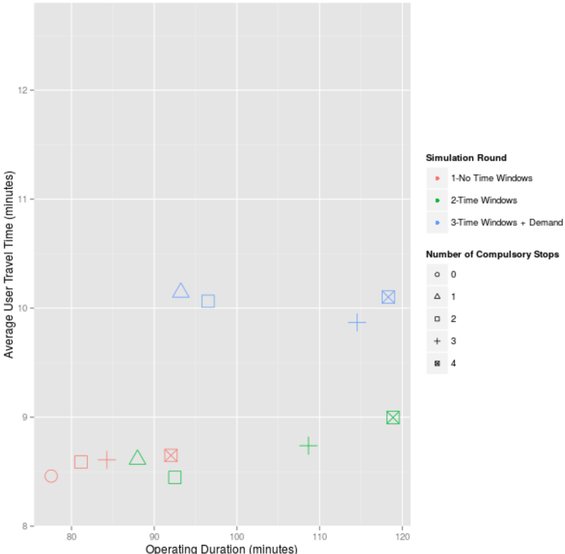
- How will cities and agencies work with these platforms to improve service, potentially with their existing rolling stock?
- Will these services be low-cost enough to serve current captive markets?
- What is the role of car-sharing (and autonomous shared vehicles) in filling this gap?

User Travel Time vs. Operator Cost for Fleet Size 2 & 3

(Where user travel time has same penalty as operating time in objective function)

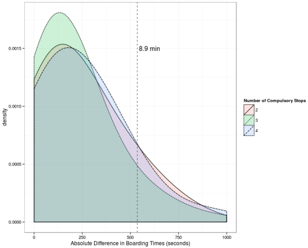


User Travel Time vs. Operator Cost for Fleet Size = 3

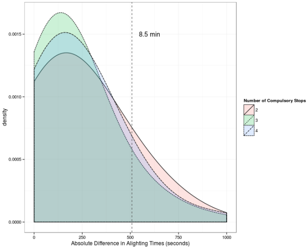


Watch out for hop-ons

Passenger Delay when Random Demand is Introduced



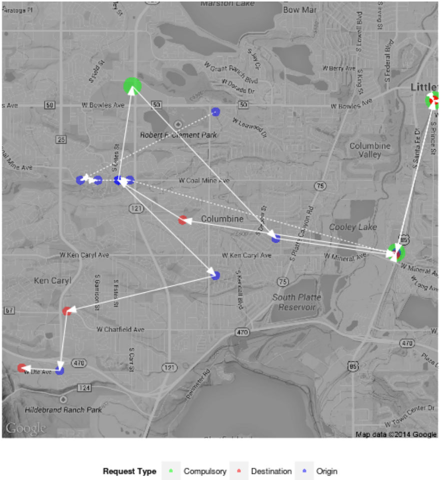
(a) Absolute Difference in Boarding Times



(b) Absolute Difference in Alighting Times

Figure: Difference in Boarding and Alighting times after Additional Demand at Compulsory Stops with Time Windows

Assessment of Appropriate Candidate “Checkpoints”- Another example



Flexible Technique: St. Charles, Illinois, USA (Chicago metro area)

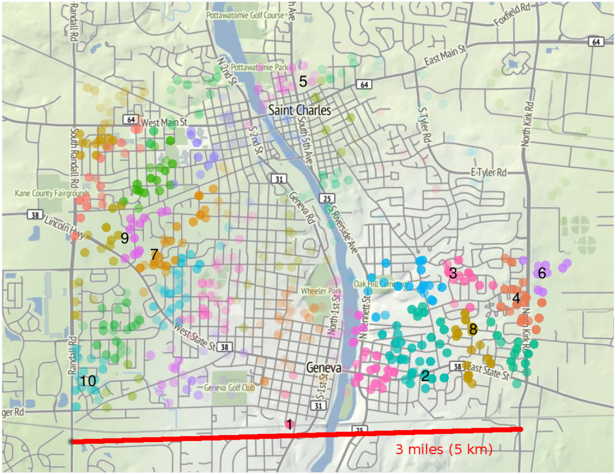


Figure: Clustering and Network Analysis of Case Study Area in St. Charles &

Flexible Technique: Joliet, Illinois, USA (Chicago metro area)