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Opportunities for Vehicle Automation to Revolutionize Transit Services

by

ALAIN L. KORNHAUSER, PHD

Professor, Operations Research & Financial Engineering
Director, Program in Transportation
Faculty Chair, PAVE
(Princeton Autonomous Vehicle Engineering)

Princeton University

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2014 FLORIDA AUTOMATED VEHICLES SUMMIT

PAVE PRINCETON AUTONOMOUS VEHICLE ENGINEERING

Opportunities for Vehicle Automation to Revolutionize Transit Services

- Automation of Conventional Fixed Guideway Transit
- Consideration of “dual-mode” Automated Transit Networks
- Automated Collision Avoidance in Conventional Buses
- Initial low-speed automonousTaxis (aTaxis)

Automation of Conventional Rail

Miami

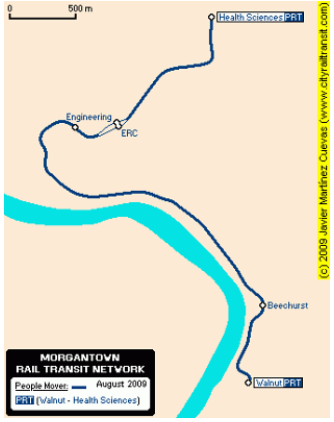
Tampa (1st in Fl)

Paris Metro (Line 14)

Honolulu (To Open in 2017)

Consideration of "dual-mode" Automated Transit Networks

- "Dual Mode"
  - Automated vehicles operating in
    - Exclusive Guideway Networks, as well as
    - Conventional roadways along with non-automated vehicles.
  - Exclusive Guideway provides the efficient "line-haul interconnector" of the more extensive but more lightly used collector/distributor " Last-mile" conventional roadways also used by conventional drivers.



Automated Collision Avoidance in Conventional Buses

- Real business case…

- I am convinced that:

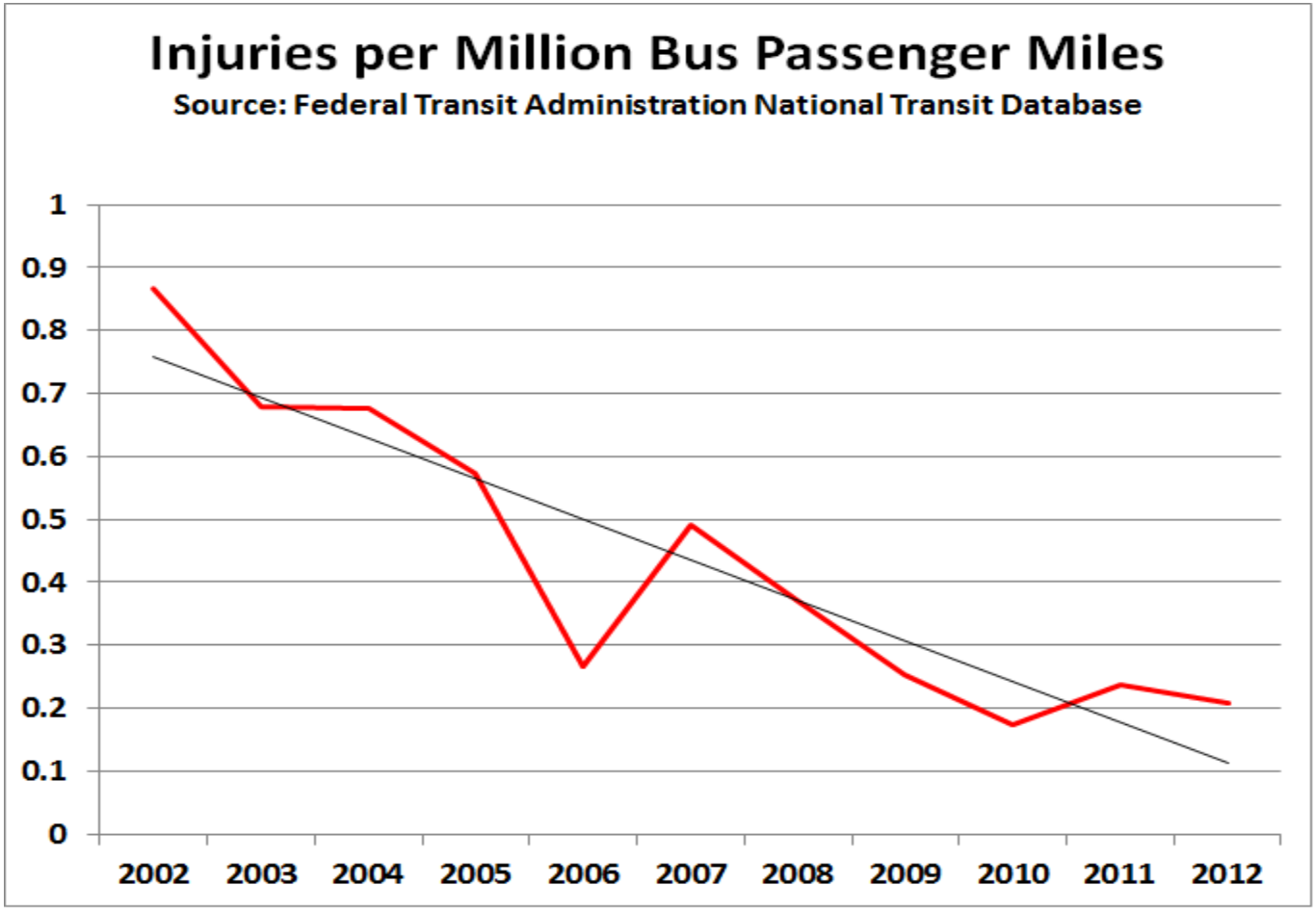
"annualized" cost of this technology

<

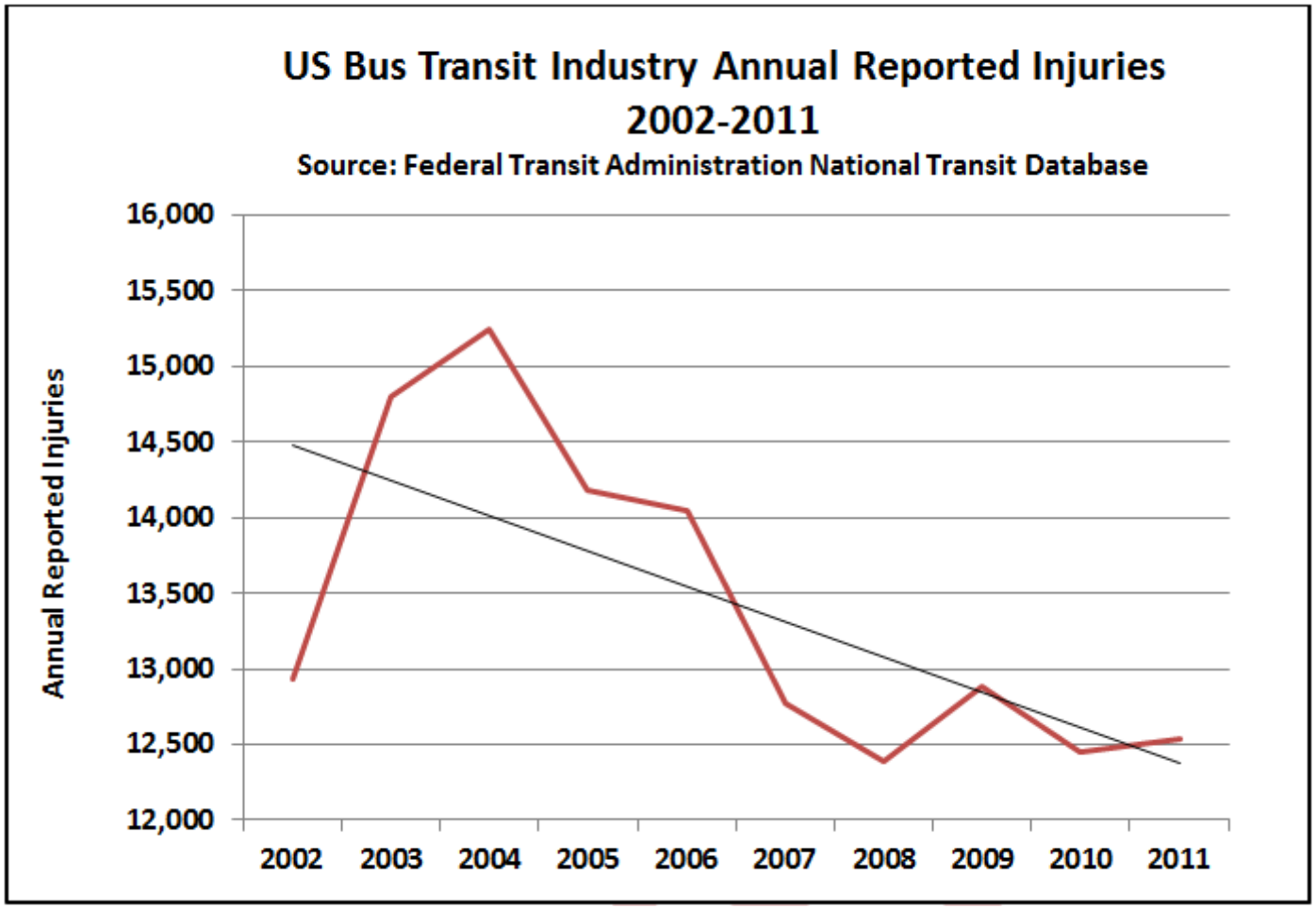
annual expected savings in accident liability expenses of the buses on which the technology is installed

  - This means that the technology is **free**

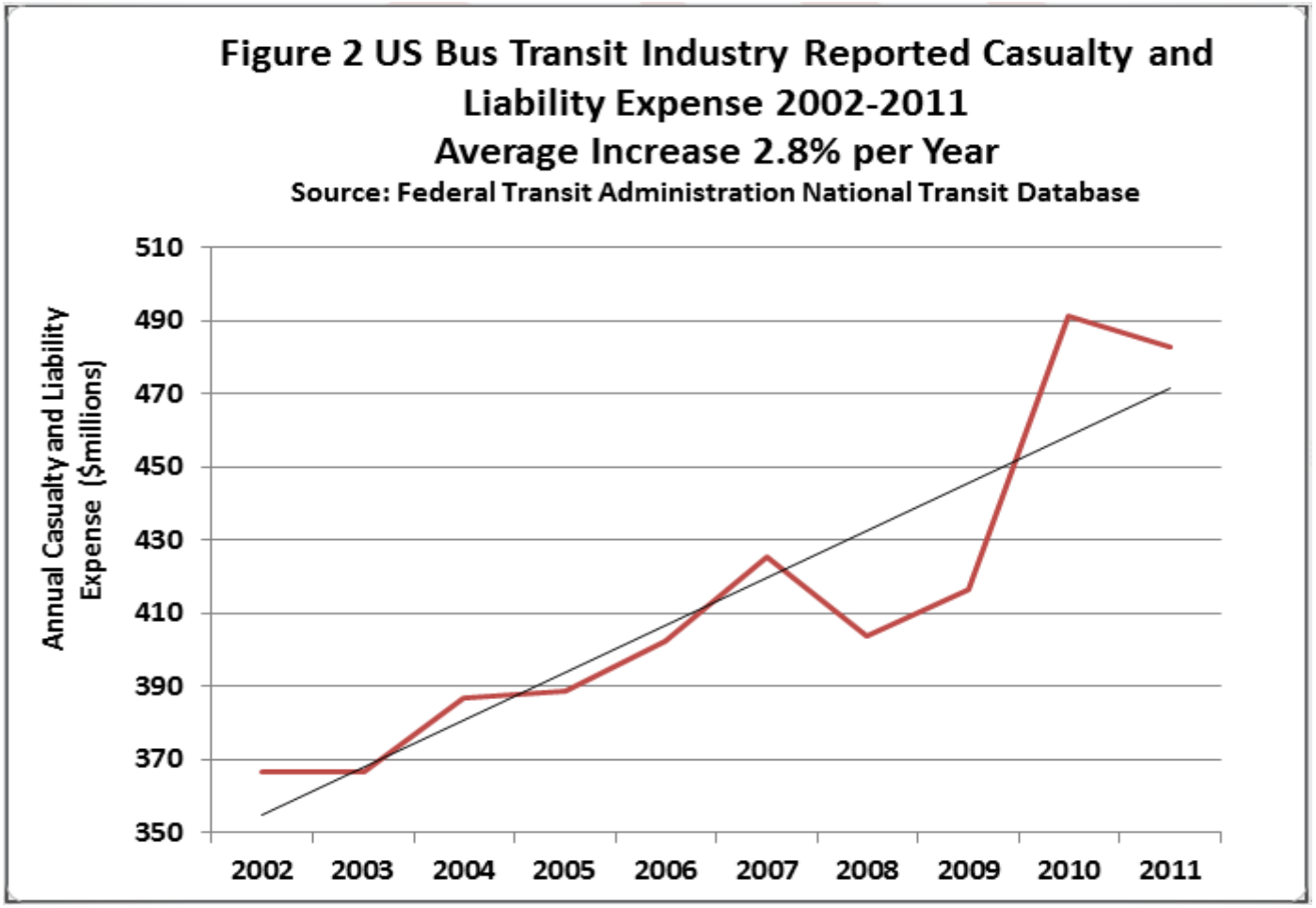
Good News! Travel by Bus is getting safer!



Good News! Injuries have been trending down!



Terrible News! Claims are going through the roof!



Casualty and Liability Claims are a Huge Drain on the Industry

- For the 10 year period 2002-2011, more than $4.1 Billion was spent on casualty and liability claims
- For many self-insured transit agencies these expenses are direct “out-of-pocket”
- Large reserves for claims must be budgeted
- Claims experience also is reflected in insurance premiums
- There are gaps in data reporting

Costs of Bus Crashes – Industry Wide

Intangible

- Human loss and suffering
- Media attention
- Good will

Tangible

- Personal injury claims
- Property damage claims
- Workers compensation
- Insurance premiums

- Vehicle repair
- Legal services
- Passenger and service delays
- Lost fare revenue
- D & A testing
- Overtime
- Sick time
- Accident investigation
- Vehicle recovery
- Hearings and discipline

NTD 2011 Bus Incidents for All Transit Agencies

Collisions	With Other Vehicle	**2,693**
	With Person	**427**
	With Fixed Object	**66**
	With Rail Vehicle	**0**
	With Bus Vehicle	**46**
	With Other	**28**
Collision Total		**3,260**
Fire Total		**304**
Security Total		**403**
NOC Total		**5,539**
Incident Total		**9,506**

NTD 2011 Bus Injuries and Fatalities for All Transit Agencies

		Fatalities	Injuries
Passenger		8	7,262
Rev Facility Occupant		7	2,107
Employees	Operator	3	923
	Employee	0	66
	Total Employees	3	989
Other Worker		0	3
Other	Bicyclist	4	123
	Ped in Crossing	11	109
	Ped not in Crossing	18	124
	Other Vehicle Occupant	32	1,594
	Other	4	615
	Trespasser	0	0
	Suicide	5	2
	Other Total	74	2,567
Total		92	12,928

2011 Nationwide Bus Casualty and Liability Expense

Source FTA NTD

Casualty and Liability Amount	Vehicle-related	$483,076,010.
Total Buses		59,871
Sub-Total Casualty and Liability Amount Per Bus		$8,069/Bus/Year

The Cost of Installing an Active Collision Avoidance System on a Bus Could be Recovered in as Little as One Year Through Reductions in Casualty and Liability Claims

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The Initial Project:

Focused on

Research, Certification and Commercialization

of

SmartDriving Technology for Buses

Team:

Princeton University

(with American Public Transit Association (APTA), Greater Cleveland Transit, and insurance pools from WA, CA, OH & VA & Munich Re (World's largest reinsurance company)

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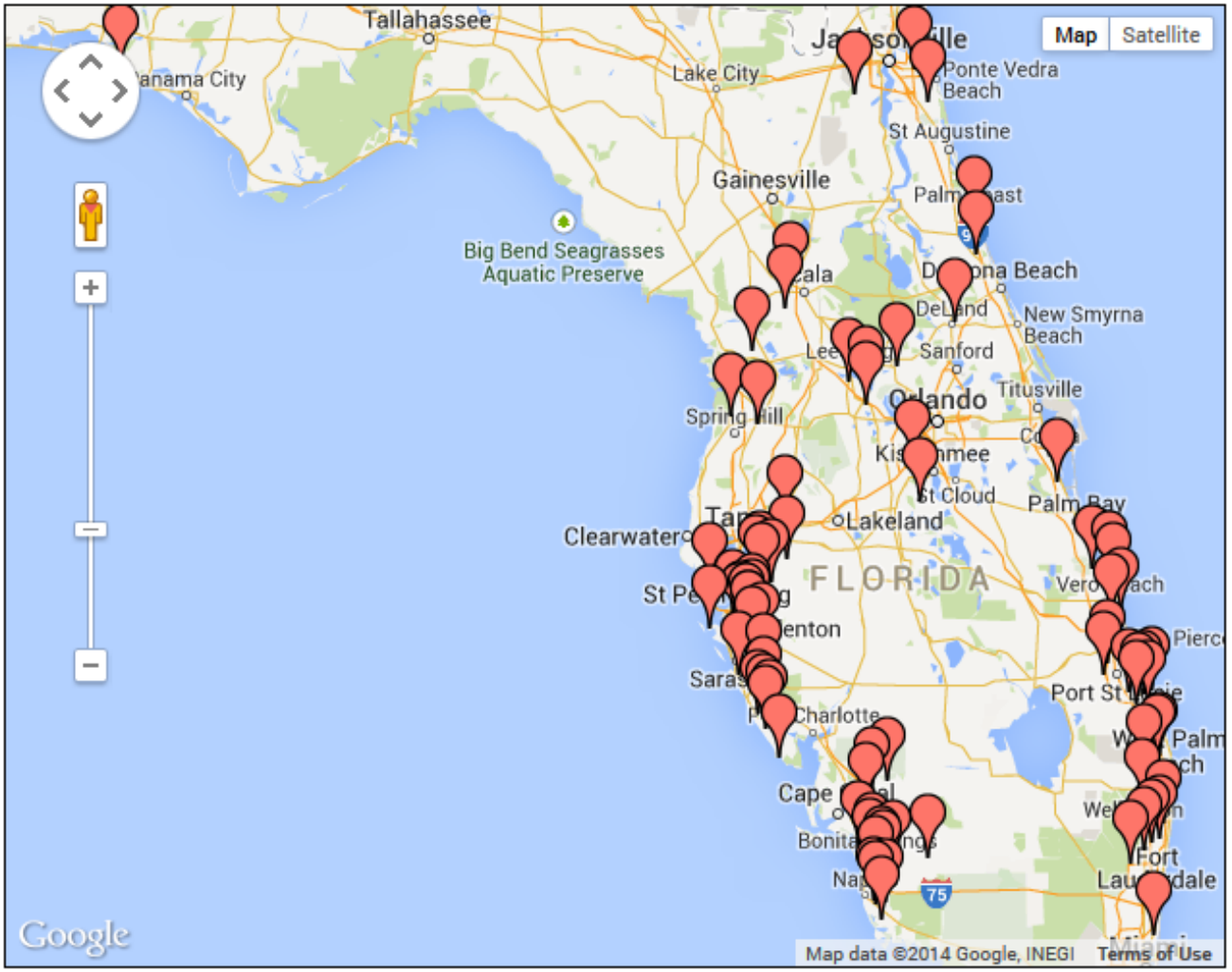
Driverless Transit Opportunities

- Initial low-speed automonousTaxis (aTaxis) operating in partially restricted/controlled roadways such as gated retirement communities.

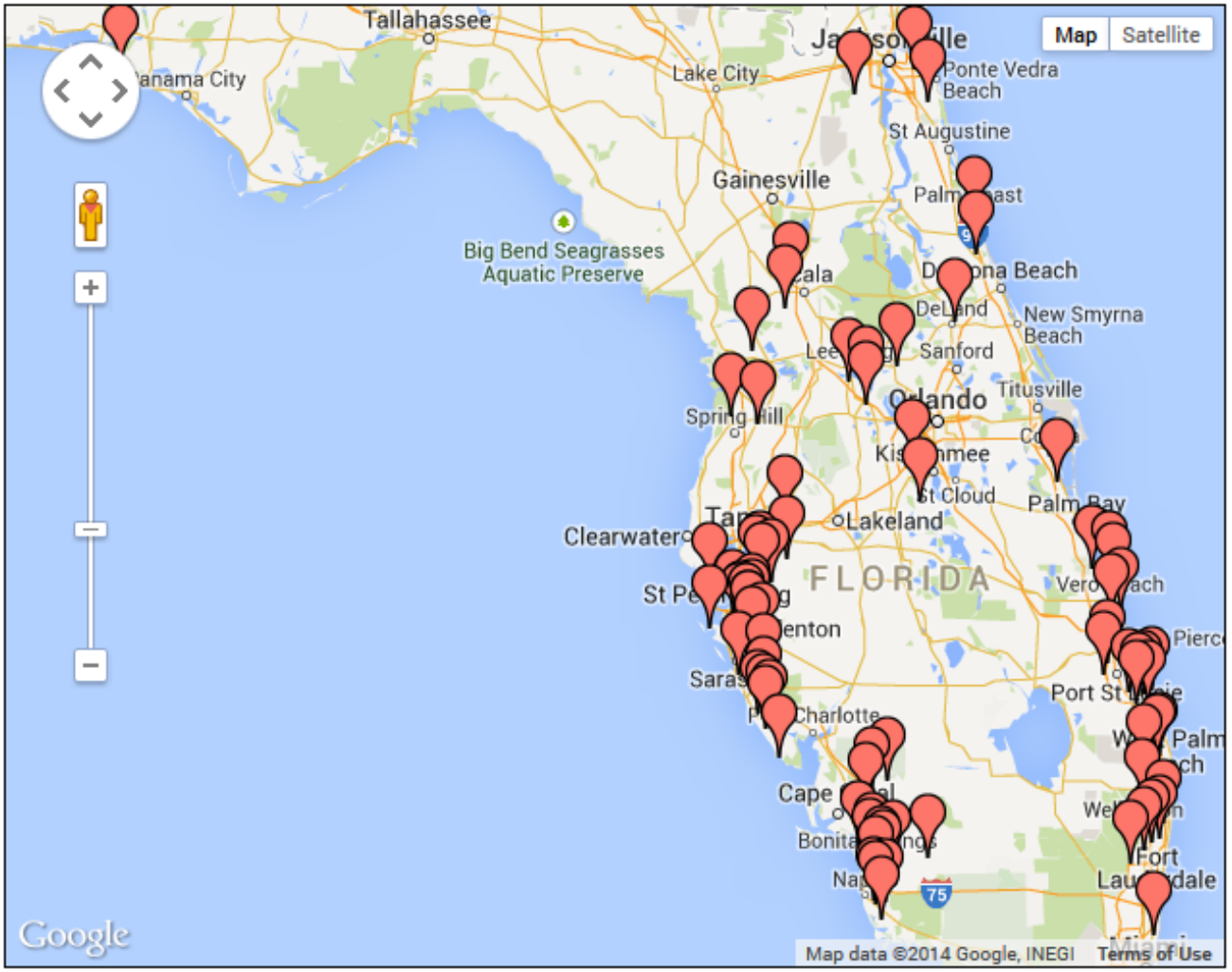
86 Private and Gated Communities in Florida



Initial Deployment…

- Needs to be Driverless
  - With Excellent Pedestrian Recognition
- Doesn't Need To Be…
  - Fast
  - Everywhere
- Let's start Slow and Narrow:
  - Like CityMobile2…
  - Say 10-15 mph, Along a Corridor

86 Private and Gated Communities in Florida



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Discussion!

Thank You

alaink@princeton.edu

www.SmartDrivingCar.com

Opportunities for Vehicle Automation to Revolutionize Transit Services

- Automation of Conventional Fixed Guideway Transit
  - Miami Metro-rail and Automated People Movers
  - Perfect for where there exists large volumes between few locations
  - Implications is that vehicles will get small and more frequent. This mindset has not been in this direction
- Consideration of "dual-mode" Automated Transit Networks
  - Make fixed guideway a slimmed down version of a normal road for exclusive use by initial set of vehicles that can evolve to also be driverless on a designated sub-network of conventional roadways.
- Automated Collision Avoidance in Conventional Buses
  - Real business case…
  - Convinced that "annualized" cost of this technology is less than the Annual expected savings in accident liability expenses of the buses on which the technology is installed
    - This means that the technology is free
- Initial low-speed automonousTaxis (aTaxis)
  - operating in partially restricted/controlled roadways such as gated retirement communities.

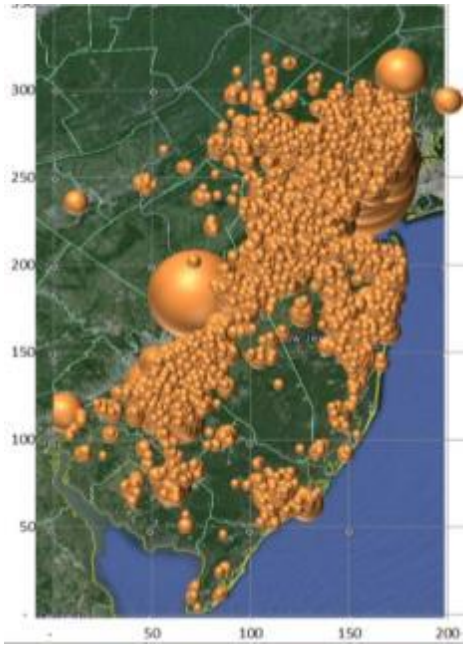
What About……

What About……

Driverless electric shuttle to be trialled in Singapore (video of Luxembourg Demonstration)

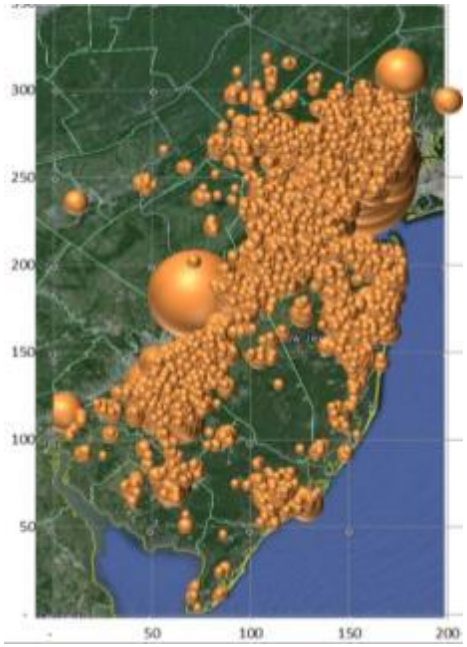
aTaxis and RideSharing

- **"AVO < 1" RideSharing**
  - Eliminate the "Empty Back-haul"; AVO Plus
- **"Organized" RideSharing**
  - Diverted to aTaxis
- **"Tag-along" RideSharing**
  - Only Primary trip maker modeled, "Tag-alongs" are assumed same after as before.
- **"Casual" RideSharing**
  - This is the opportunity of aTaxis
  - How much spatial and temporal aggregation is required to create significant casual ride-sharing opportunities.



Spatial Aggregation

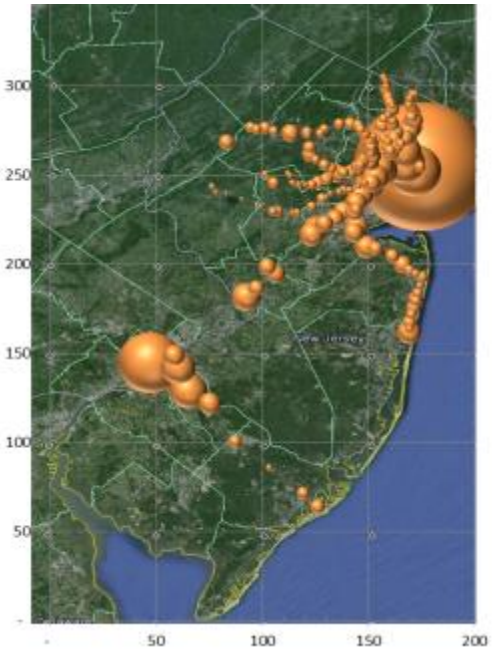
- **By walking to a station/aTaxiStand**
  - **At what point does a walk distance makes the aTaxi trip unattractive relative to one's personal car?**
  - **¼ mile (5 minute) max**
- **Like using an Elevator!**



Elevator

Spatial Aggregation

- By walking to a station/aTaxiStand
  - A what point does a walk distance makes the aTaxi trip unattractive relative to one's personal car?
  - ¼ mile (5 minute) max
- By using the rail system for some trips
  - Trips with at least one trip-end within a short walk to a train station.
  - Trips to/from NYC or PHL



Spatial Aggregation

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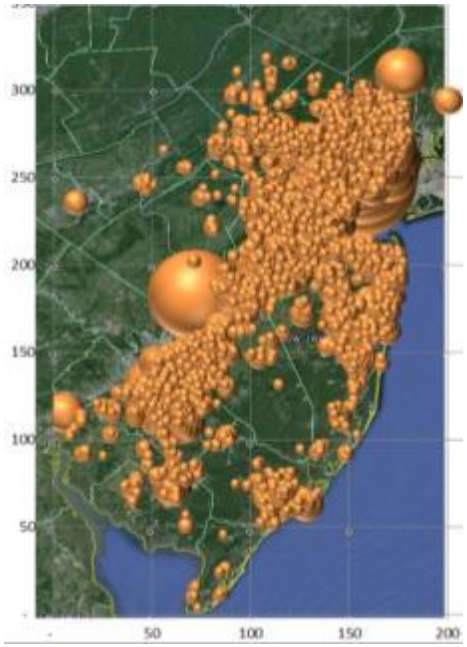
  - ¼ mile (5 minute) max
- By using the rail system for some trips
  - Trips with at least one trip end within a short walk to a train station.
  - Trips to/from NYC or PHL
- **By sharing rides with others that are basically going in my direction**
  - **No trip has more than 20% circuity added to its trip time.**



Pixelation of New Jersey

NJ State Grid

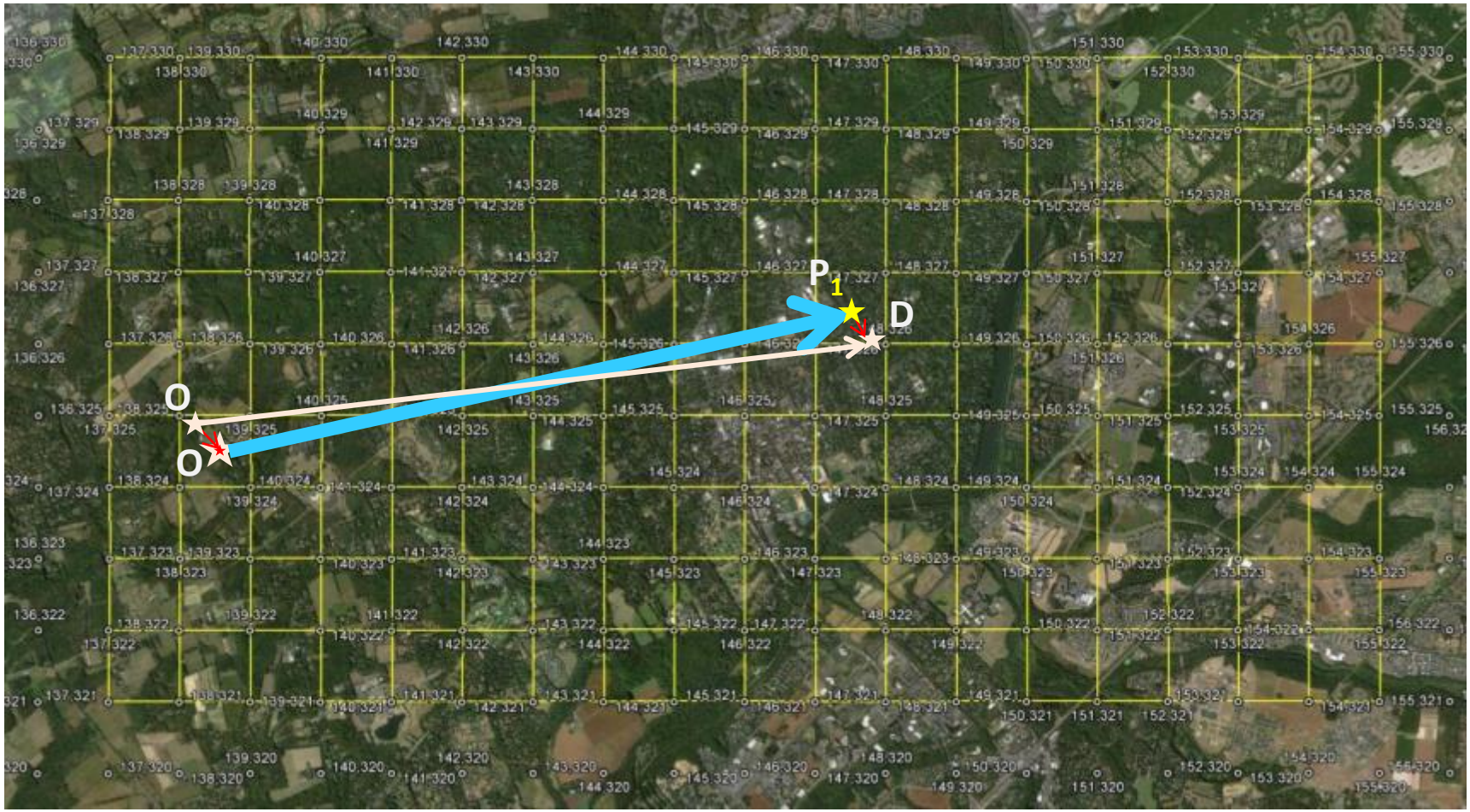
Zoomed-In Grid of Mercer

Pixelating the State with half-mile Pixels

xPixel = *floor{108.907 * (longitude + 75.6)}*
yPixel = *floor{138.2 * (latitude – 38.9))*

An aTaxiTrip

{oYpixel, oXpixel, oTime (Hr:Min:Sec) ,dYpixel, dXpixel, Exected: dTime}



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Common Destination (CD)
CD=1p: Pixel -> Pixel (p->p) Ride-sharing

TripMiles = 3*L*

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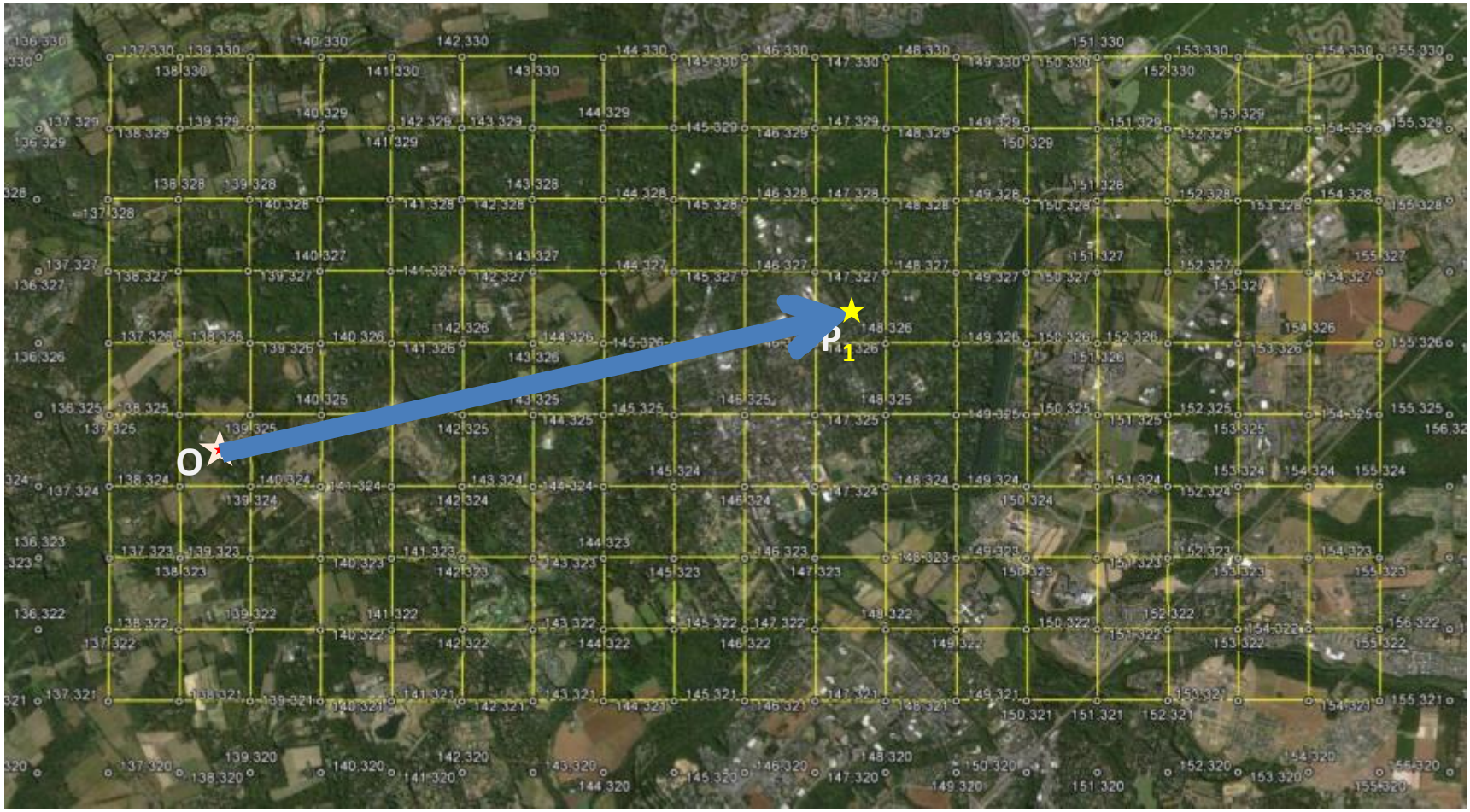

PersonMiles = 3L
aTaxiMiles = L
AVO = PersonMiles/aTaxiMiles = 3

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NJ Transit Train Station "Consumer-shed"

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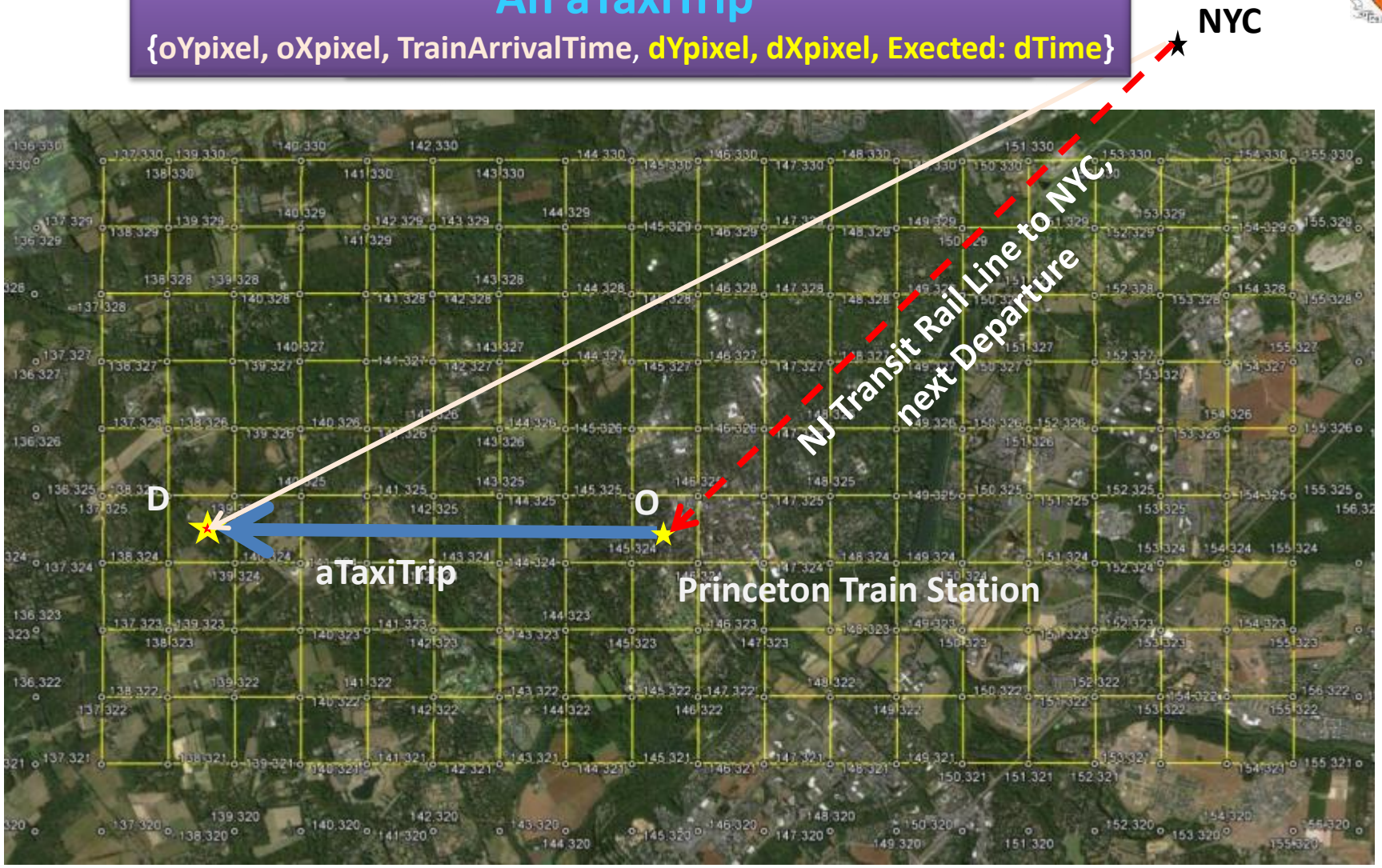
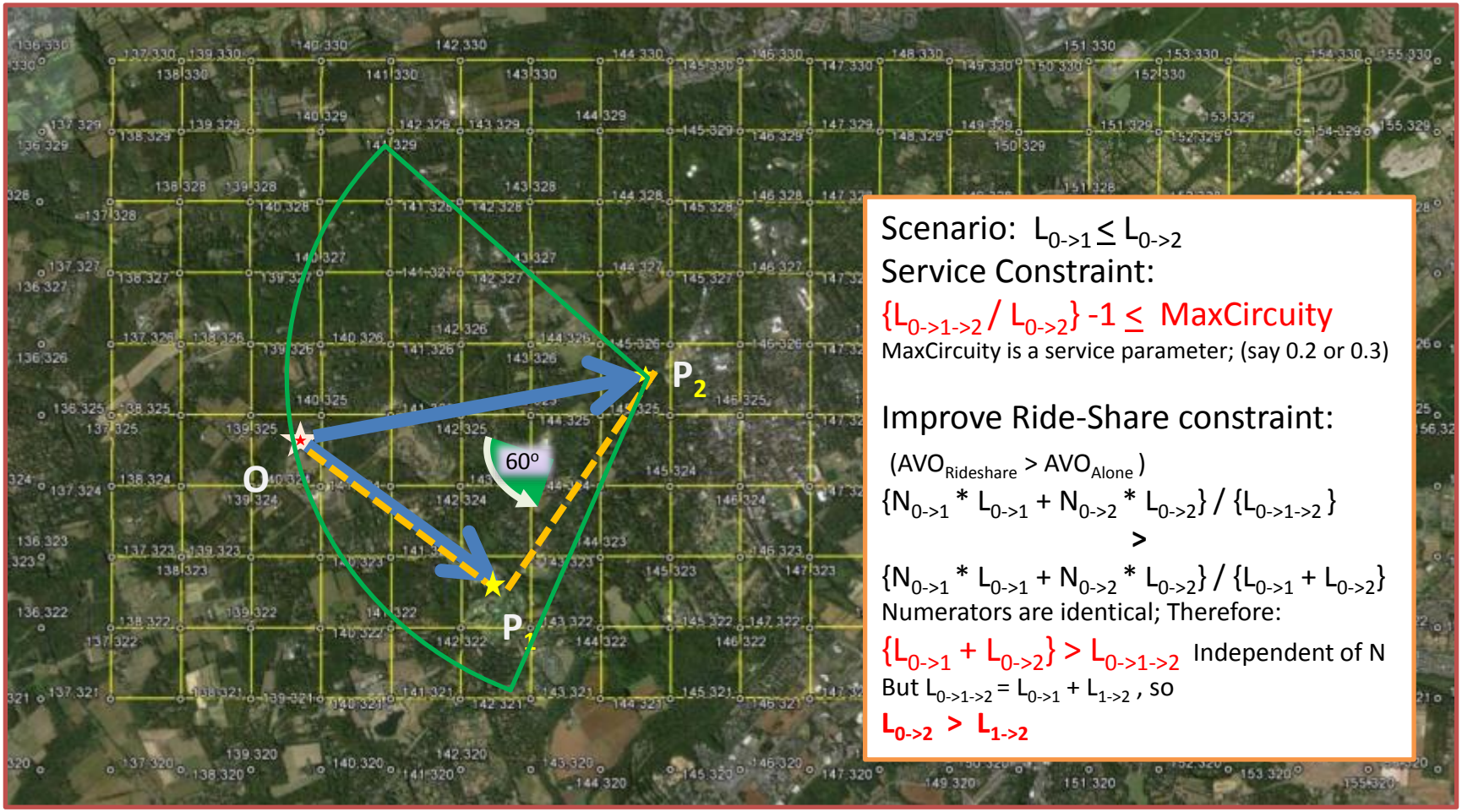
An aTaxiTrip

{oYpixel, oXpixel, TrainArrivalTime, dYpixel, dXpixel, Exected: dTime}



CD= 2p: Pixel ->2Pixels Ride-sharing



Scenario: $L_{0->1} \leq L_{0->2}$

Service Constraint:

$\{L_{0->1->2} / L_{0->2}\} - 1 \leq$ MaxCircuity

MaxCircuity is a service parameter; (say 0.2 or 0.3)

Improve Ride-Share constraint:

$(AVO_{Rideshare} > AVO_{Alone})$

$\{N_{0->1} * L_{0->1} + N_{0->2} * L_{0->2}\} / \{L_{0->1->2}\}$

>

$\{N_{0->1} * L_{0->1} + N_{0->2} * L_{0->2}\} / \{L_{0->1} + L_{0->2}\}$

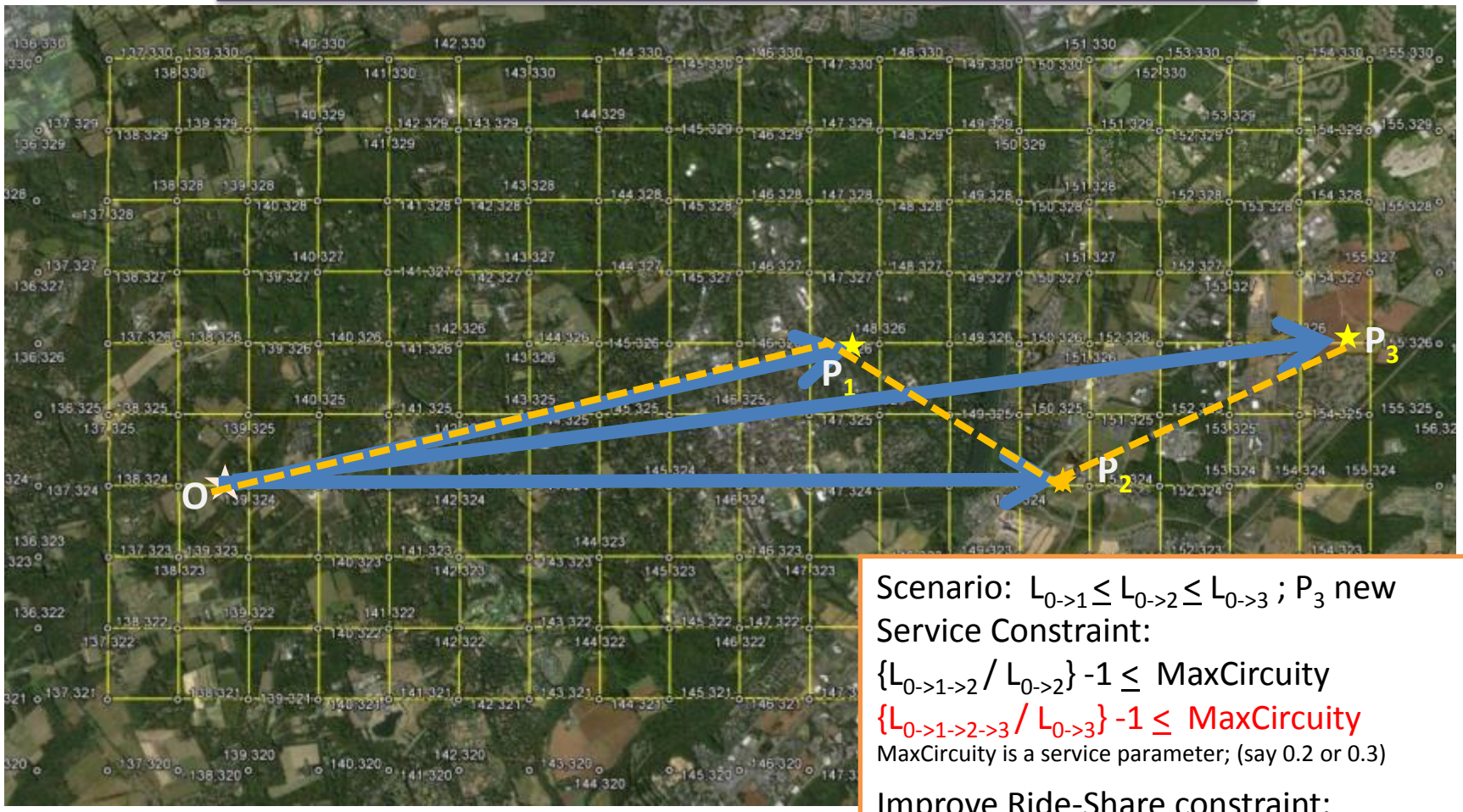
Numerators are identical; Therefore:

$\{L_{0->1} + L_{0->2}\} > L_{0->1->2}$ Independent of N

But $L_{0->1->2} = L_{0->1} + L_{1->2}$, so

$L_{0->2} > L_{1->2}$

CD= 3p: Pixel ->3Pixels Ride-sharing; P_3 New



Scenario: $L_{0->1} \leq L_{0->2} \leq L_{0->3}$; P_3 new

Service Constraint:

$\{L_{0->1->2} / L_{0->2}\} - 1 \leq$ MaxCircuity

$\{L_{0->1->2->3} / L_{0->3}\} - 1 \leq$ MaxCircuity

MaxCircuity is a service parameter; (say 0.2 or 0.3)

Improve Ride-Share constraint:

$(AVO_{Rideshare\ 1,2} > AVO_{Alone})$

$\{L_{0->1} + L_{0->2}\} > L_{0->1->2}$

$(AVO_{Rideshare\ 1,2,3} > AVO_{Rideshare\ 1,2} + AVO_{3\ Alone})$;

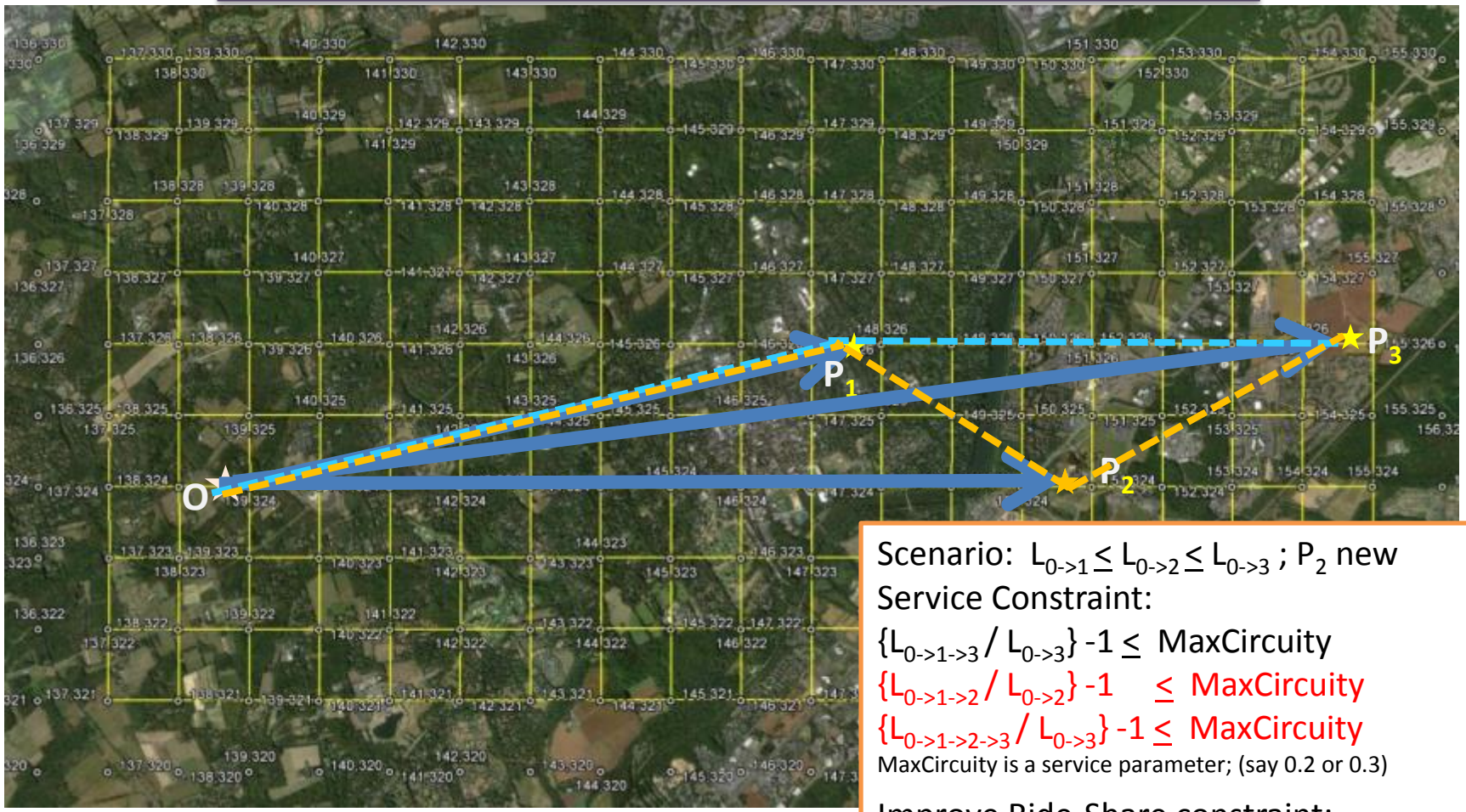
$\{N_{0->1} * L_{0->1} + N_{0->2} * L_{0->2} + N_{0->3} * L_{0->3}\} / \{L_{0->1->2->3}\}$

$> \{N_{0->1} * L_{0->1} + N_{0->2} * L_{0->2} + N_{0->3} * L_{0->3}\} / \{L_{0->1->2} + L_{0->3}\}$

Numerators are identical; Therefore:

$\{L_{0->1->2} + L_{0->3}\} > L_{0->1->2->3}$

CD= 3p: Pixel ->3Pixels Ride-sharing; P_2 New



Scenario: $L_{0->1} \leq L_{0->2} \leq L_{0->3}$; P_2 new

Service Constraint:

$\{L_{0->1->3} / L_{0->3}\} - 1 \leq$ MaxCircuity

$\{L_{0->1->2} / L_{0->2}\} - 1 \leq$ MaxCircuity

$\{L_{0->1->2->3} / L_{0->3}\} - 1 \leq$ MaxCircuity

MaxCircuity is a service parameter; (say 0.2 or 0.3)

Improve Ride-Share constraint:

$(AVO_{Rideshare\ 1,3} > AVO_{Alone})$

$\{L_{0->1} + L_{0->3}\} > L_{0->1->3}$

$(AVO_{Rideshare\ 1,2,3} > AVO_{Rideshare\ 1,3} + AVO_{2\ Alone})$;

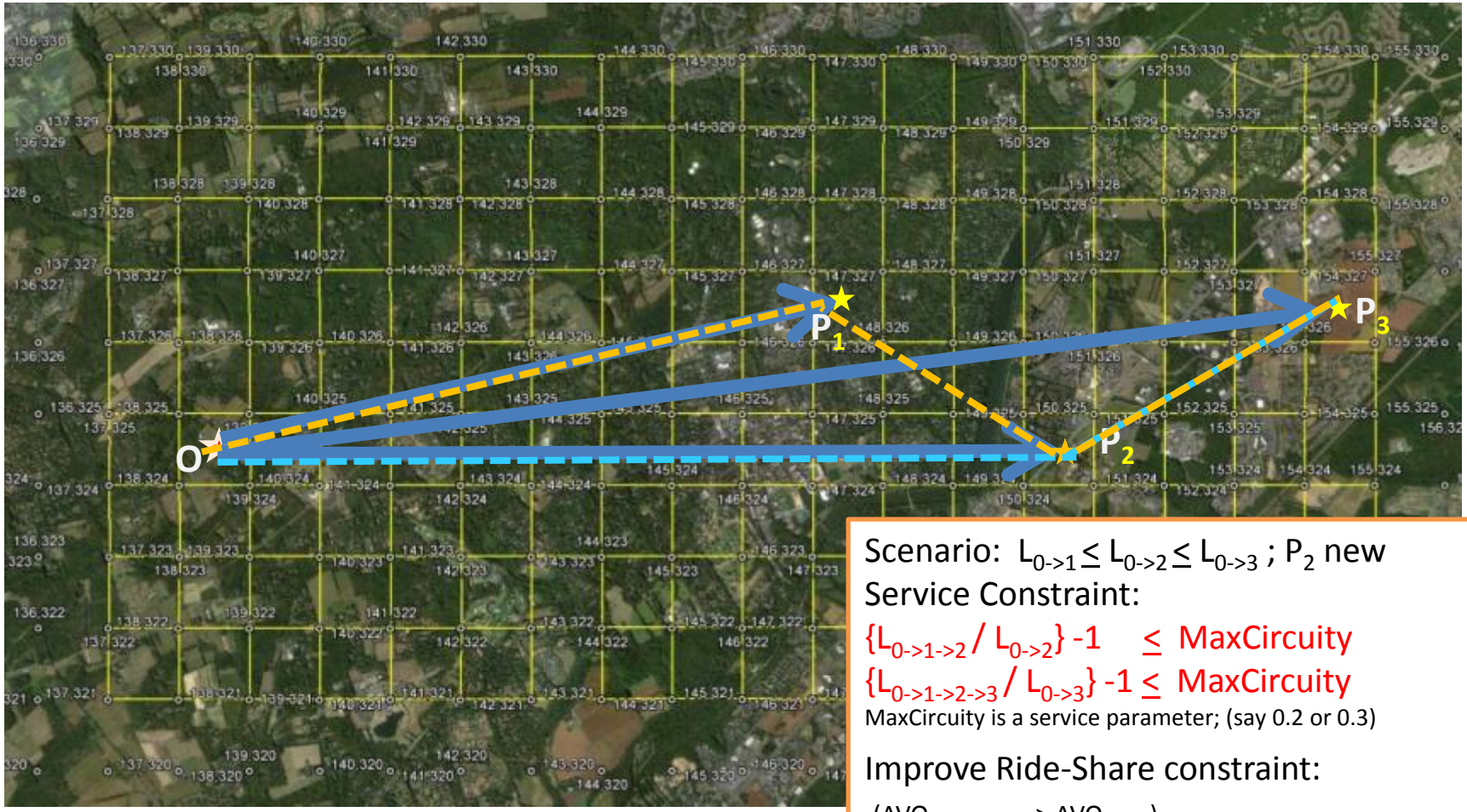
$\{N_{0->1} * L_{0->1} + N_{0->2} * L_{0->2} + N_{0->3} * L_{0->3}\} / \{L_{0->1->2->3}\}$

$> \{N_{0->1} * L_{0->1} + N_{0->2} * L_{0->2} + N_{0->3} * L_{0->3}\} / \{L_{0->1->3} + L_{0->2}\}$

Numerators are identical; Therefore:

$\{L_{0->1->3} + L_{0->2}\} > L_{0->1->2->3}$

CD= 3p: Pixel ->3Pixels Ride-sharing; P_1 New



Scenario: $L_{0->1} \leq L_{0->2} \leq L_{0->3}$; P_2 new

Service Constraint:

$\{L_{0->1->2} / L_{0->2}\} - 1 \leq$ MaxCircuity

$\{L_{0->1->2->3} / L_{0->3}\} - 1 \leq$ MaxCircuity

MaxCircuity is a service parameter; (say 0.2 or 0.3)

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$(AVO_{Rideshare\ 1,2,3} > AVO_{Rideshare\ 1,2} + AVO_{3\ Alone})$;

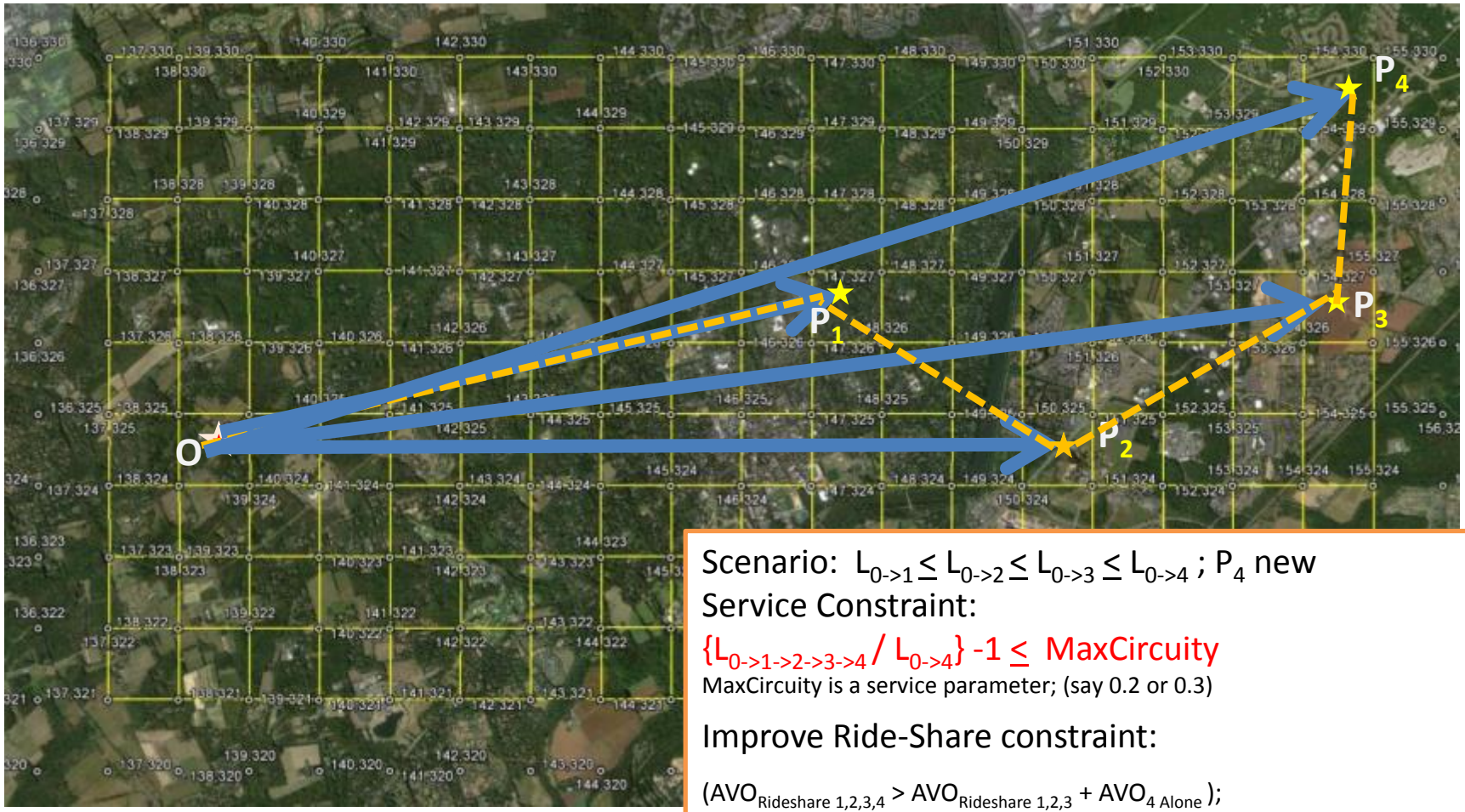
$\{N_{0->1} * L_{0->1} + N_{0->2} * L_{0->2} + N_{0->3} * L_{0->3}\} / \{L_{0->1->2->3}\}$

$> \{N_{0->1} * L_{0->1} + N_{0->2} * L_{0->2} + N_{0->3} * L_{0->3}\} / \{L_{0->1->2} + L_{0->3}\}$

Numerators are identical; Therefore:

$\{L_{0->1->2} + L_{0->3}\} > L_{0->1->2->3}$

CD= 4p: Pixel ->3Pixels Ride-sharing; P_4 New



Scenario: $L_{0->1} \leq L_{0->2} \leq L_{0->3} \leq L_{0->4}$; P_4 new

Service Constraint:

$\{L_{0->1->2->3->4} / L_{0->4}\} - 1 \leq$ MaxCircuity

MaxCircuity is a service parameter; (say 0.2 or 0.3)

Improve Ride-Share constraint:

$(AVO_{Rideshare\ 1,2,3,4} > AVO_{Rideshare\ 1,2,3} + AVO_{4\ Alone})$;

$\{N_{0->1} * L_{0->1} + N_{0->2} * L_{0->2} + N_{0->3} * L_{0->3} + N_{0->4} * L_{0->4}\} / \{L_{0->1->2->3->4}\}$

$> \{N_{0->1} * L_{0->1} + N_{0->2} * L_{0->2} + N_{0->3} * L_{0->3} + N_{0->4} * L_{0->4}\} / \{L_{0->1->2->3} + L_{0->4}\}$

Numerators are identical; Therefore:

$\{L_{0->1->2->3} + L_{0->4}\} > L_{0->1->2->3->4}$

Elevator Analogy of an aTaxi Stand Temporal Aggregation

Departure Delay: DD = 300 Seconds

Elevator Analogy of an aTaxi Stand 60 seconds later

Typical Daily NJ-wide AVO

CD: Common Destinations; DD: Departure Delay (in Seconds)