Cornell University
Operations Research and
Information Engineering

Operations Research in EMS in the Past, Present and Future

Shane G. Henderson

http://people.orie.cornell.edu/~shane

Joint work with many folks!

Thanks: NSF CMMI 0758441, CMMI 0926814, CMMI 1200315, Optima Corporation, Toronto EMS, Dave Lyons, Ambulance Victoria, Armann Ingolfsson, Andrew Mason

Who Am I?

St John

Co-developed BARTSim 1997-99
Acquired by Optima Corporation, now known as Optima Live/Predict/…

optima
PEOPLE MOBILISATION

Working loosely with Optima.

Ambulance Victoria, Toronto EMS have kindly shared data

Scheduling daily patient transfers around Ontario, positioning fixed-wing aircraft and helicopters for urgent and emergent calls

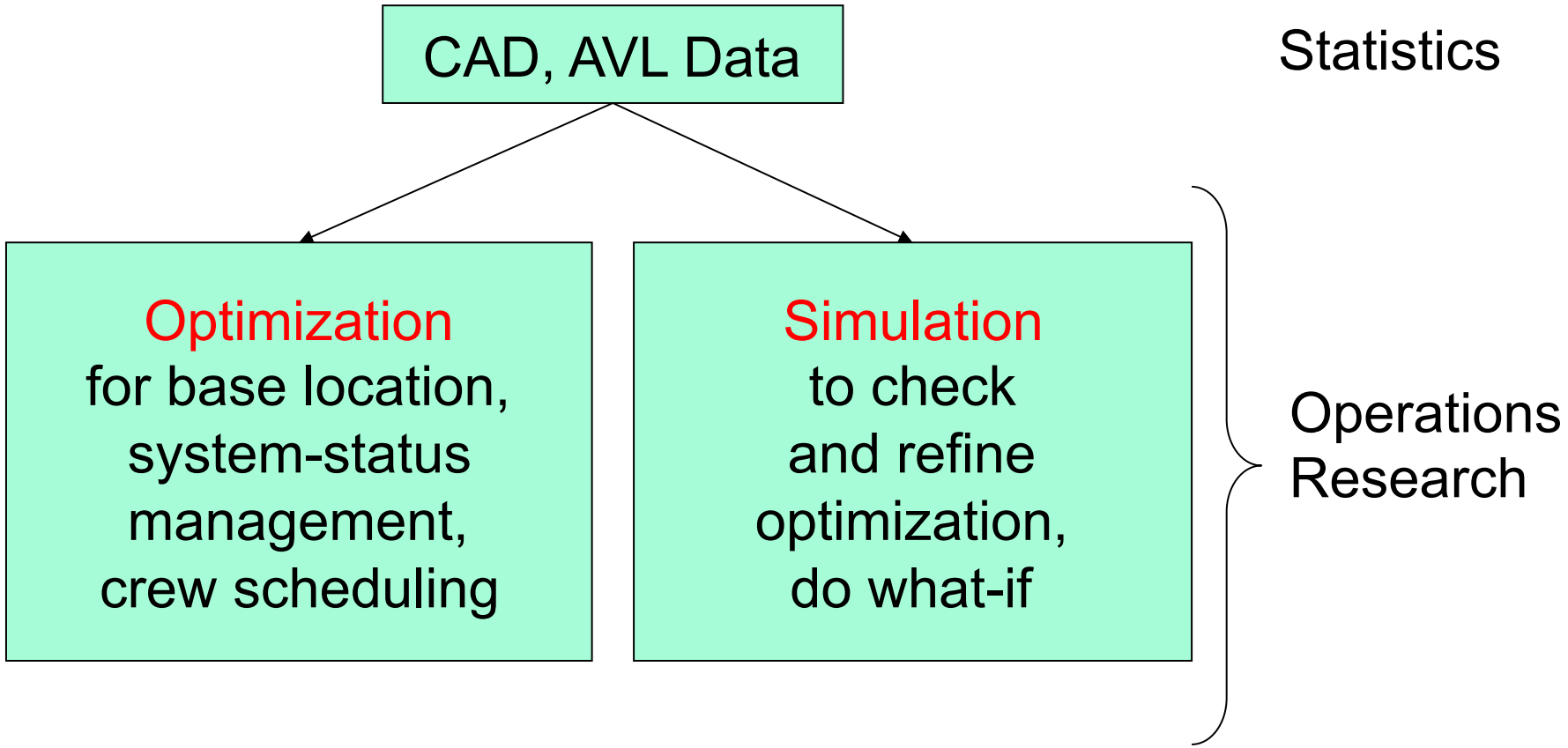
Some Day-to-Day Questions

- How many ambulances do we need?
  - At what times?
  - Where?
- What happens to performance if
  - We close Base 3?
  - Central hospital closes its spinal unit?
  - A “big event” knocks out some of the fleet?
- What crew schedules and rosters should we use?

Some Higher-Level Questions

- What benefits might we get from system-status management?
- Should we use a tiered fleet?
- How should national resources be divided between regions?

Statistics and Operations Research in EMS



My Plan For Today

- Optimization and simulation
- Case: Ithaca Fire Department
- Case: Ornge
- Policy questions
  - Economies of scale
  - System Status Management
- Future Research

Optimization and Simulation

Some Questions

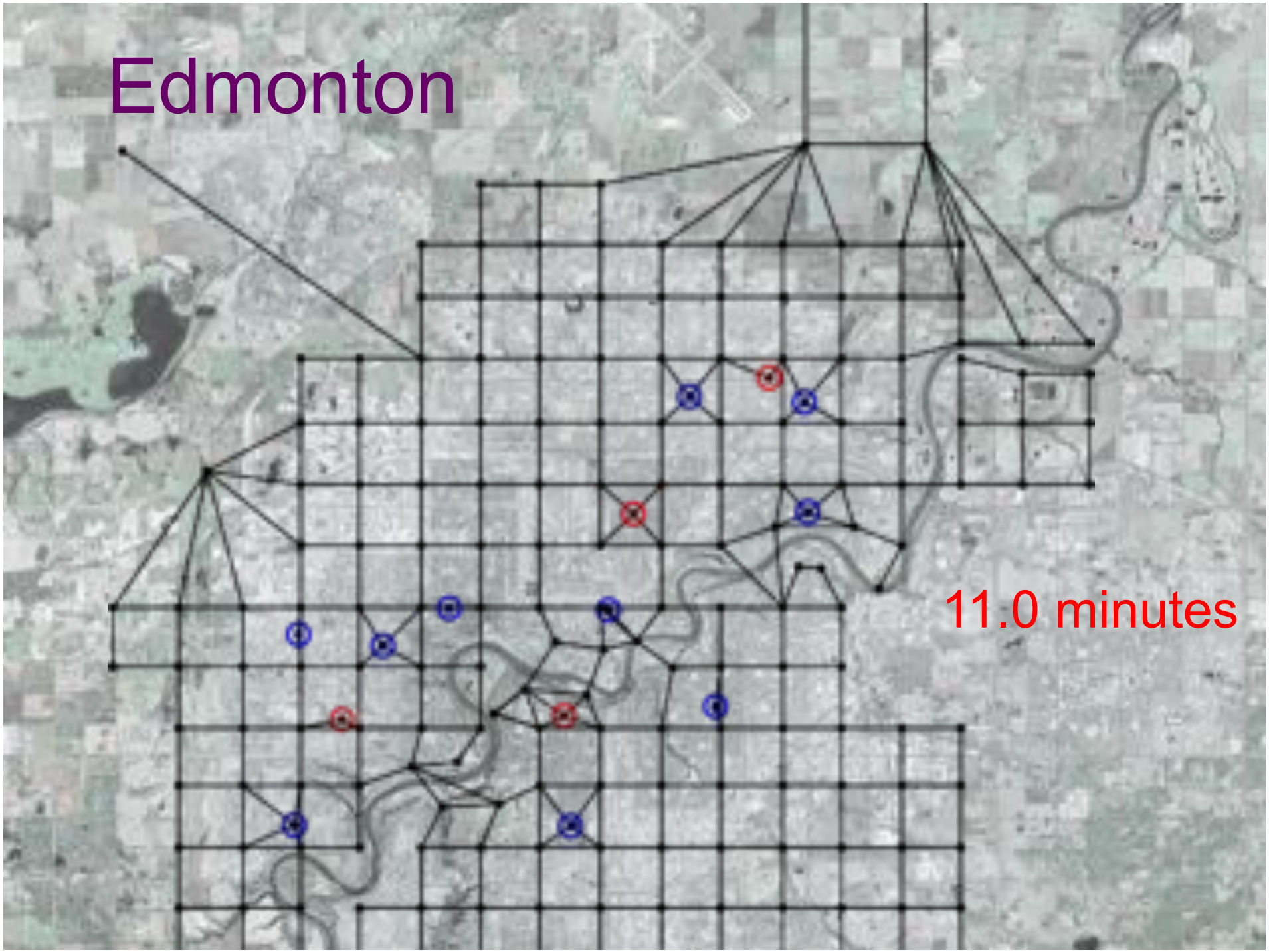
- We're considering a new base. Where is the ideal location?
- Are our bases in the right places?
- What locations are best for System Status Management?
- Given where all my units are now, where should I send a newly free unit?

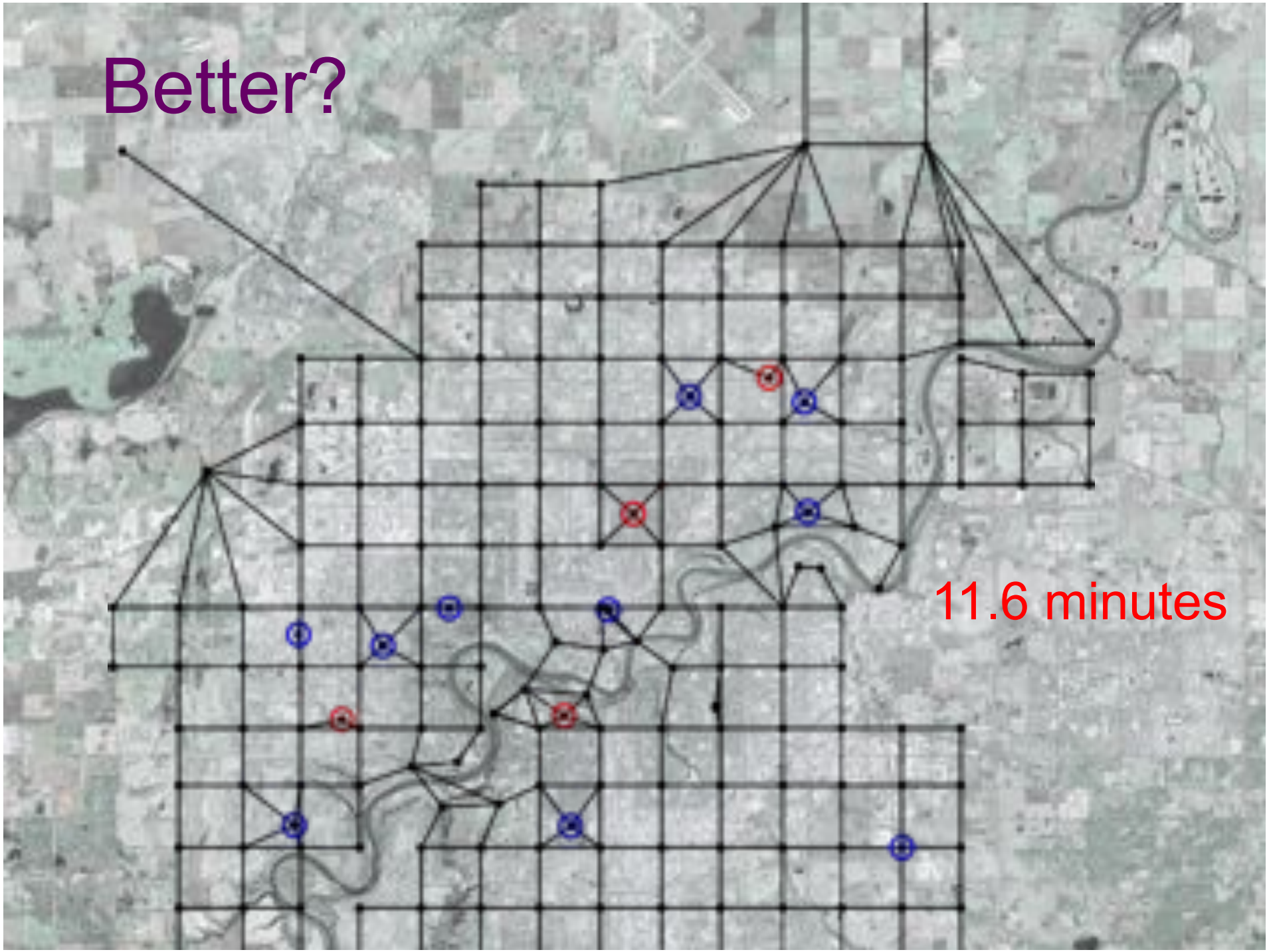
One Way to Do It

- Download calls and locations to GIS
- Stare at the map for a while
- Pick location(s)
- Argue, argue, argue
- Are you sure?

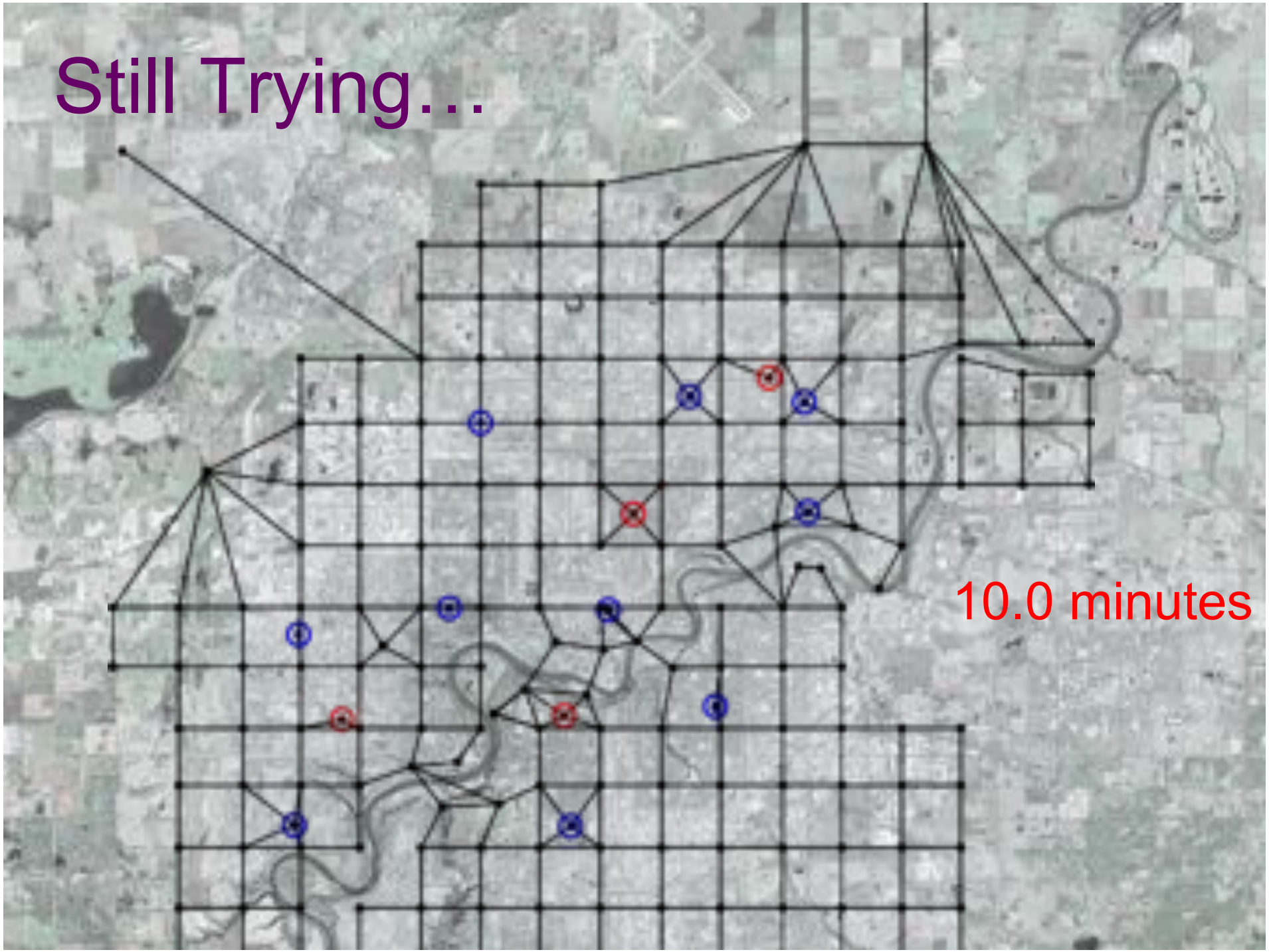
A Better Way

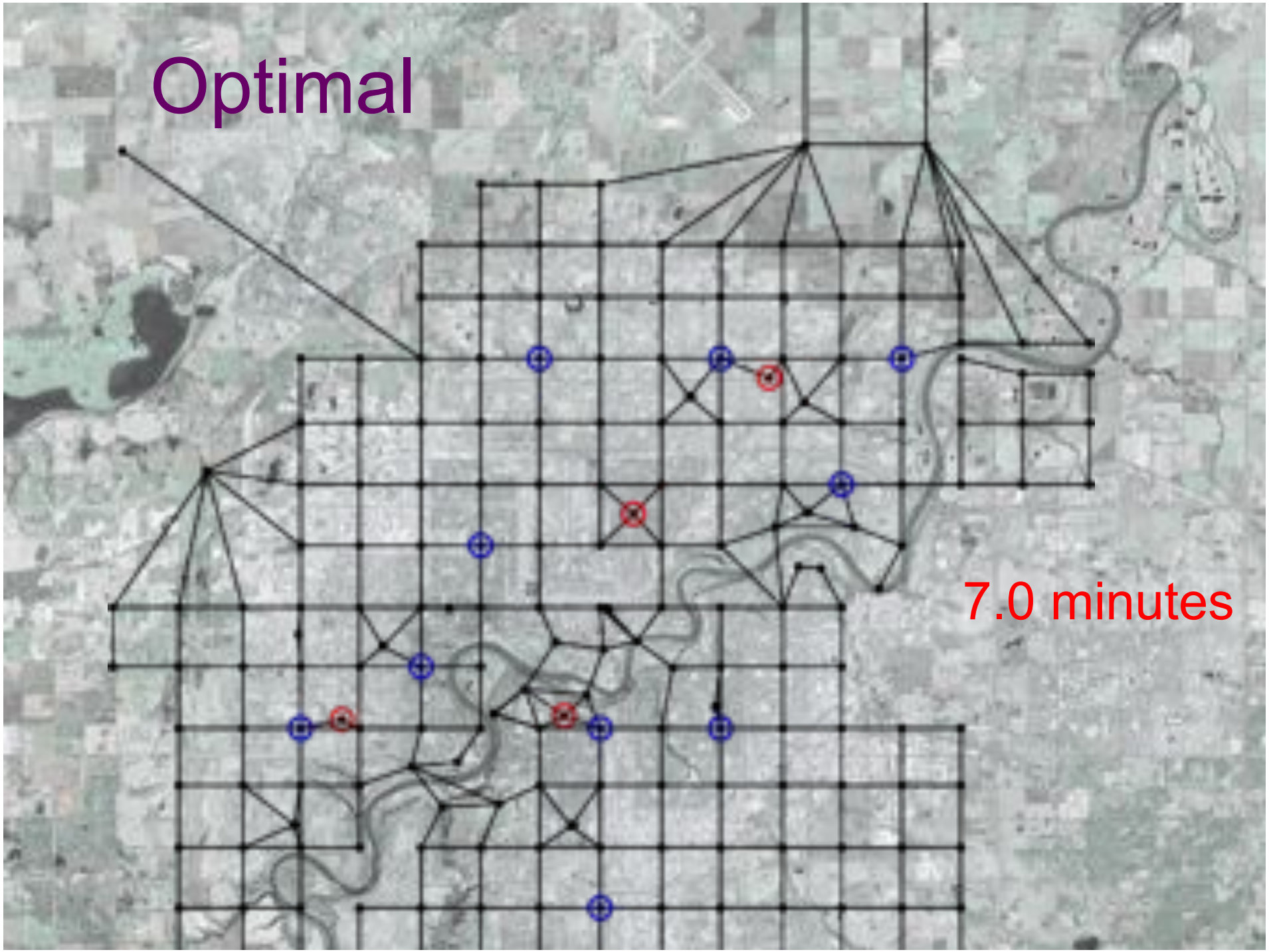
- Use optimization
- Search over all possible locations, and find the best (usually under simplifying assumptions that make the math work out)
- Not sure about those assumptions?
- Test with a detailed simulation
- For example, which potential base locations give the smallest average travel time to calls?

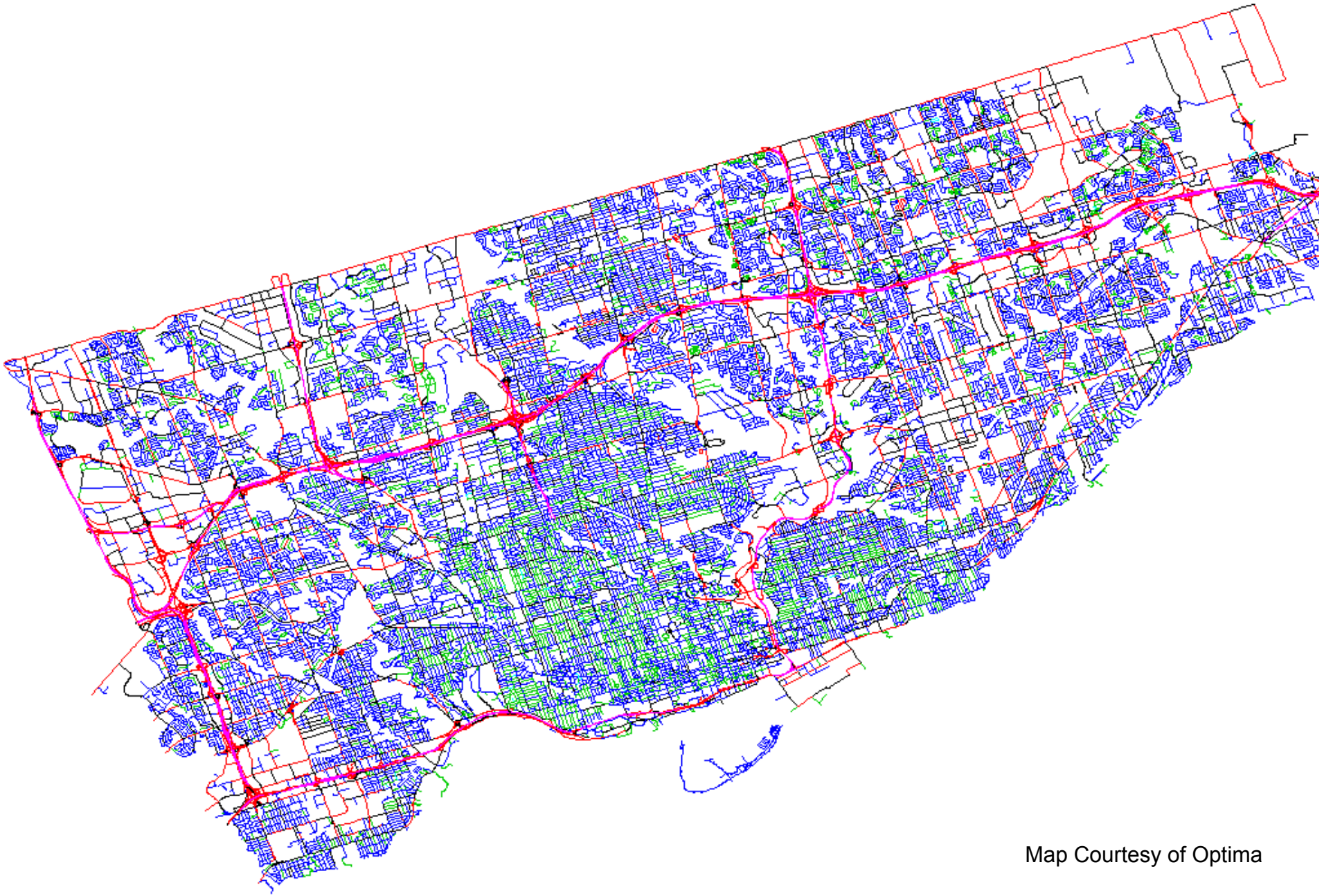

Edmonton
11.0 minutes


Better?
11.6 minutes

Still Trying…




Optimal
7.0 minutes

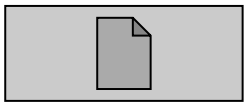


Map Courtesy of Optima

Optimization

- A method for searching over huge numbers of options to identify the best
- Have to make simplifying assumptions that ensure that the math works
- Very mature field
  - Used in airlines, bike sharing, refineries, network design, composite material design…
  - Constant use in EMS since the 70s

Simulation



- Computer model of operations
- As detailed as you like (modulo $$)
- Test planned changes before implementation
- Great for
  - Testing ideas without risk
  - Explaining ideas to stakeholders
- Can't do "search" like with optimization

Simulation

- Very mature field
  - Used in hospital layout, container freight planning, trucking, traffic control, food safety, …
- Constant use in EMS since the 70s
- Optimization and simulation can “calm” the conversation
  - Evidence-based decision making

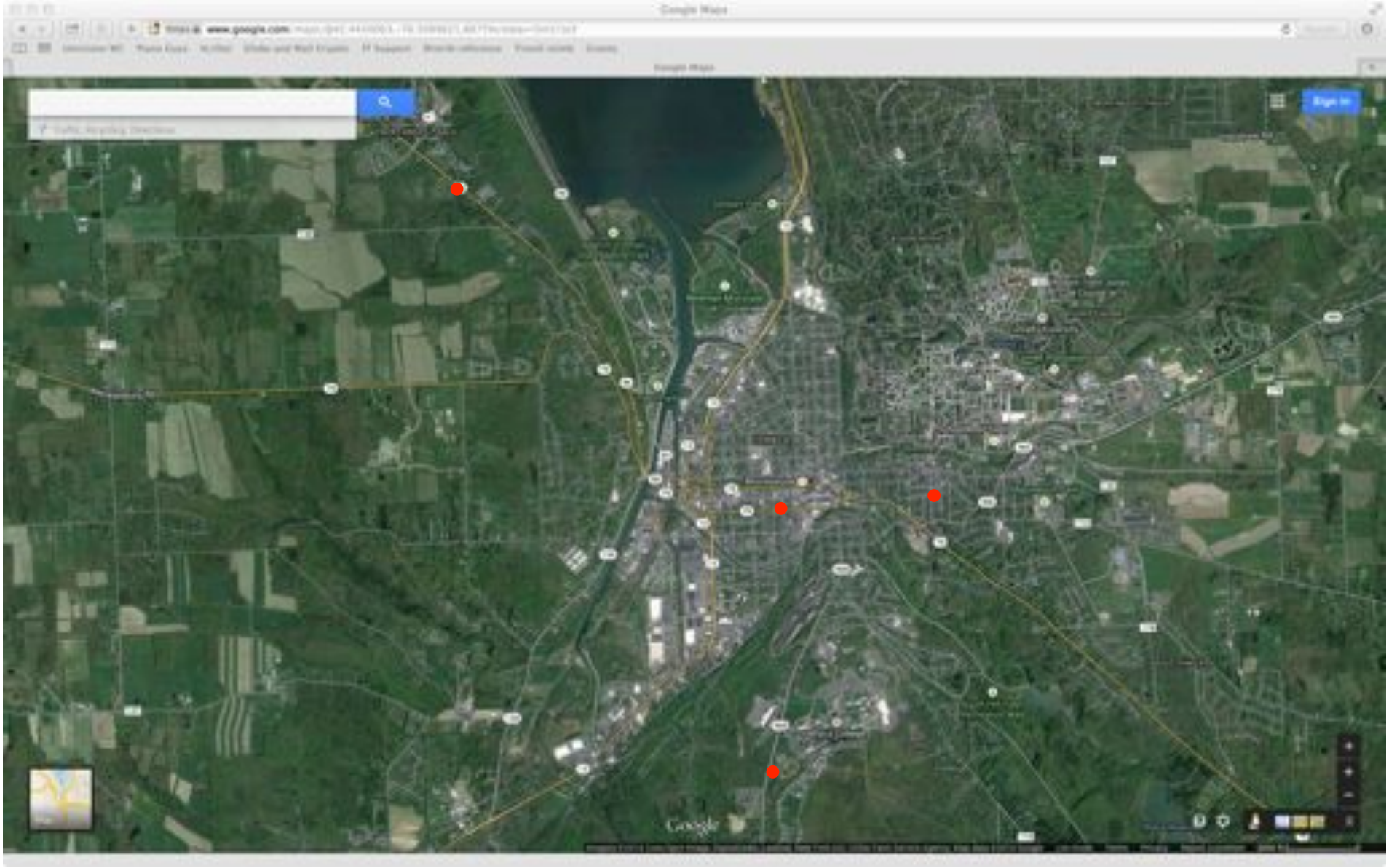
Case Study

Ithaca Fire Dept (IFD): 4 engines, 1 ladder truck

What if IFD had one more/one less engine?

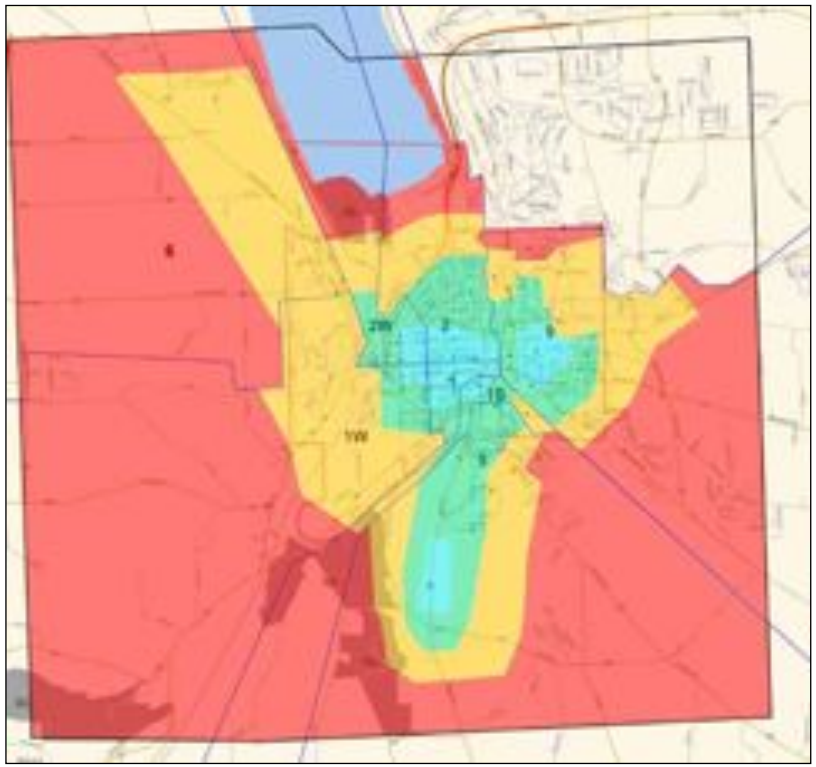
Or if one base were moved?

Master of Engineering Student Team, 2003

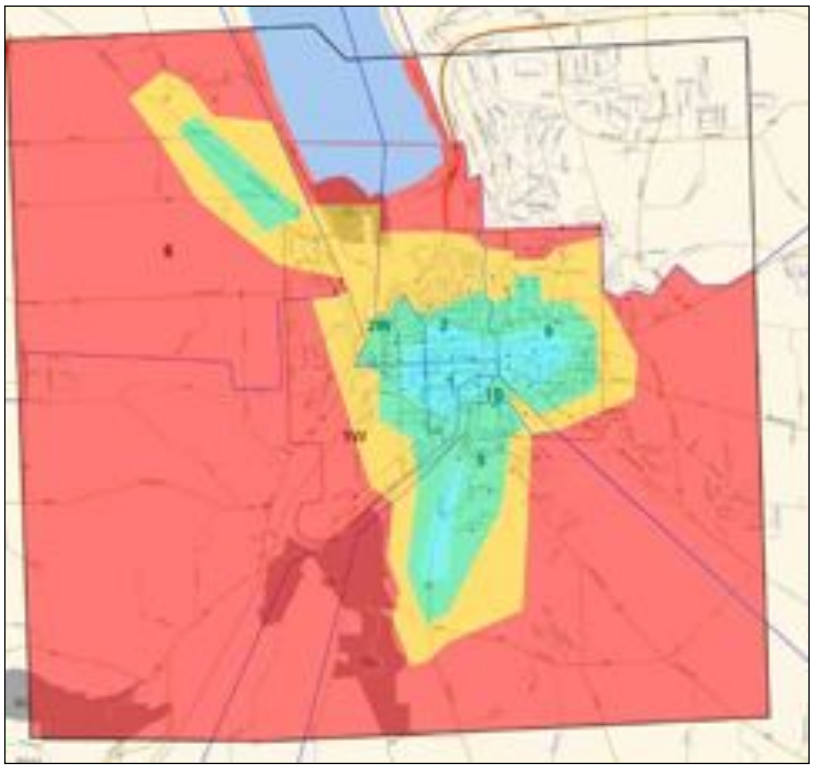


Based on 2001 data	% of first unit responses in 4 mins	% of full service responses in 8 mins
4 engines	xx	xx
5 engines	xx	xx
4 engines, move West Hill station	xx	xx

< 2 min
< 3 min
< 4 min
First Unit Average Travel Time > 4 min



Current situation



Base case simulation

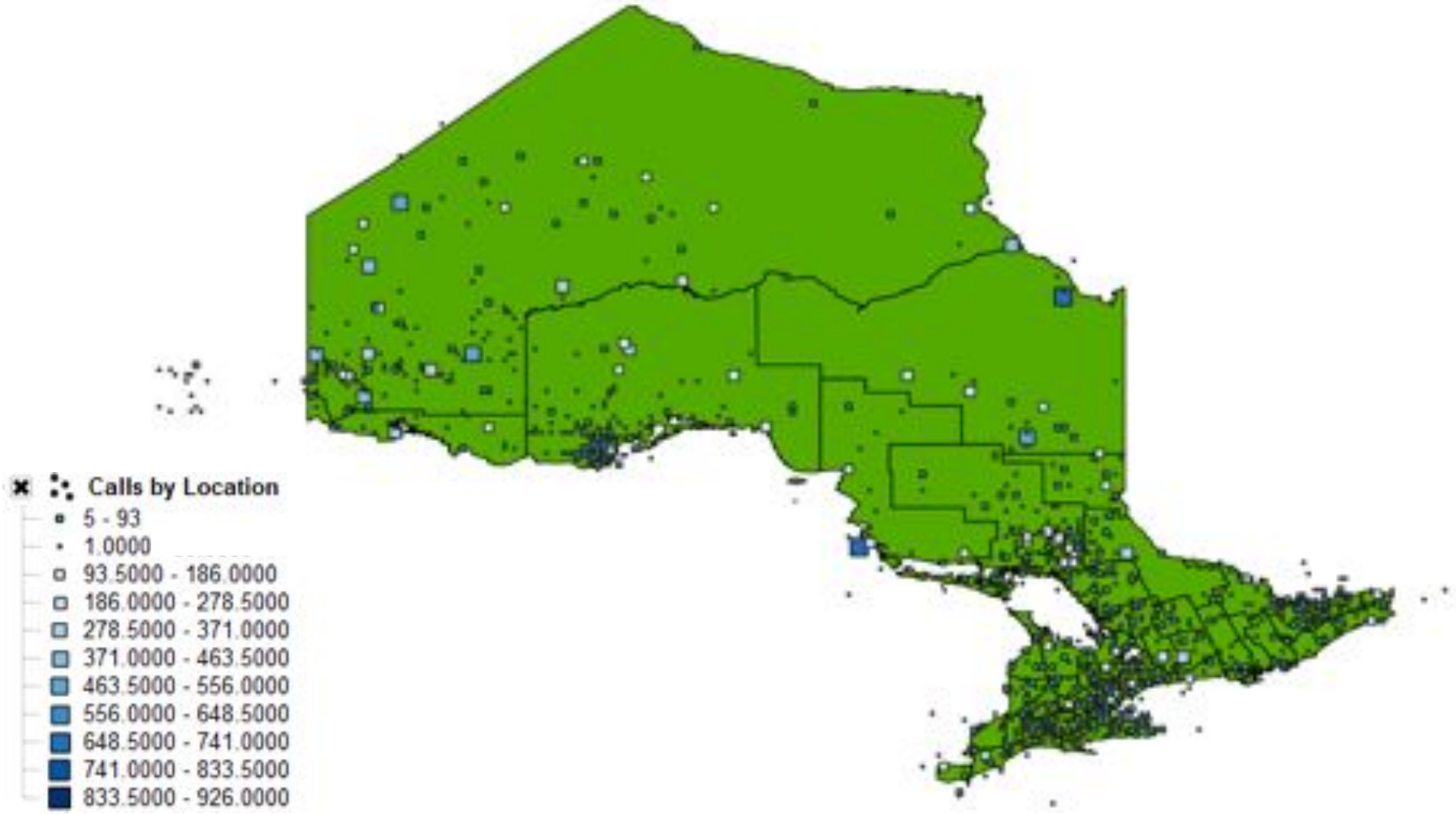
Case Study

Ornge, Ontario Air Ambulance

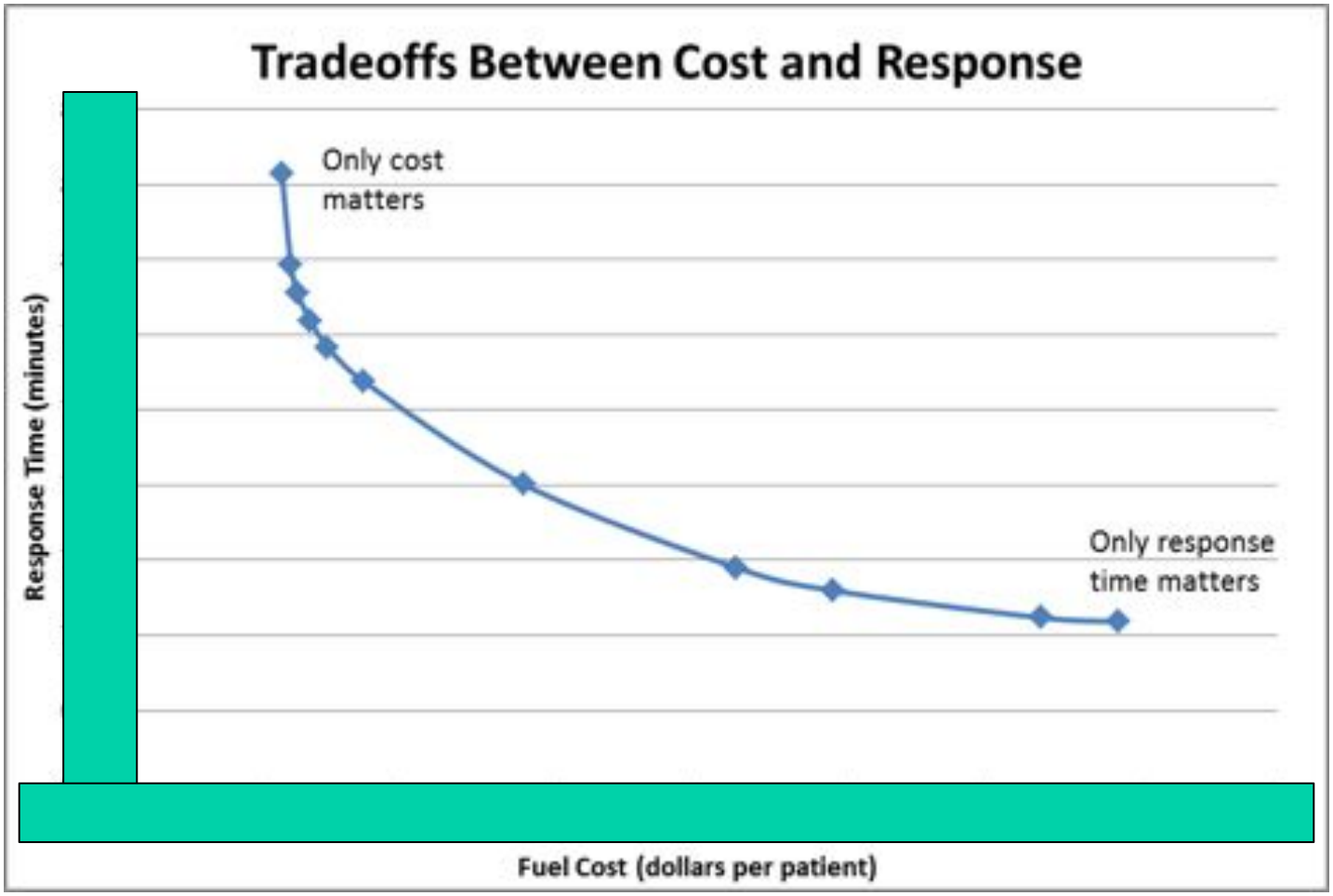
Scene calls/urgent/emergent and planned transports (day ahead)

Master of Engineering Student Teams, 2008-14

Spatial Distribution of Call Arrivals



Urgent/Emergent Locations



Day-Ahead Transports

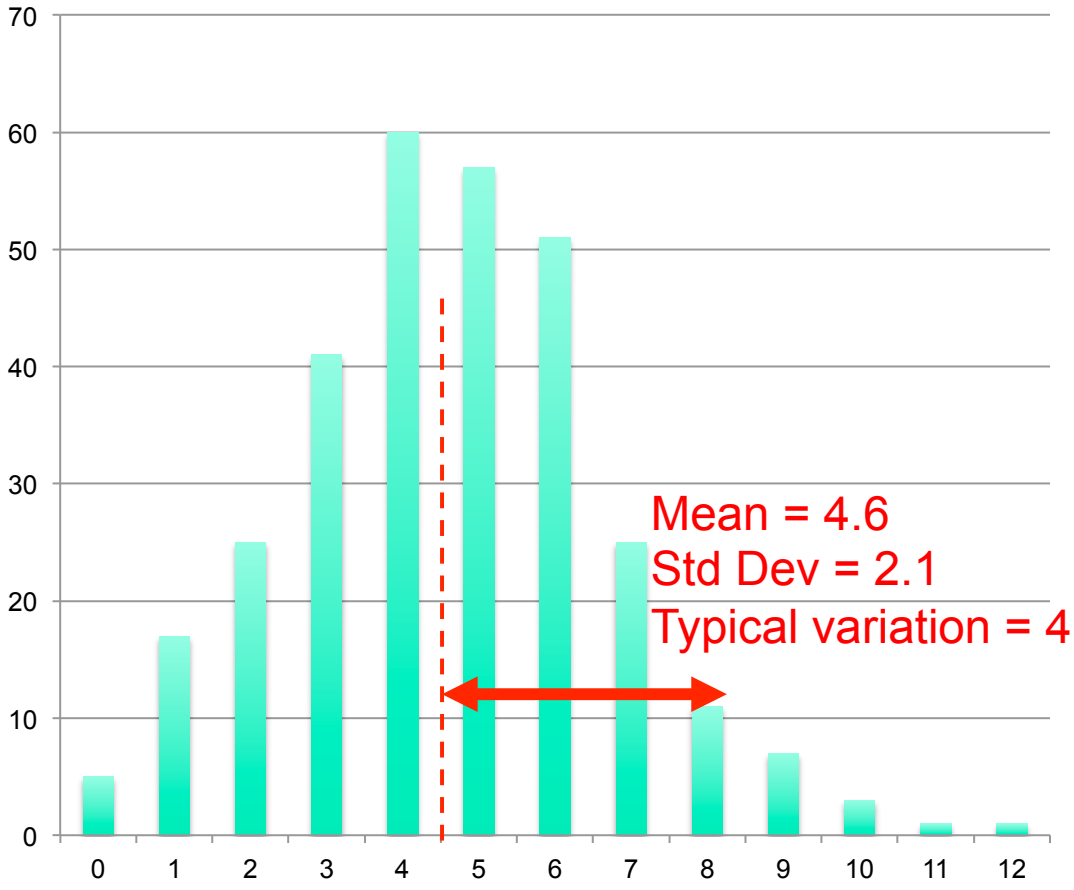
- Plan tonight for tomorrow's schedule
- Use "schedule repair" to fix the schedule after disruption
- Optimization tools in daily use at Ornge
- In a study without schedule repair
  - Original 12% savings prediction over experienced flight planners
  - 7% savings ($ / km) realized

Economies of Scale

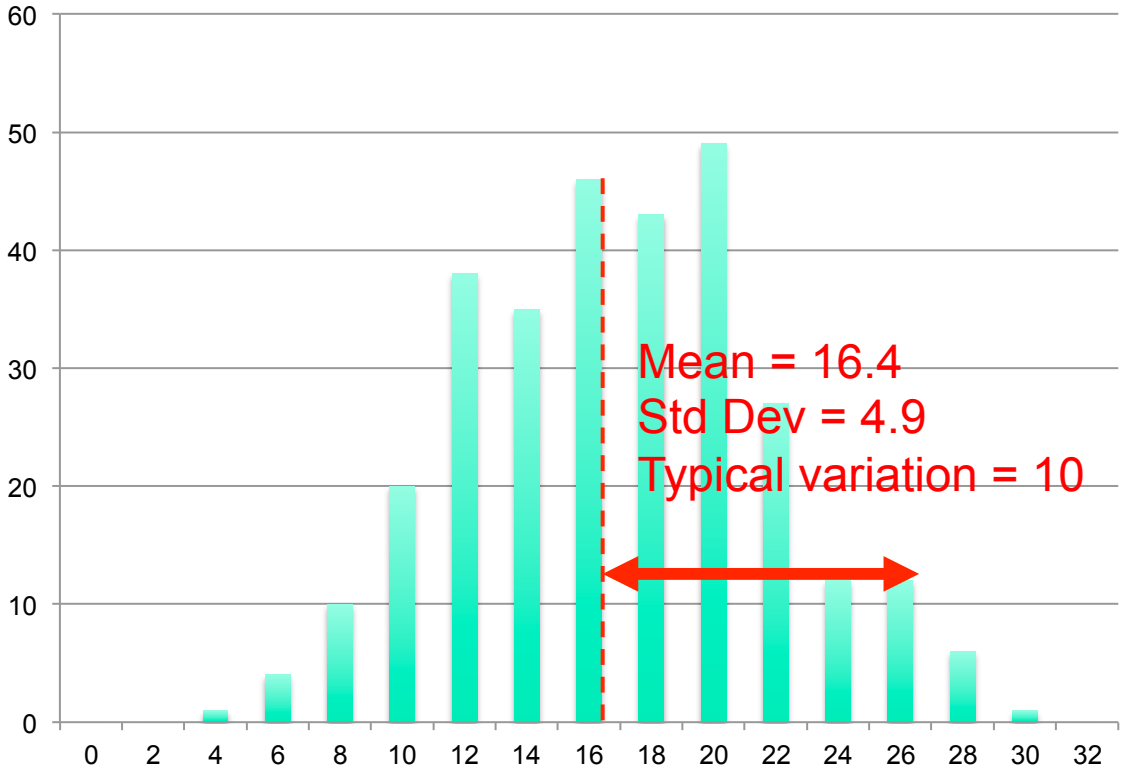
At quiet times, you have to run at lower utilization than busy times to achieve the same on-time performance

Rural areas must run at lower utilization than urban areas to achieve the same response-time performance

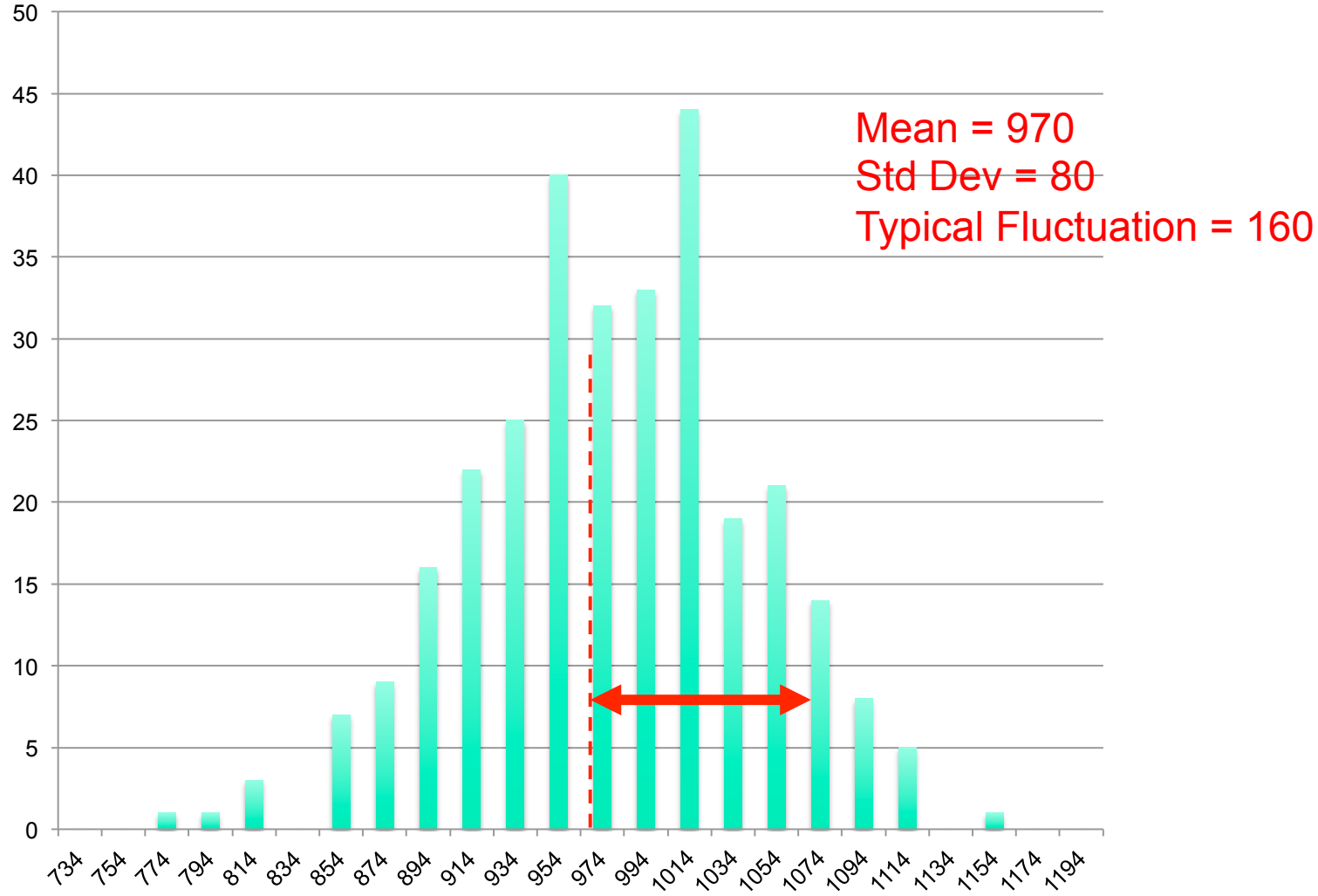
Calls in One Day: Small Town



Calls in One Day: Medium



Calls in One Day: Large



Number of Calls in One Day

Average # Calls	Standard Deviation
4.6	2.1
16.4	4.9
970	80

As average gets big, standard deviation gets big too,

but becomes a far smaller fraction of expected load

Impact on Deployment

- Need to plan for *N* calls + 2 standard deviations, where *N* = average
- Small *N*: 2 std deviations a big deal
- Big *N*: 2 std deviations fairly small
- Conclusion: Graveyard shift needs lower utilization for the same on-time %
- Conclusion: Small towns need lower utilization for the same on-time %

More Policy Questions

- ALS only or tiered fleet?
  - Either can work well under conditions
- What does optimal dispatch look like?
  - Quiet stations take low-priority calls in busy areas
- System status management?
  - Largest gains when performance is currently “modest”
  - e.g., from 75% on time to 80% on time

Accessing These Tools

- Need to partner with specialists
  - Company and/or university
- Special software tools

What should be next in research?

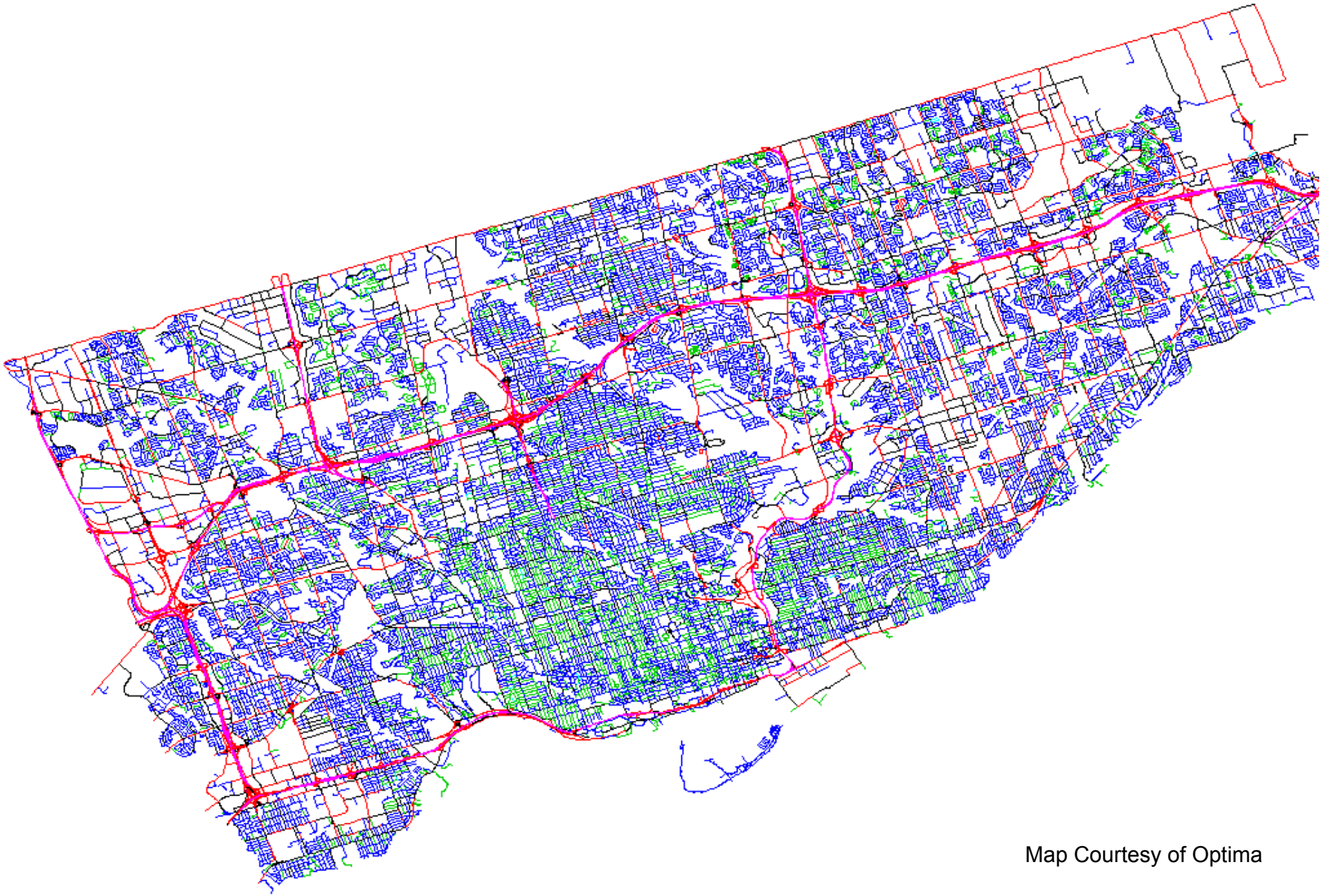
(My shopping list)

System Status Management

- Plans need to be practical
  - Can't move crews too frequently
- Can we find better plans?
- Finding an "optimal" plan is probably out of reach. Can we find bounds?
  - Would tell us when need more resources
  - Or a different way of doing things…
  - Also tell us when there's no point in searching further for better plans

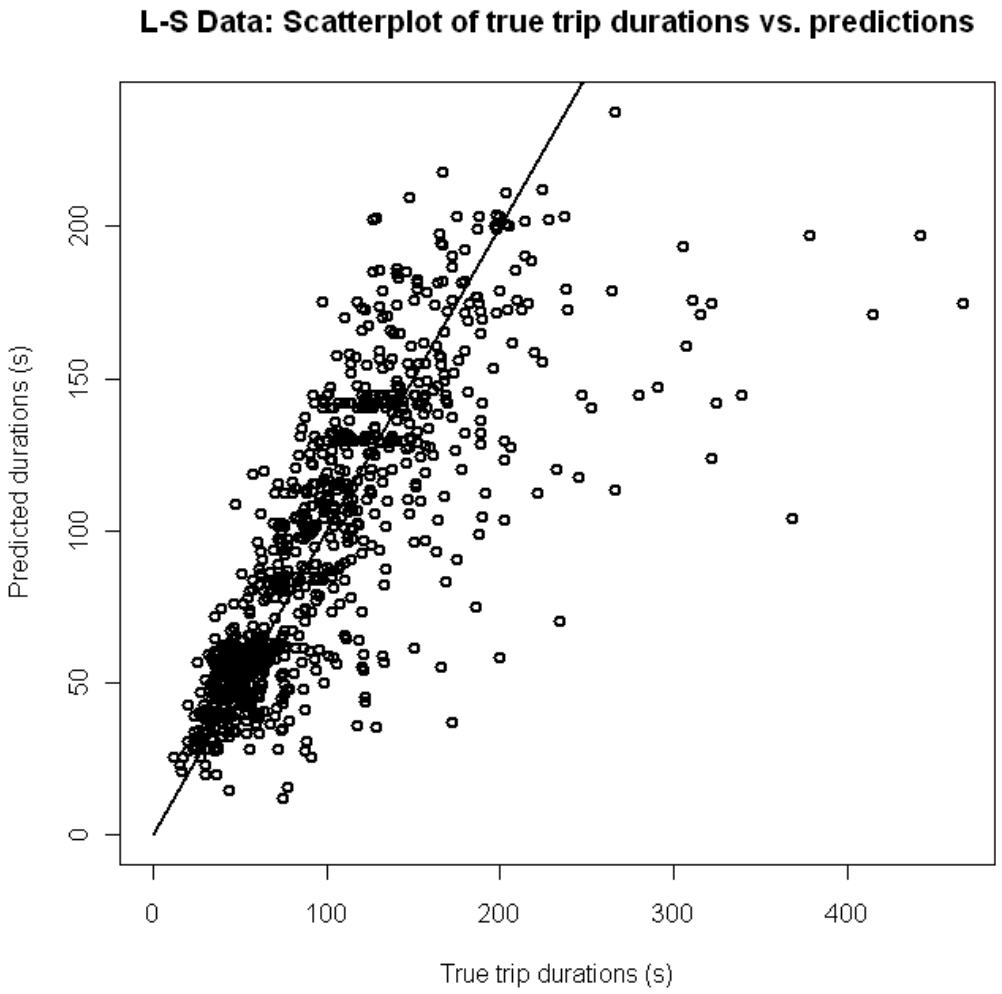
Improve Statistical Modeling

- These tools require
  - Arrival rates in time
  - Spatial distribution of calls
  - Travel times on road networks



Map Courtesy of Optima

True vs. Modeled Durations



What Might Be Next

- Currently using historical data
- What about real-time information?
  - Need to connect CAD to, e.g., Waze or Tom-Tom or … ?
  - Waze etc give non-L&S speeds
  - Need to do lots of queries to select posts
  - Still need historical predictions/data

Systems-Level Models

- What is the best way to deliver pre-hospital care?
  - GP system (Netherlands)
  - Doctor on ambulance (Germany)
  - Cardiac arrest volunteers?
  - Paramedics on motorbikes?
- How to share resources across different regions?
  - Borrow from call-center literature
  - But ambulances can't team up as easily

Other Ideas for Impact?

How Can You Learn More?