Predicting Road Traffic Route Flows and Multi-class Link Flows Uniquely for Urban Transportation Planning

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Objectives of this talk

- Quickly review the status of traffic assignment;
- Introduce a new method for finding unique route flows and class-specific link flows;
- Examine the effect of introducing restrictions on the use of certain links by trucks;
- Illustrate the properties of the method with an experiment;
- Conclusions.

What is the Traffic Assignment Problem?

- Traditionally, a method for "loading" origin-destination (OD) flows onto a road network;
- A behavioral model of route choice in a congested urban road network;
- A method for determining link flows and travel times and costs for:
  - computing origin-destination-mode flows;
  - computing emissions from cars and trucks;
- Inputs for analyses using route flows and multi-class link flows.

Brief history of Traffic Assignment

1952: Early conceptual discussion in US

1952: Wardrop proposed criteria for route choice

1956: Beckmann formulated the user-equilibrium route choice problem with variable demand

1958: Algorithms for the shortest route problem

1958-75: Heuristic methods for assigning traffic

1973: Solution of Beckmann's formulation with the linear approximation method (Frank-Wolfe)

1975: First link-based practitioner codes (FW)

1982: First route-based practitioner code

1990~: Research on quick-precision methods

Quick-precision assignment methods

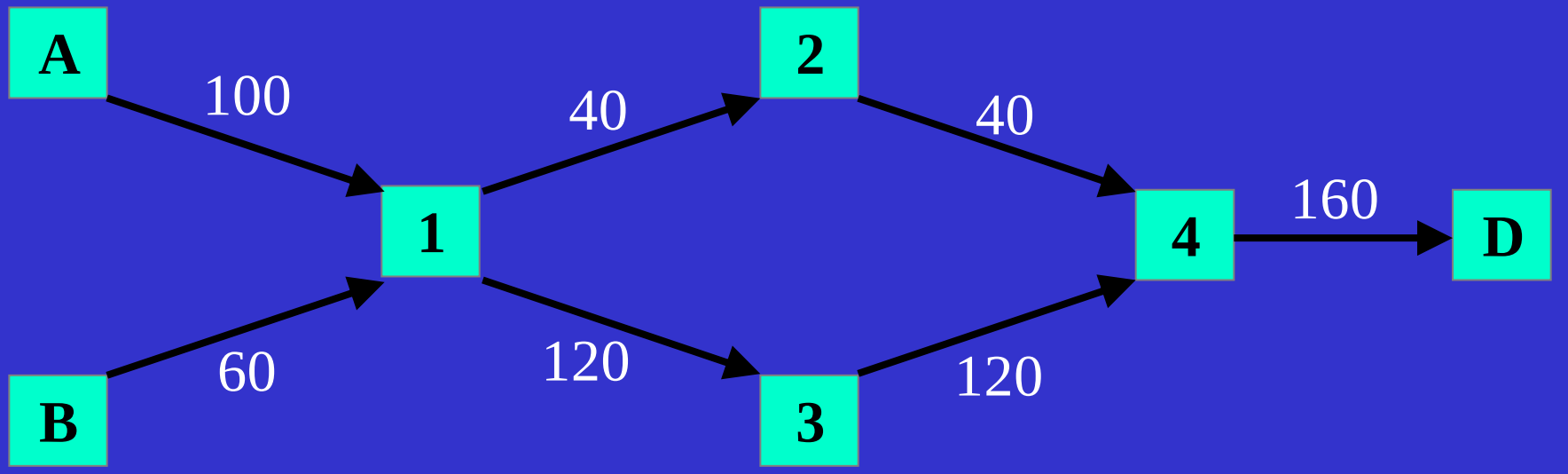
1992	DSD, Larsson and Patriksson
1994	Gradient Projection, Jayakrishnan et al.
2002	Origin-Based Assignment, Bar-Gera
2006	Algorithm B, Dial
2009	Projected Gradient, Florian et al.
2009*	LUCE, Gentile and Meschini
2010	TAPAS, Bar-Gera
2011	Improved Origin-Based Algorithms, Nie
2012	Applications of TAPAS, Bar-Gera et al.

* Unpublished; presentation year is indicated.

Who needs route flows or link flows by class?

- Select link analysis to determine the source of link flows by their origins and destinations;
- Link flows by user class for project evaluation;
- Estimation of OD flows from class link flows or OD flows for a subarea of a region, such as for micro-simulation;
- License plates surveys to validate model results against survey data, or for designing a survey;
- This talk examines the effects of truck restrictions on car and truck link flows and route flows.

Multiple user-equilibrium route flow solutions



From	To	Route	Flow		
			h^*	h^1	h^2
A	D	A→1→2→4→D	25	40	0
		A→1→3→4→D	75	60	100
B	D	B→1→2→4→D	15	0	40
		B→1→3→4→D	45	60	20

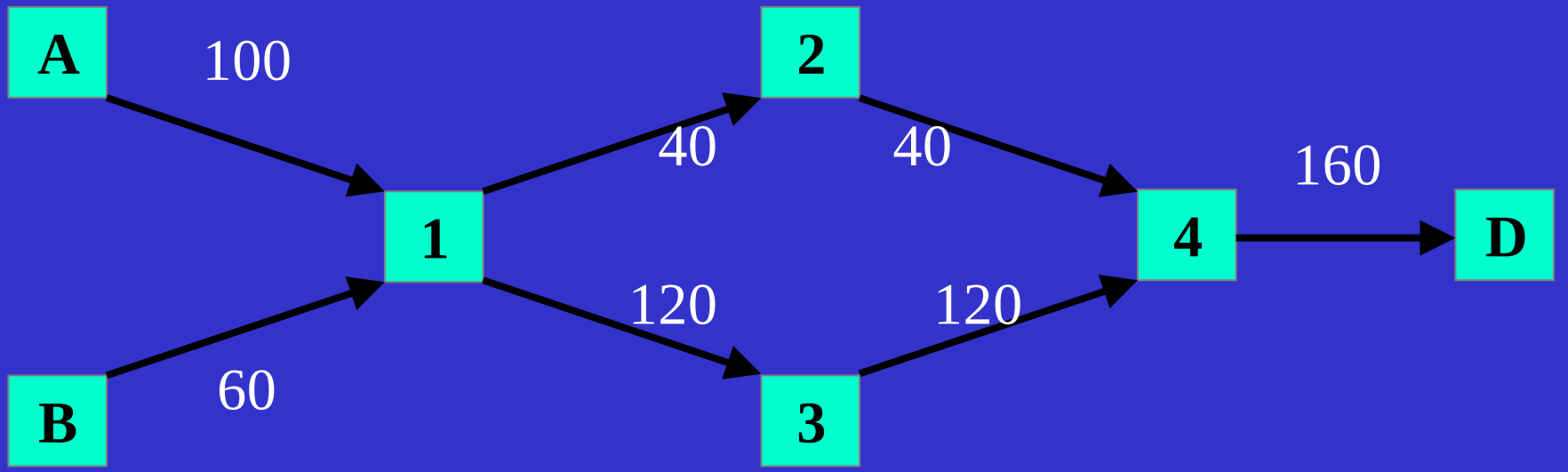
How to choose a single route flow solution?

Proportionality Condition

Same proportions apply to all travelers facing a choice between a pair of alternative segments.

Consider the pair of segments [1,2,4] and [1,3,4].

First segment's proportion is 40/(40+120)=1/4.



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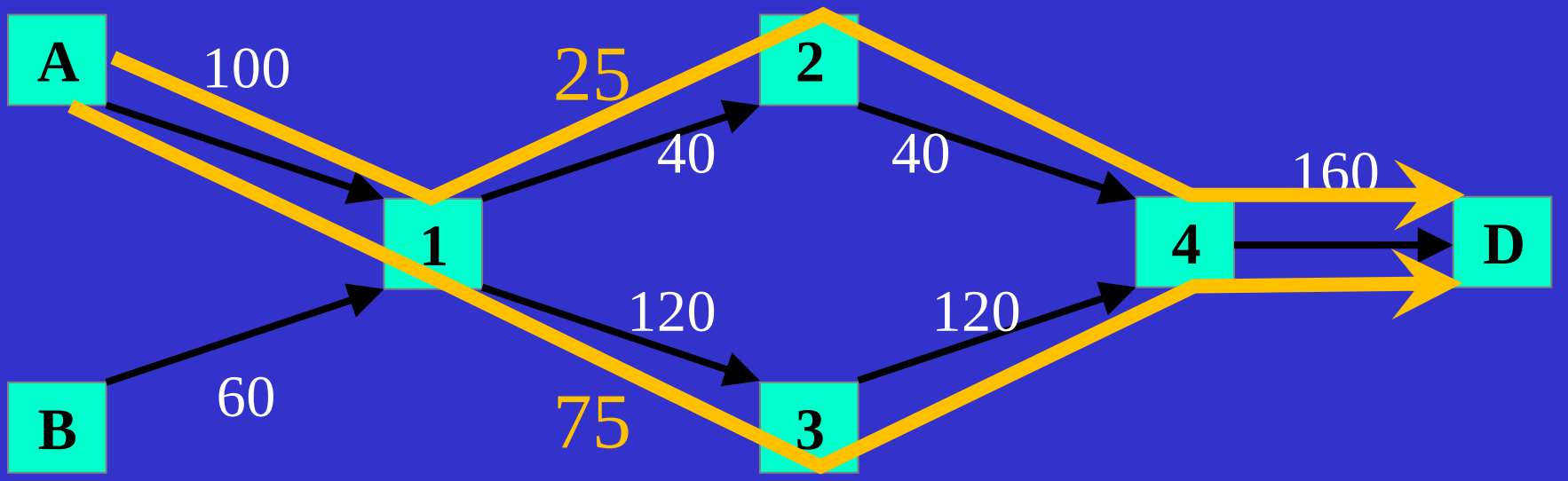

For trips from A to D the proportion is 25/(25+75)=1/4.

How to choose a single route flow solution?

Proportionality Condition

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Consider the pair of segments [1,2,4] and [1,3,4].

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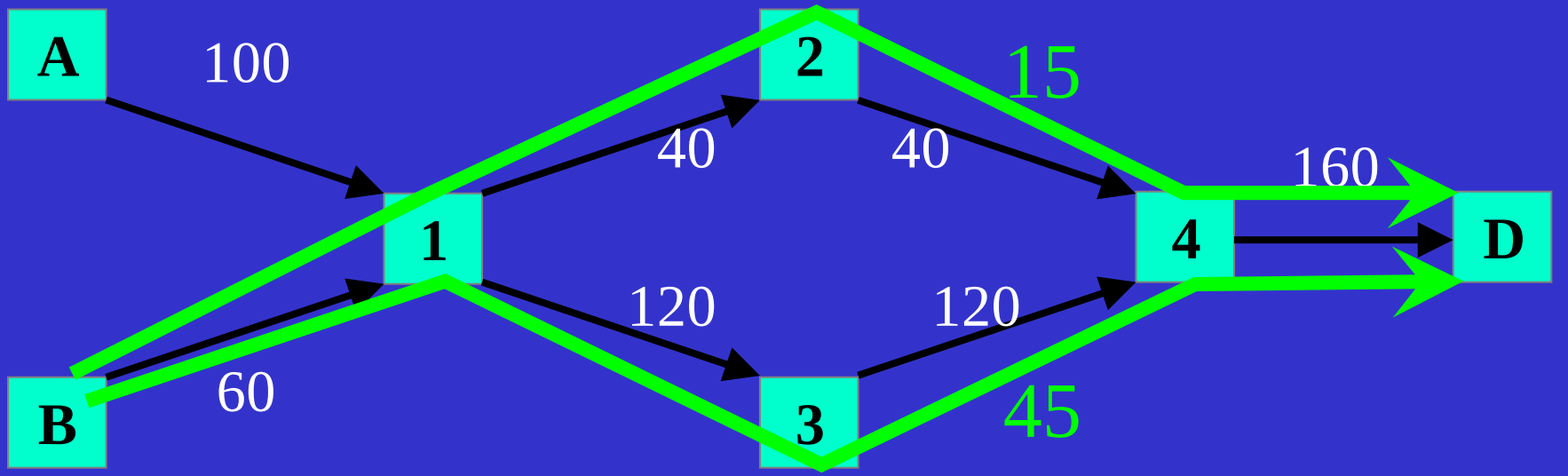
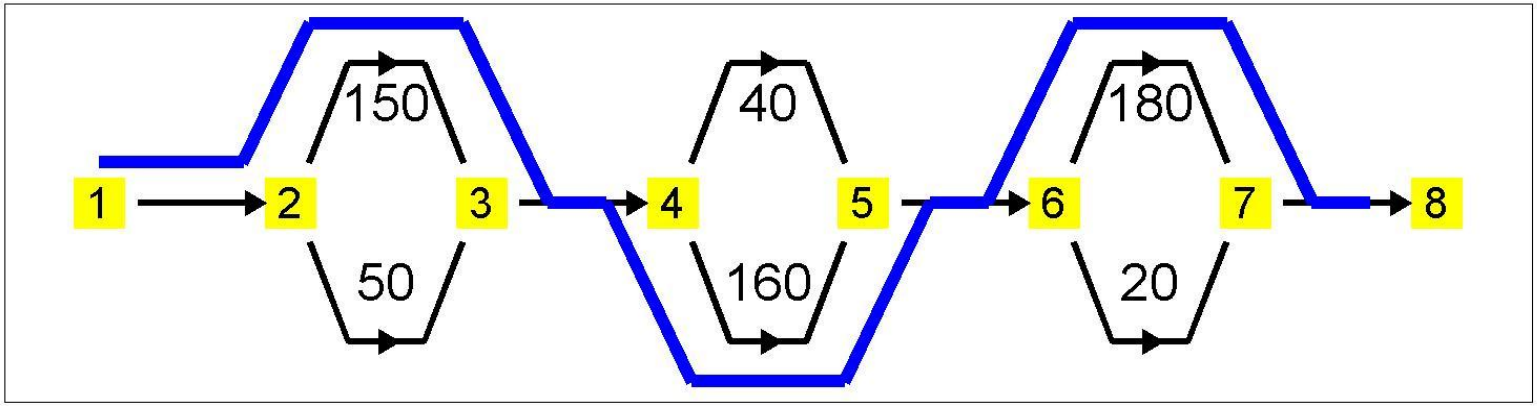


For trips from B to D the proportion is 15/(15+45)=1/4.

Proportionality Condition

- Same proportions of flow for the two segments.
- Origin and destination do not matter.
- Previous or subsequent decisions do not matter.



By proportionality, flow on designated route is:
200 * (150/200) * (160/200) * (180/200) = 108

Basis for the proportionality condition

Reasons:

- Simple, reasonable, consistent, stable, and useful.
- Proportionality is testable.
- Are there any other practical suggestions?

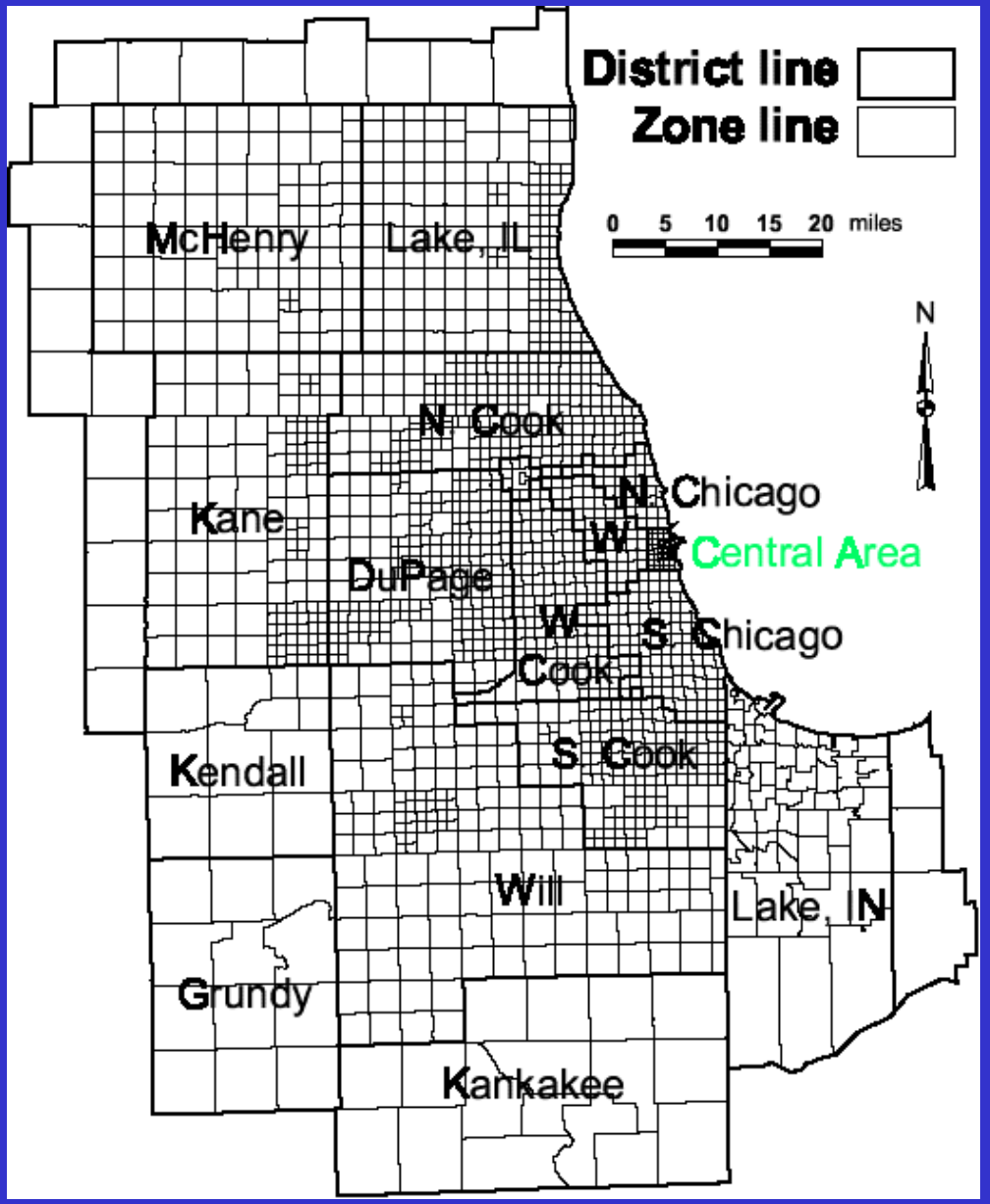
Implications:

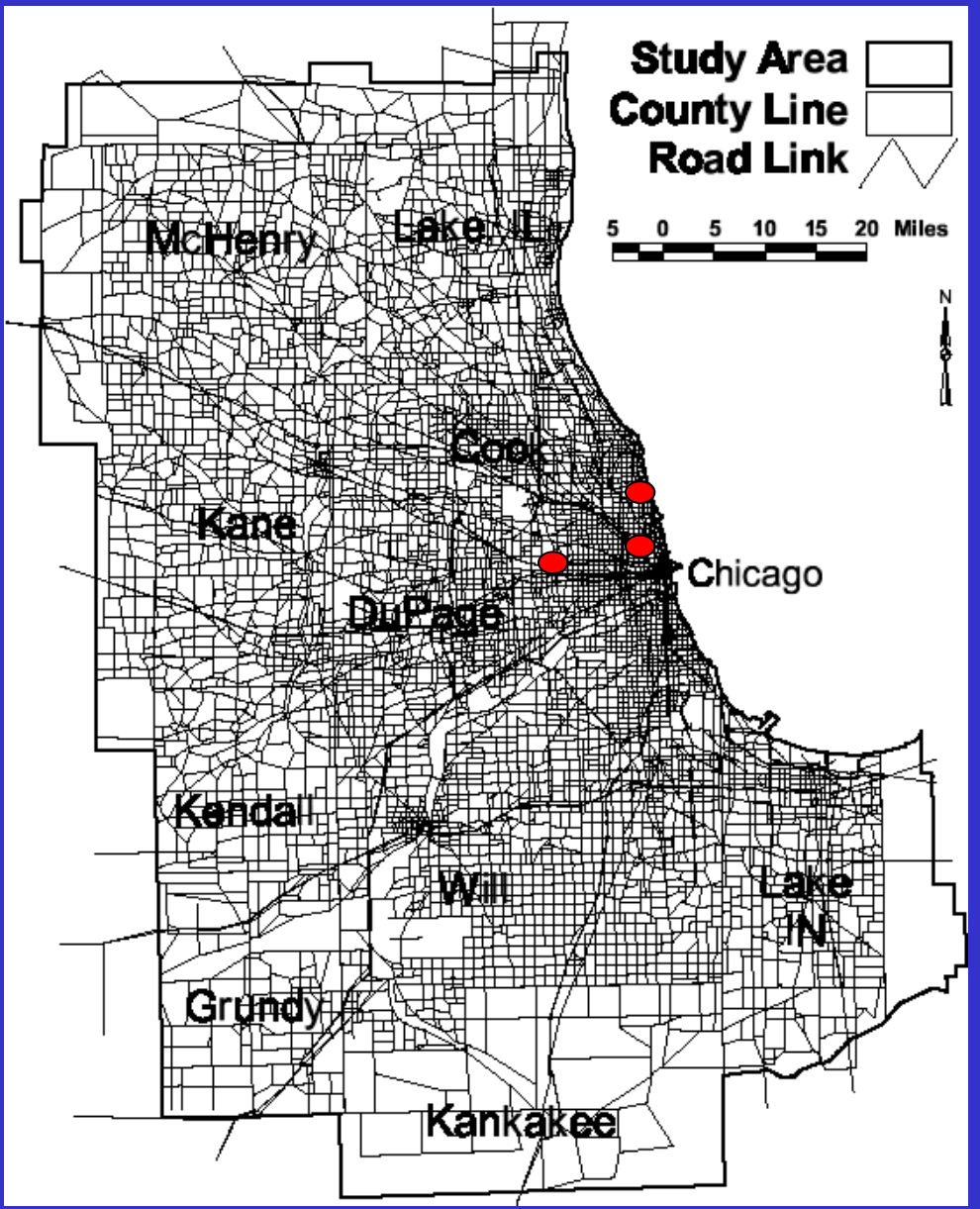
The set of routes should be consistent, so that any user-equilibrium (UE) route that can be used, keeping the same total link flows, should be used:

"No user-equilibrium route is left behind."

Traffic Assignment by Paired Alternative Segments (TAPAS) implements the proportionality condition.

Chicago regional zone system and road network





Solution algorithms

- A person trip matrix was created with Bar-Gera's Origin-based Assignment (OBA) algorithm using an iterative scheme to determine O-D-mode flows consistent with UE travel times, given truck flows.
- The car and truck trip matrices were assigned to UE travel time routes with a two-class TAPAS code.
- In one solution, trucks were restricted from using:
  - car-only lanes of the Kennedy and Dan Ryan Expressways
  - Lake Shore Drive
  - boulevards and parkways

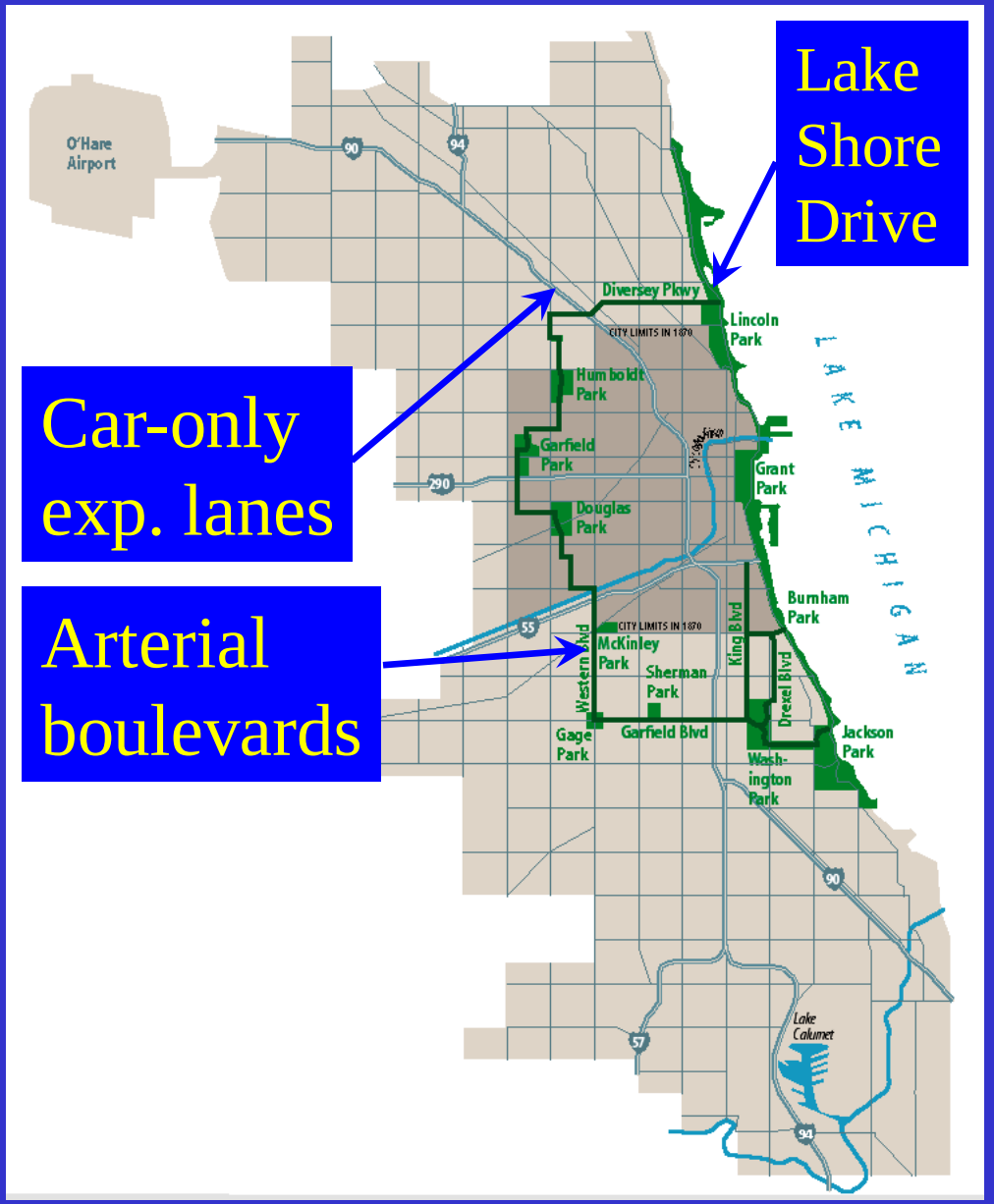
Construction of trip matrices for our experiments

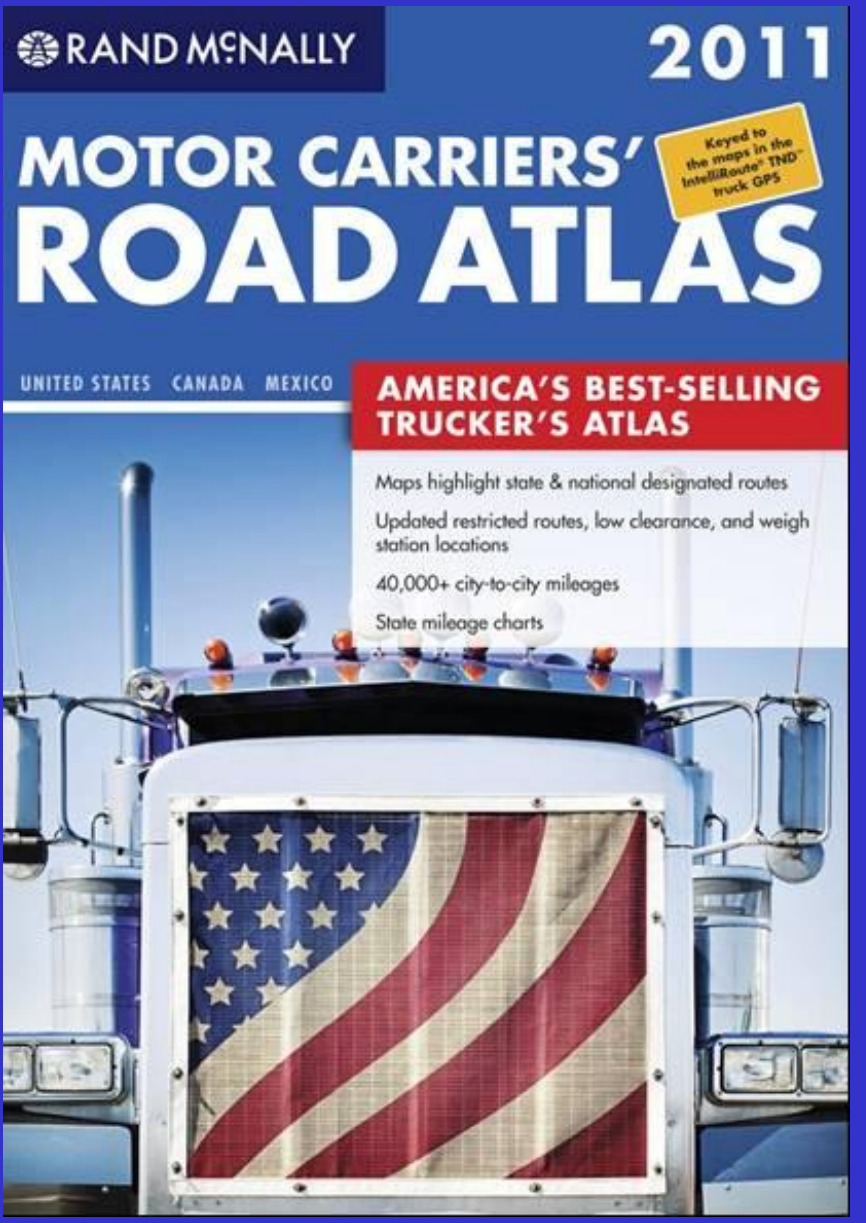
- Person trips are directly related to the given number of origins and destinations and inversely related to UE travel time, distance and tolls:

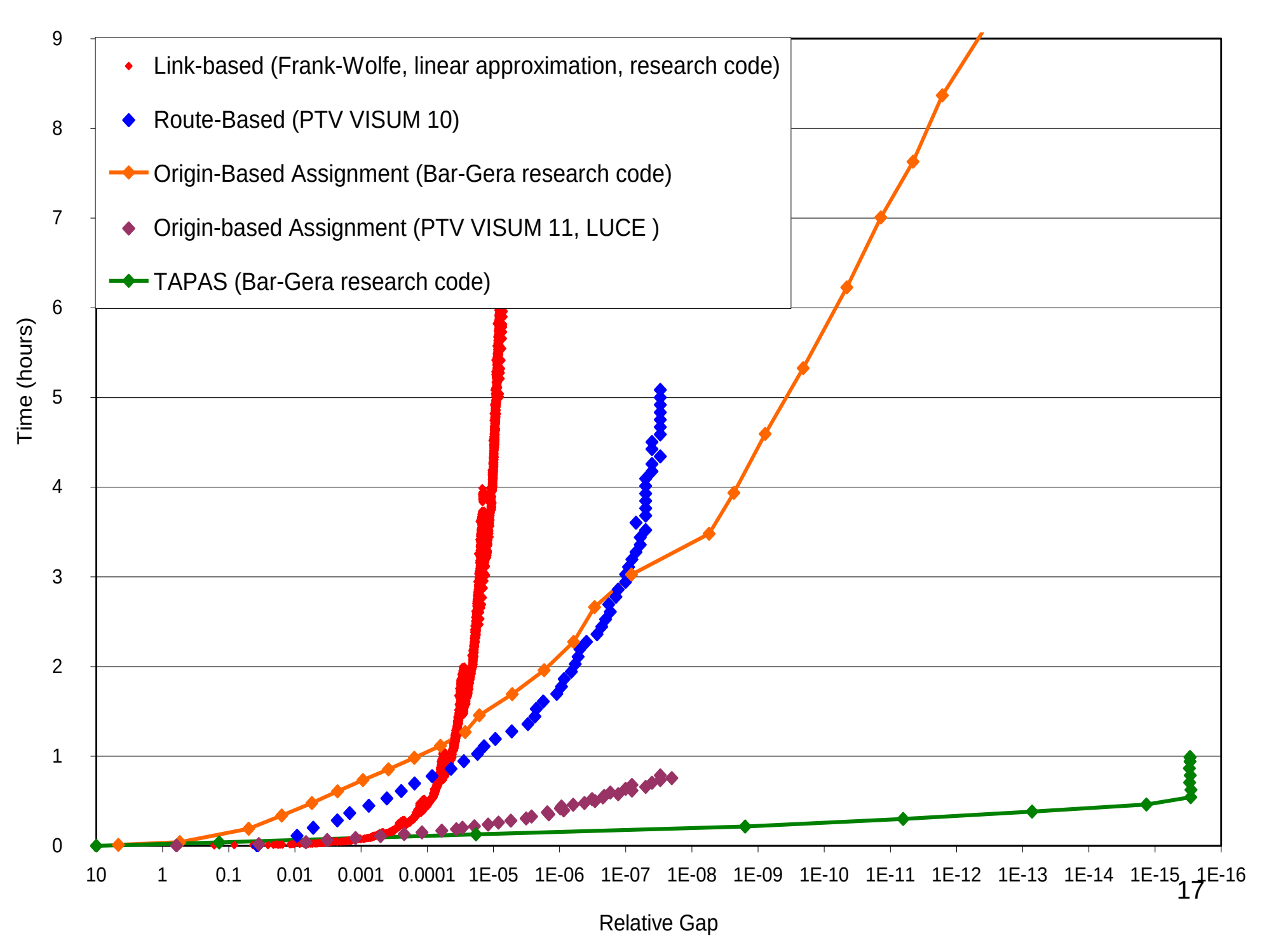
$$d_{pq}^{m} = R_p \, S_q \exp\left(-\beta u_{pq}^{m}\right)$$

- This function results in many small OD flows < 1;
- Cost sensitivity parameter β = 0.20 determines mode and trip length with a moderate level of endogenous congestion;
- Truck trips are exogenous, and represented in car equivalent units.

Truck restrictions on boulevards and arterials



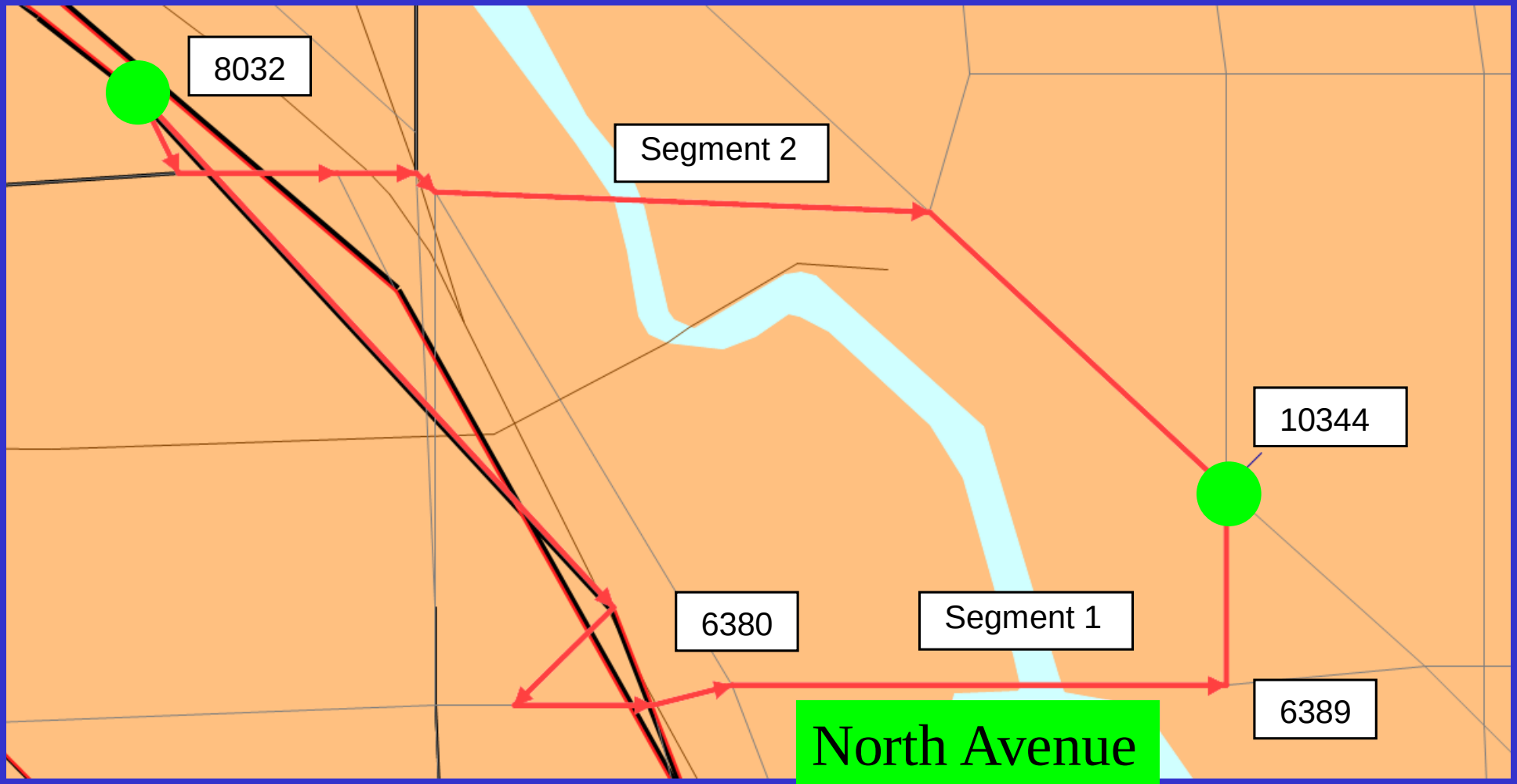



Link-based (Frank-Wolfe, linear approximation, research code)
Route-Based (PTV VISUM 10)
Origin-Based Assignment (Bar-Gera research code)
Origin-based Assignment (PTV VISUM 11, LUCE)
TAPAS (Bar-Gera research code)
Time (hours)
0
1
2
3
4
5
6
7
8
9
10
1
0.1
0.01
0.001
0.0001
1E-05
1E-06
1E-07
1E-08
1E-09
1E-10
1E-11
1E-12
1E-13
1E-14
1E-15
1E-16
Relative Gap

Analysis of a Pair of Alternative Segments

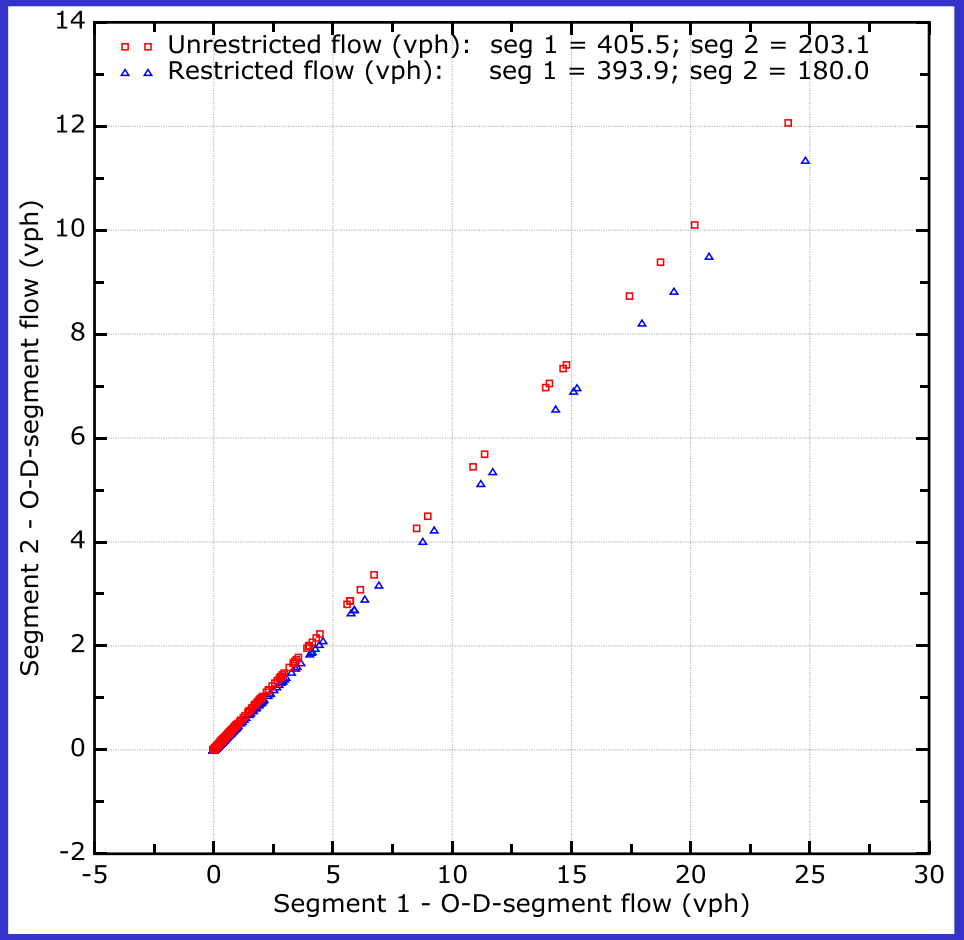
- Pairs of alternative segments (PAS), as in the simple example, are the organizing concept of TAPAS;
- Each PAS consists of two segments (sequences of links) with precisely the same travel time;
- According to the proportionality condition, flows for every OD pair should be allocated to the segments in the same proportion;
- Thus, we can check whether this condition is observed in the solution, and how the truck restrictions alter these proportions.

North Avenue Pair of Alternative Segments

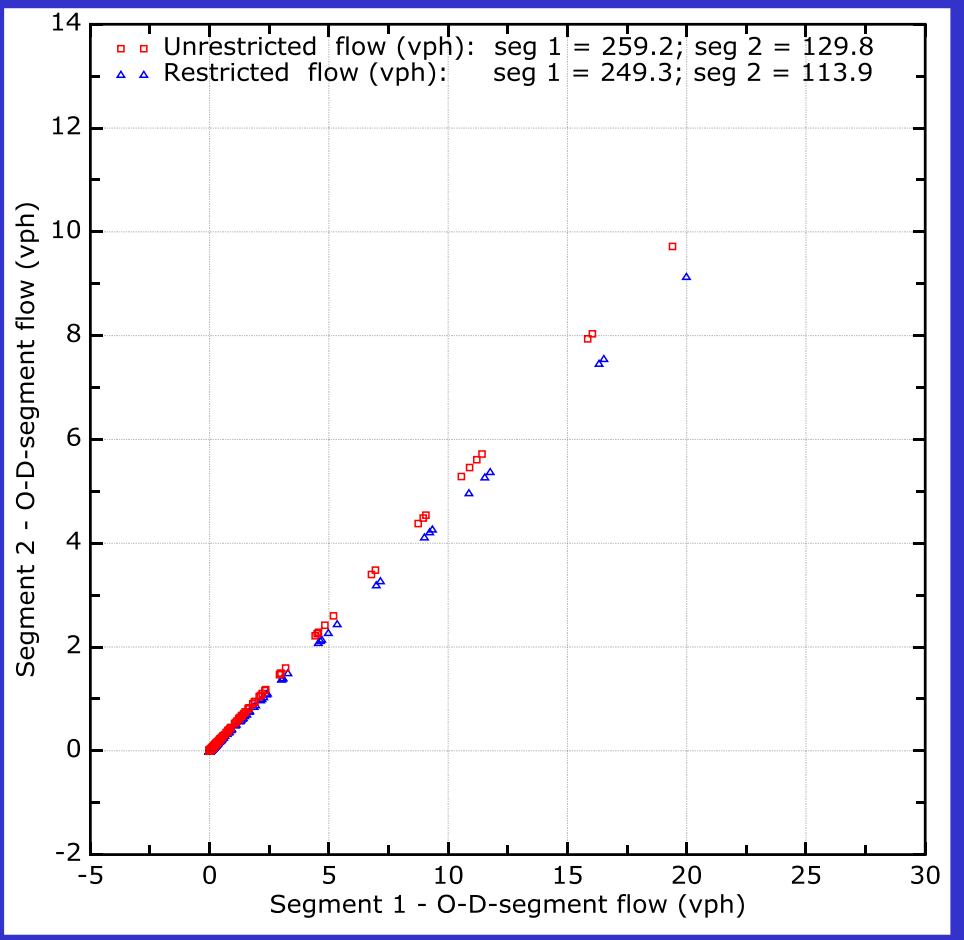


North Avenue Pair of Alternative Segments: total and car OD flows for unrestricted and restricted links

unrestricted total flows - 683 red pairs
restricted total flows - 678 blue pairs

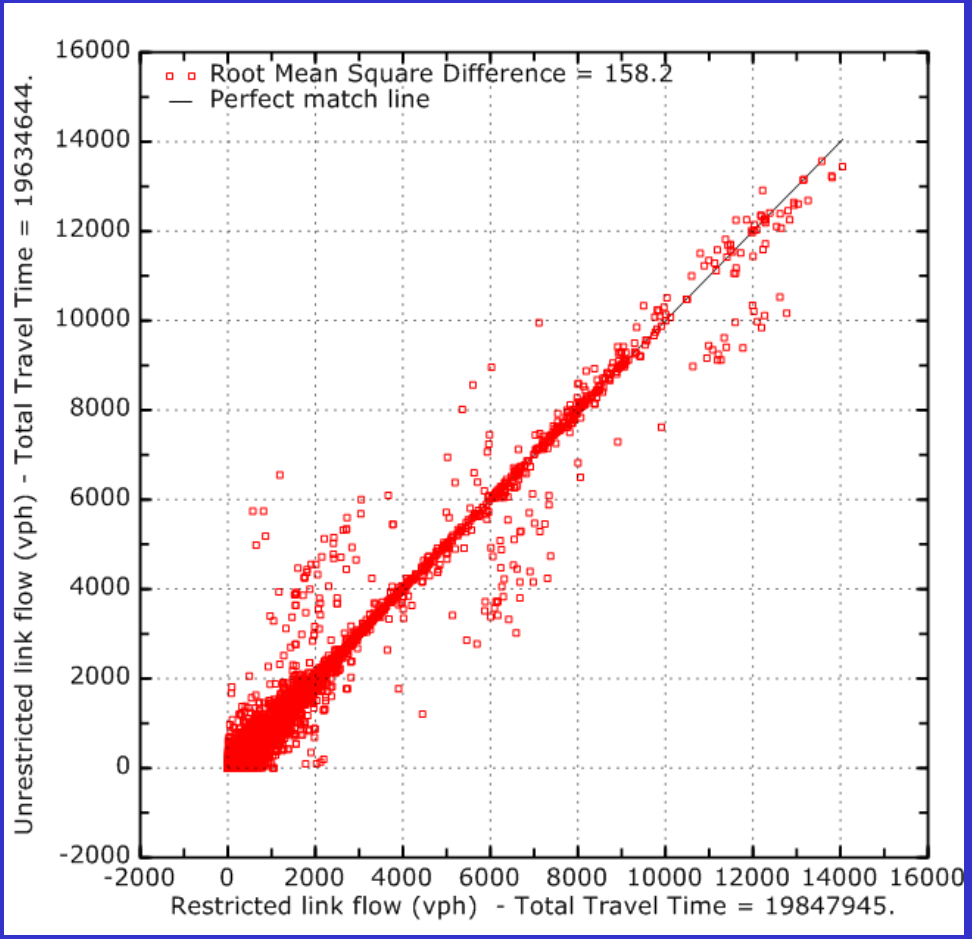


unrestricted car flows - 680 red pairs
restricted car flows - 670 blue pairs

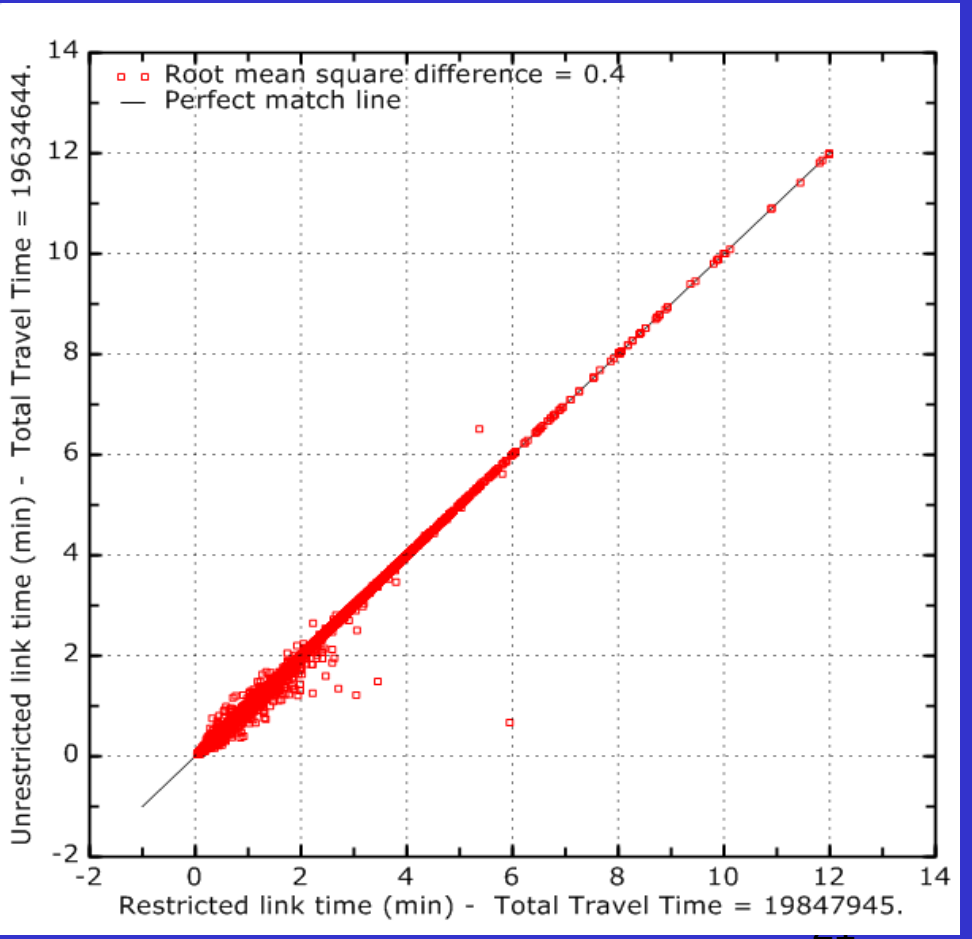


Comparison of total link flows and link travel times on networks unrestricted and restricted for trucks

unrestricted total link flows vs. restricted total link flows

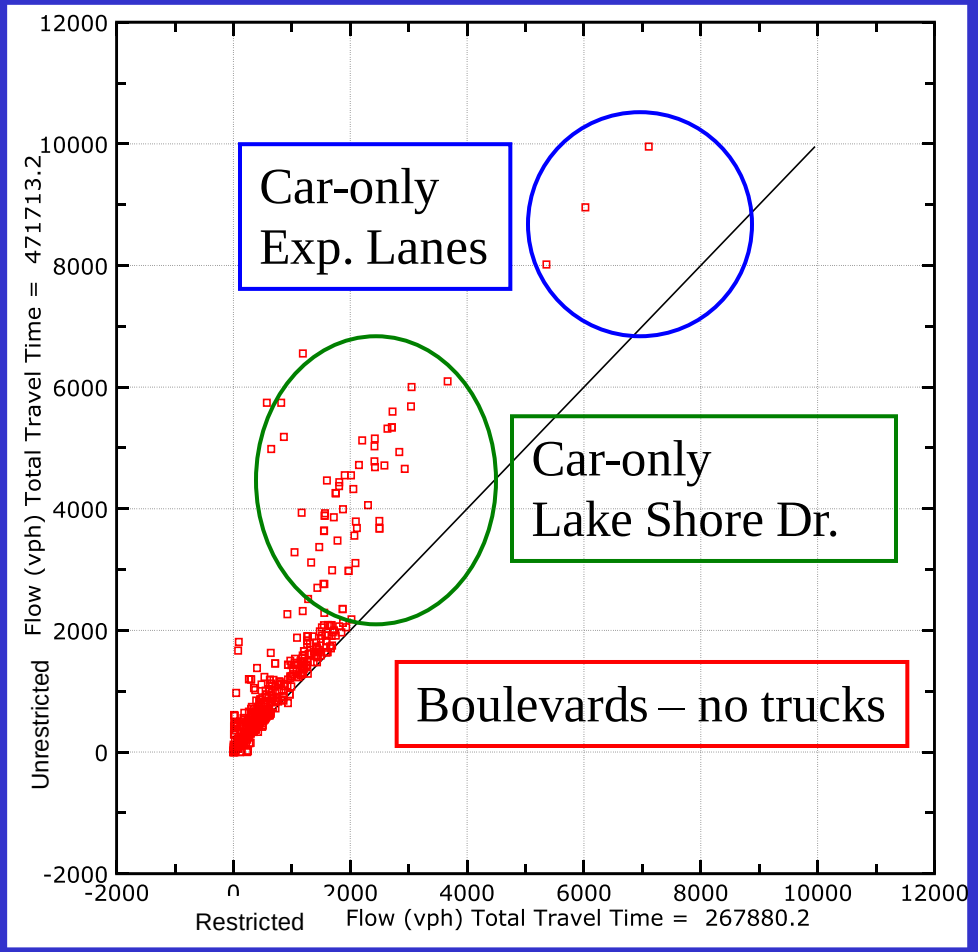


unrestricted total link times vs. restricted total link times

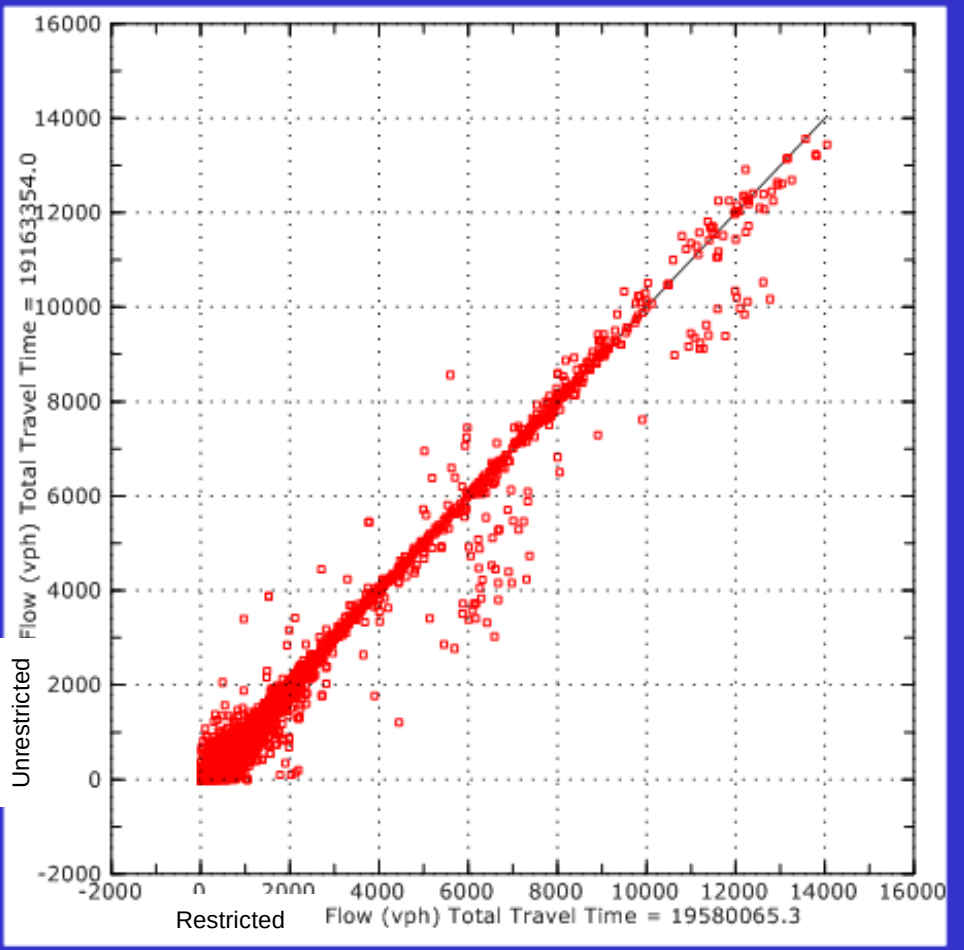


Comparison of total link flows on unrestricted and restricted links by restriction status

unrestricted link flows vs. restricted link flows: 562 restricted links

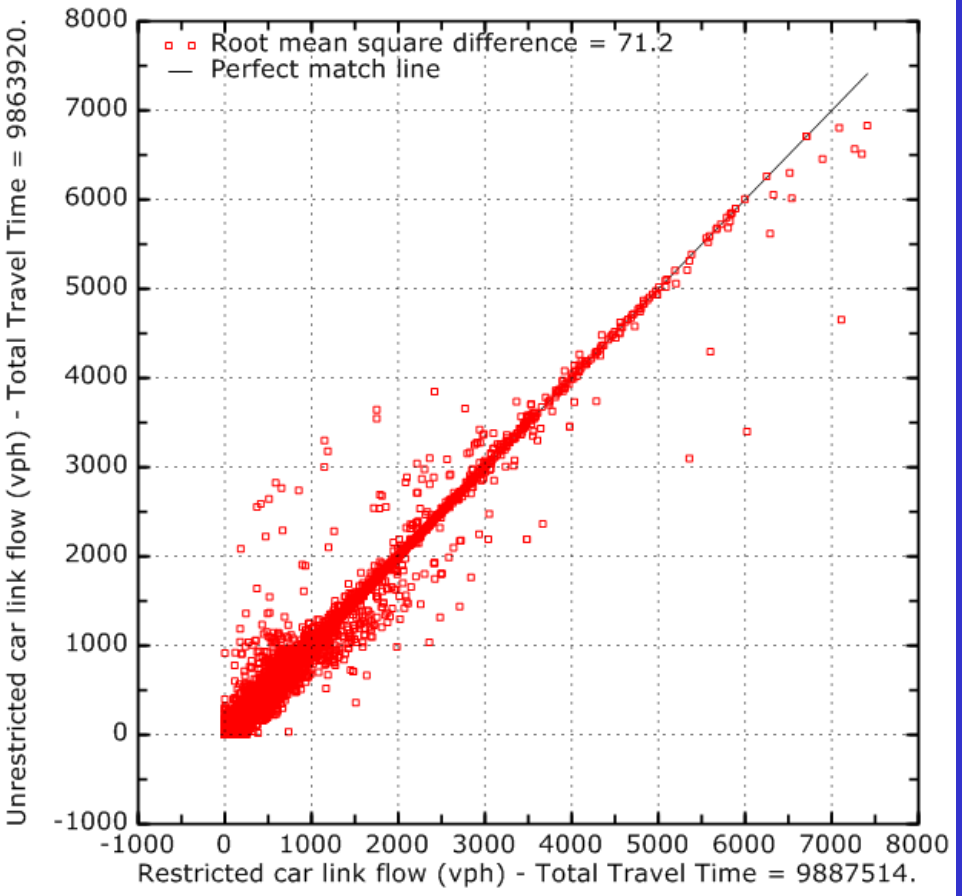


unrestricted link flows vs. restricted link flows: 38,456 unrestricted links

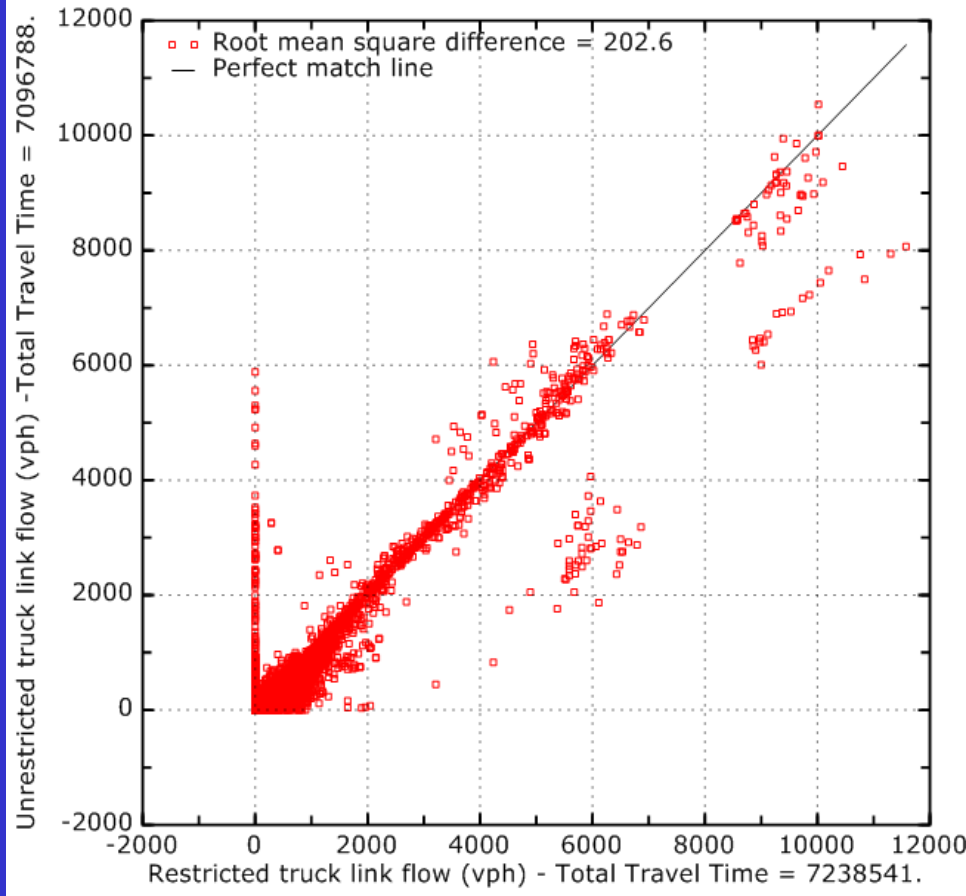


Comparison of car and truck link flows on networks unrestricted and restricted for trucks

unrestricted car link flows vs. restricted car link flows



unrestricted truck link flows vs. restricted truck link flows

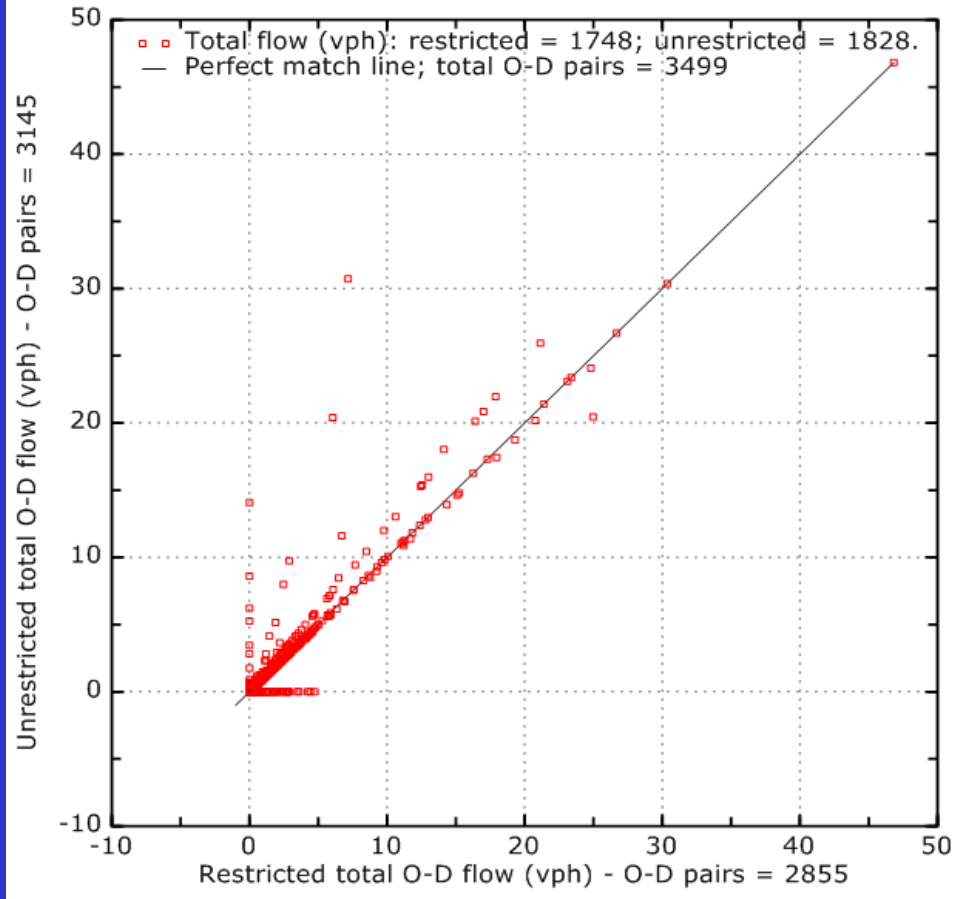


Select link analyses of North and Harlem Avenues

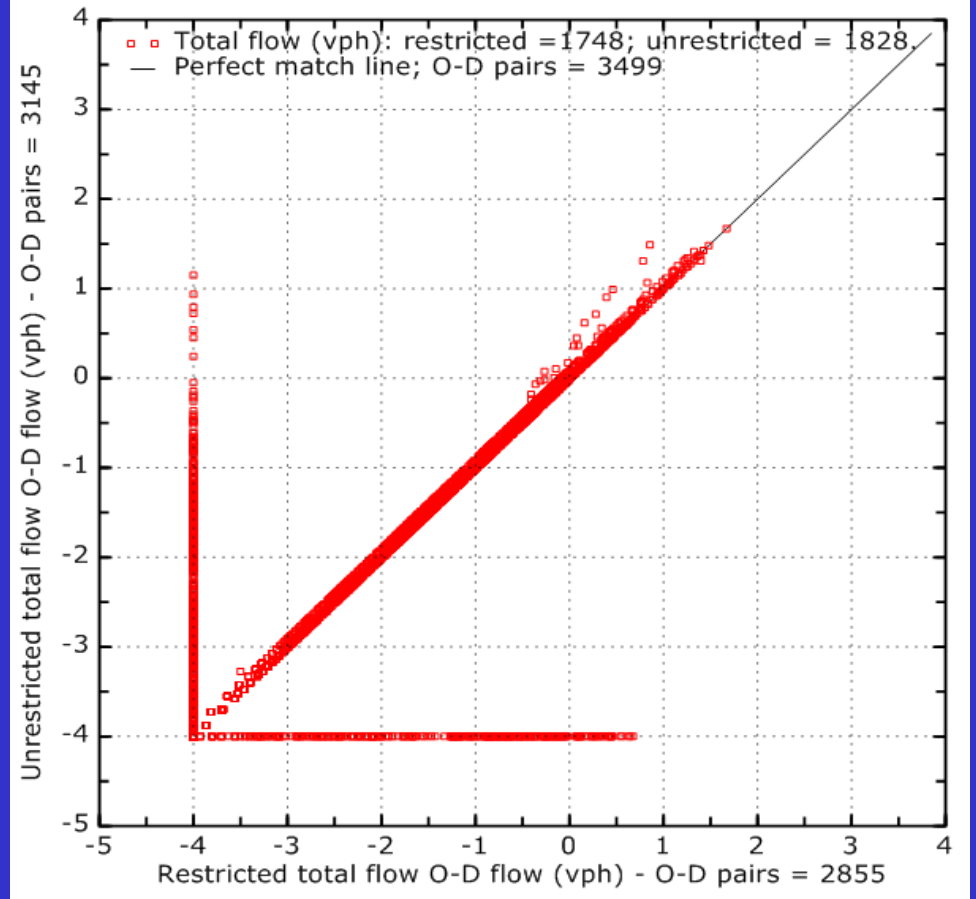
- The following figures depict Select Link Analyses for a four-lane urban arterial with no truck restrictions;
- Each symbol represents the route flow using the selected link from an origin to a destination;
- Positions of the symbols, on or off the 45 degree diagonal, show how the flow for each OD pair changes in response to network truck restrictions;
- Plots on both the linear and log scale enhance our understanding of the effect of truck restrictions.

North Avenue EB Select Link Analyses: total OD flows for unrestricted and restricted truck networks

linear - unrestricted total OD flows vs. restricted total OD flows

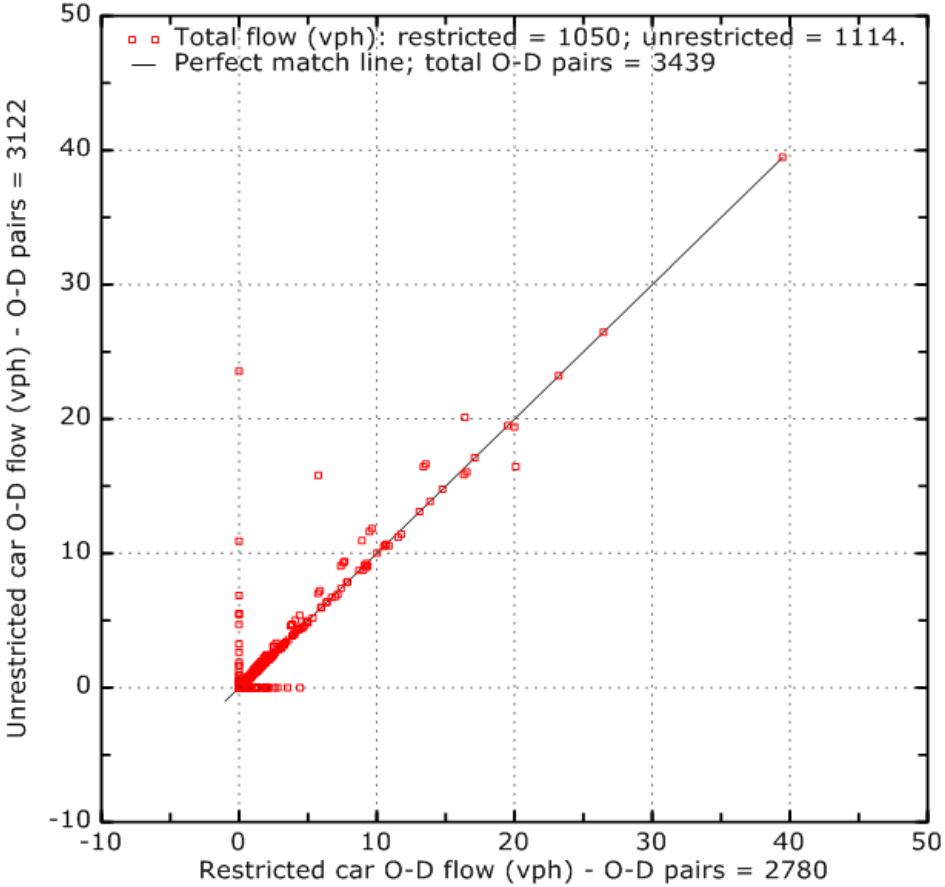


log - unrestricted total OD flows vs. restricted total OD flows

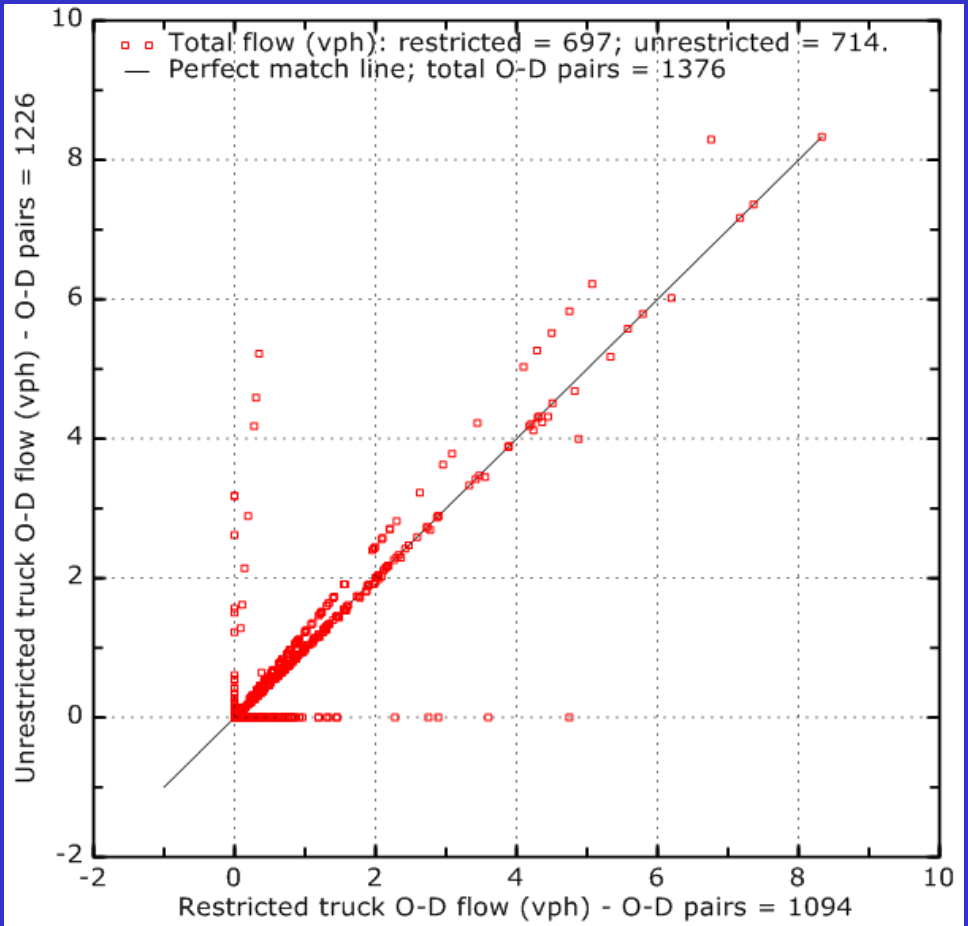


North Avenue EB Select Link Analyses: car and truck OD flows for unrestricted and restricted truck networks

linear - unrestricted car OD flows vs. restricted car OD flows



linear - unrestricted truck OD flows vs. restricted truck OD flows



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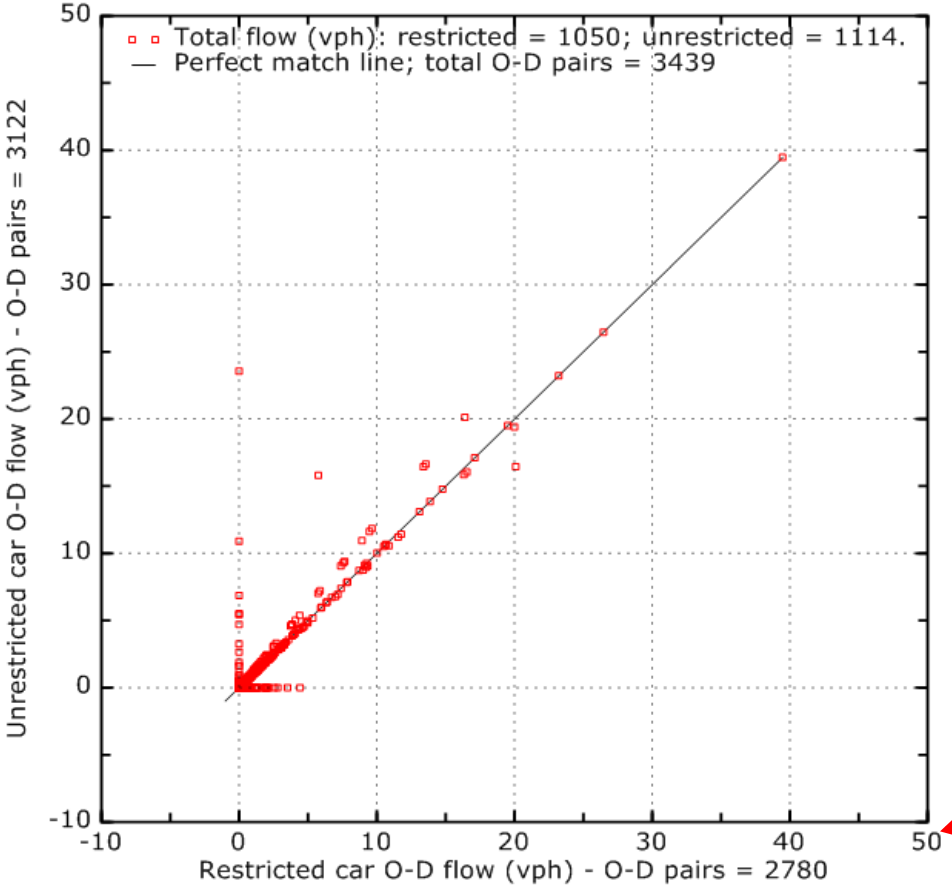
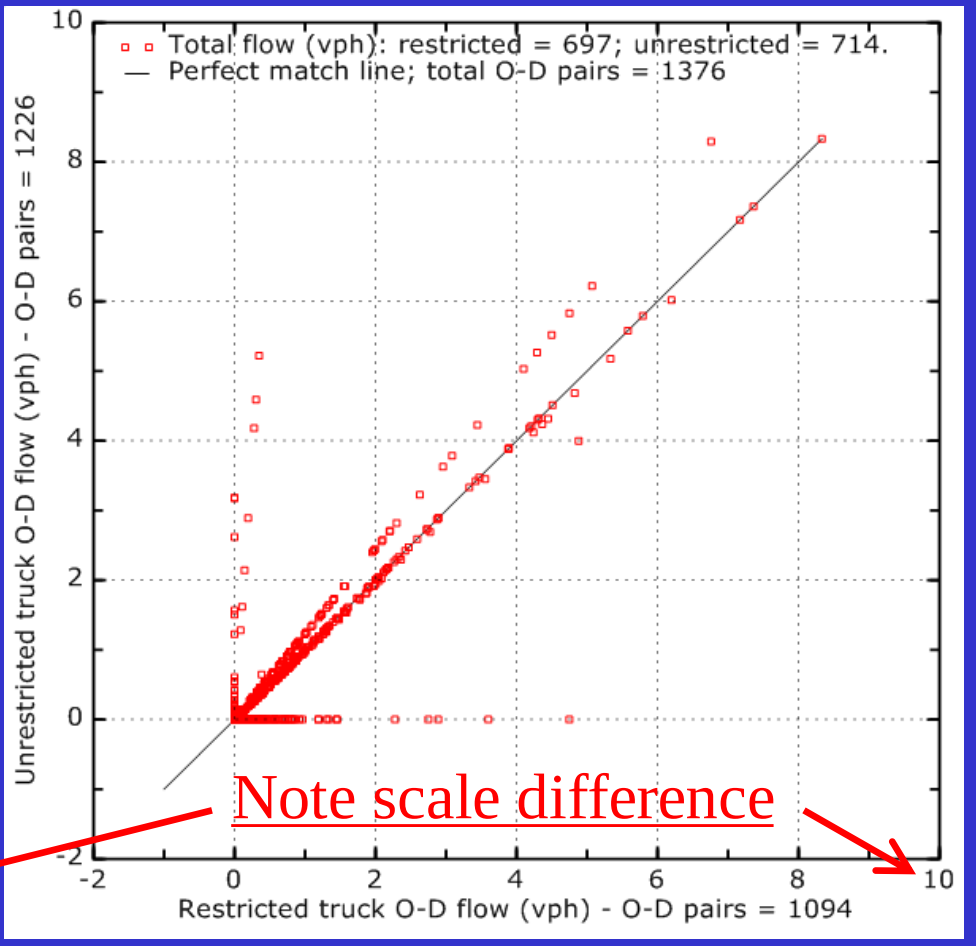
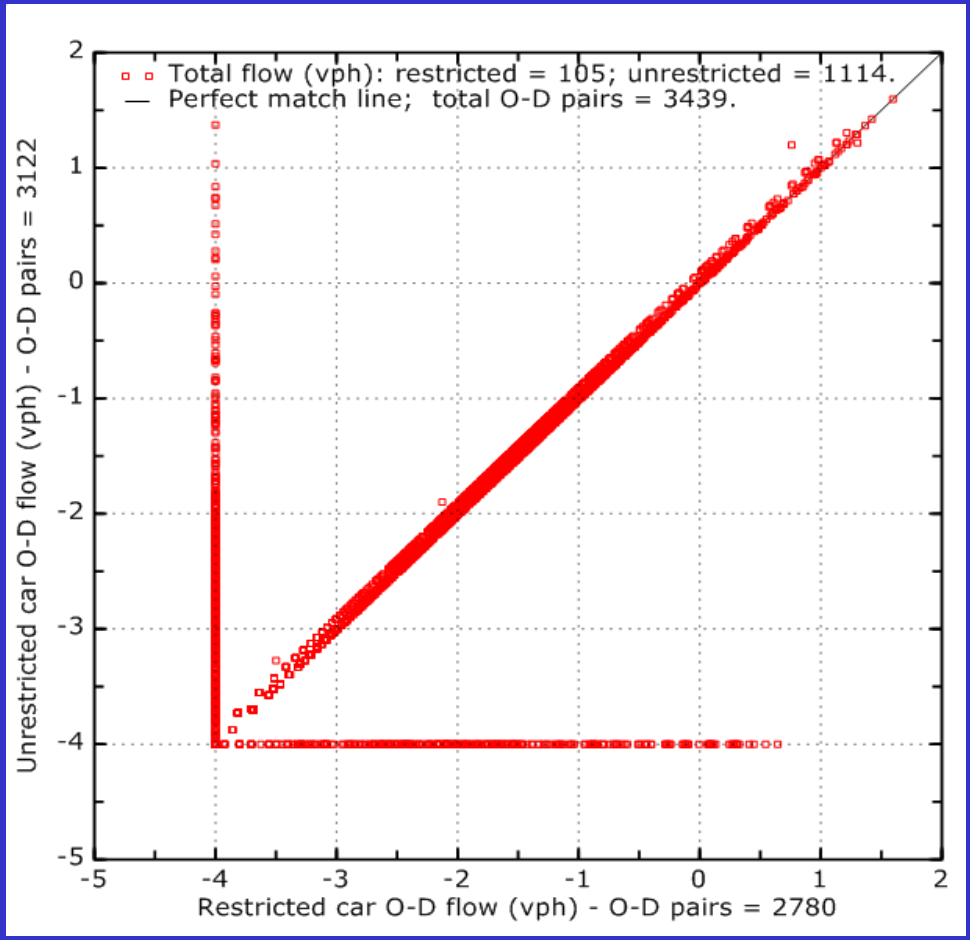


linear - unrestricted truck OD flows vs. restricted truck OD flows

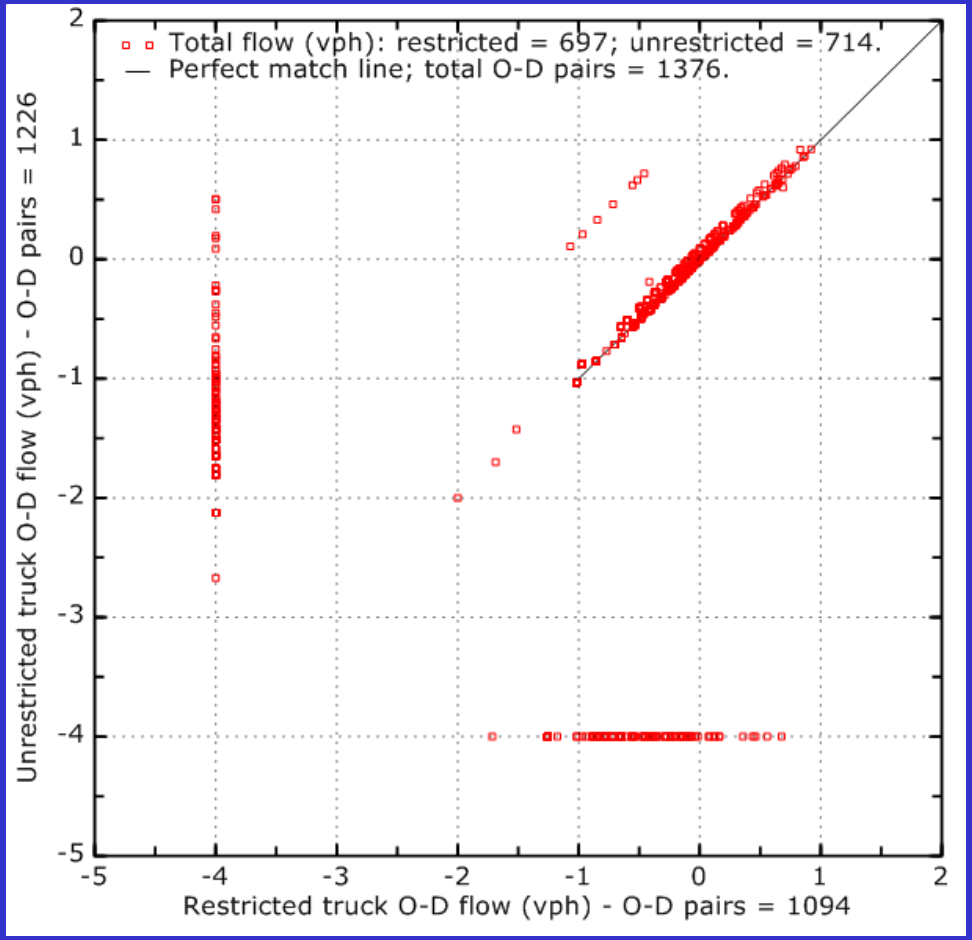


North Avenue EB Select Link Analyses: car and truck OD flows for unrestricted and restricted truck networks

log - unrestricted car OD flows vs. restricted car OD flows

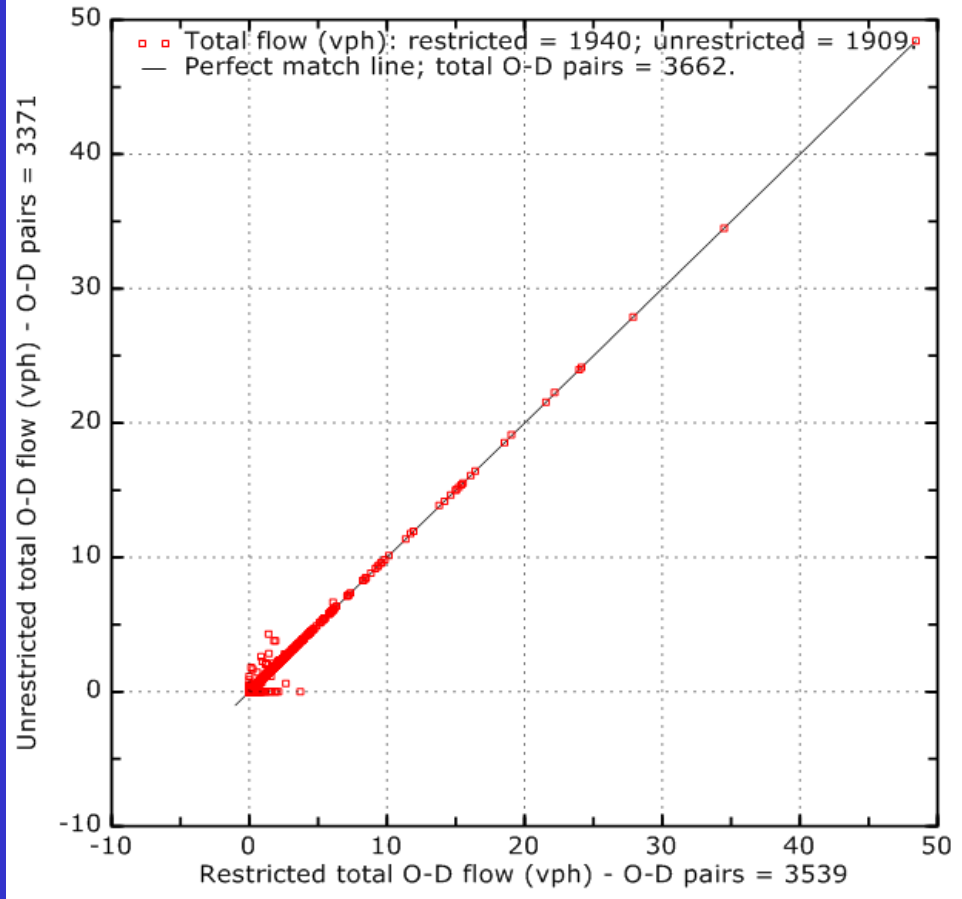


log - unrestricted truck OD flows vs. restricted truck OD flows

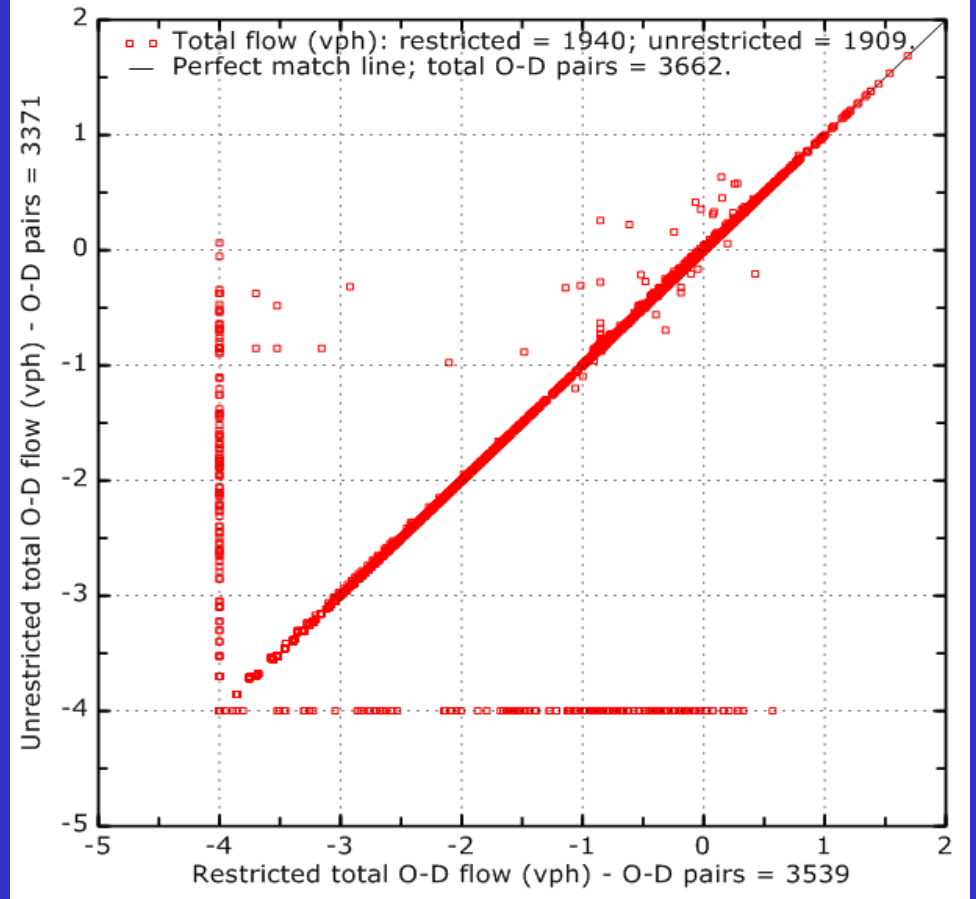


Harlem Avenue SB Select Link Analyses: total OD flows for unrestricted and restricted networks

linear - unrestricted total OD flows vs. restricted total OD flows

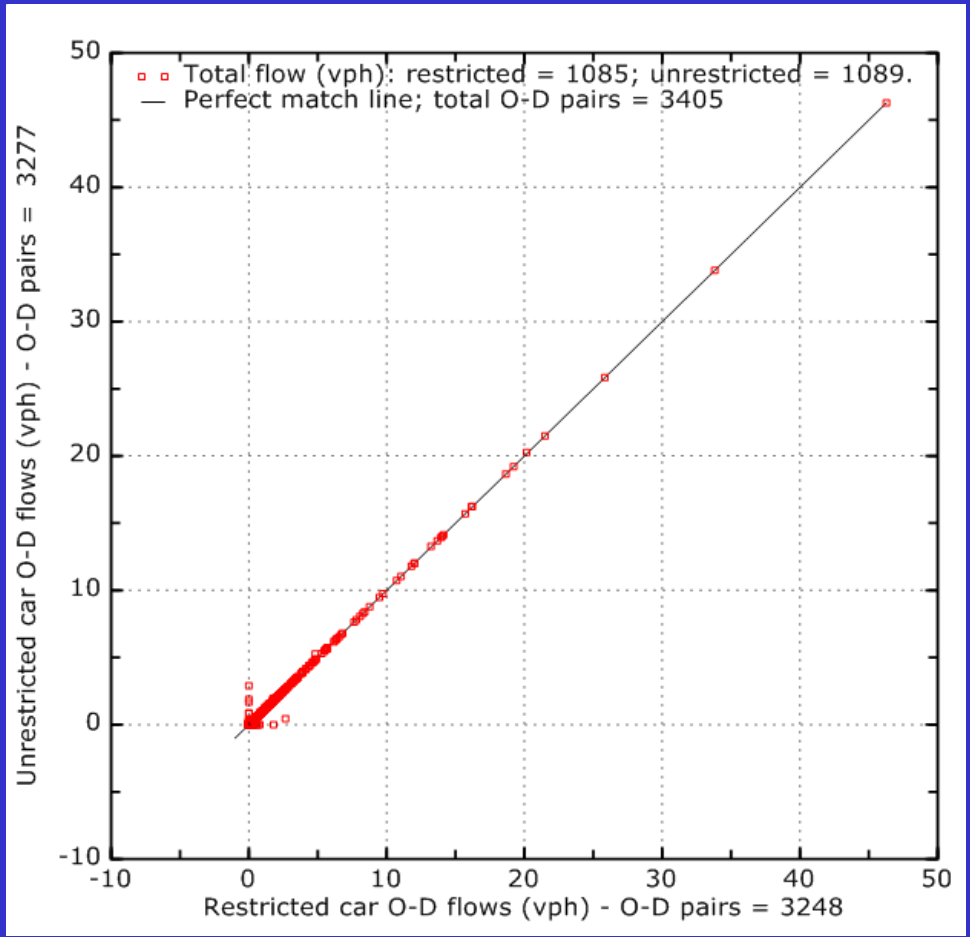


log - unrestricted total OD flows vs. restricted total OD flows

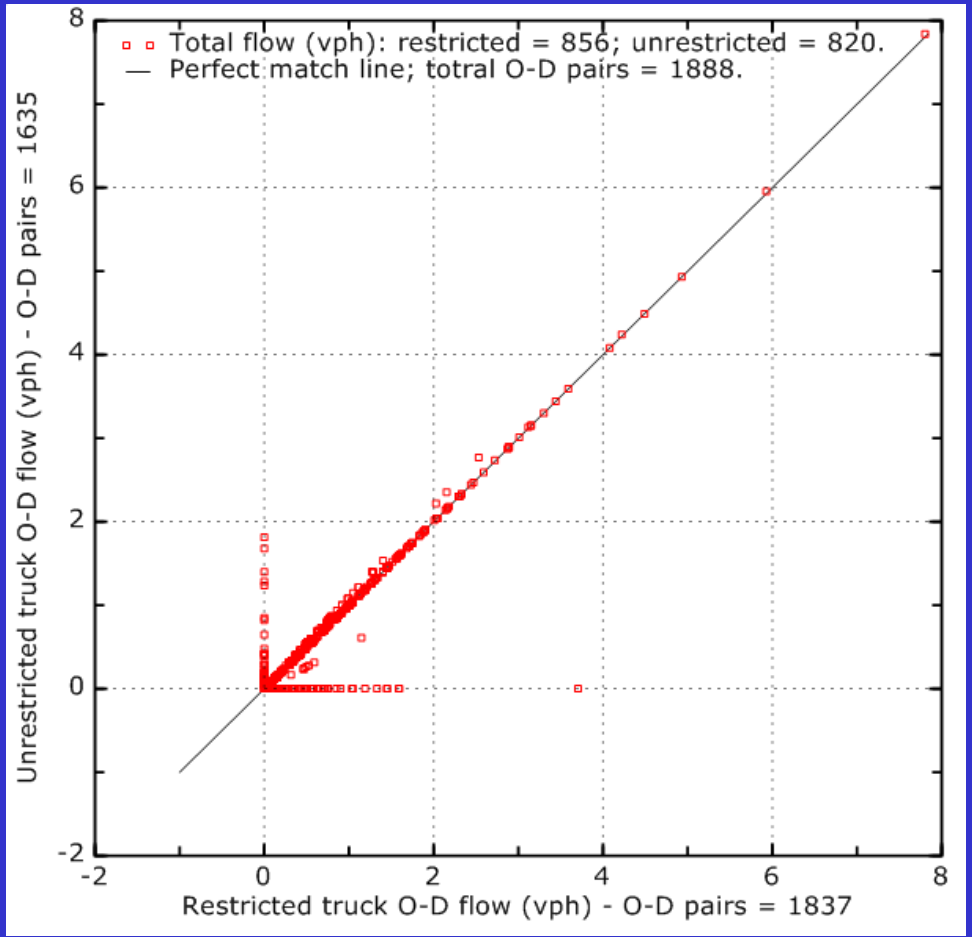


Harlem Avenue SB Select Link Analyses: car and truck OD flows for unrestricted and restricted networks

linear - unrestricted car OD flows vs. restricted car OD flows



linear - unrestricted truck OD flows vs. restricted truck OD flows



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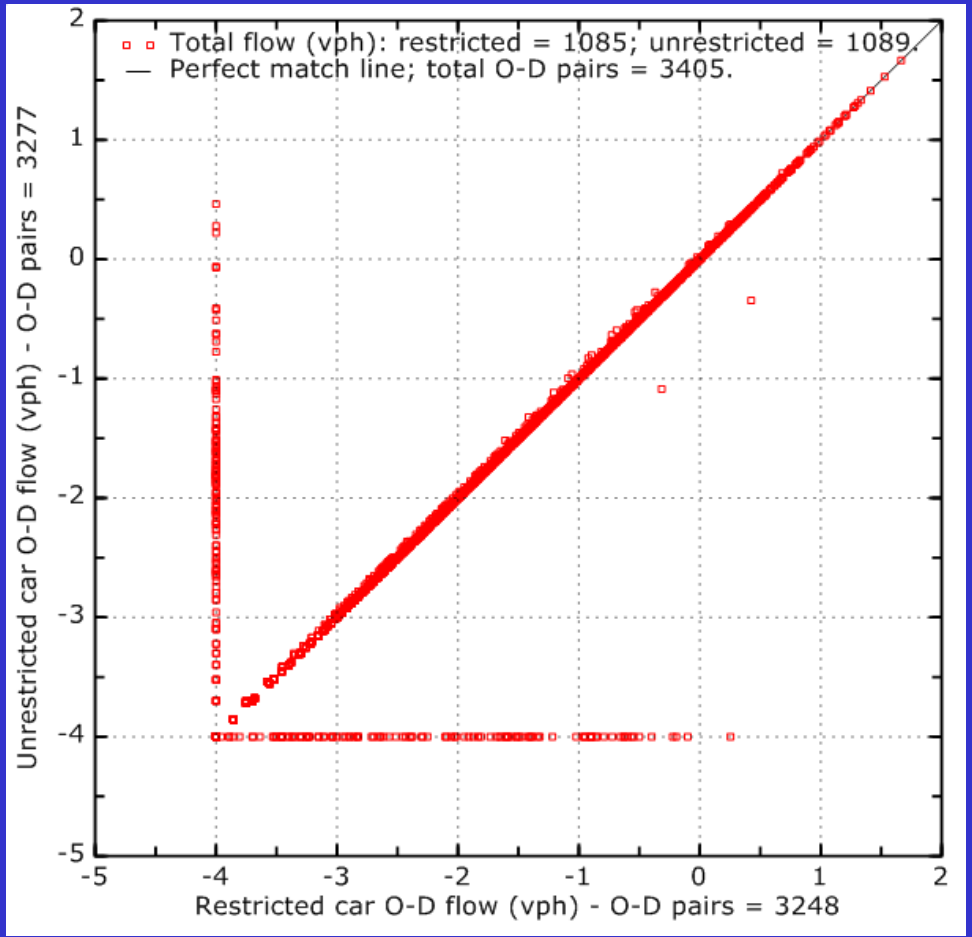
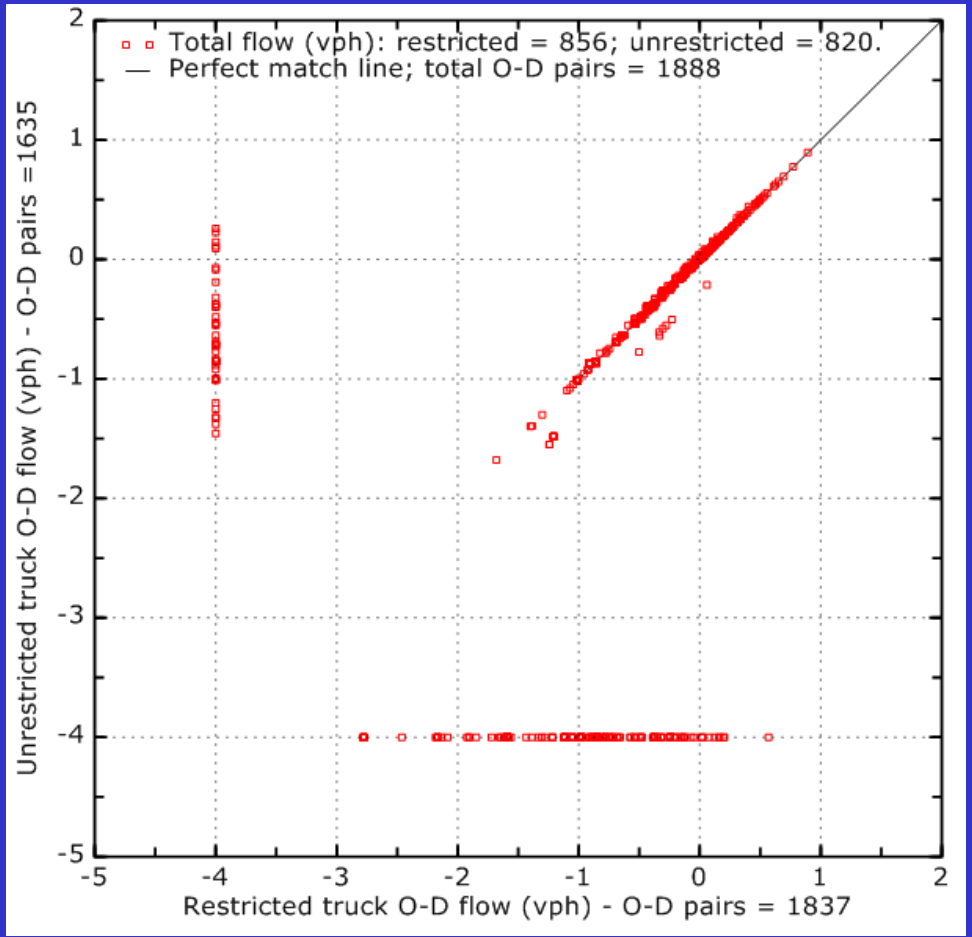


log - unrestricted truck OD flows vs. restricted truck OD flows



Conclusions

- The charts show substantial differences with respect to class link flows in response to different network representations;
- Multi-class assignments are clearly needed to account for effects of these network representations.
- The proportionality condition can now be applied to determine uniquely route flows and class link flows. Without proportionality, such flows have no validity.
- This innovation represents a major advance in the quality of traffic assignments in planning practice. It is now an option in TransCAD and VISUM.

Questions and comments?