



# DRIVEN BY TIME WINDOWS: PREDICTIVE STRATEGIES FOR REAL-TIME PICK-UP AND DELIVERY OPERATIONS

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Industry Workshop: The Fight for the Last Mile

Northwestern University Transportation Center Oct 29<sup>th</sup>, 2013



# Outline

- Part I: Background
  - Industry Overview
  - Innovations
  - Challenges
- Part II: Real Time Urban Freight Distribution
  - Research Problem
  - Modeling Framework
  - Large Network Application
- Part III: Closing Remarks

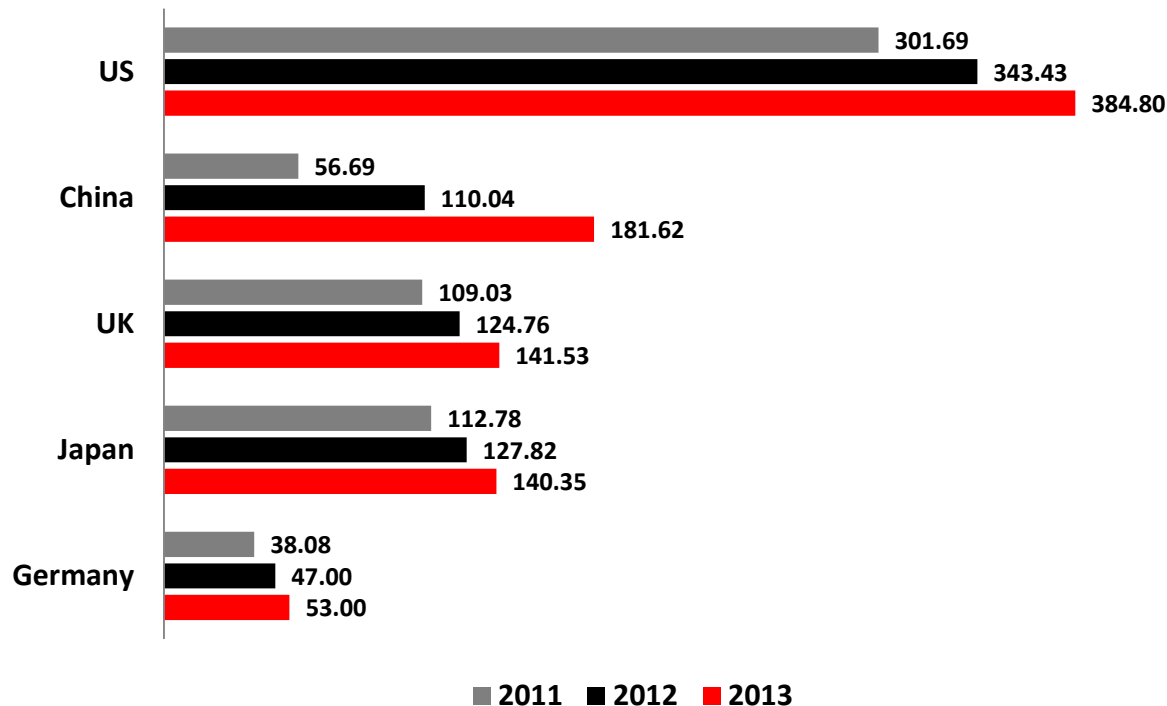


# PART I: BACKGROUND

# Growth Engine: E-Commerce

- Global ecommerce sales passed \$1 trillion in 2012.

**Top 5 Countries, Ranked by B2C Ecommerce Sales  
2012-2013 (\$ billions)**



# Industries



TARGET



Search

Manage My NutriFilter®

### Aisles/Departments

- Produce >
- Meat & Seafood >
- Deli >
- Dairy >
- Beverages >
- Bakery >
- Frozen >
- Grains, Pasta & Beans >
- Baking & Cooking Needs >
- Condiments & Sauces >
- Soups & Canned Goods >
- Snacks >
- Breakfast & Cereal >
- Alcoholic Beverages >
- Laundry, Paper & Cleaning >
- Office, Home & Garden >
- Health & Beauty >
- Baby & Childcare >
- Pet Store >

### More

- Organic
- Chicago's Best
- Market Day
- Prepared Foods
- Store Brands

## Frozen



## Frozen Vegetables

Handy, convenient  
and as  
nutritious as fresh.

Shop Now →

### Frozen Specials [view all specials](#)



Peapod Frozen Fruit  
16 oz  
**On Sale: 2 for \$5**

Shop



Tyson Any'tizers & More  
25 - 32 oz  
**On Sale: \$8.99**

Shop



Hot Buy! Blue Bunny Ice Cream  
1.75 quart  
**On Sale: 2 for \$7**

Shop

### Recommendations For You

## Kitchen Basics®



Add Flavor.  
Use Stock  
vs. Water



Ginger Vegetable  
Stir Fry

Shop Now

## Delivery & Pick-up Times


**Service Fees**

Delivery Fees ▾

Pick-up Fee ▾

**Your Delivery Address**

Your Delivery Address will show up here once you check out and complete registration



**FREE**  
No Pick-up Fee

**PICK UP YOUR GROCERIES FREE. NO MINIMUM.**

Pick-up your groceries in as little as 5 minutes.

[Learn More](#)

**VALUE DAYS**  
Save You Money ▶

Order for **Delivery**
 Order for **Pick-up**

<<
 

SUN 27 Unavailable	<b>MON 28</b>	TUE 29 October	WED 30 October	THU 31 Value Day	FRI 1 November	SAT 2 November
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6:00 AM – 8:00 AM		Green	<a href="#">Select</a>
7:00 AM – 9:00 AM			<a href="#">Select</a>
7:00 AM – 1:00 PM		Unattended	<a href="#">Select</a>
7:30 AM – 1:00 PM		ETA	Save \$2.00 <a href="#">Select</a>
8:00 AM – 10:00 AM			<a href="#">Select</a>
9:00 AM – 11:00 AM			<a href="#">Select</a>
10:00 AM – 12:00 PM			<a href="#">Select</a>
11:00 AM – 1:00 PM			<a href="#">Select</a>
4:00 PM – 6:00 PM			<a href="#">Select</a>
4:00 PM – 9:30 PM		Unattended	<a href="#">Select</a>
4:30 PM – 10:00 PM		ETA	Save \$2.00 <a href="#">Select</a>
5:00 PM – 7:00 PM			<a href="#">Select</a>
6:00 PM – 8:00 PM			<a href="#">Select</a>
7:00 PM – 9:00 PM			<a href="#">Select</a>
8:00 PM – 10:00 PM		Green	<a href="#">Select</a>

< Previous Available Day Next Available Day >

# Service Evolution I

Google Shopping Express

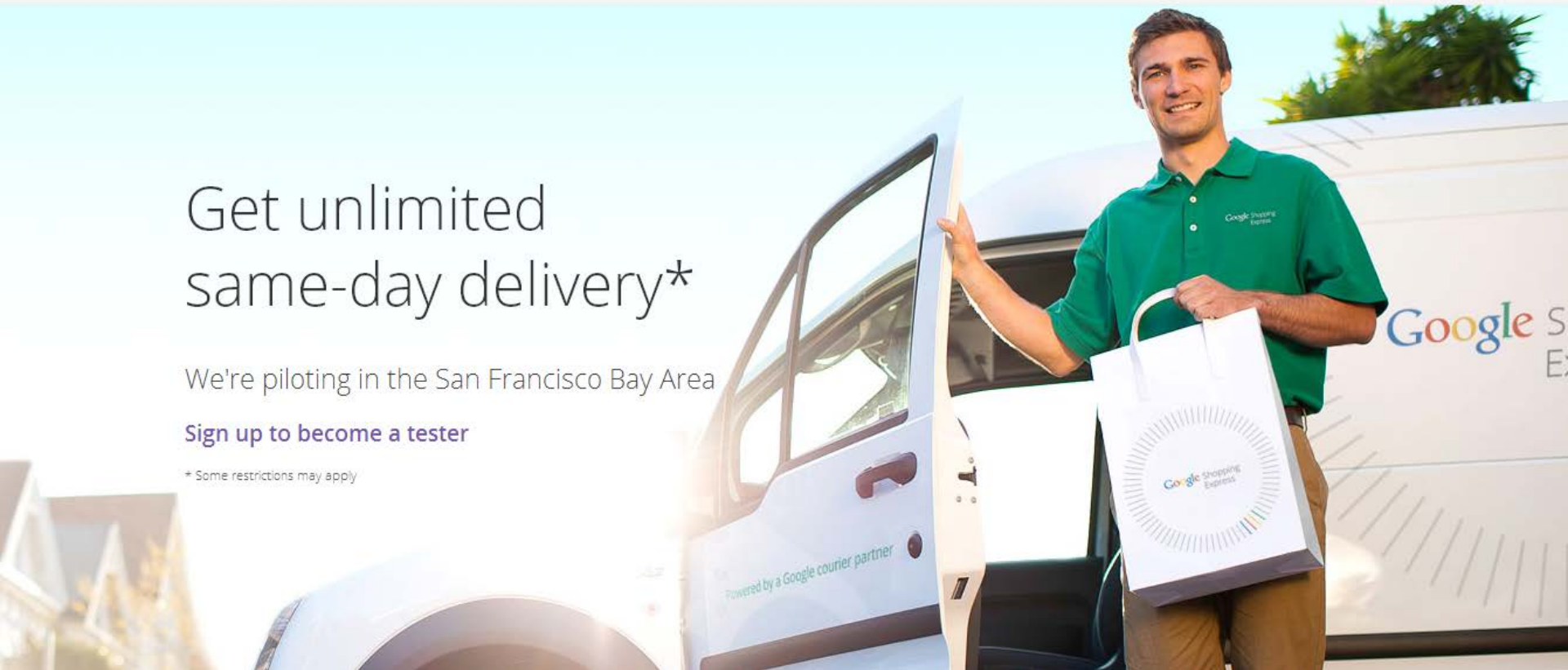
Already using Google Shopping Express? [Sign in to shop.](#)

Get unlimited  
same-day delivery\*

We're piloting in the San Francisco Bay Area

[Sign up to become a tester](#)

\* Some restrictions may apply





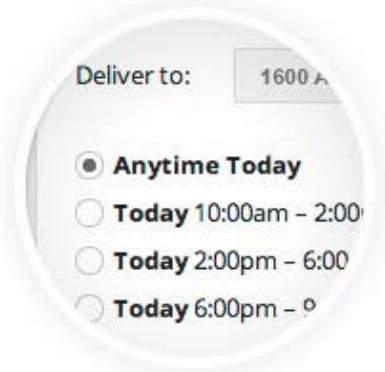
# Service Revolution II

## How it works



Find what you need

Browse local stores online in one place



Select a delivery window

Provide delivery instructions for our couriers



Get it delivered today

Live life on your schedule



# Big Players' Strategy

- Closely guarded: *ahead of the curve* vs. *wait & see*
- UPS and FedEx outsource part of their last mile delivery to USPS, allowing them to maximize the efficiency of their operations.



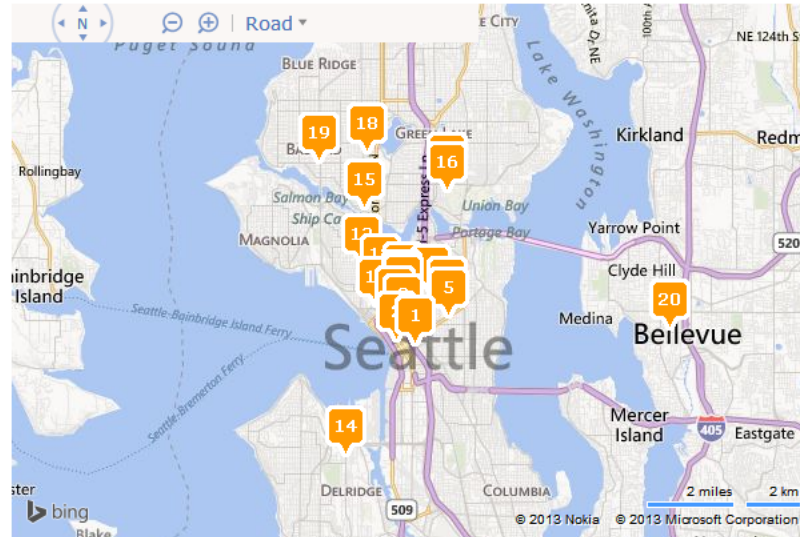
# Amazon Locker

[Your Account](#) > [Manage Addresses and 1-Click Settings](#) > [Amazon Locker Search Results](#)

## Amazon Locker Search Results

**Results for "seattle"**

<b>1</b>	Amazon Locker - Aurora 700 5th Ave, Located in Seattle Muni Tower, Seattle WA 98104-5058 <a href="#">Map details</a>	Mon - Fri: 05:00 - 22:00 Sat, Sun: 08:00 - 20:00	<a href="#">Select</a>
<b>2</b>	Amazon Locker - Spruce 1301 1st Ave, Located in Harbor Steps NE Twr, Seattle WA 98101-2074 <a href="#">Map details</a>	Open 24hrs	<a href="#">Select</a>
<b>3</b>	<b>Restricted Access</b> - This locker is available only to those with authorized access to this building. <input type="checkbox"/> I confirm that I have access to this location <a href="#">Learn more</a>		
<b>3</b>	Amazon Locker - Caldera 600 Pine St, Located in Pacific Place, Seattle WA 98101-0000 <a href="#">Map details</a>	Mon - Sun: 06:00 - 02:00	<a href="#">Select</a>
<b>4</b>	Amazon Locker - Victor 2121 6th Ave, Located in Via6, Seattle WA 98121-2513 <a href="#">Map details</a>	Open 24hrs	<a href="#">Select</a>
<b>4</b>	<b>Restricted Access</b> - This locker is available only to those with authorized access to this building. <input type="checkbox"/> I confirm that I have access to this location <a href="#">Learn more</a>		
<b>5</b>	Amazon Locker - Pearl 1522 E Madison St, Located in 7-Eleven, Seattle WA 98122-4014 <a href="#">Map details</a>	Open 24hrs	<a href="#">Select</a>
<b>6</b>	Amazon Locker - Arizona 201 Boren Ave N, Located in Amazon Campus, Seattle WA 98109-5304 <a href="#">Map details</a>	Mon - Sun: 07:00 - 22:00	<a href="#">Select</a>
<b>7</b>	Amazon Locker - Ruby 333 Boren Ave N, Located in Amazon Campus, Seattle WA 98109-5306 <a href="#">Map details</a>	Mon - Fri: 07:00 - 00:30 Sat, Sun: 08:00 - 00:30	<a href="#">Select</a>
<b>8</b>	Amazon Locker - Morris 103 15th Ave E, Located in 7-Eleven, Seattle WA 98112-5209 <a href="#">Map details</a>	Open 24hrs	<a href="#">Select</a>



you that are open late.

# Innovative Delivery Services



Amsterdam



Berlin



UK



Zurich

# Challenges

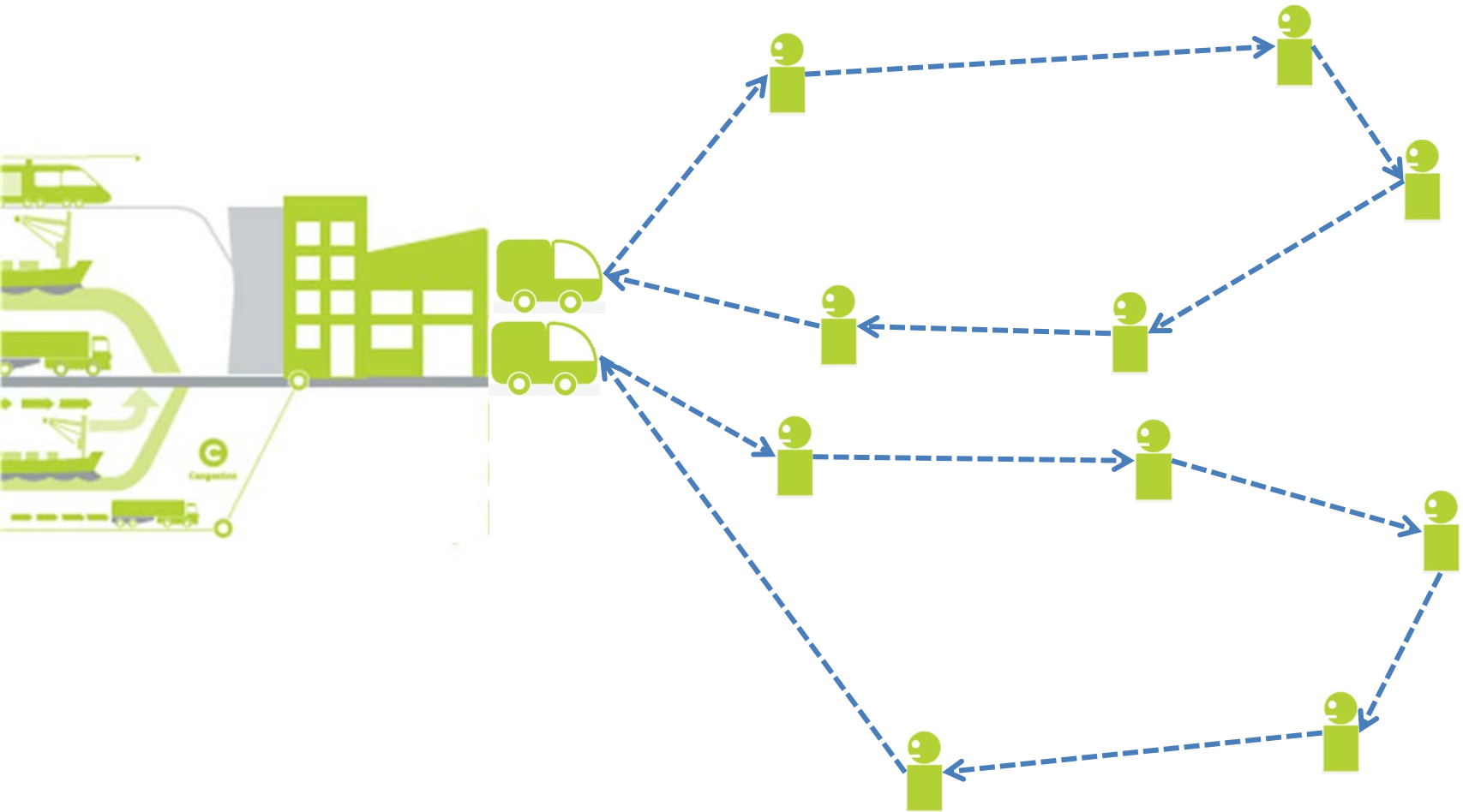
- Urban Congestion
- Disruptive Events on Road Network
- Vehicle size and Delivery Time Regulations
- Limited Physical Parking
- Loading and Vehicle Utilization Efficiency
- Customer Satisfaction



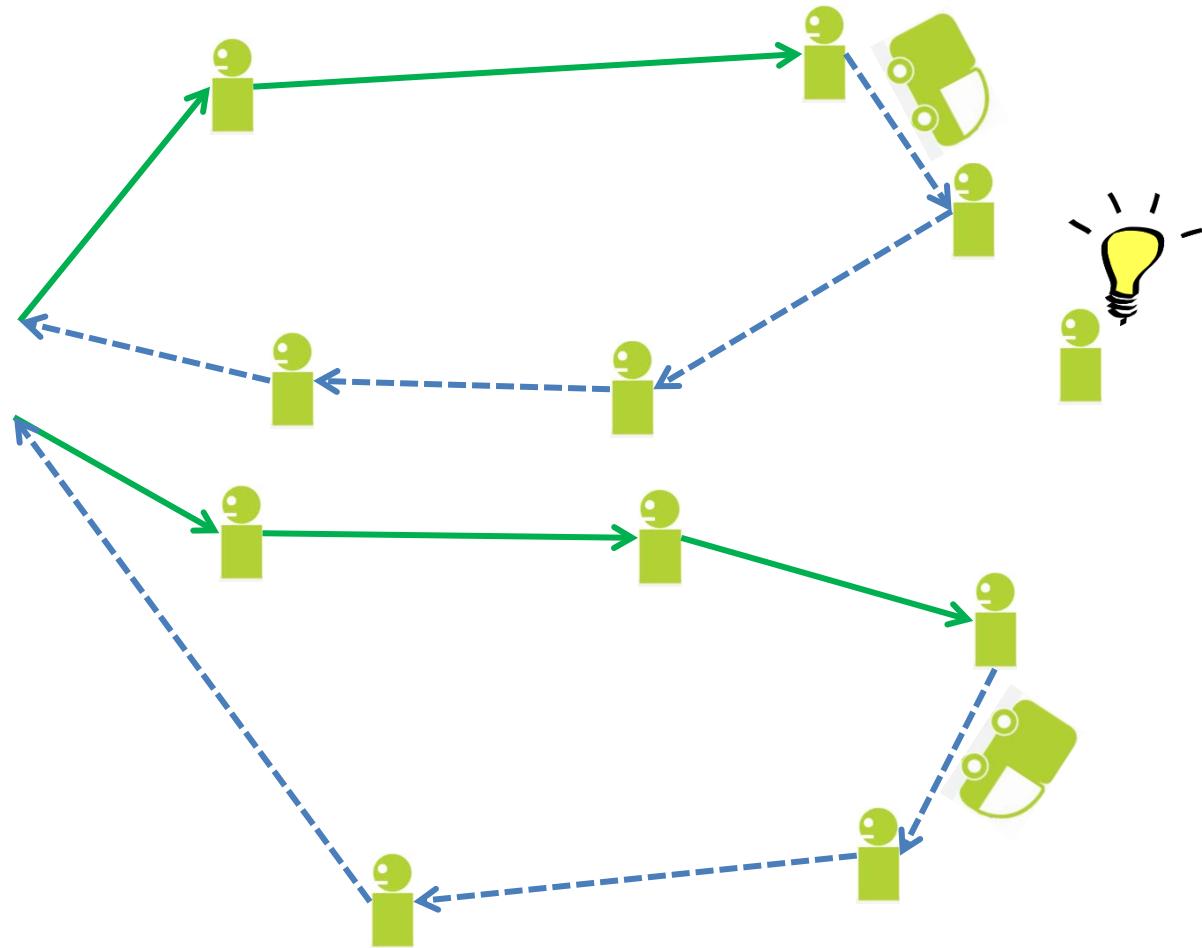
**PART II:**

**REAL TIME URBAN FREIGHT DISTRIBUTION**

# Research Problem



# Research Problem II







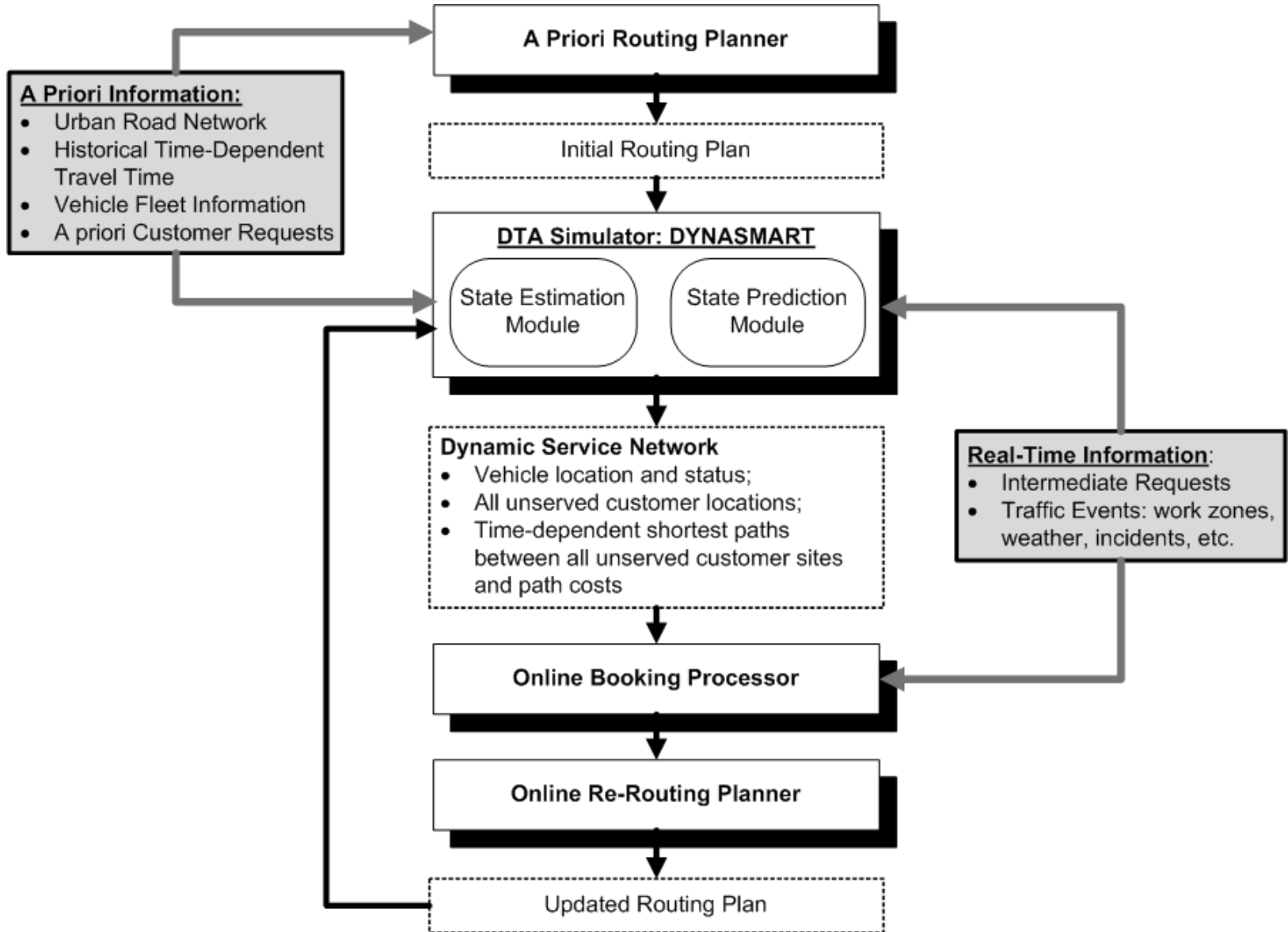
# Real-Time Urban Freight Distribution

- Customer Requests
  - All commodities are *heterogeneous* (impossible to rearrange delivery requests once vehicles are out of depot)
  - A Priori requests (*known before operation*): a *mixture of pickup and delivery requests*
  - Intermediate Requests (*revealed during operation*): *pickup only*
  - All pickup loads are *brought back to depot*
- Prevailing and *anticipated* traffic information

# Key Features of the Problem

- **Multiple sources of uncertainty:**
  - Customer request arrival time;
  - Customer request location;
  - Customer request load (size and type).
- **Information**
  - Detailed urban road networks (signals, one-way streets, etc.);
  - Prevailing traffic information;
  - Predicted traffic information.

# Modeling Framework

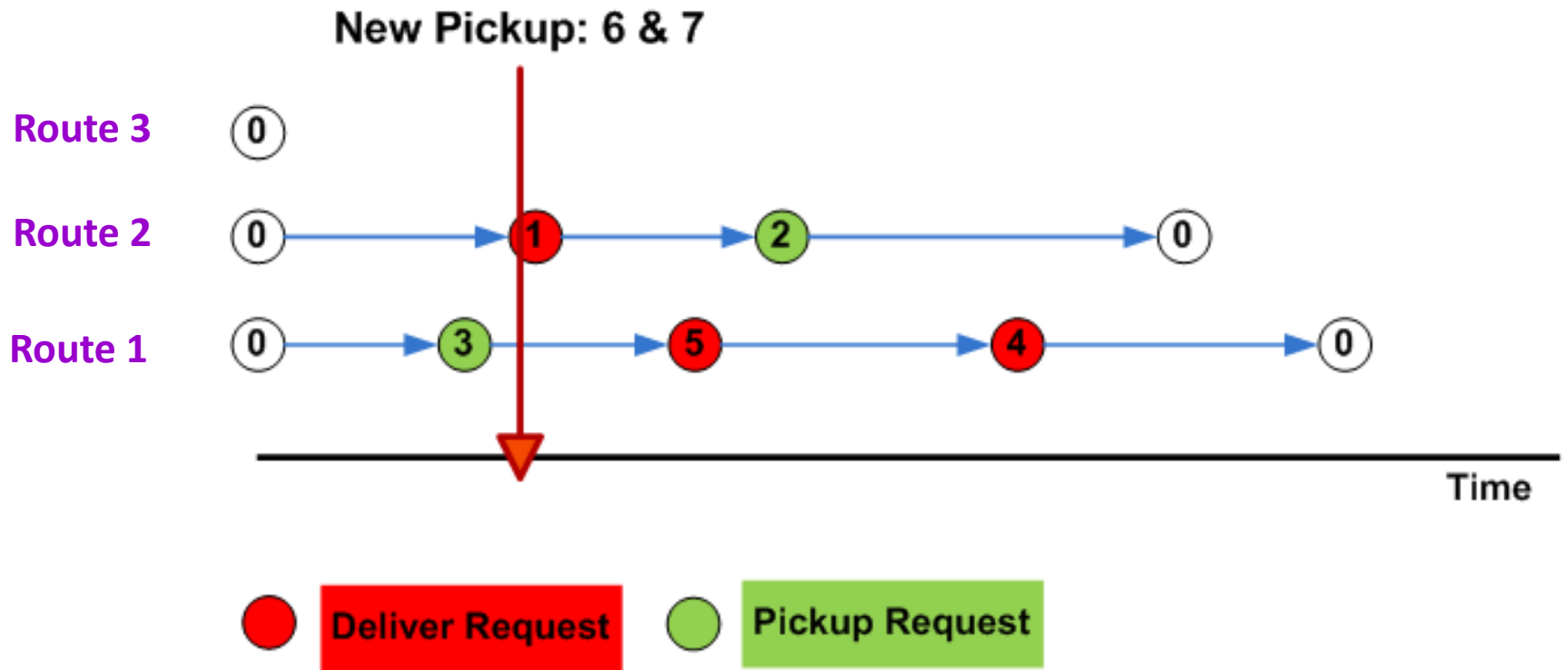


# DTA Model & Simulator

- Emulates the actual **traffic flow propagation and provides predicted traffic conditions**.
- Models various **traffic events**, e.g. accidents, lane closures, etc.
- Loads, simulates and tracks individual **vehicle tour** on a realistic representation of road network to **assist evaluating** the routing designs.

# Online Re-Routing: arrival of new loads

Historical Travel Time  
Data Base



# Online Re-Routing: arrival of new information

Updated Travel Time  
Data Base



Anticipated Traffic Information

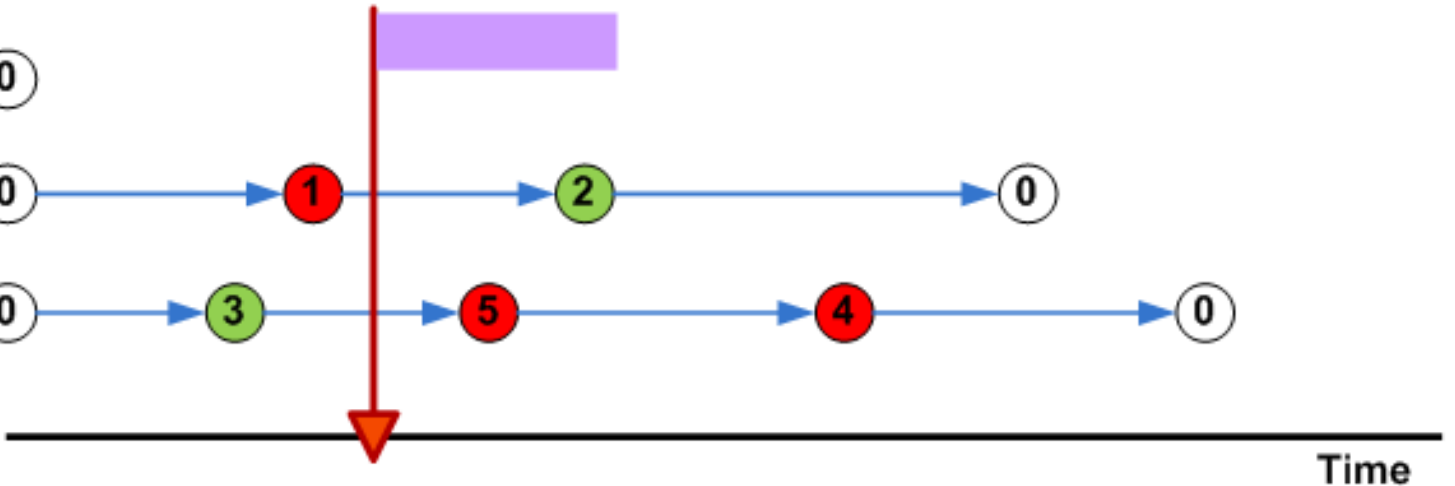
Route 3



Route 2



Route 1



Deliver Request



Pickup Request

# Online Re-Routing: combination of the two

Updated Travel Time  
Data Base



Anticipated Traffic Information  
New Pickup: 6 & 7

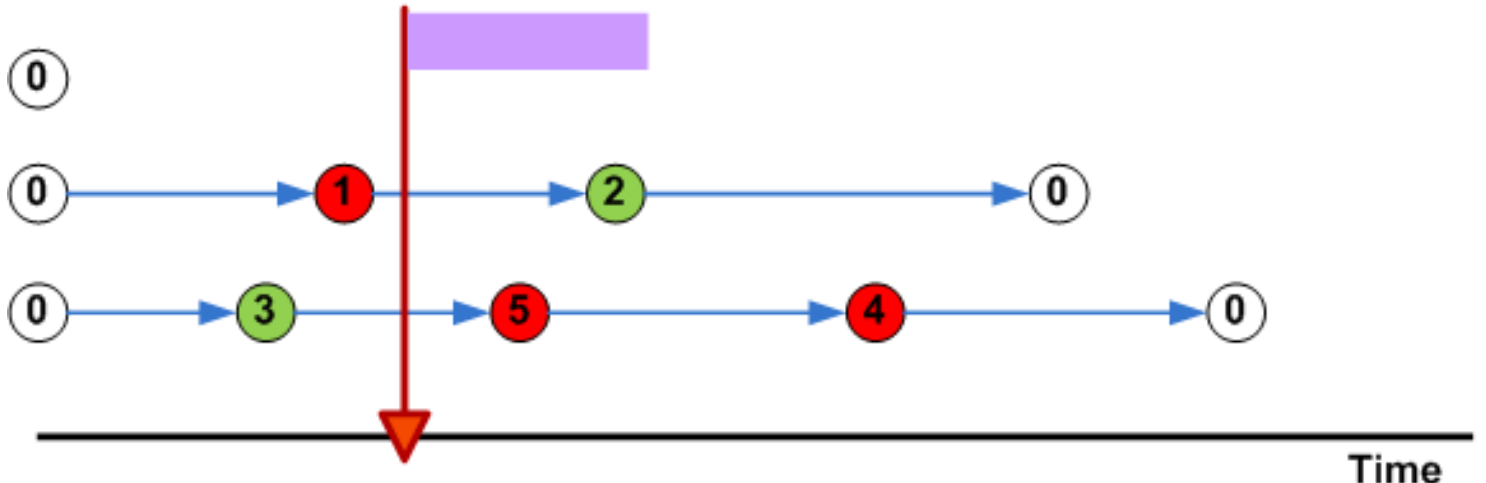
Route 3



Route 2



Route 1



 Deliver Request

 Pickup Request



# Chicago Network and Settings



## Network Size:

- ❑ Nodes: 1,578
- ❑ Links: 4,805
- ❑ TAZs: 218
- ❑ OD: 1.16 million vehicles (6am-8pm)

## General Settings:

- ❑ Operational Hour: 8am – 6pm
- ❑ Customer Base: 500
- ❑ Time Window: 3hrs
- ❑ TD Travel Time Info. : 10min resolution

Instances	# of A Priori Requests	# of Intermediate Requests
100aPriori	500	0
75aPriori	375	125
50aPriori	250	250
25aPriori	125	375

# Results: Normal Day Operations

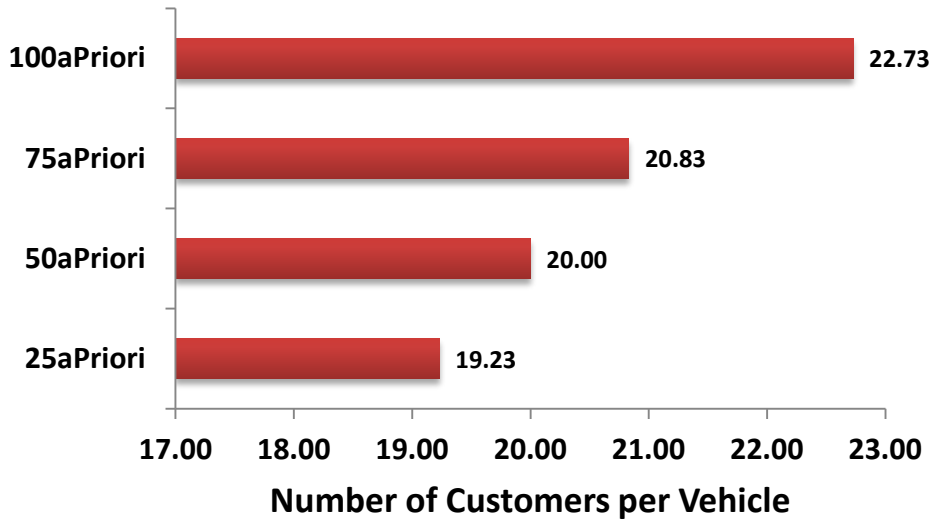
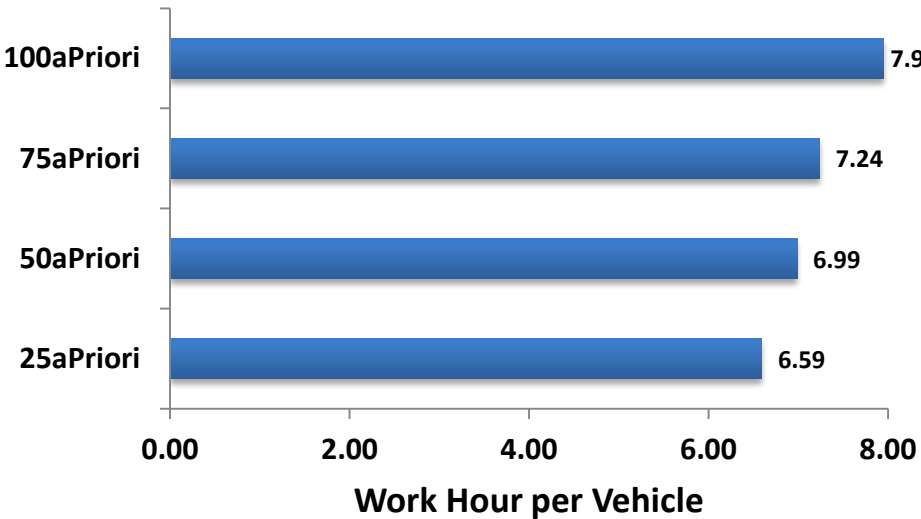
	totDuration <sup>1</sup> (hr)	totTravelTime (hr)	totDistance (mile)	#. Of Veh
100aPriori	174.91	38.13	1468.30	22
75aPriori	171.44	54.08	2188.81	24
50aPriori	174.63	54.83	2167.85	25
25aPriori	173.70	56.87	2150.21	26

<sup>1</sup>: totDuration includes travel time, service time and waiting time for all routes.



# Vehicle Utilization: Normal Day

- Work Hour per Vehicle =  $\text{totDuration}/\text{no. of Vehicle}$
- Number of Customer per Vehicle =  $\text{totCustomer}/\text{no. of Vehicle}$

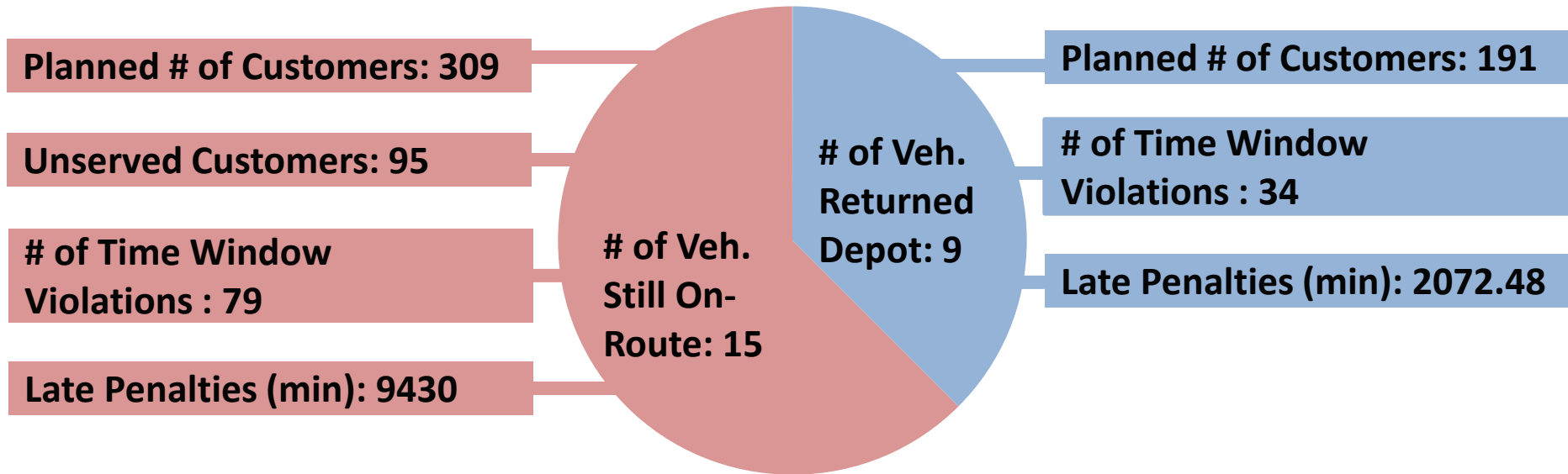


# Evaluation under Snowy Day

- Weather Data: Chicago, Feb. 26<sup>th</sup>, 2013
- Performance Measures from the Simulator:
  - Simulated total travel time;
  - Planned travel time (normal day);
  - Planned number of customers (normal day);
  - Number of unserved customers under snow ;
  - Number of violations of time window;
  - Total late penalty due to time-window violations.



# 75aPriori: Heavy Snow



Planned # of Customers: 309

Unserved Customers: 95

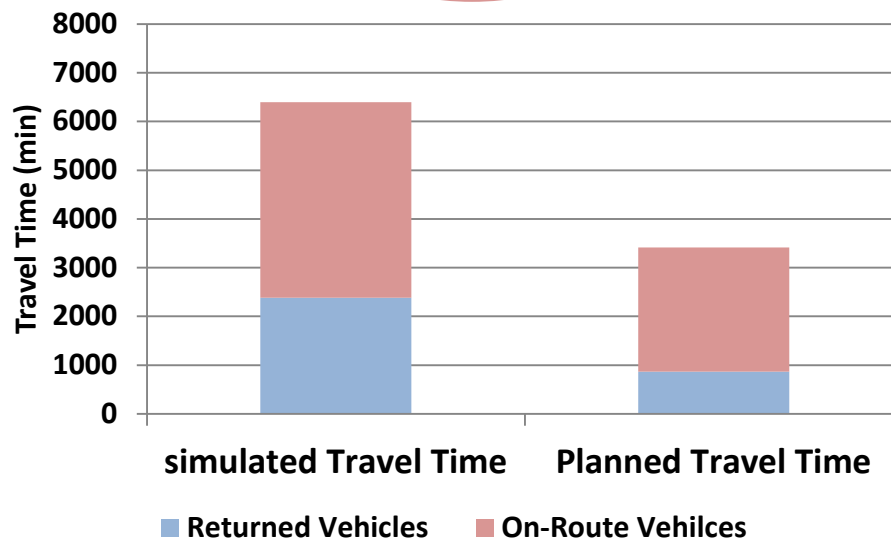
# of Time Window Violations : 79

Late Penalties (min): 9430

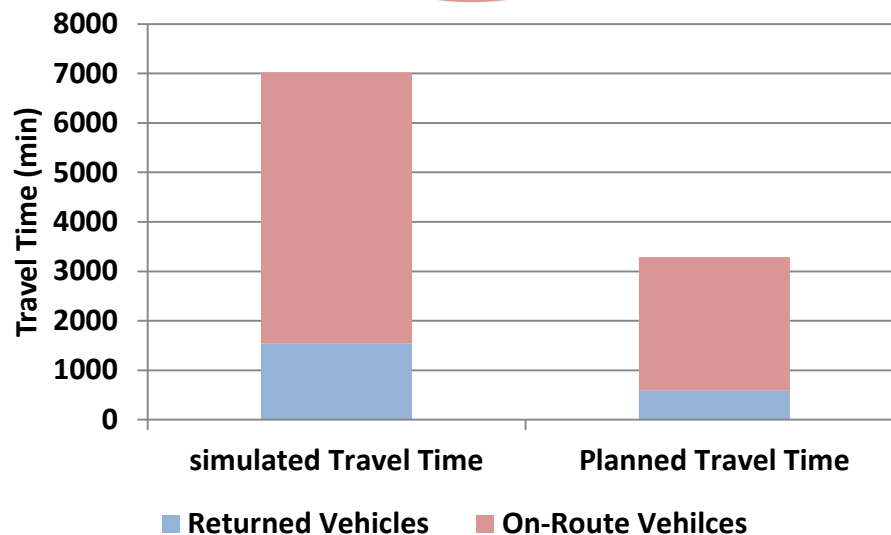
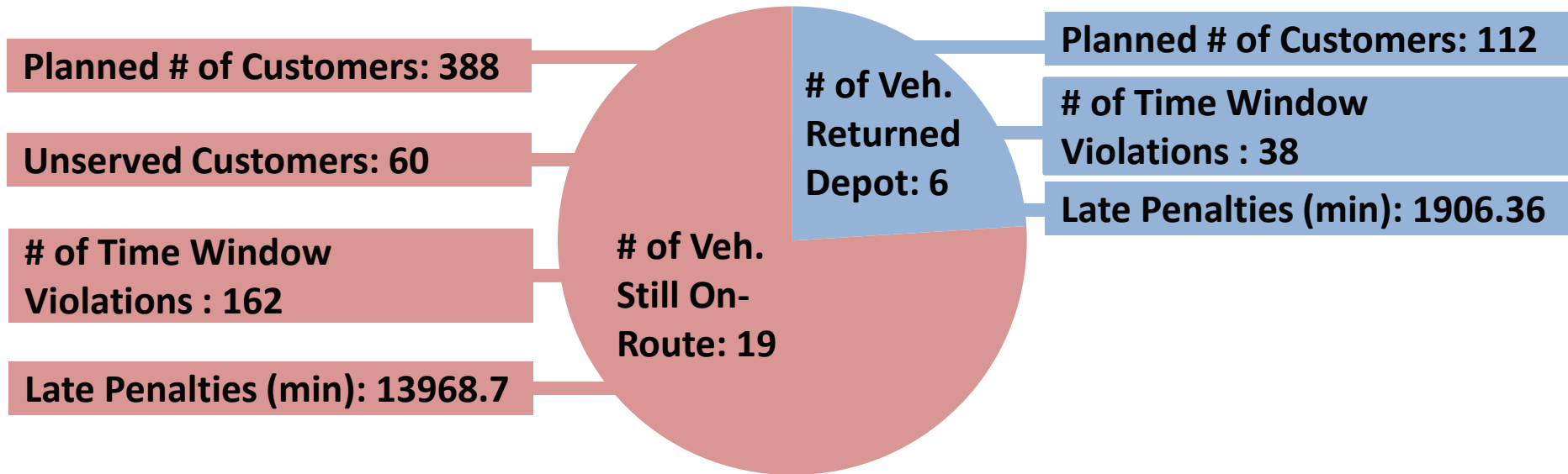
Planned # of Customers: 191

# of Time Window Violations : 34

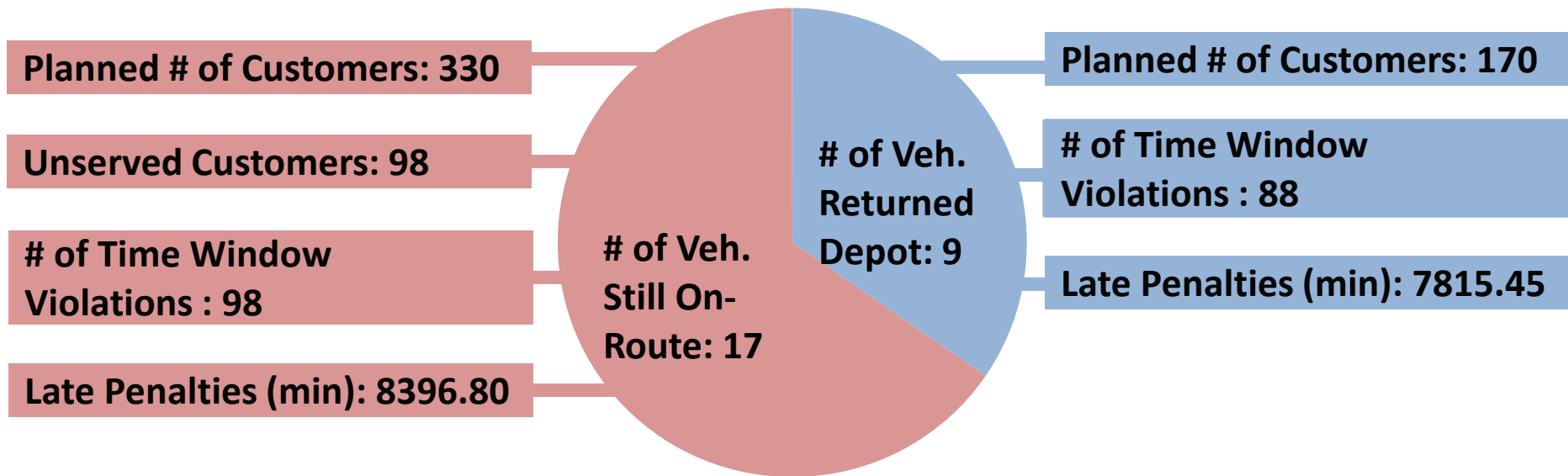
Late Penalties (min): 2072.48



# 50aPriori: Heavy Snow



# 25aPriori: Heavy Snow



Planned # of Customers: 330

Unserved Customers: 98

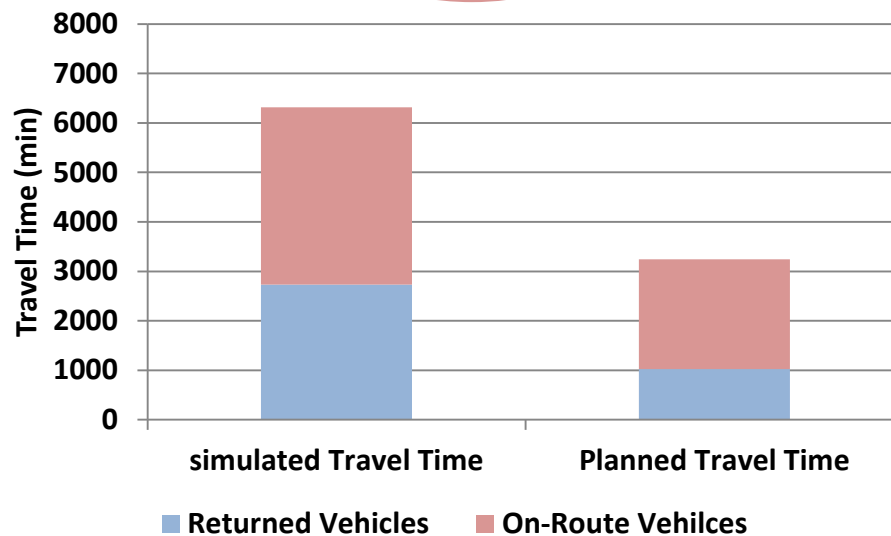
# of Time Window Violations : 98

Late Penalties (min): 8396.80

Planned # of Customers: 170

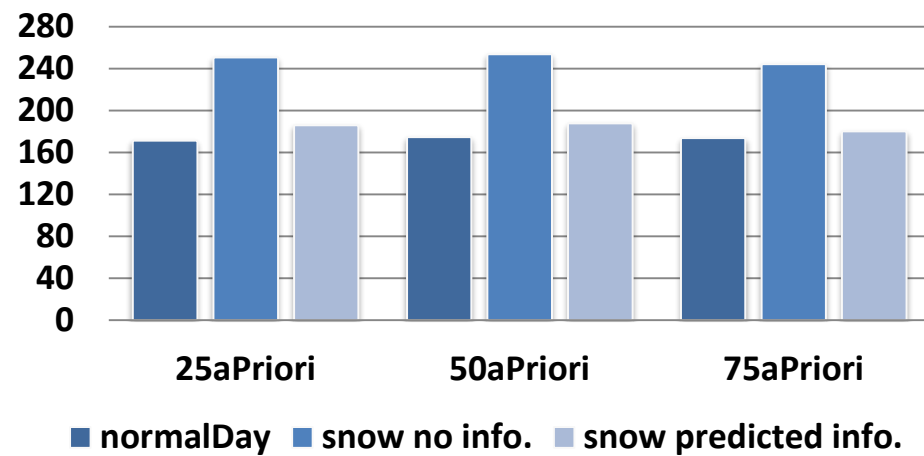
# of Time Window Violations : 88

Late Penalties (min): 7815.45

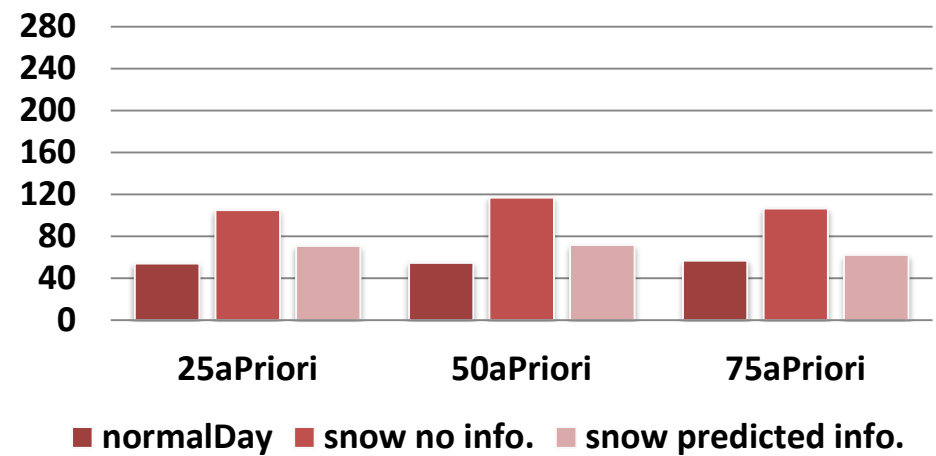


# Solutions with Perfect Predicted Information I

## Total Duration (hour)



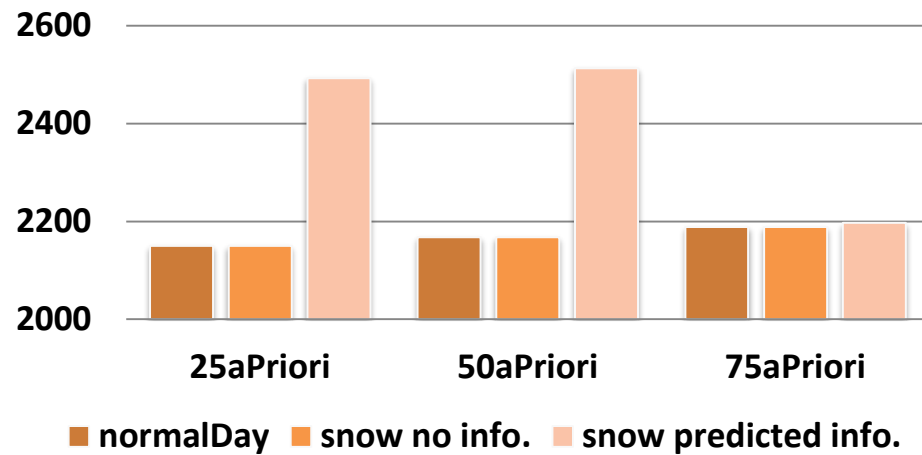
## Total Travel Time (hour)



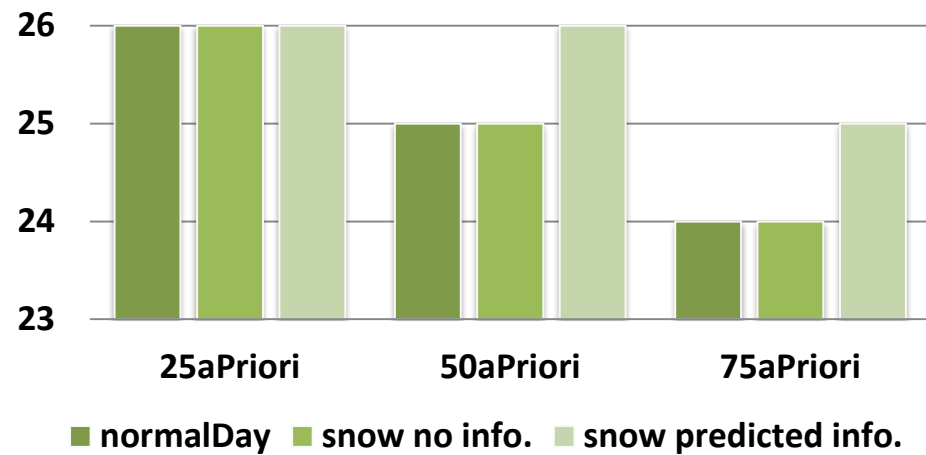


# Solutions with Perfect Predicted Information I

## Total Travel Distance (mile)



## Number of Vehicles



# Potential Benefits

- Improve information utilization.
- Reduce operation cost.
- Increase customer satisfaction.
- Evaluate the efficiency and effectiveness of city logistics services.



# **PART III: CLOSING REMARKS**

# Closing Remarks

- Showcases value of predictive analytics in urban routing for time-sensitive pick-up and delivery
  - Traffic prediction unique feature
  - New effective real-time routing procedures with new demands and information
- Efficiency tool as competitive pressures increase in fight for last mile
- Next:
  - Focus on acceptance/rejection decision; revenue management and pricing
  - Field test with actual data