TMIP
Better Methods. Better Outcomes.

TMIP Webinar Series

Tour-Based & Supply Chain Freight Modeling in Chicago

Date:

January 31, 2013

Speakers:

Kermit Wies (CMAP)
Monique Urban (CS)
Maren Outwater (RSG)

U.S. Department of Transportation
Federal Highway Administration

Disclaimer

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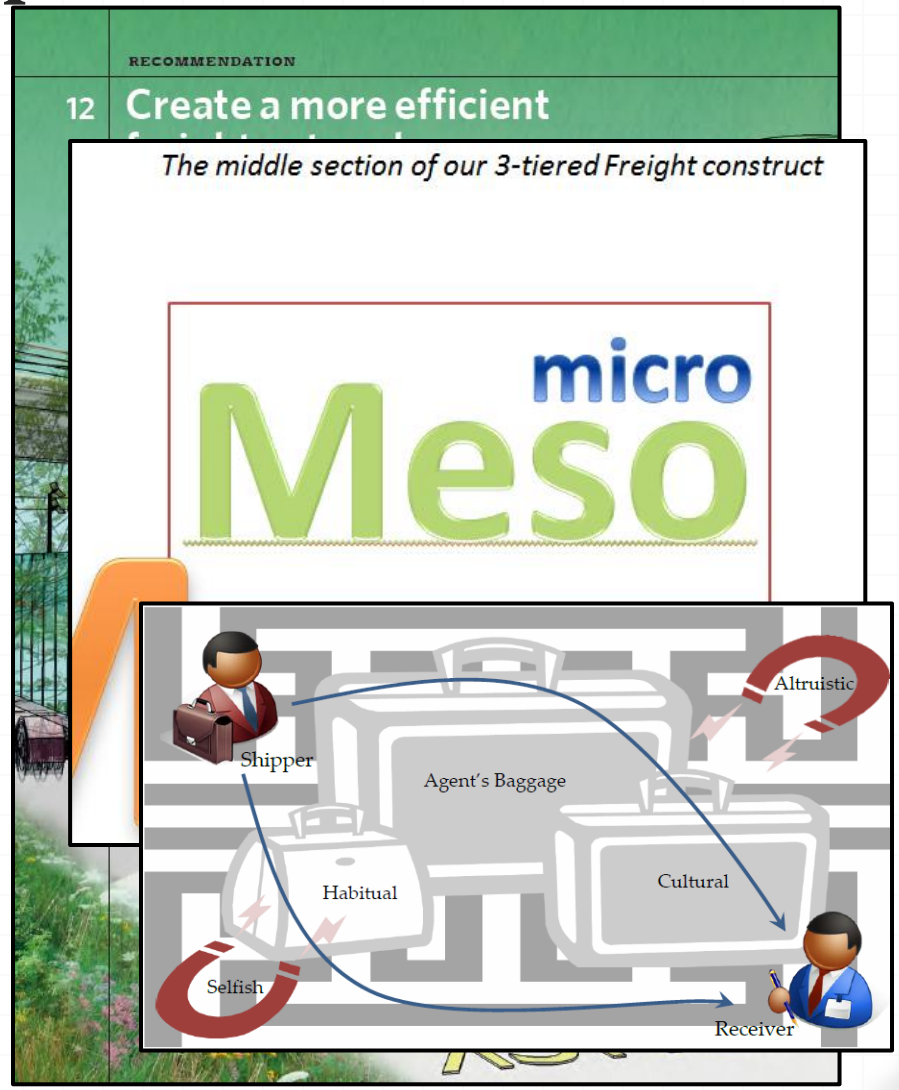
Kermit Wies (CMAP)

Freight Modeling at CMAP

cmap.illinois.gov/catmug

Advanced Freight Model Development

- GO TO 2040 Freight Chapter
  - National policy
  - Economic development
  - Infrastructure
- Three-tiered freight analysis
  - Macro = Economic choice
  - Meso = Supply chain
  - Micro = Network operations
- Implementation strategy
  - Agent-based
  - Microsimulation



Today's topic: Mesoscale model development

- Two rounds of development: CS and RSG
- Data resources (or lack thereof)
- Getting started
- Sensitivity/Scenarios
- Using the application

Two rounds of development: CS and RSG

- **CS**: designed the model and prepared the original code in SAS
- **RSG**: Extended the design and rewrote the code in R

Data Resources

(or lack thereof)

- Basic demonstration uses currently available data:
  - Freight Analysis Framework
  - County Business Patterns
  - Make-Use Tables
  - Regional Model Data
  - National Freight Networks
- Parameter estimation:
  - heuristic
  - empirical

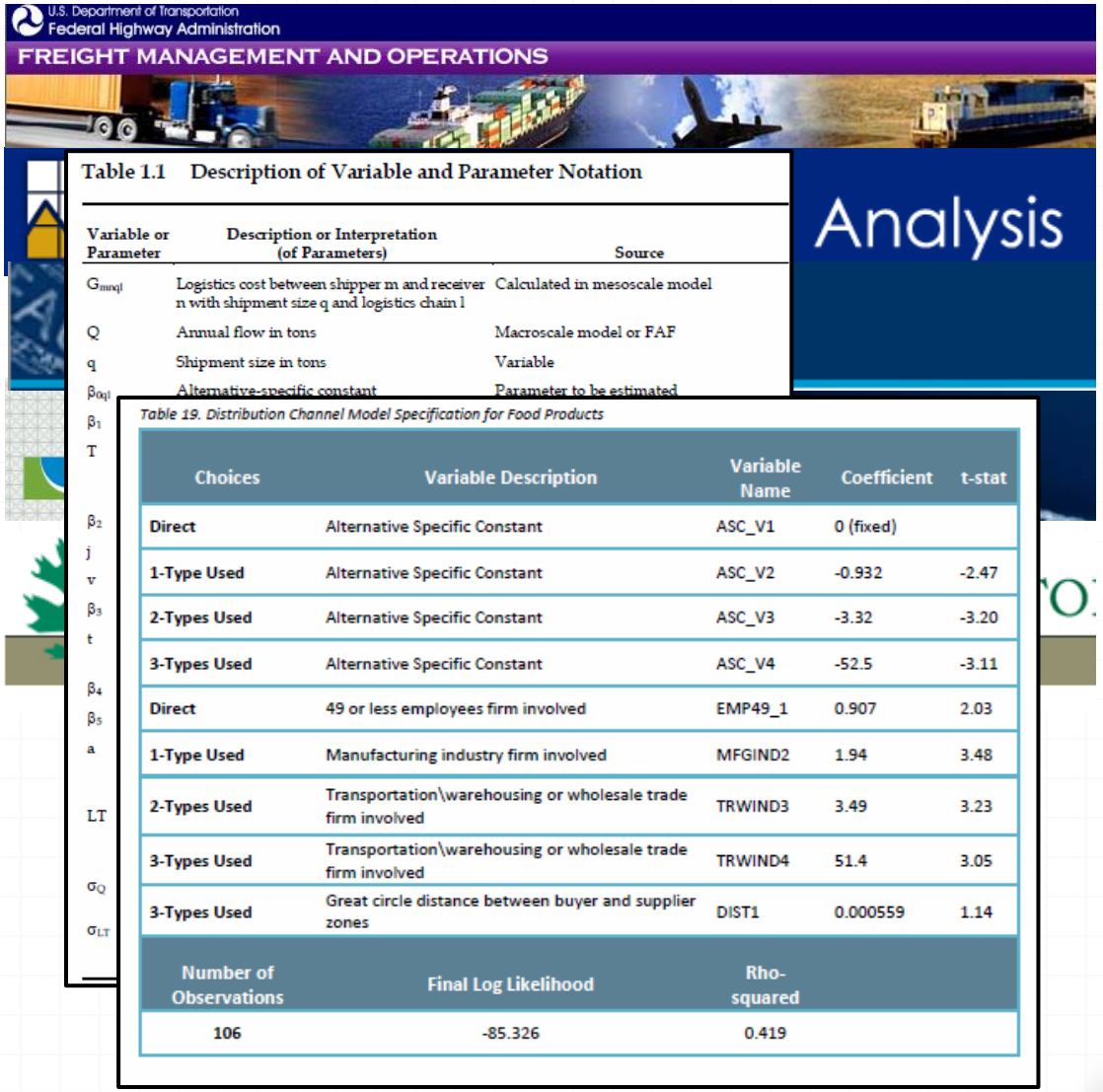


Table 1.1 Description of Variable and Parameter Notation

Variable or Parameter	Description or Interpretation (of Parameters)	Source
G_{mnql}	Logistics cost between shipper m and receiver n with shipment size q and logistics chain l	Calculated in mesoscale model
Q	Annual flow in tons	Macroscale model or FAF
q	Shipment size in tons	Variable
β_{0ql}	Alternative-specific constant	Parameter to be estimated
β_1		
T		
β_2		
j		
v		
β_3		
t		
β_4		
β_5		
a		
LT		
σ_Q		
σ_{LT}		

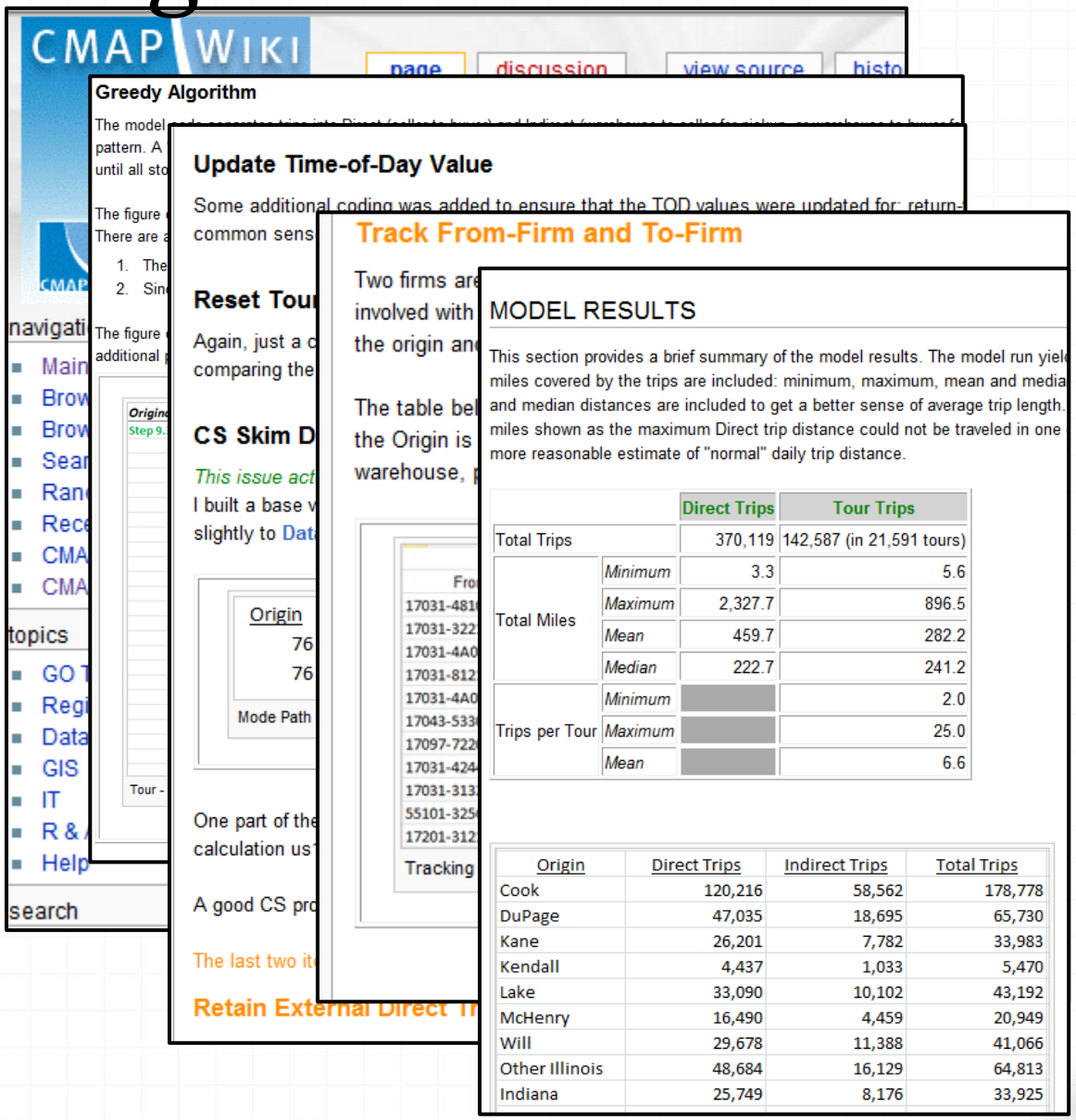
Table 19. Distribution Channel Model Specification for Food Products

Choices	Variable Description	Variable Name	Coefficient	t-stat
Direct	Alternative Specific Constant	ASC_V1	0 (fixed)	
1-Type Used	Alternative Specific Constant	ASC_V2	-0.932	-2.47
2-Types Used	Alternative Specific Constant	ASC_V3	-3.32	-3.20
3-Types Used	Alternative Specific Constant	ASC_V4	-52.5	-3.11
Direct	49 or less employees firm involved	EMP49_1	0.907	2.03
1-Type Used	Manufacturing industry firm involved	MFGIND2	1.94	3.48
2-Types Used	Transportation\warehousing or wholesale trade firm involved	TRWIND3	3.49	3.23
3-Types Used	Transportation\warehousing or wholesale trade firm involved	TRWIND4	51.4	3.05
3-Types Used	Great circle distance between buyer and supplier zones	DIST1	0.000559	1.14

Number of Observations	Final Log Likelihood	Rho-squared
106	-85.326	0.419

Getting Started

- Learn R
- Understand logic
- Scrutinize data
- Understand output



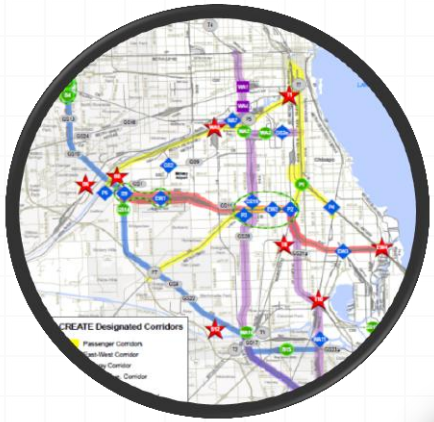
		Direct Trips	Tour Trips
Total Trips		370,119	142,587 (in 21,591 tours)
Total Miles	*Minimum*	3.3	5.6
	Maximum	2,327.7	896.5
	Mean	459.7	282.2
	Median	222.7	241.2
Trips per Tour	*Minimum*		2.0
	Maximum		25.0
	Mean		6.6

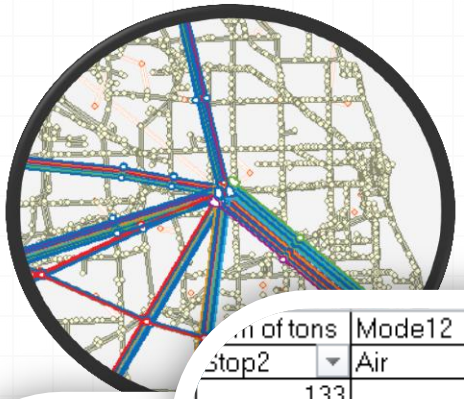
Origin	Direct Trips	Indirect Trips	Total Trips
Cook	120,216	58,562	178,778
DuPage	47,035	18,695	65,730
Kane	26,201	7,782	33,983
Kendall	4,437	1,033	5,470
Lake	33,090	10,102	43,192
McHenry	16,490	4,459	20,949
Will	29,678	11,388	41,066
Other Illinois	48,684	16,129	64,813
Indiana	25,749	8,176	33,925

Sensitivity/Scenarios

- Reduce Rail Delays
- Add Rail Capacity

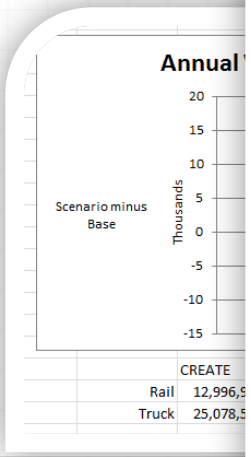
Scenario: Reduce Rail Delays

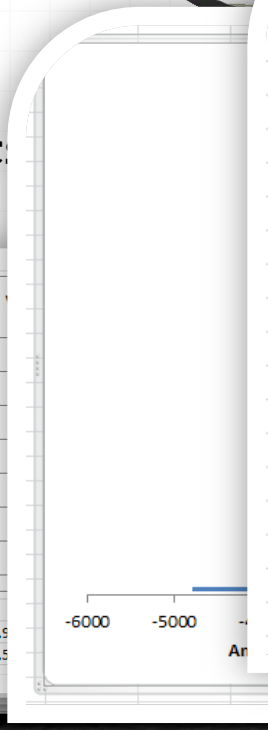




How? • Cut logistic

And So?





...n of tons	Mode12					
Stop2	Air	Carload	FTL	IMX	LTL	Water
133			573,751		313,068	
134			190,026		403,251	
135			538,124		646,568	
136			583,473		889,647	
137			1,310,221		1,440,695	
138			1,105,178		1,073,521	
139			1,046,149		1,065,541	
141	534				11,216	
142	414				4,228	
143	101				413	
144	102				1,175	
145			9,054,154			12,1
146			4,386,813			11,9
147		12,363,735	6,769,180	316,258	352,691	
148		13,690,575	3,986,273	436,852	765,753	
149		21,122,258	17,098,886	215,199	403,706	
150		148,914,677	132,423,650	13,529,372	12,716,689	
(blank)						
Grand Total	1,152	196,091,245	179,065,879	14,497,680	20,088,162	24,0

Scenario: Add Rail Capacity

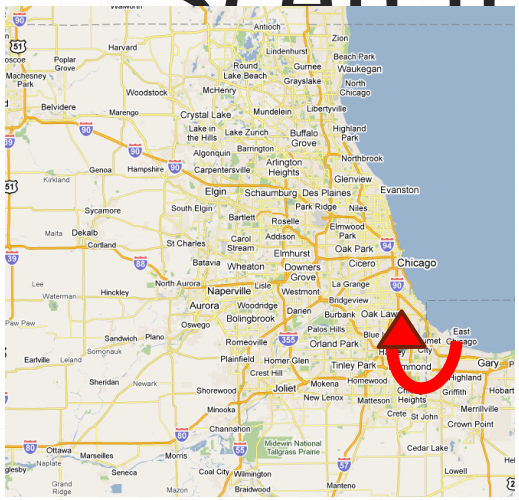
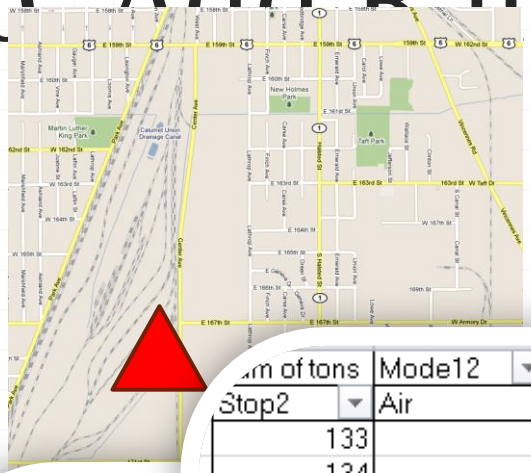


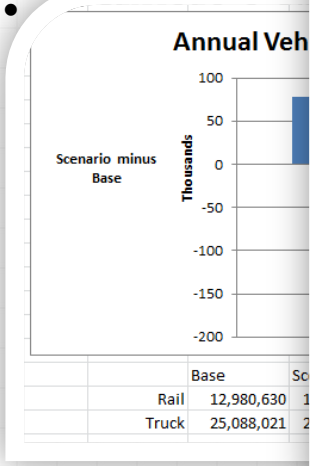
Figure 1: Regional map



How?

- Add a rail lo
- Add a truck
-

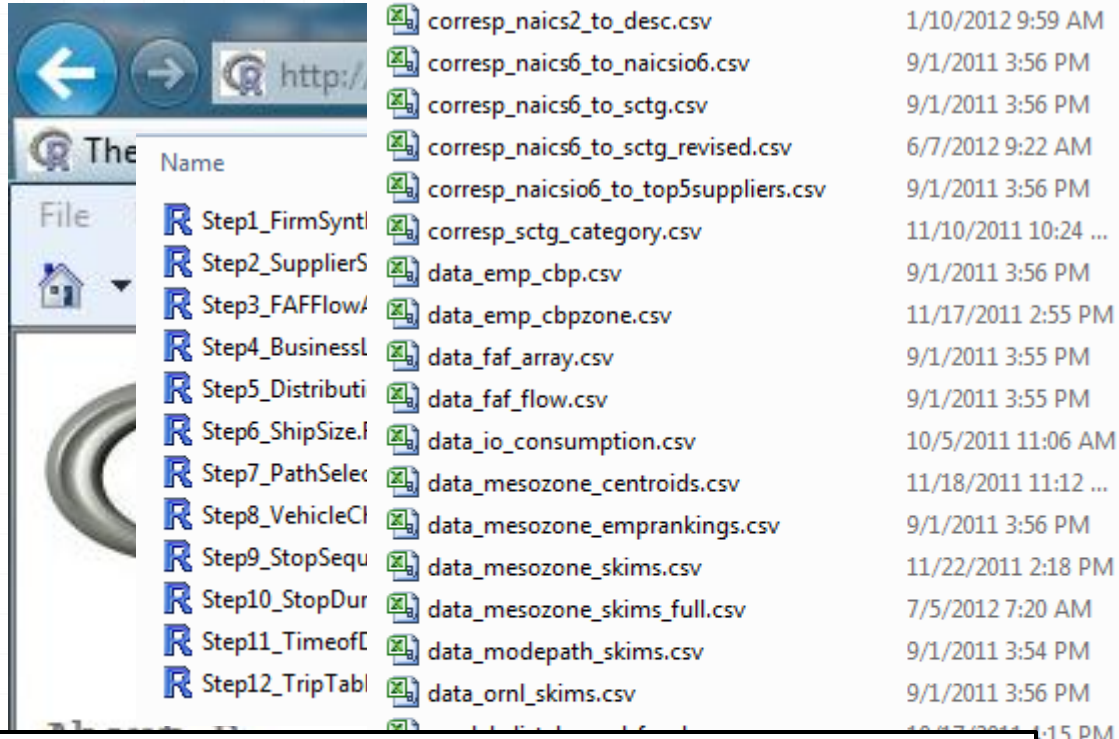
And So?



m of tons	Mode12				
Stop2	Air	Carload	FTL	IMX	LTL
133			566,665		304,050
134			180,535		389,185
135			528,652		625,256
136			584,484		892,127
137			1,315,699		1,444,359
138			1,107,372		1,076,237
139			1,047,080		1,064,813
141	534				11,216
142	414				4,228
143	101				413
144	102				1,175
145			8,748,564		
146			4,635,327		
147		5,925,400	3,497,289	132,879	149,794
148		27,290,572	18,796,401	2,066,439	2,064,962
149		21,491,286	15,399,415	305,805	678,294
150		140,148,655	121,007,962	12,008,208	11,305,016
(blank)					
Grand Total	1,152	194,855,914	177,415,445	14,513,331	20,011,125

Using the Application

- Install R
- Inspect Code
- Inspect Inputs
- Let 'er Rip
- Inspect Outputs



- Outputs folder has summary files created by script. Some of the more interesting are:
  - 3_fafflow_valuetonsbyloc.csv – tons & value (all/food/mfg) b/n CMAP-CMAP, CMAP-Ext, Ext-CMAP
  - 5_distchannel_allsctg.csv – shipments by distribution channel type b/n CMAP-CMAP, CMAP-Ext, Ext-CMAP
  - 6_shipsize_allcommodities.csv – shipment size by dist. Channel
  - 7_modepath_allcommodities – shipments by mode (from/to/within CMAP) [everything still annual values at this point]
  - 8_vehtourpat_allcommodities – **daily** shipments by veh type & direct/tour
  - 9_stopseq_numstopspertour.csv – freq. dist of stops per tour
  - 9_stopseq_tourcatbyshipsize.csv – shipments by tour category & shipment size
  - 10_stopdur_durationbytourtype.csv – shipments by stop duration & tour type
  - 11_tod_todbytourtype.csv – shipments by TOD & tour type

Monique Urban (CS)

Freight Modeling at CMAP

Overview

- Objective of Study
- Evolution of Freight Modeling
- Modeling Steps
- Results

Objective
An Innovative New Freight Model

- **Regional freight questions (examples)**
  - **How do fuel prices impact mode share?**
  - **Would a new airport relieve congestion at existing airports?**
  - **Would a new intermodal terminal reduce truck drayage?**
  - **How many trucks would use new truck-only lanes?**

The Evolution of Freight Models

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The CMAP Approach to Advanced Freight Modeling

Macroscale Model

- Position of the Chicago region in local, national, and global trading arenas

Mesoscale Model

- Goods movement to/from individual businesses in the Chicago region

Microscale Model

- Microsimulation of goods movements

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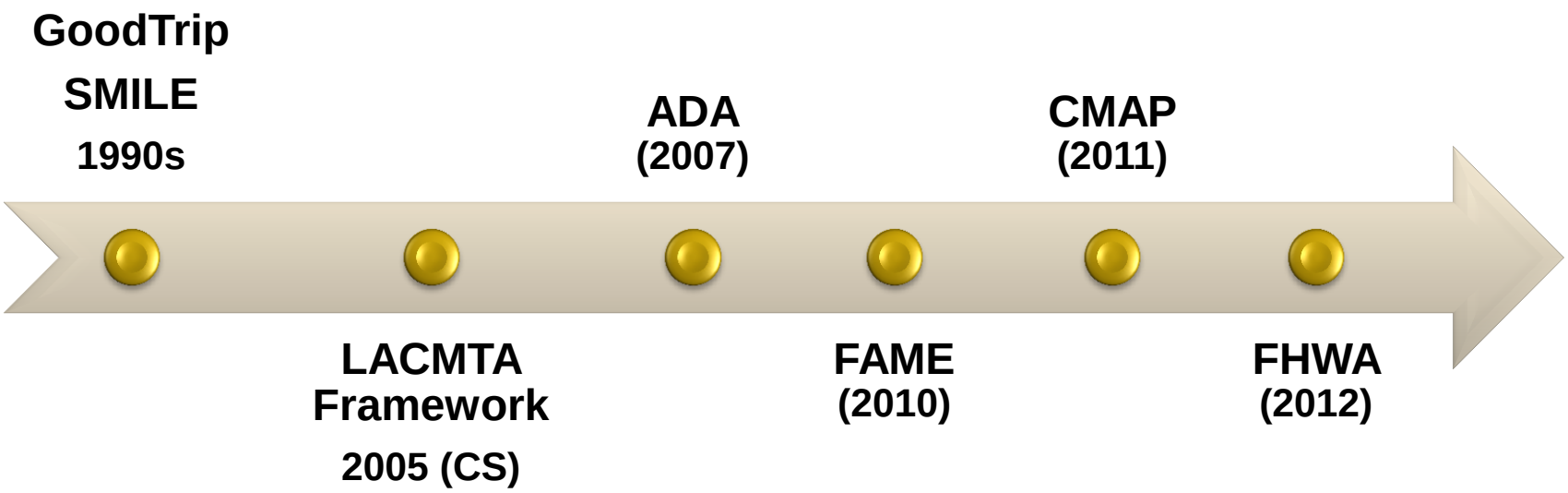
Recent Developments in Advanced Freight Modeling



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CMAP's Innovative Approach to Freight Forecasting

Agent-Based

Driven by Business Economics

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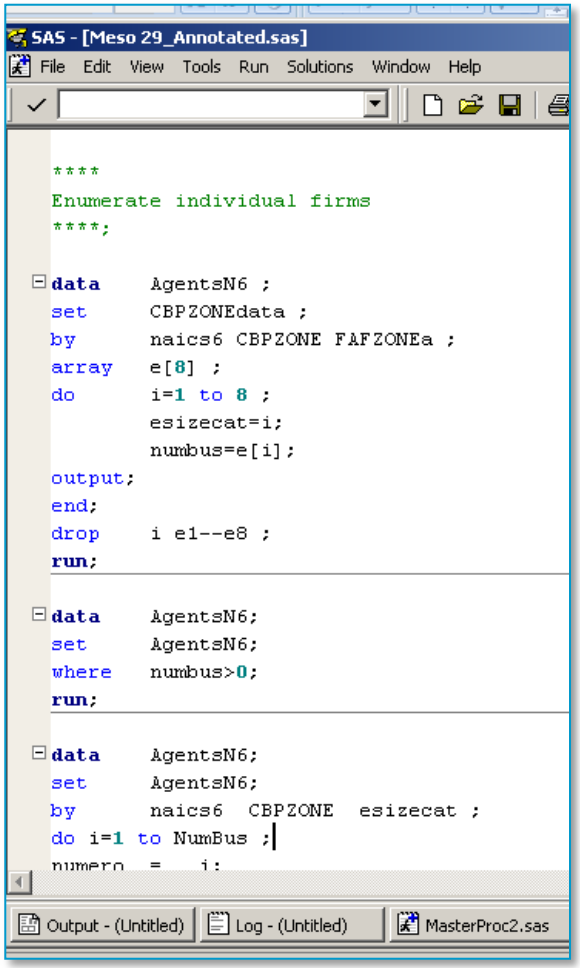
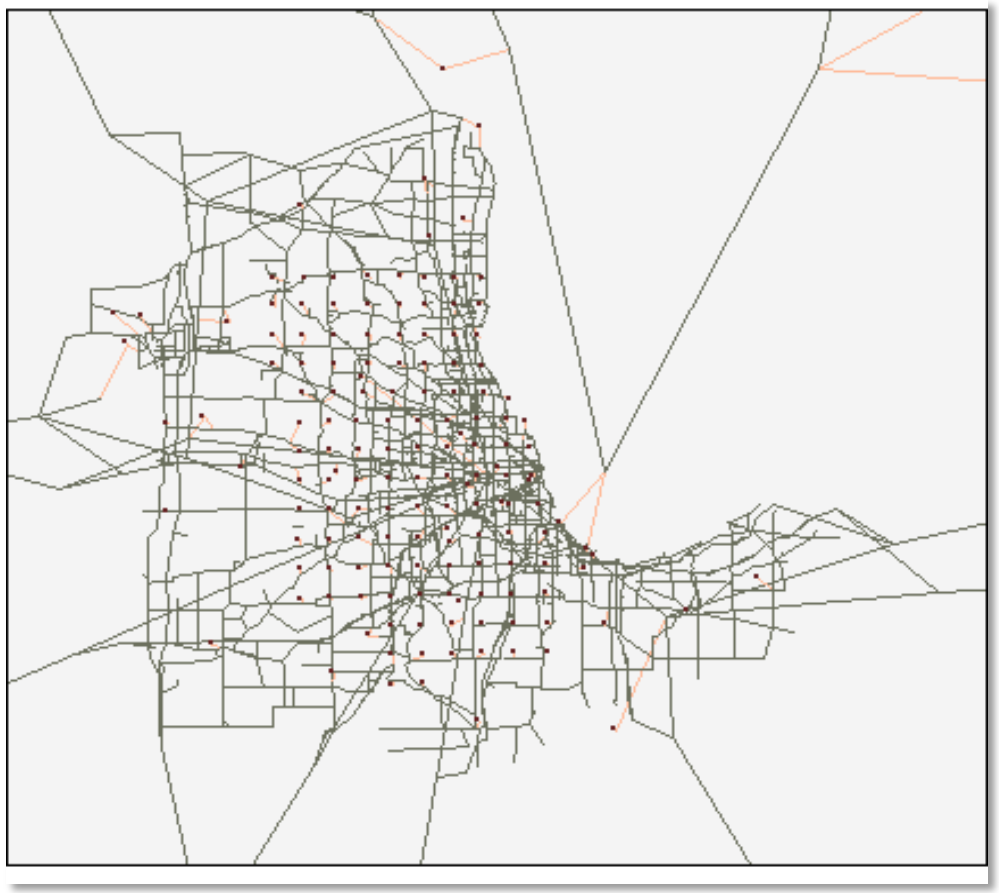
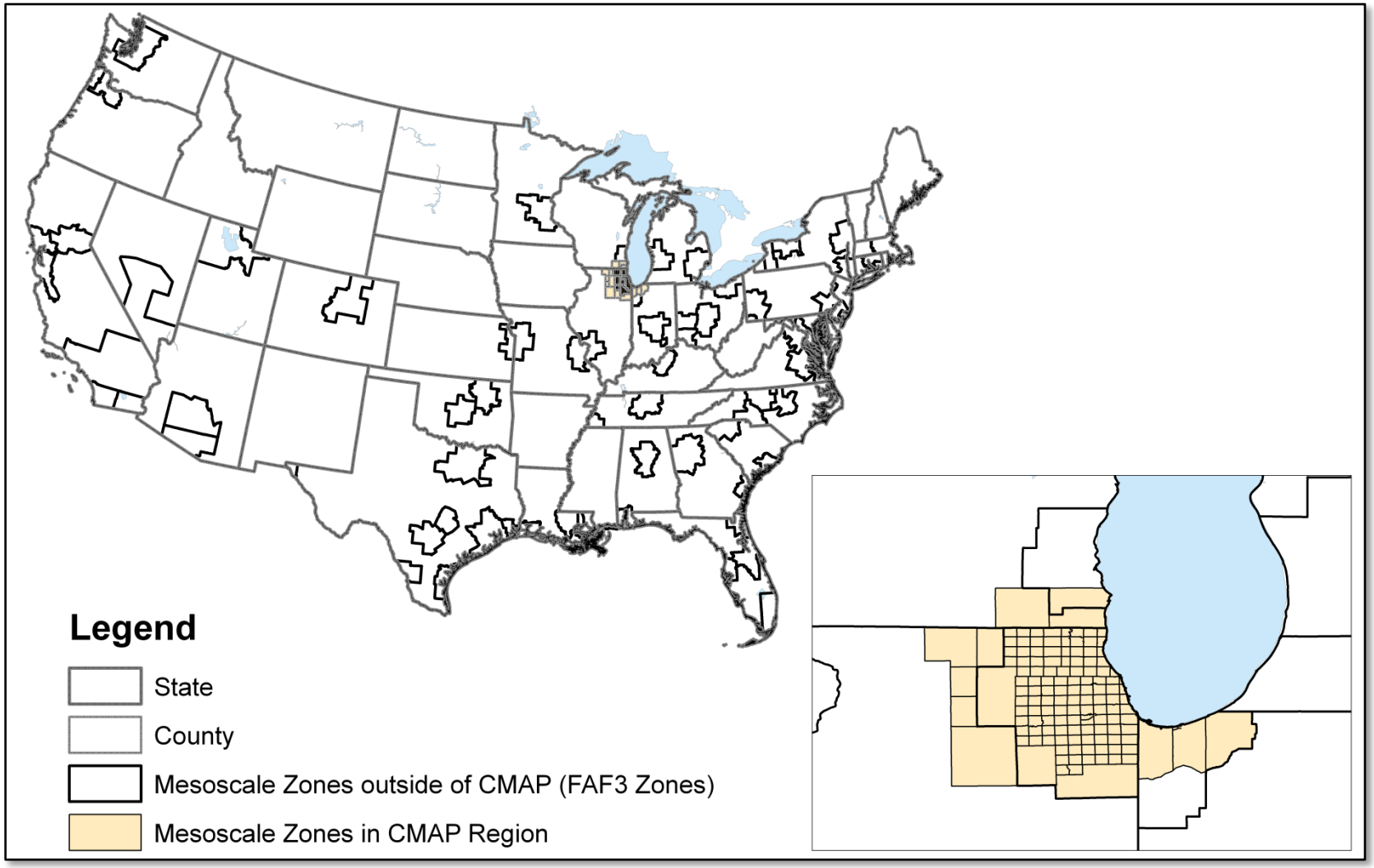
Project Specifications
Fully Functioning Software





Source: CMAP Mesoscale Model (2011)
-CMAP model network
-Oak Ridge National Laboratories
-Army Corps of Engineers
-Cambridge Systematics

Project Specifications (continued)
Meaningful for Analysis of Chicago Region



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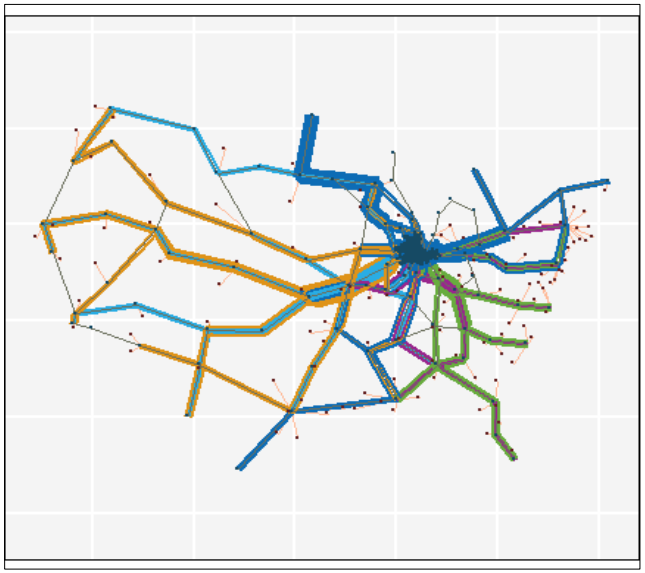
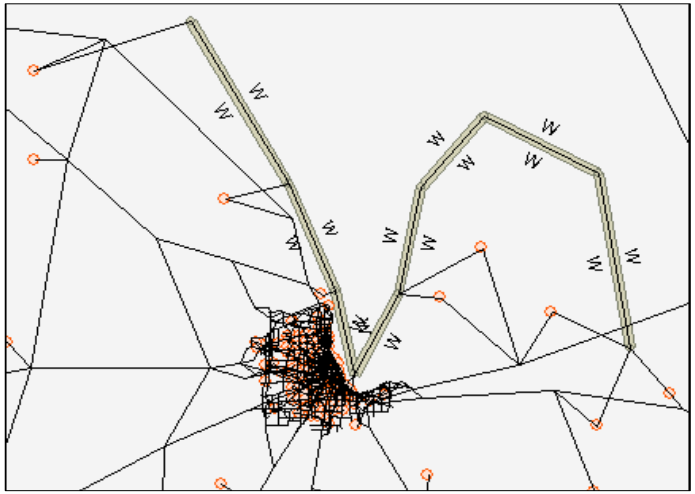
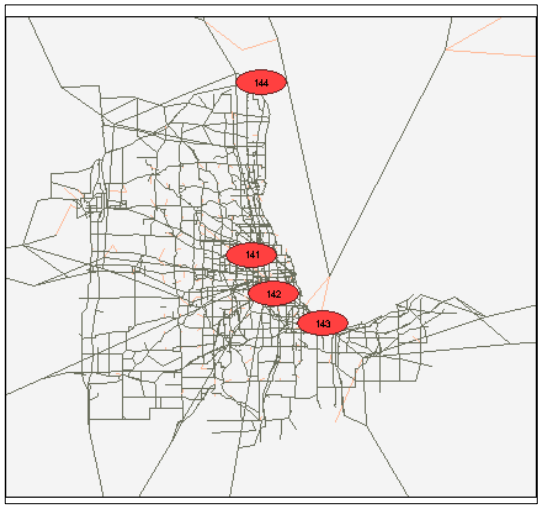
Multimodal Network Development



Rail – National, Regional



Water – Regional (Great Lakes)



Airports

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Project Specifications (continued)
Evaluate Transportation Decisions (1)

Rail
Carload, Intermodal (IMX)

Water

Rail-Truck Intermodal

Air

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Project Specifications (continued)
Evaluate Transportation Decisions (2)

Truck with Container

Truck
FTL: Full Truckload
LTL: Less-than-Truckload

Logistics Handling →
Transloading, Distribution

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Mesoscale Model Overview

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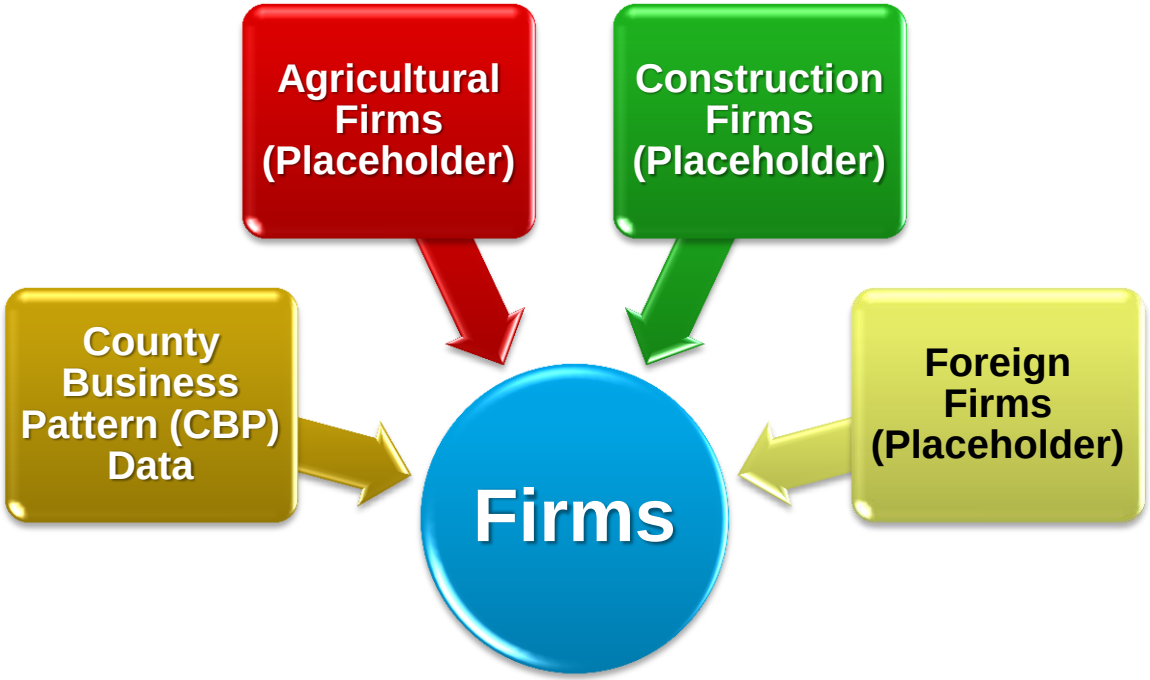
“Step 0”: Prepare Macroscale Flow Data

- **Placeholder dataset: FHWA Freight Analysis Framework 3 (FAF3) commodity flows**
- **Origins, destinations of commodity shipments**
- **Sample firms:**
  - **Manufacturing, mining, wholesale sectors**
  - **Select retail and service establishments**

→ Supplier (shipper), buyer (receiver), and wholesale (shipper and receiver) firms

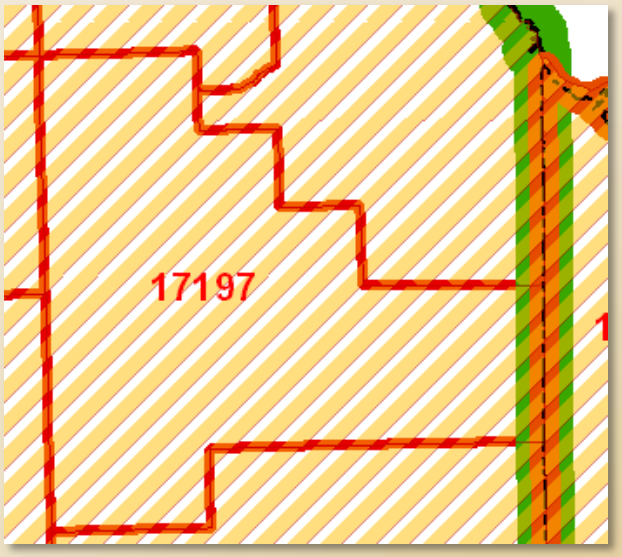
Generate Individual Firms



* Characterize firms – Buyer? Supplier? Both?
* Identify top commodities traded
* Wholesale firms – simulate type of goods traded

Firm Location Model

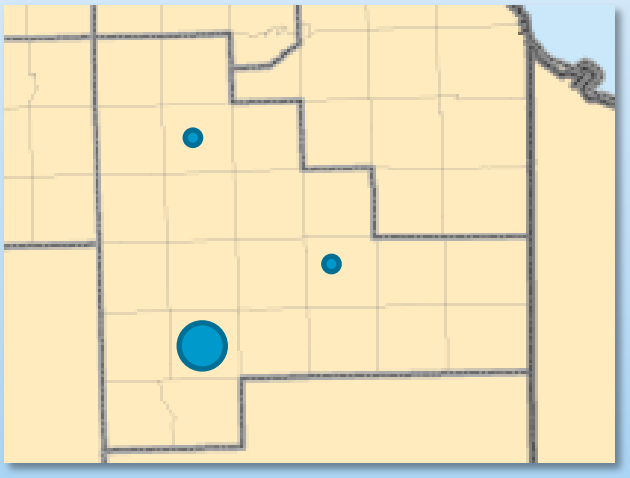
CBP Data at County Level



- 2 firms with 1-10 employees
- 1 firm with 100-250 employees

CMAP Land Use Data

Simulate Mesozone Location



1. Firm #1 in Mesozone 23
2. Firm #2 in Mesozone 57
3. Firm #3 in Mesozone 59

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Supplier Selection

- Identify *potential* trading partners (FAME)
  - » Utilizes information from Input-Output Make and Use Table (Bureau of Economic Analysis)
  - » Candidate partners must be part of Macroscale commodity flow table
- Supply chain formation
  - » Each buyer selects a supplier
  - » Model with asserted parameters (based on FAME formulation)

Consumer Business Size (Number of Employees)	Coefficient							
	Producer Business Size (Number of Employees)			Great Circle Distance Between Consumer and Producer (Miles)				
	1 to 99	100 to 499	500+	Over 1,509	596 to 1,509	150 to 595	1 to 149	0 (Intracounty)
1 to 99	0.2	0.2	0.4	-0.4	-0.3	-0.2	0	0.1
100 to 499	0.2	0.6	0.6	-0.2	-0.1	-0.05	0	0.1
500+	0.4	0.6	0.6	-0.1	-0.05	0	0	0.1

Flow Apportionment

- Input – aggregate commodity flows
- Disaggregate flows among supplier-buyer pairs
  - » Based on buyer firm size (number of employees)
  - » Tons of goods consumed per buyer employee
    - – By industry
    - – Derived from Make-Use table

→ Output – annual tons traded between supplier and buyer

Path Selection

- **Inputs**
  - » **Path information from model network**
  - » **Annual transport and logistics cost formulation**
    - – **Ben-Akiva and de Jong (ADA)**
    - – **Cost by mode**
    - – **Travel time and reliability needs**
    - – **Loss and damage**
    - – **Vary by shipment frequency, commodity type**
- **Each supply chain selects a transport and logistics path**

Prepare for Assignment

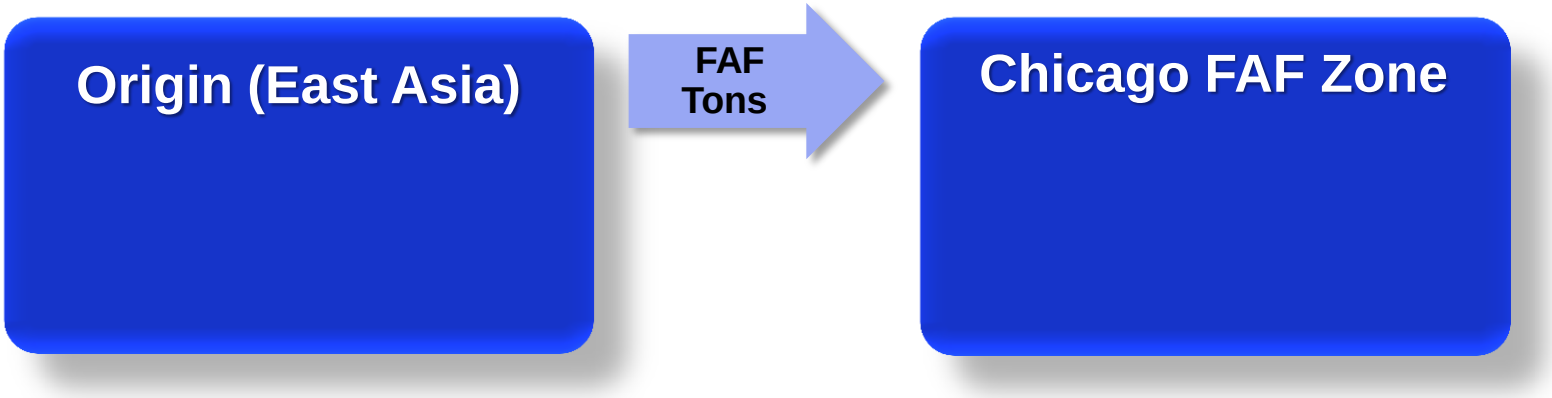
- **Key output – freight vehicle trip table by:**
  - **Commodity**
  - **Shipment size**
  - **Shipment frequency**
  - **Mode (truck, rail, air, water) and submode (TL, container, etc.)**
  - **Origin TAZ, destination TAZ, and intermediate logistics stop nodes**

SUPPLY CHAIN EXAMPLE

Supply Chain Example

Consumer Goods from Overseas Manufacturer to Retailers

Input Flows from Macroscale Model



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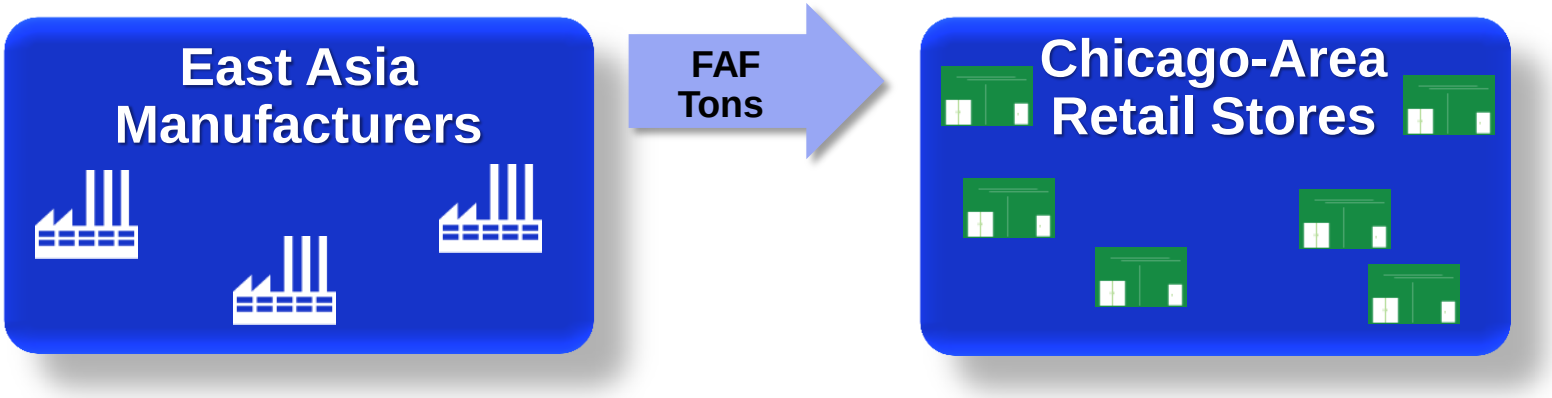
Supply Chain Example

Consumer Goods from Overseas Manufacturer to Retailers

Generate Firms



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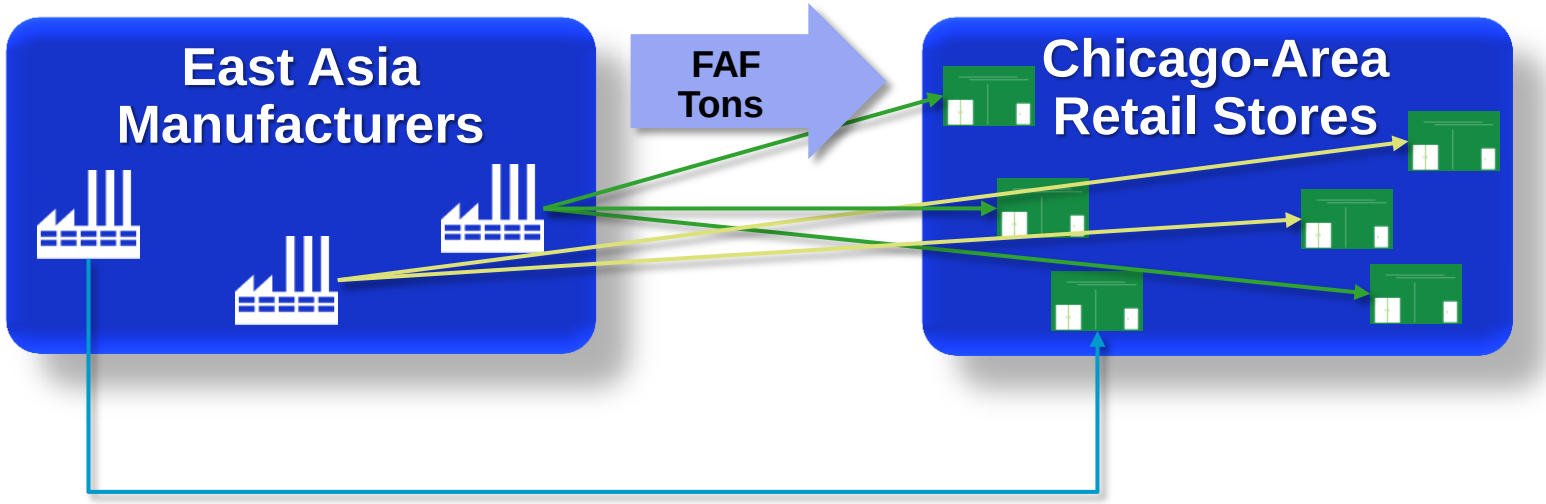
Supply Chain Example

Consumer Goods from Overseas Manufacturer to Retailers

Form Supply Chains



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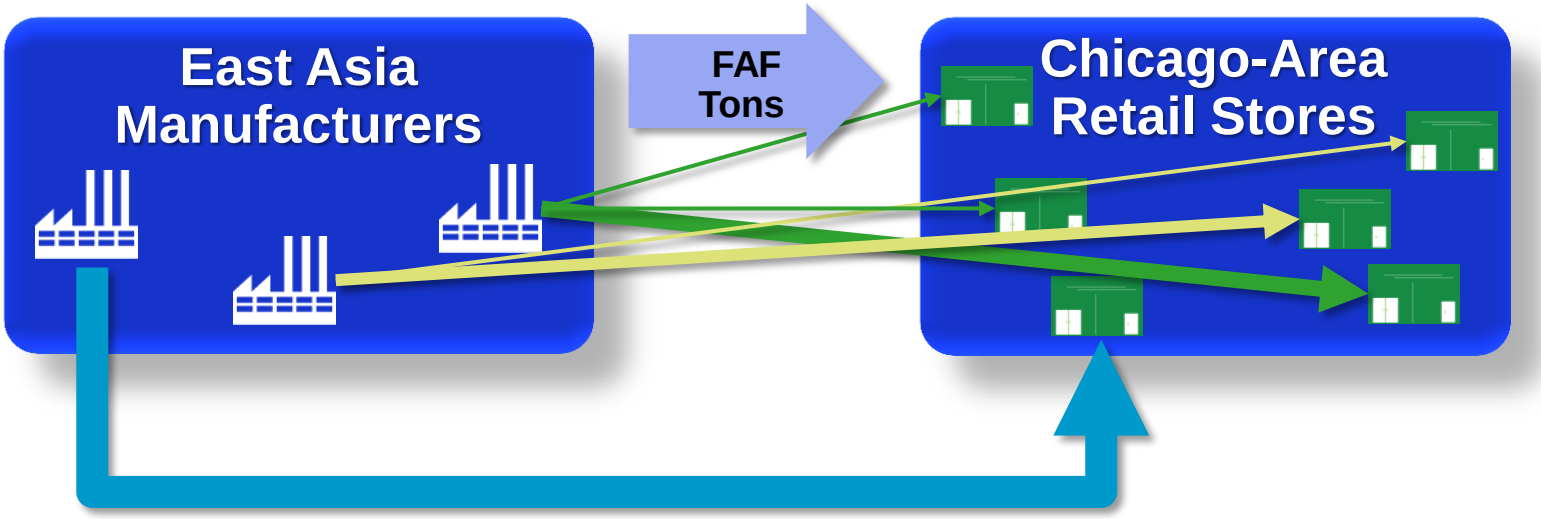
Supply Chain Example

Consumer Goods from Overseas Manufacturer to Retailers

Apportion Flows Among Supply Chains



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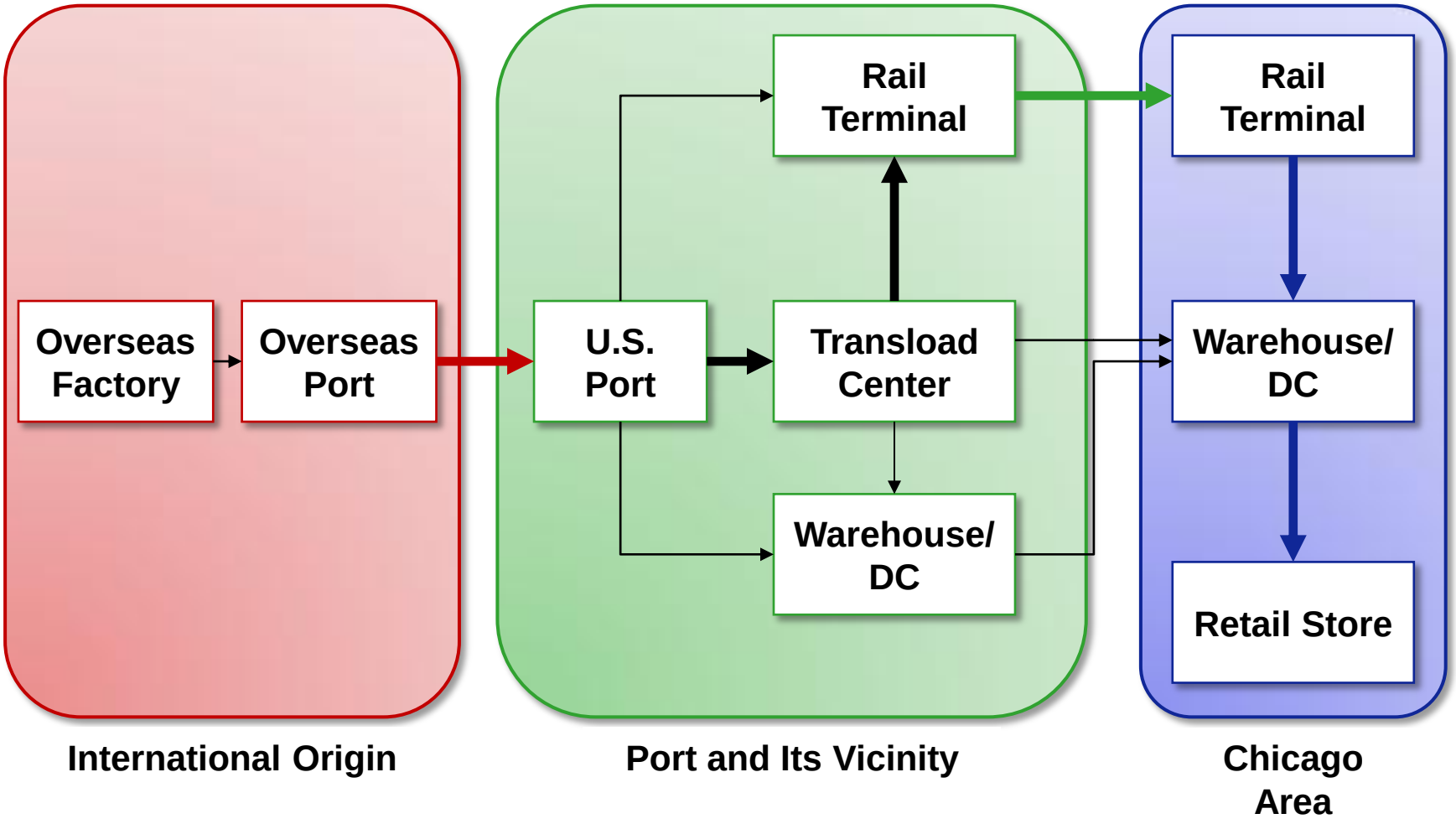
Supply Chain Example
Consumer Goods from Overseas Manufacturer to Retailers

Path Selection Overview

Supply Chain Example

Consumer Goods from Overseas Manufacturer to Retailers



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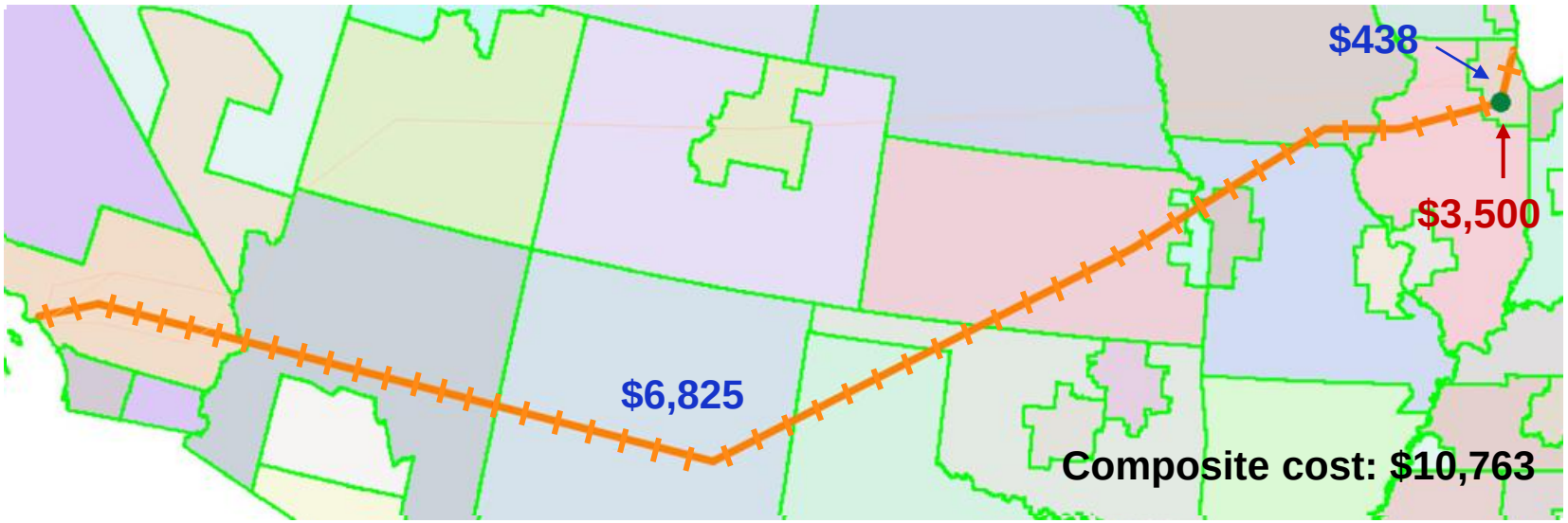
Evaluation of Transport and Logistics Decisions:
Path Enumeration

Example:

Port of Los Angeles to Chicago

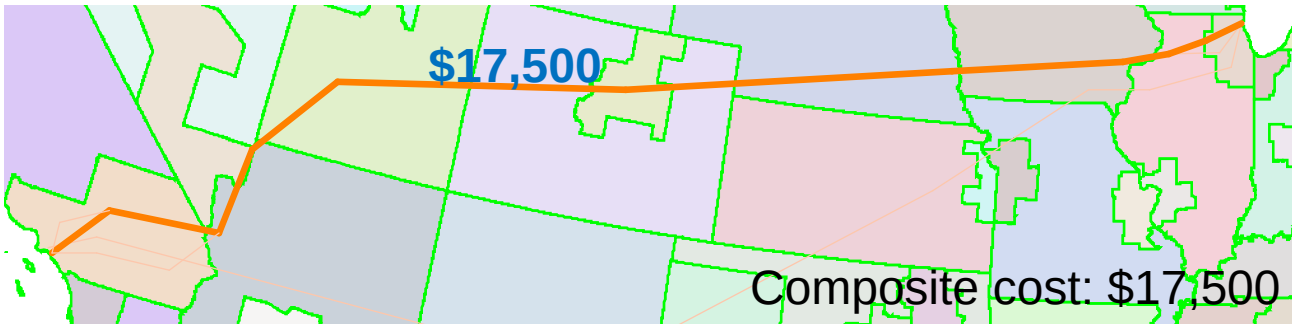
Shipment Size: 140 tons in seven 40’ containers

Option B: Intermodal to Chicago area, then truck

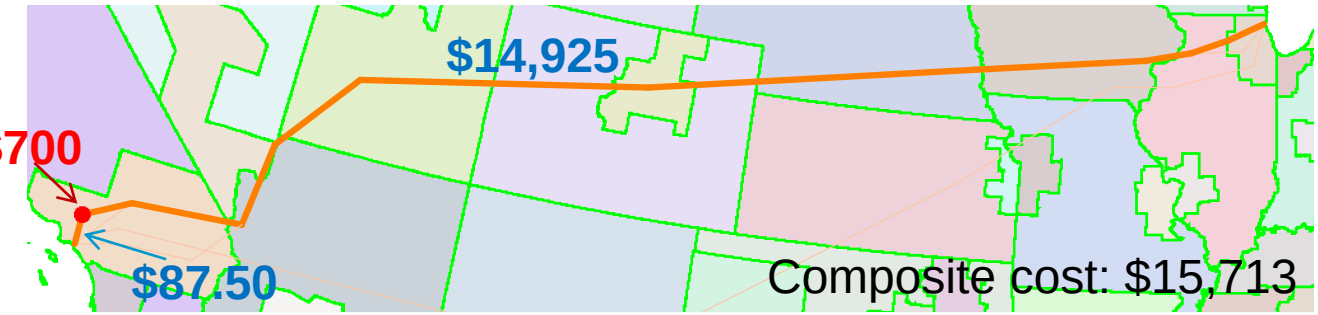


Evaluation of Transport and Logistics Decisions:
Path Selection

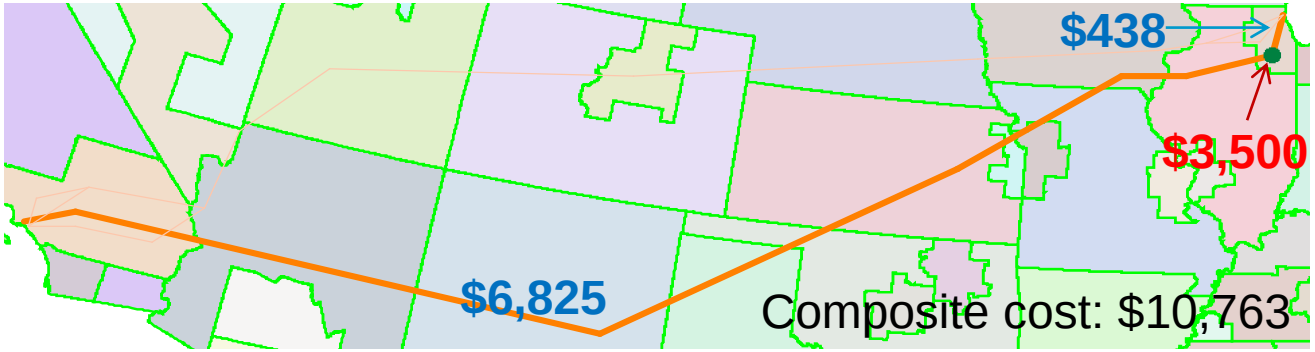
Option A:Truck hauls container entire distance



Option B: Transload then Truckload



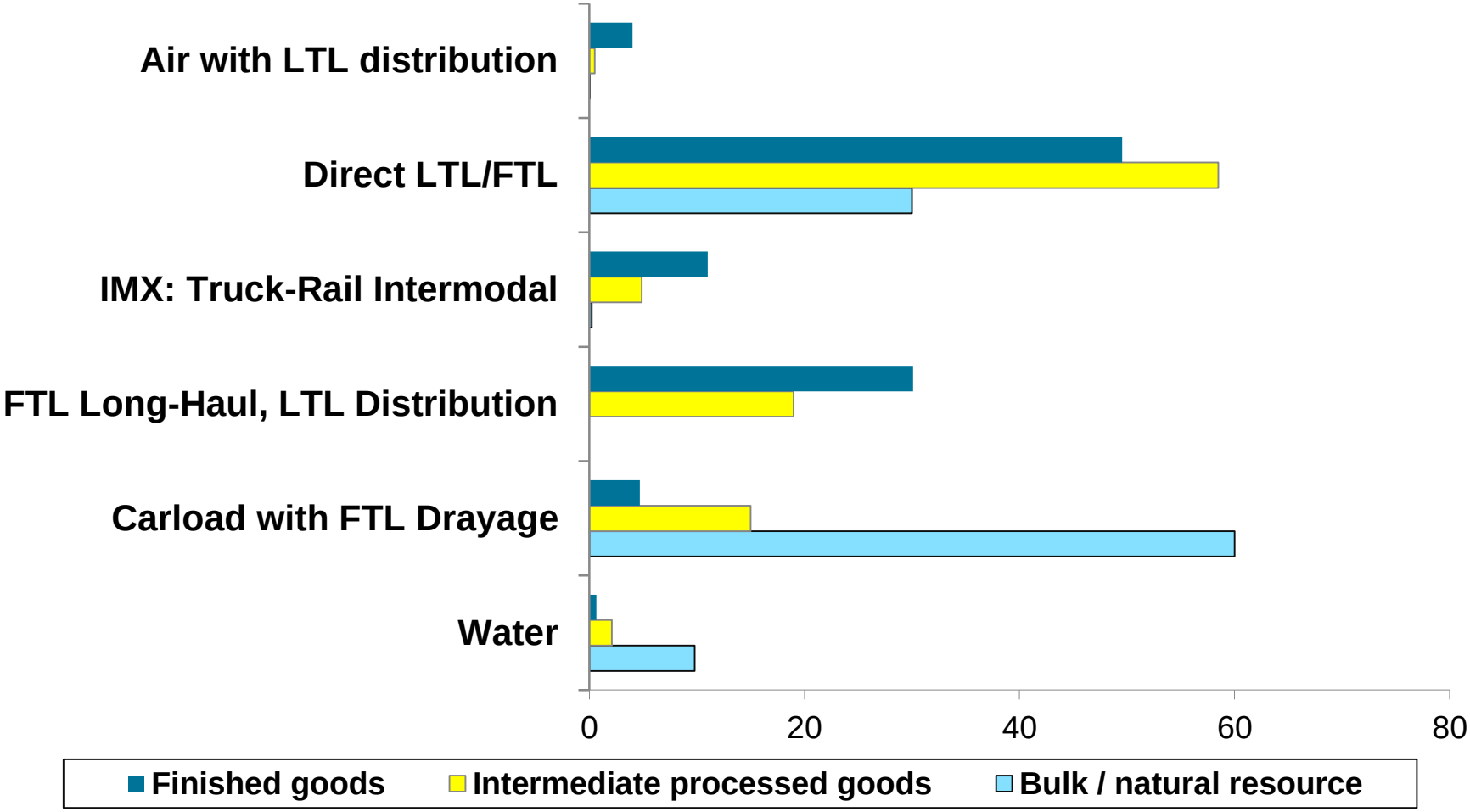
Option C: Intermodal rail to intermodal yard in Chicago area, then Truck



EXAMPLE RESULTS

Example Results

Percentage of Goods by Path Type



Source: CMAP Mesoscale Model (2011) and Cambridge Systematics.

CAMBRIDGE SYSTEMATICS

Example Results

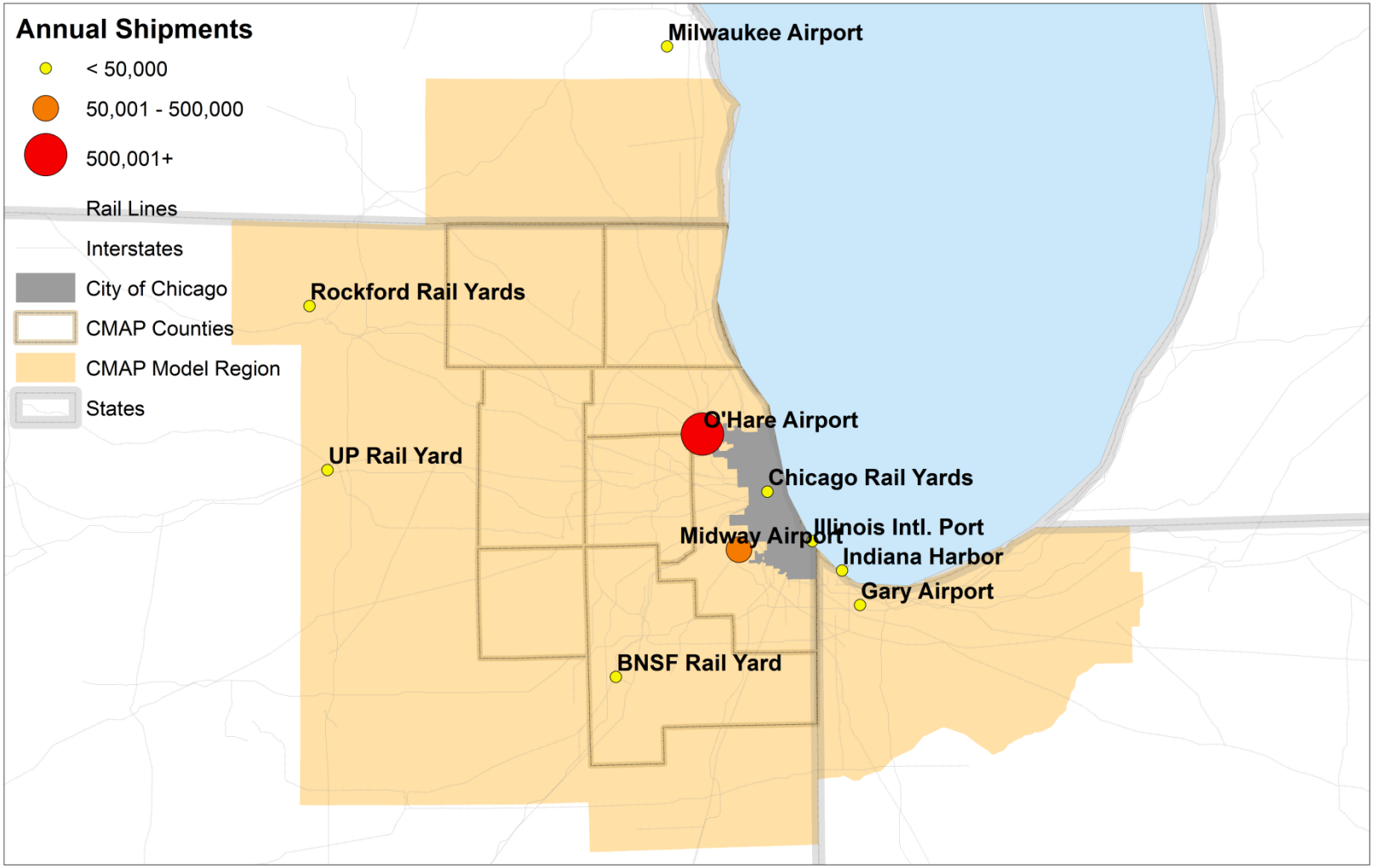
Annual Shipments and Drayage Trucks by Facility

Logistics Handling Facilities	Number of Dray Trucks		Number of Shipments
	Full Truckload (FTL)	Less-than-Truckload (LTL)	
Truck Terminals			
(Various)	8,974	136,512	11,938,571
Airports			
O'Hare	0	155,258	3,585,833
Midway	0	10,156	352,592
Gary	0	23	2,057
Milwaukee	0	31	1,771
Water Ports			
Illinois International Port	2,776	0	522
Indiana Harbor	2,134	0	346
Intermodal Yards			
Rockford-Area Rail Yards	2,679	888	441
Global III-Rochelle	2,445	1,488	883
Logistics Park – Elwood	4,545	623	485
Central Chicago rail yards	36,900	25,149	14,937
All Logistics Nodes	60,453	330,128	15,898,438

Source: CMAP Mesoscale Model (2011) and Cambridge Systematics.

CAMBRIDGE SYSTEMATICS

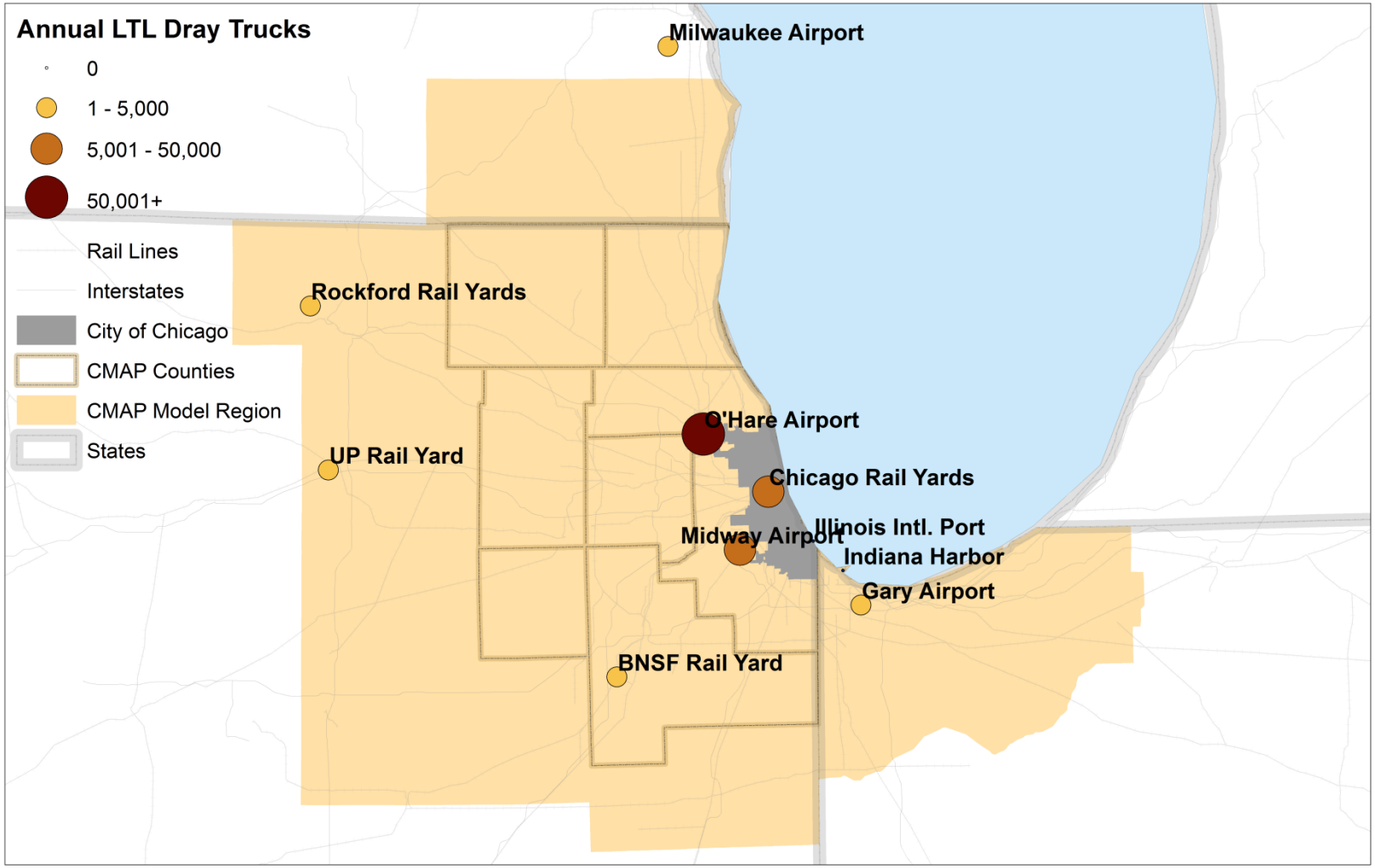
Example Results: Rail, Air, & Water Terminals
Number of Shipments



Source: CMAP Mesoscale Model (2011) and Cambridge Systematics.

Example Results: Rail, Air, & Water Terminals

Less than Truckload Drayage Trucks

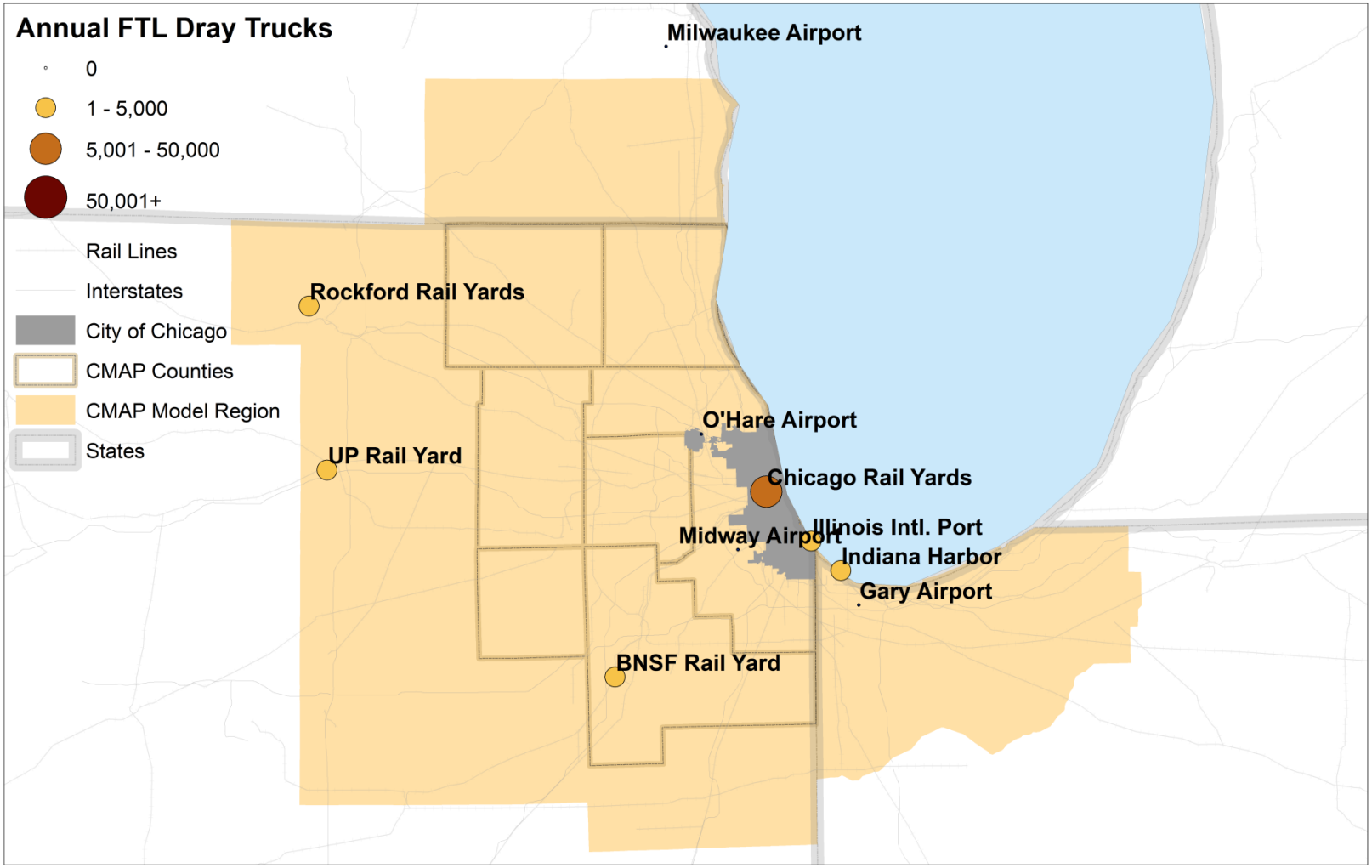


Source: CMAP Mesoscale Model (2011) and Cambridge Systematics.

CAMBRIDGE SYSTEMATICS

Example Results: Rail, Air, & Water Terminals

Full Truckload Drayage Trucks



Source: CMAP Mesoscale Model (2011) and Cambridge Systematics.

Summary and Next Steps

- **The CMAP Mesoscale Model**
  - » **Leading edge of freight modeling tools**
  - » **Agent-based approach to modeling freight movements**
  - » **Driven by economic principles**
  - » **Generate insights into broad range of questions**
- **Model enhancements**
  - » **Data collection**
    - – **Stated preference surveys of businesses**
    - – **Path cost data**
  - » **Model calibration and validation**

Maren Outwater (RSG)

Freight Modeling at CMAP

TMIP

Project Goal

Identify a framework that can be adopted by MPOs in the U.S. for use in evaluating transportation investments and their impacts on freight mobility.

- Current freight forecasting methods do not address complexities of freight demand.
- Freight forecasting requires a different approach than passenger forecasting.
- New techniques should be considered
  - Disaggregate
  - Tour-based
  - Econometric
  - Supply chains

Freight Forecasting Model Improvements

Address current weaknesses identified in standard practice freight forecasting

- The lack of detail at the traffic analysis zone level
  - Synthesize firms and goods movements at the zone level
- The lack of information about the local pickup and delivery trips
  - Specifically model the delivery system at the end of the supply chain
- The need to estimate shifts in long-haul and short-haul demand resulting from regional investments
  - Connect movements from supplier to buyer by modeling in a single framework
- The ability to capture trip-chaining that occurs
  - Represent distribution channels in the supply chain and touring during deliveries
- The need to represent commodities produced and consumed by different industries
  - Represent commodity movements as links between buyers and suppliers

Advanced Freight Forecasting Models

3 Types Emerging

Supply Chain Models

- Tend to be National in scope
- Some examples at State and Regional levels

Hybrid Models

- Combined supply chain and tour-based models
- For Regional/Statewide planning, but with a National component

▪ Mode and path selection

eling truck movements

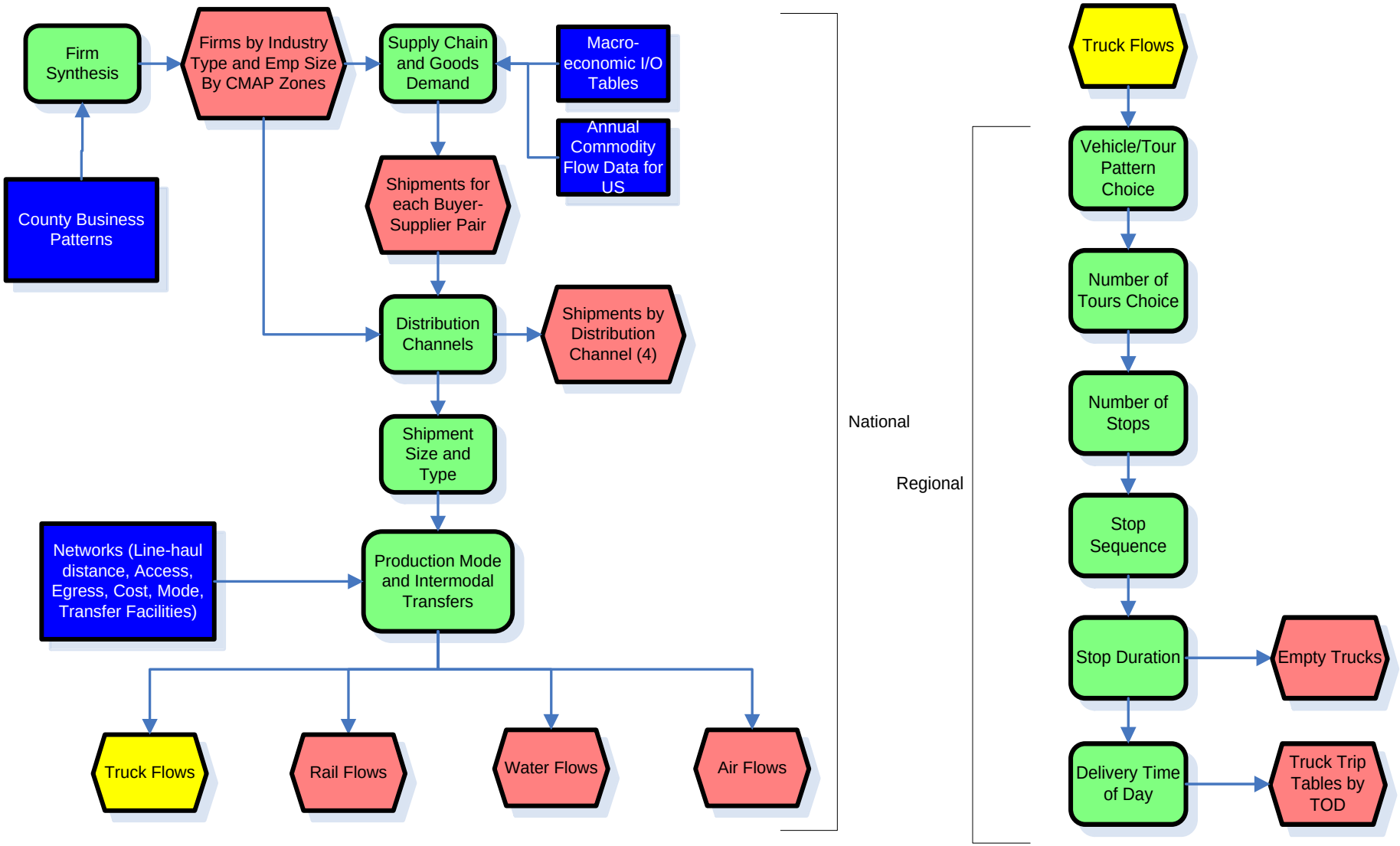
ents such as tour generation,

dels, and time of days models

incrementally

- Models shipments using the supply chain framework
- Regional pick up and delivery of shipments is handled by touring trucks

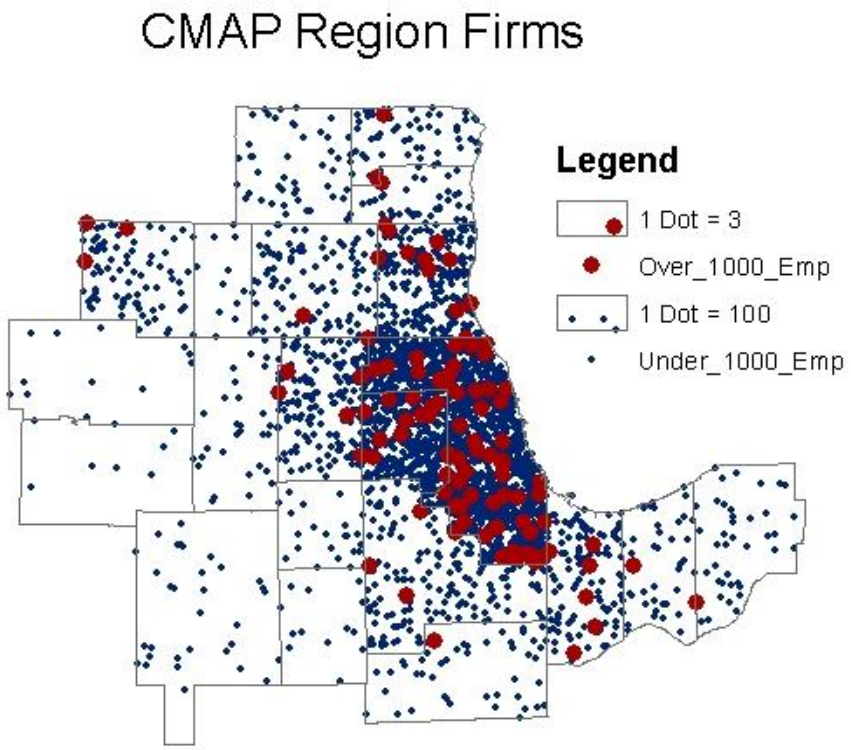
FHWA Freight Forecasting Framework in Chicago



National Supply Chain Models

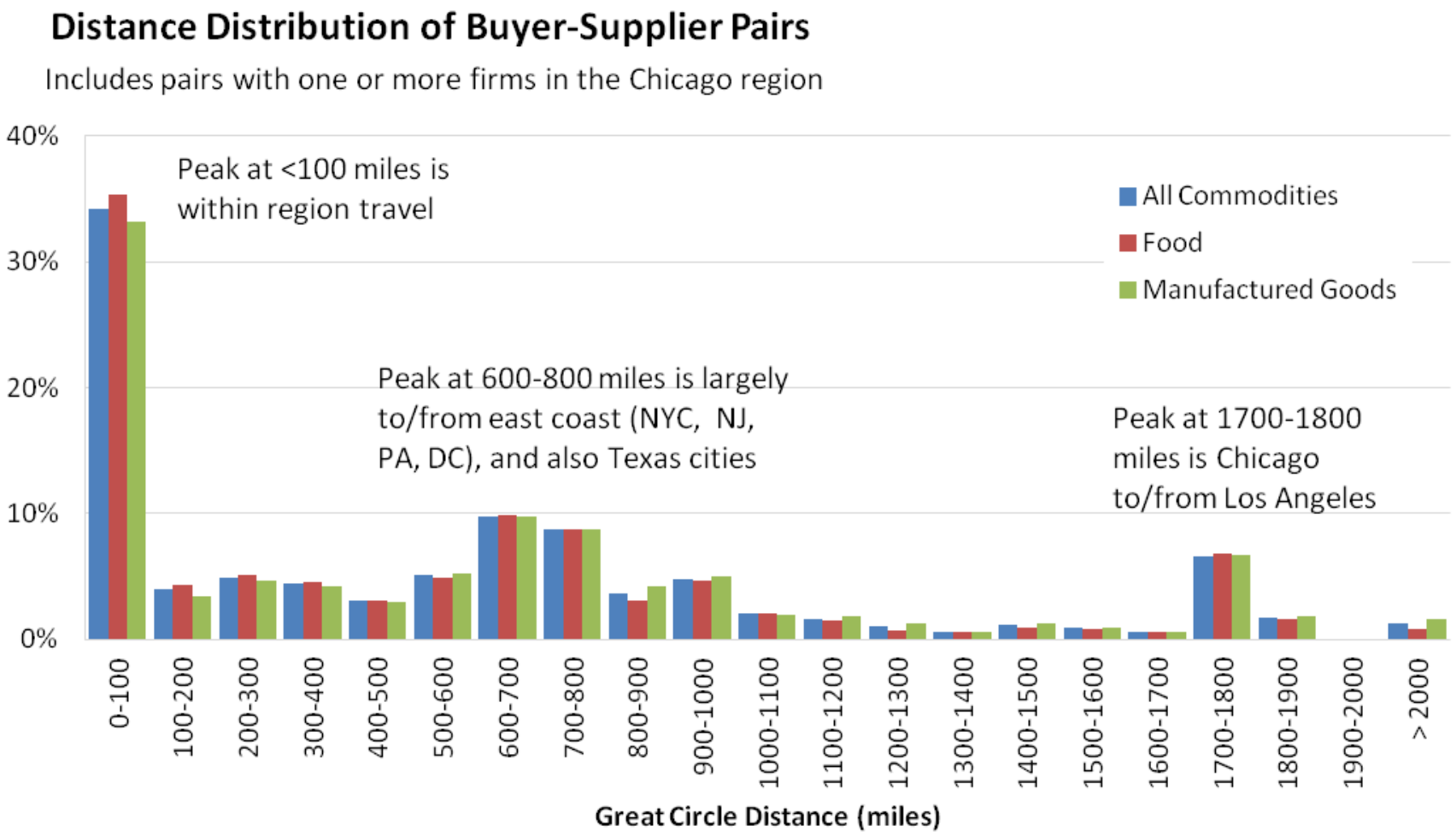
Firm Synthesis

- Firms are synthesized for the entire U.S. with a high level of industrial sector detail, and across several employment categories
- Spatial resolution is more detailed than is used nationally (counties are smaller than FAF zones)



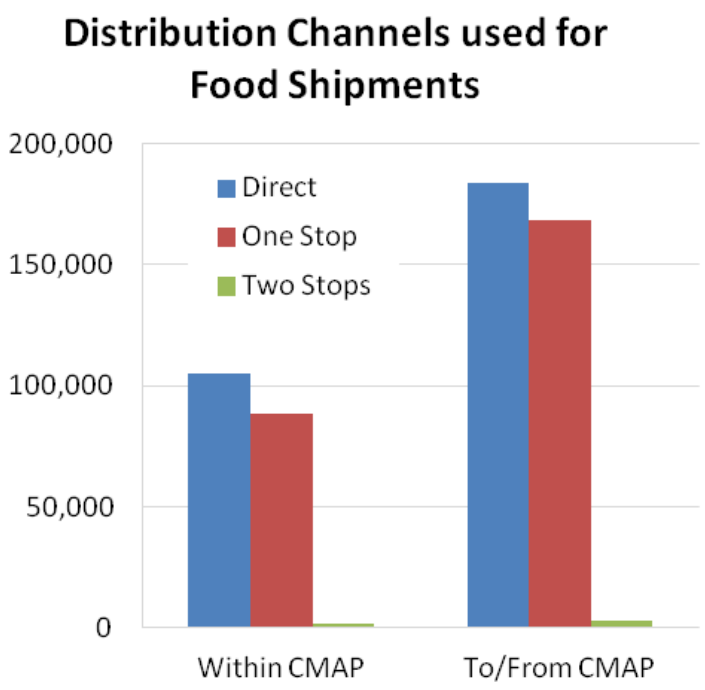
Supplier Selection Results

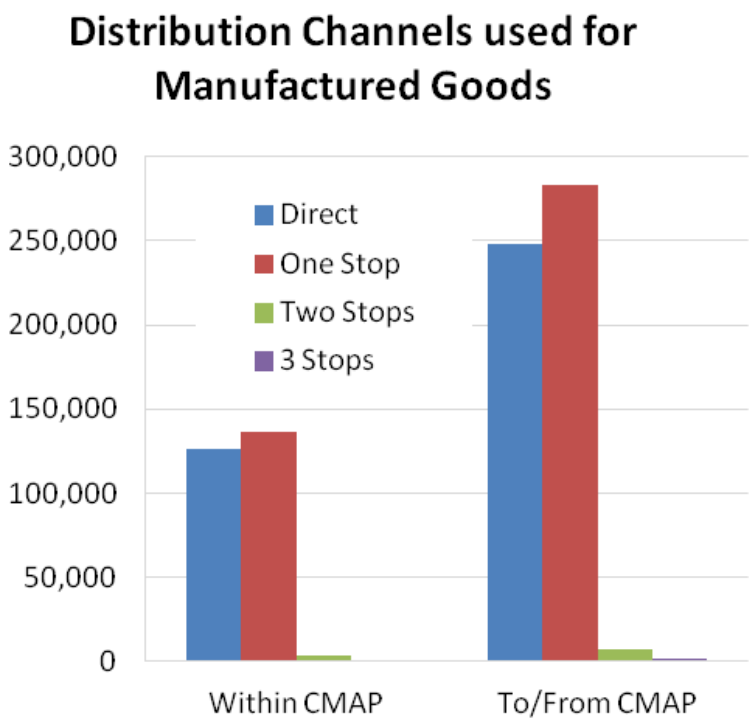
- The model builds 2.8 million buyer-supplier pairs with one of the pair in the Chicago region
- The distance distribution of buyer-supplier pairs reflects the spatial distribution of commodity flows



Distribution Channel Results

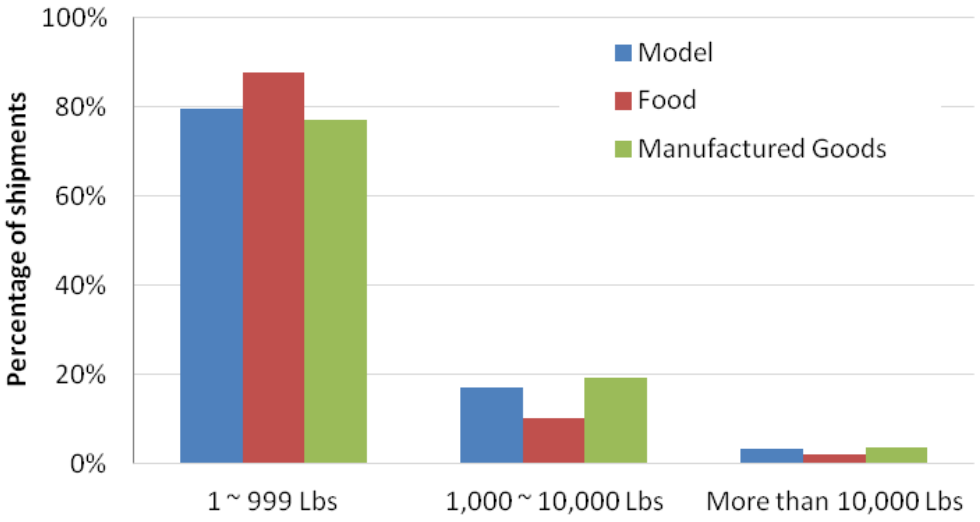
Direct distribution channels and channels involving a single type of stop are evenly split and account for almost all of the shipments

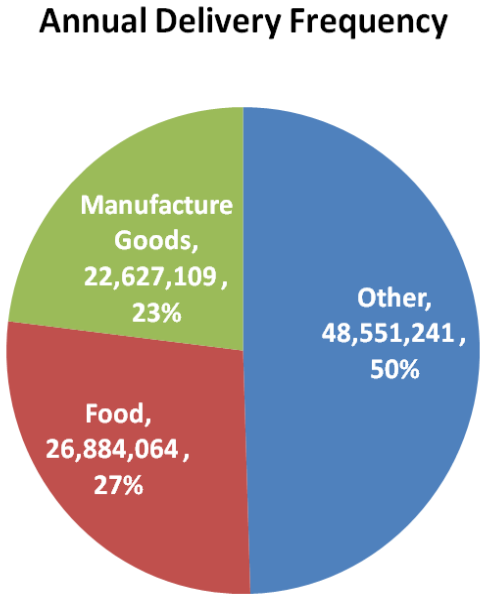




Shipment Size and Frequency Models

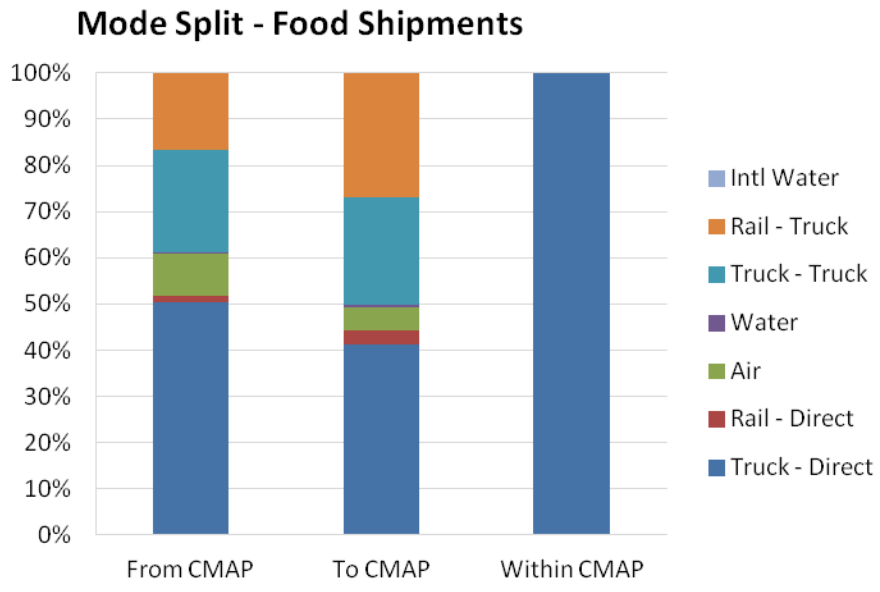
- Small shipments (<1,000 lb) make up the largest proportion of shipments
- There is relatively little variation between the commodities: a slightly higher proportion of food shipments are small
- Annual shipment frequency is calculated by dividing the annual flow for each supplier-buyer pair by the shipment size

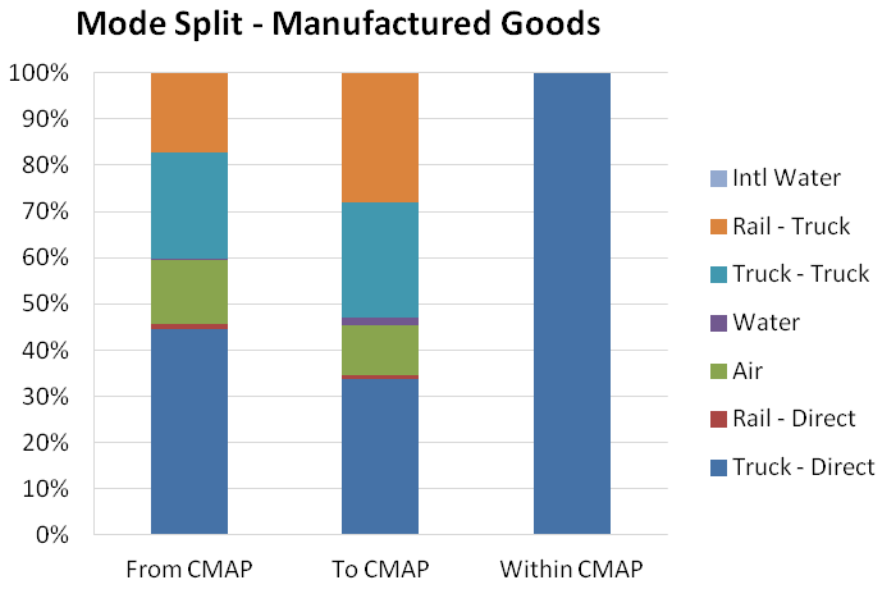




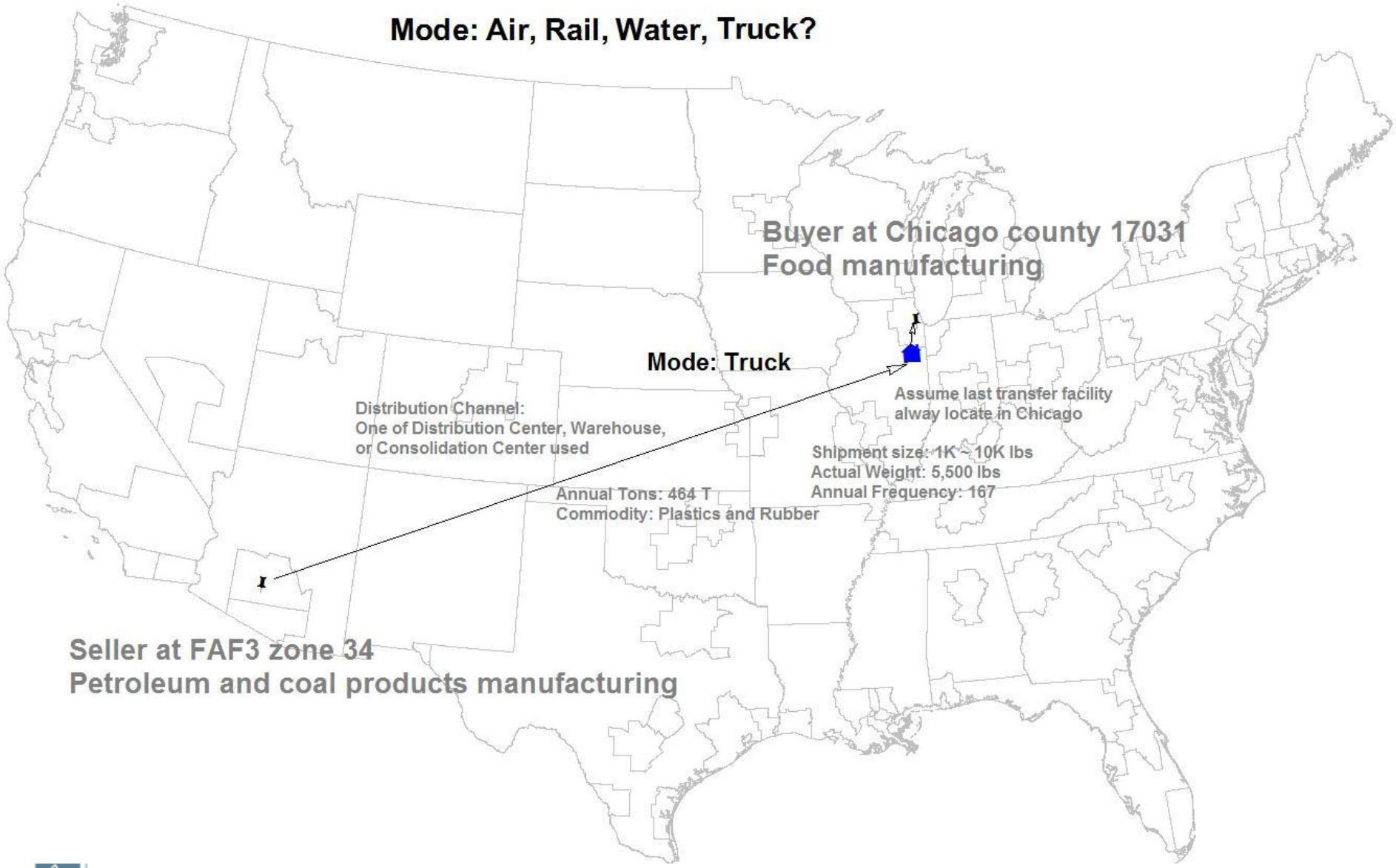
Mode and Transfer Results

- Within Chicago movement is all via truck
- Longer movements include significant intermodal elements, including conversion between (for example) FTL and LTL



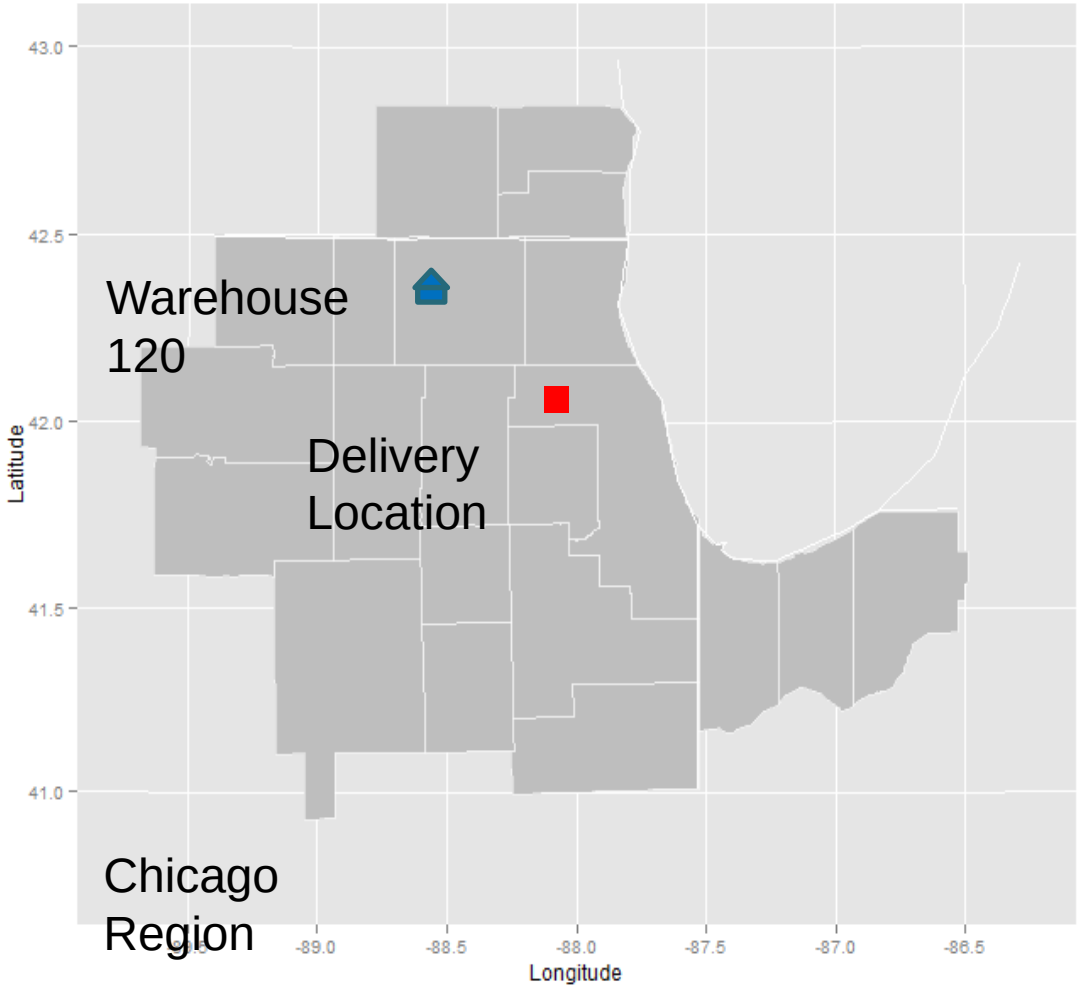


National Model Sequence



Regional Tour-based Models

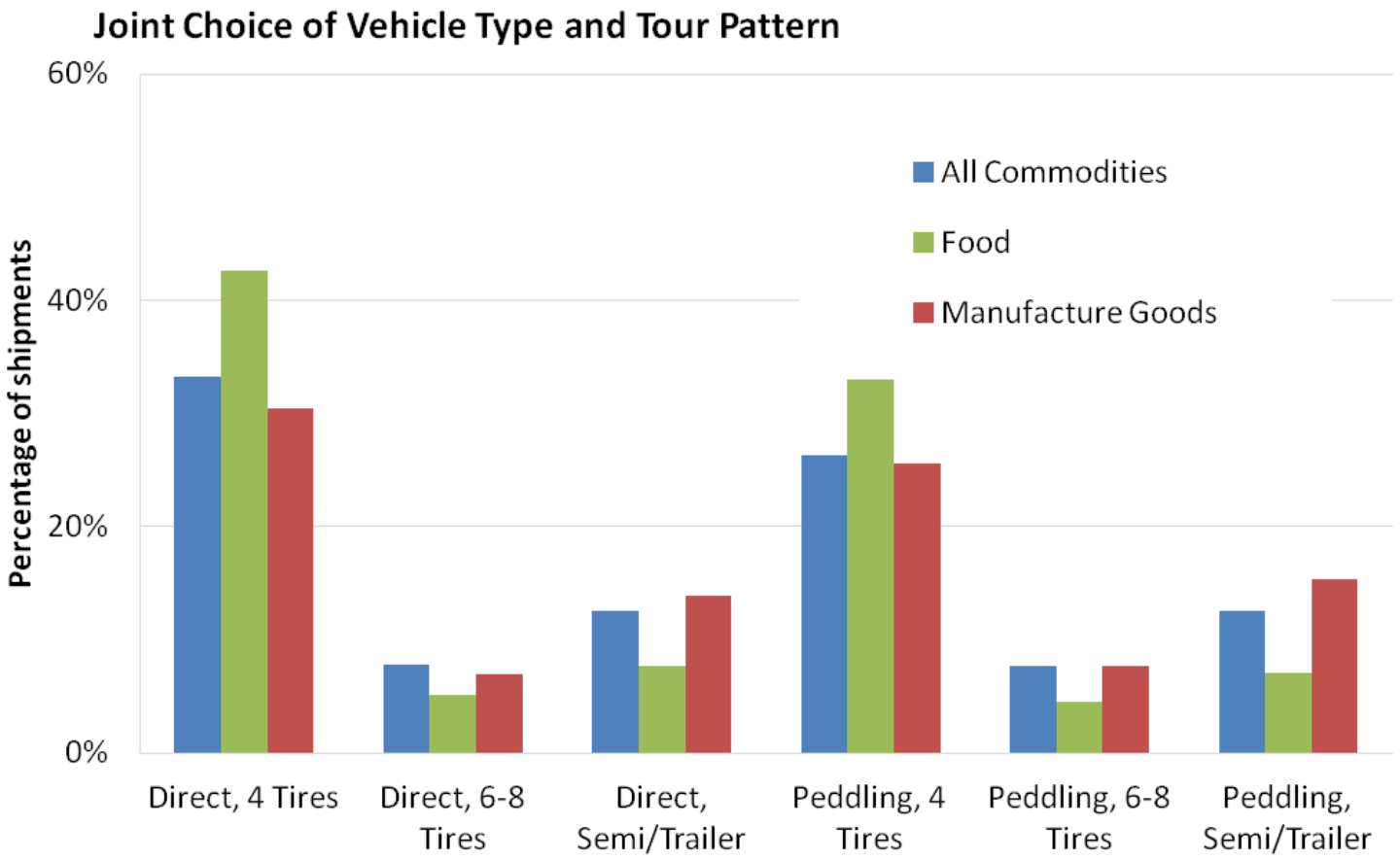
Convert to Daily Shipments and Select Warehouse



- Convert annual to daily shipments
- Identify warehouse/ distribution center locations from the synthesized business establishments
- Assign shipments to a warehouse/ distribution center

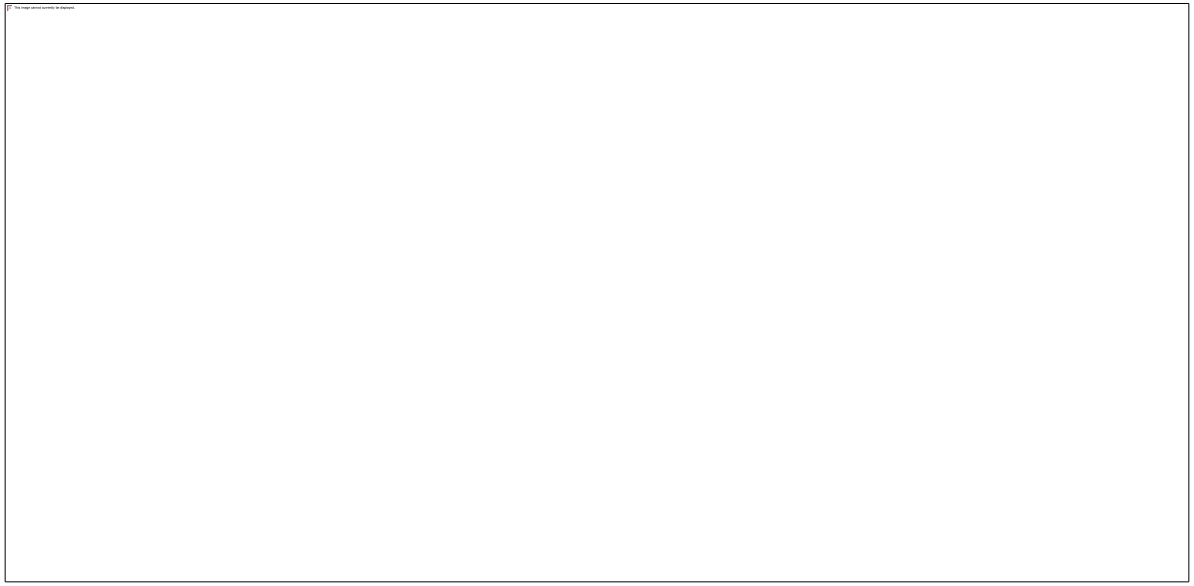
Select Vehicle Type and Tour Pattern

- Results produce the majority of tours using smaller 2 axle trucks
- There are slightly fewer peddling tours than direct tours

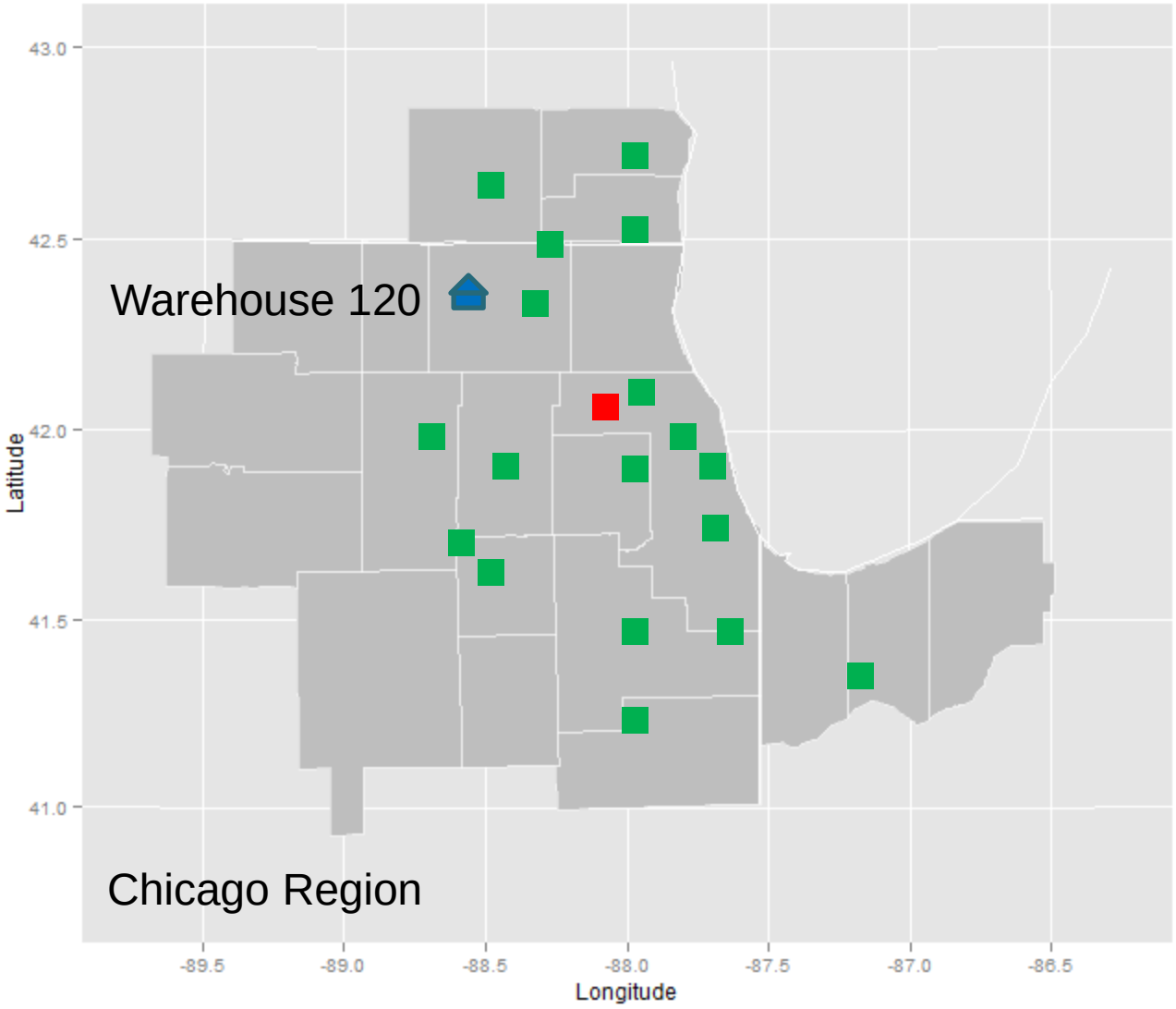


Allocate Shipments to Tours and Stops

- The model allocates most shipments to single tour patterns
- Larger shipments are most likely to be in multiple tour patterns
- There is a long tail of tours with many stops



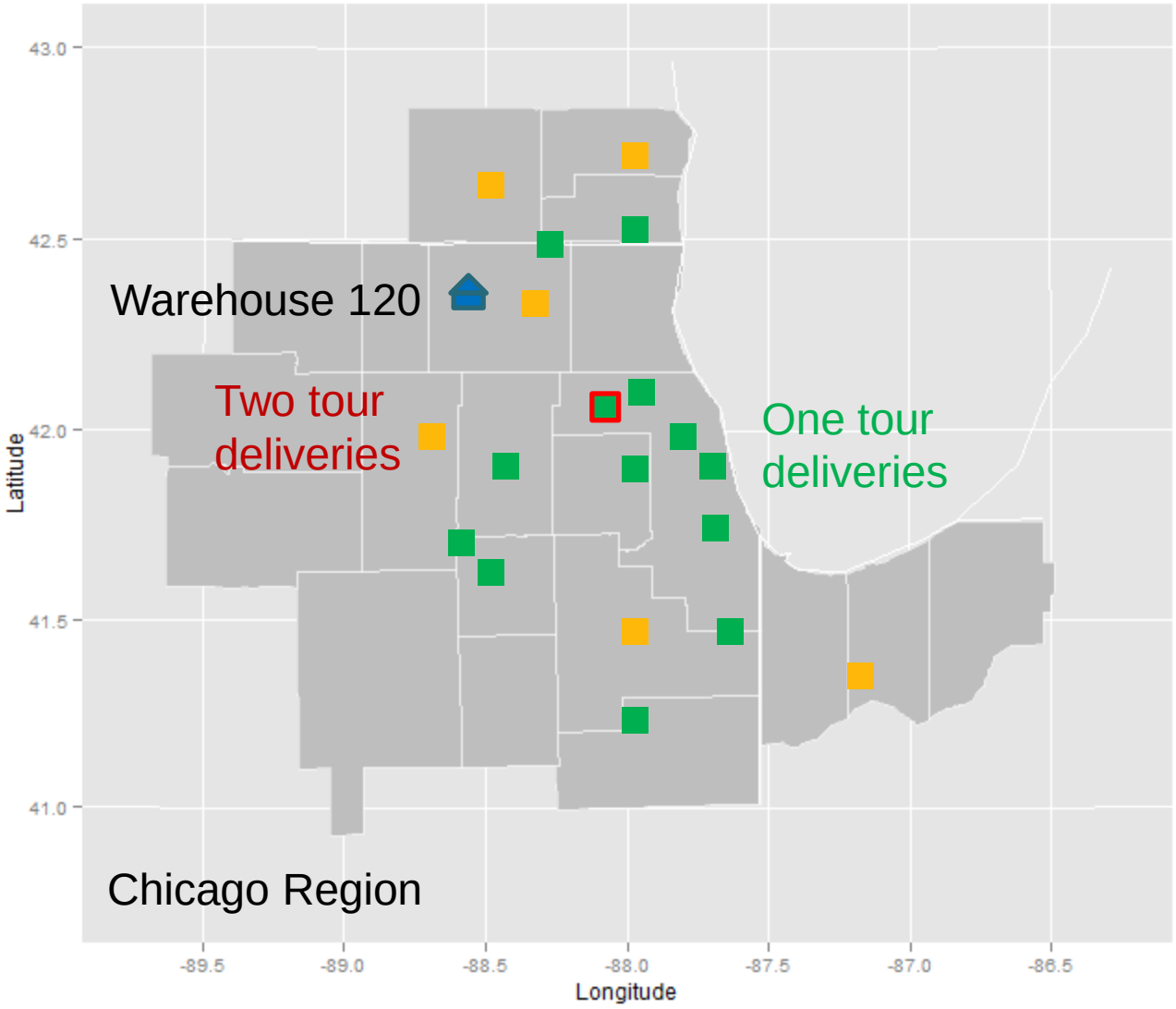
Regional Model Sequence



All shipments from a warehouse with the same vehicle type and tour type

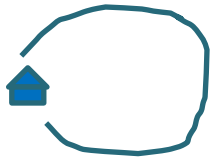
Our delivery is one of several from that warehouse that will be delivered by the same vehicle type – these must be grouped into tours and sequenced for delivery

Regional Model Sequence

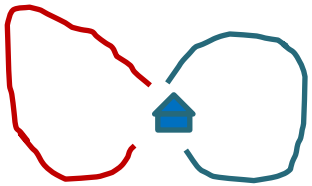


Number of tours

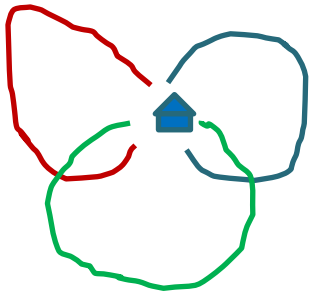
An MNL choice model is used to assign deliveries to tours patterns with one tours, two tours, three tours or four tours



One tour

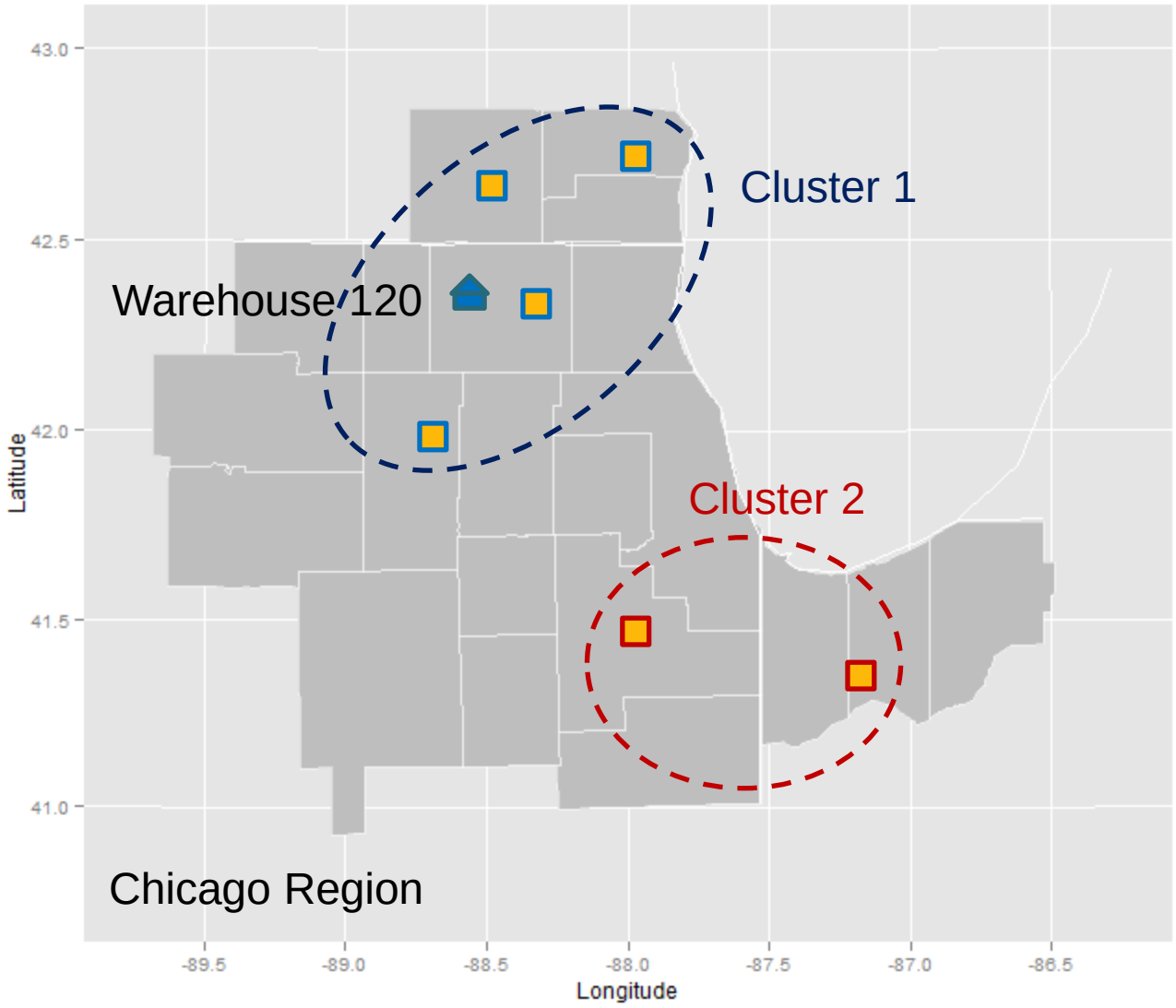


Two tours



Three tours

Regional Model Sequence

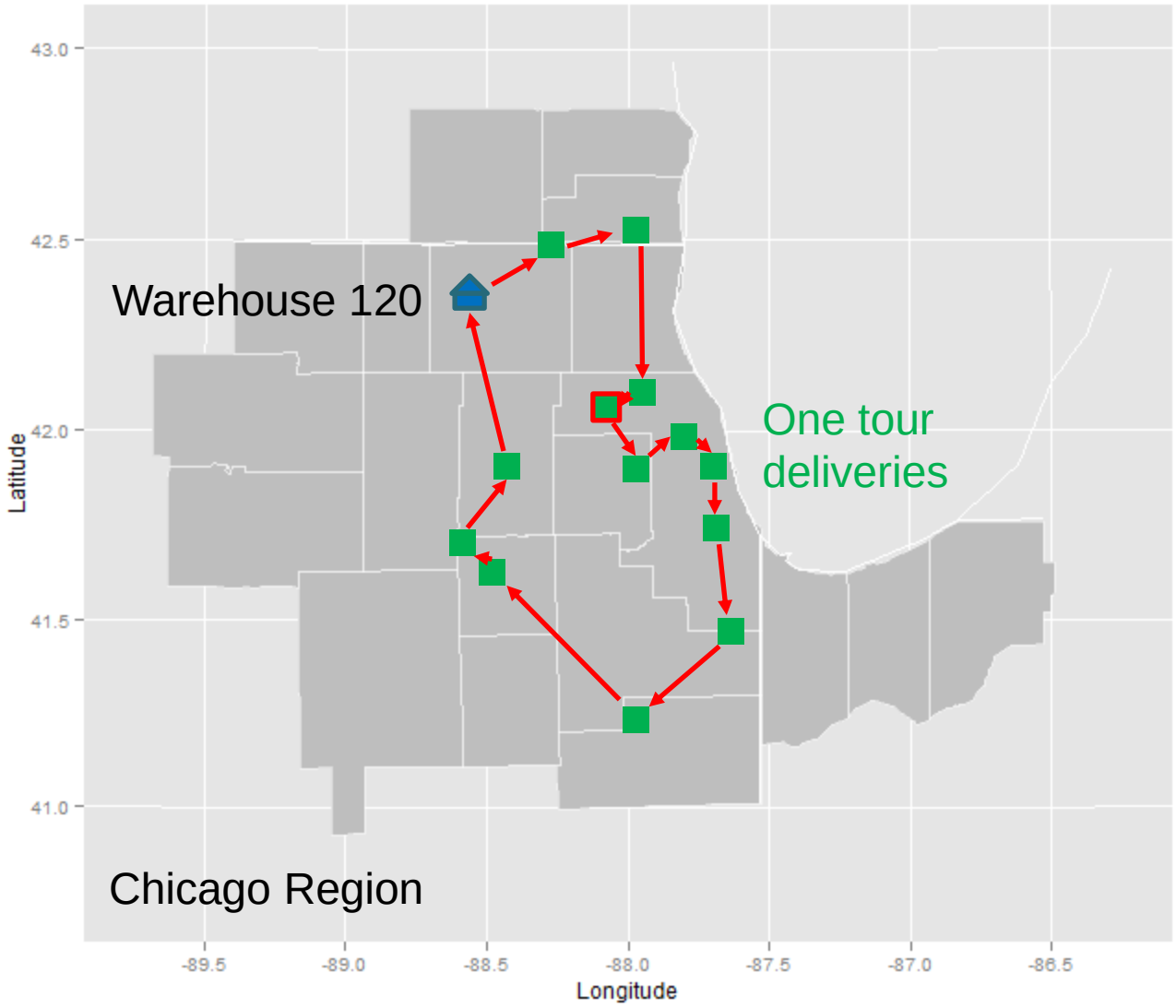


Stop Clustering

For deliveries in two or more tour patterns, the stops are assigned to a specific tour using hierarchical clustering

This technique groups together spatially close deliveries

Regional Model Sequence



Stop Sequencing

A greedy algorithm is used to sequence the stops, which is much simpler and more realistic (according to Texas data) than a traveling salesman algorithm

1. First delivery is the closest to the warehouse
2. Second delivery is the closest to the first delivery point
3. Etc., until all deliveries are made

Regional Model Sequence

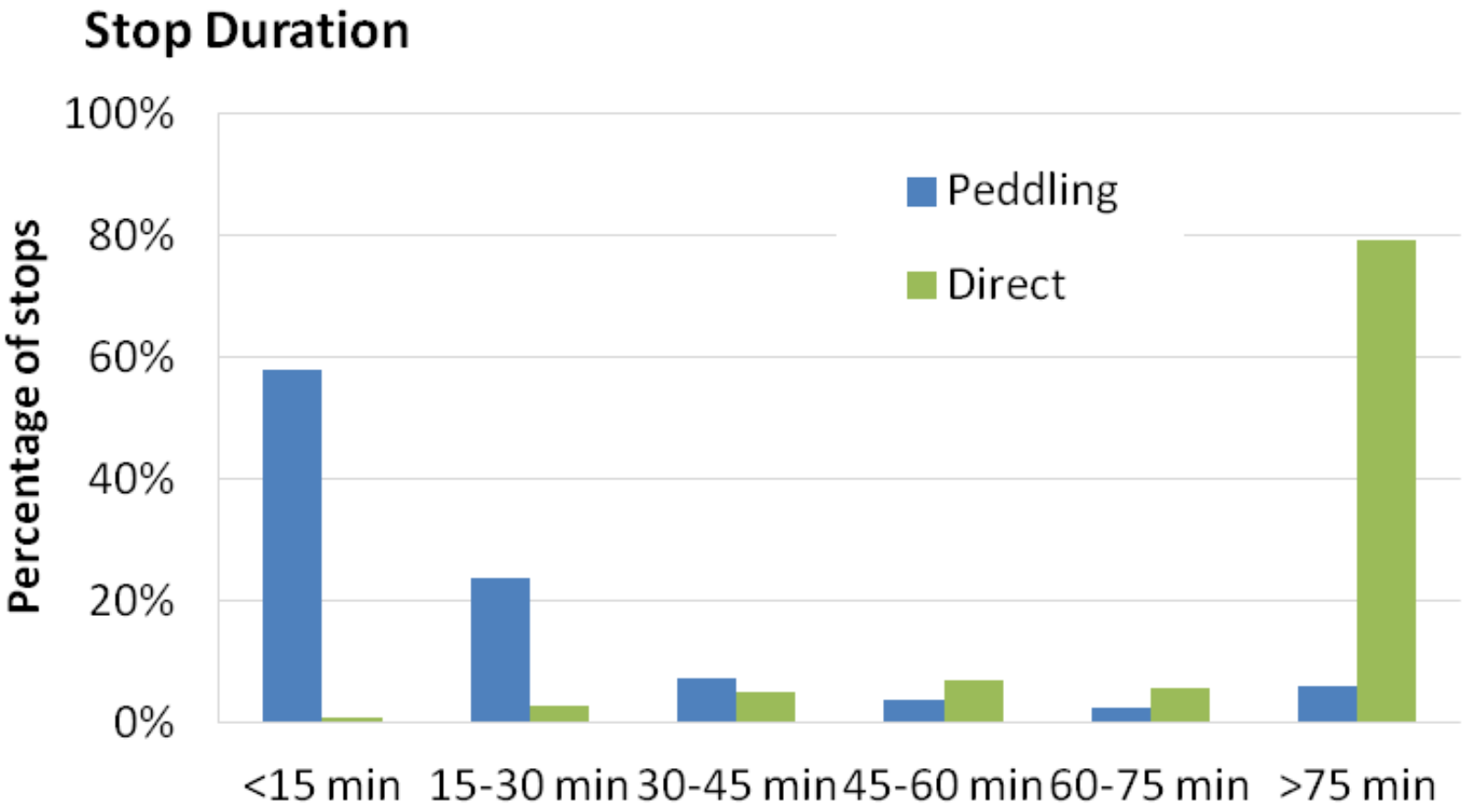
Stop Sequencing

A greedy algorithm is used to sequence the stops, which is much simpler and more realistic (according to Texas data) than a traveling salesman algorithm

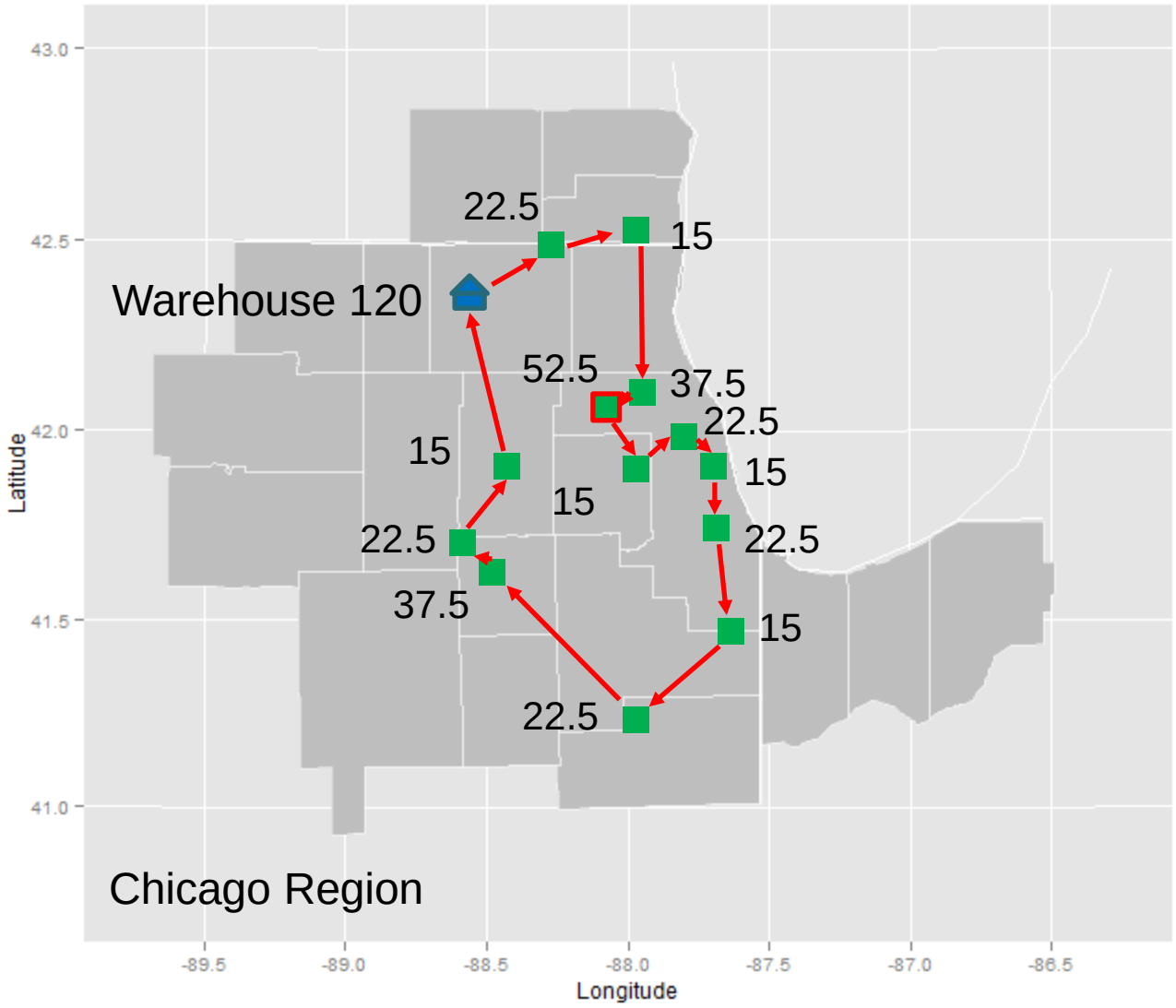
1. First delivery is the closest to the warehouse
2. Second delivery is the closest to the first delivery point
3. Etc., until all deliveries are made

Stop Duration

The model predicts that stops will generally be short on peddling tours and long on direct tours



Regional Model Sequence

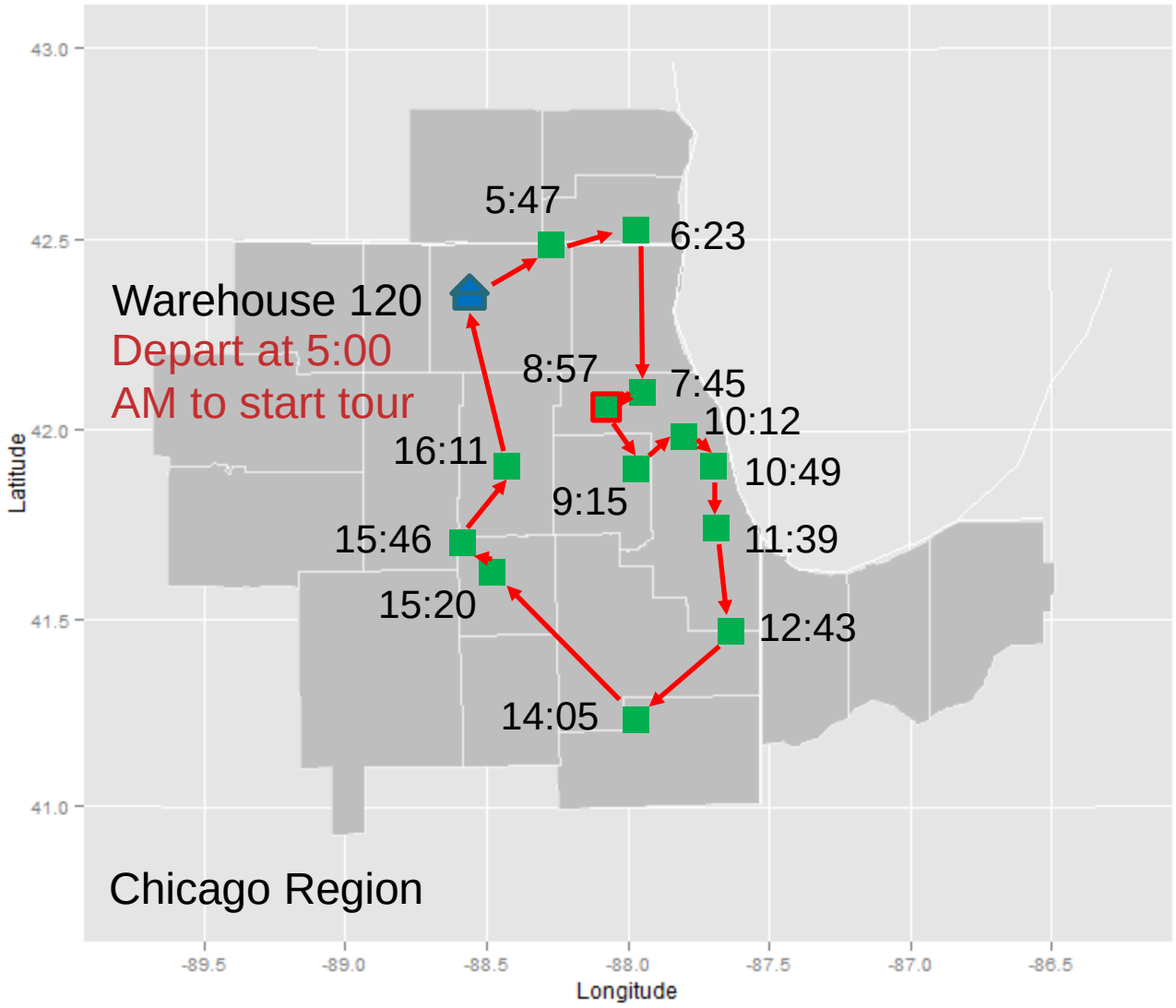


Stop Duration

An MNL choice model, estimated using the Texas survey data, is used to simulate the duration at each stop

Stop durations are short for stops in tours with a lot of stops, and are longer for larger loads

Regional Model Sequence



Tour start time

A final MNL choice model, again estimated using the Texas survey data, is used to predict the tour start time

With the stop durations and travel times from skim data, the departure time of each trip can be calculated, to give a complete trip list

Demonstration and Implementation

Demonstration in Chicago

Model framework was estimated and then applied in Chicago

- Estimation work used sources such as FAME survey data (UIC) and Texas Commercial Vehicle Survey
- Models were estimated for two commodities – food and manufacture goods
- Application combined the elements of the model developed by Cambridge Systematics as part of their work on the CMAP Mesoscale Freight Model with all of the new components
- Programmed in R, open source statistical programming language
- Software was recently completed and turned over to CMAP for testing
- Final report submitted to FHWA and available for distribution

Application Development in R

- **Scripting Software**
  - R version 2.14
- **Runtime**
  - Total run time is 80-90 minutes
- **Hardware**
  - Manufacturer: HP Z200 Workstation
  - Processor: Intel Core i7 CPU 870 @ 2.93 GHz
  - Installed RAM: 12.0 GB
  - OS: Windows 7 Professional (64-bit)

Model Component	Run Time (minutes)	Notes
Firm synthesis	13	Synthesize 8 million firms and choose buyers (7.5 million) and suppliers firm types (1.4 million) for CMAP simulation
Supplier selection	24	Match supplier firm types for about 3 million firms
Supply chain and goods demand	19	Apportion FAF flows for 3 million buyer supplier pairs and locate 8 million firms to mesozones
Distribution channel	1.0	Predict distribution channels for 3 million buyer-supplier pairs using logit shares
Shipment size	1.5	Estimates annual shipment size and frequency
Mode-Path selection	20	Evaluation of annual logistics and transport costs for 54 mode-paths
Vehicle choice and tour pattern	1.5	Daily simulation for 300k deliveries\pick-ups from warehouses
Stop clustering and sequencing	1.5	Clusters and sequences stops on tours
Stop duration	0.2	Estimates stop duration
Time of day	1.5	Constructs tours from start time and stop duration

Implementation of this Framework in Florida

Florida is developing a statewide multi-modal freight model to …

Enhance Florida's statewide freight forecasting capabilities

- Represent characteristics of firms and shipments
  - Synthesize firms and goods movements at the zone level
- Represent supply chains and distribution channels
  - Link commodity movements between buyers and suppliers
- Estimate shifts in long-haul and short-haul demand resulting from statewide investments
  - Connect movements from supplier to buyer in a single framework
- Include all modes (air, water, rail, road)

Provide a framework to support enhancements to regional freight forecasting

- Capture trip-chaining that occurs
  - Represent distribution channels in the supply chain
  - Represent touring during pick up and delivery of goods

Policy Sensitivity for the Florida Statewide Model

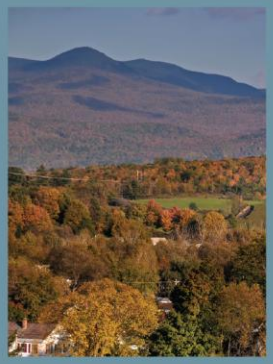
Statewide Policies

- Changes in land use and economy: spatial distribution of employment and mix of industries
- Changes in transportation supply
  - Major highway network changes
  - Changes to rail capacity
  - Intermodal facility capacity changes, including deep water ports and airports
- Changes in distribution center network
  - New facilities (with regional significance)
- Changes in commodity flow origins and destinations outside Florida

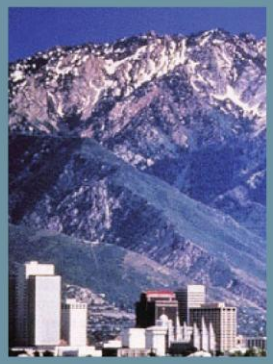
Regional Policies

- Regional model input is the output from the statewide model, so statewide model's sensitivity feeds through to regional model
- Local (more detailed) distribution of employment and land use affects local truck travel patterns
- Local changes in transportation supply, non-truck traffic growth causing congestion, and resulting truck travel times
- Local policies such as truck routes, truck prohibitions, delivery windows, and size limits can be modeled

Contact


Vermont


Chicago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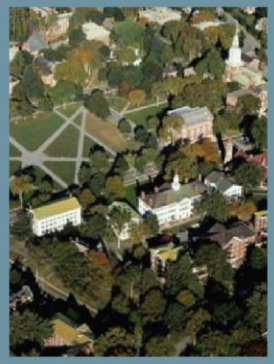
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Question & Answer

Please use the Q/A pod to type and submit questions for our presenters