INBOUND SHIPMENT COORDINATION

SENIOR DESIGN FINAL PRESENTATION

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PROJECT OVERVIEW

Problem	< 2% of shipments are part of multi-stop pickups
Design Strategy	Integer programming
Deliverable	Excel tool of 1,233 vendor groups
Project Value	14,923 multi-stop pickup opportunities $9.1M reduction in transportation costs

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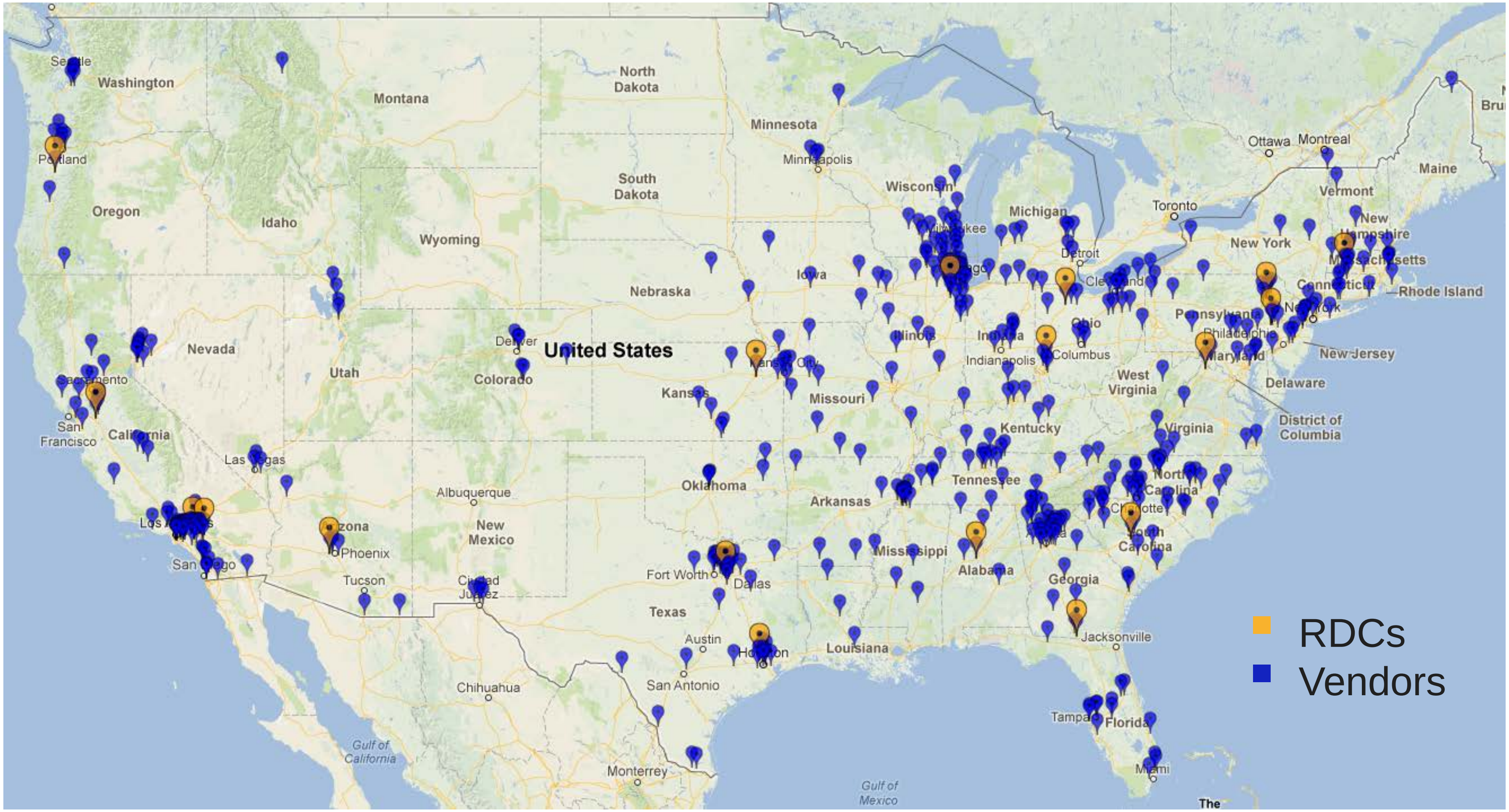
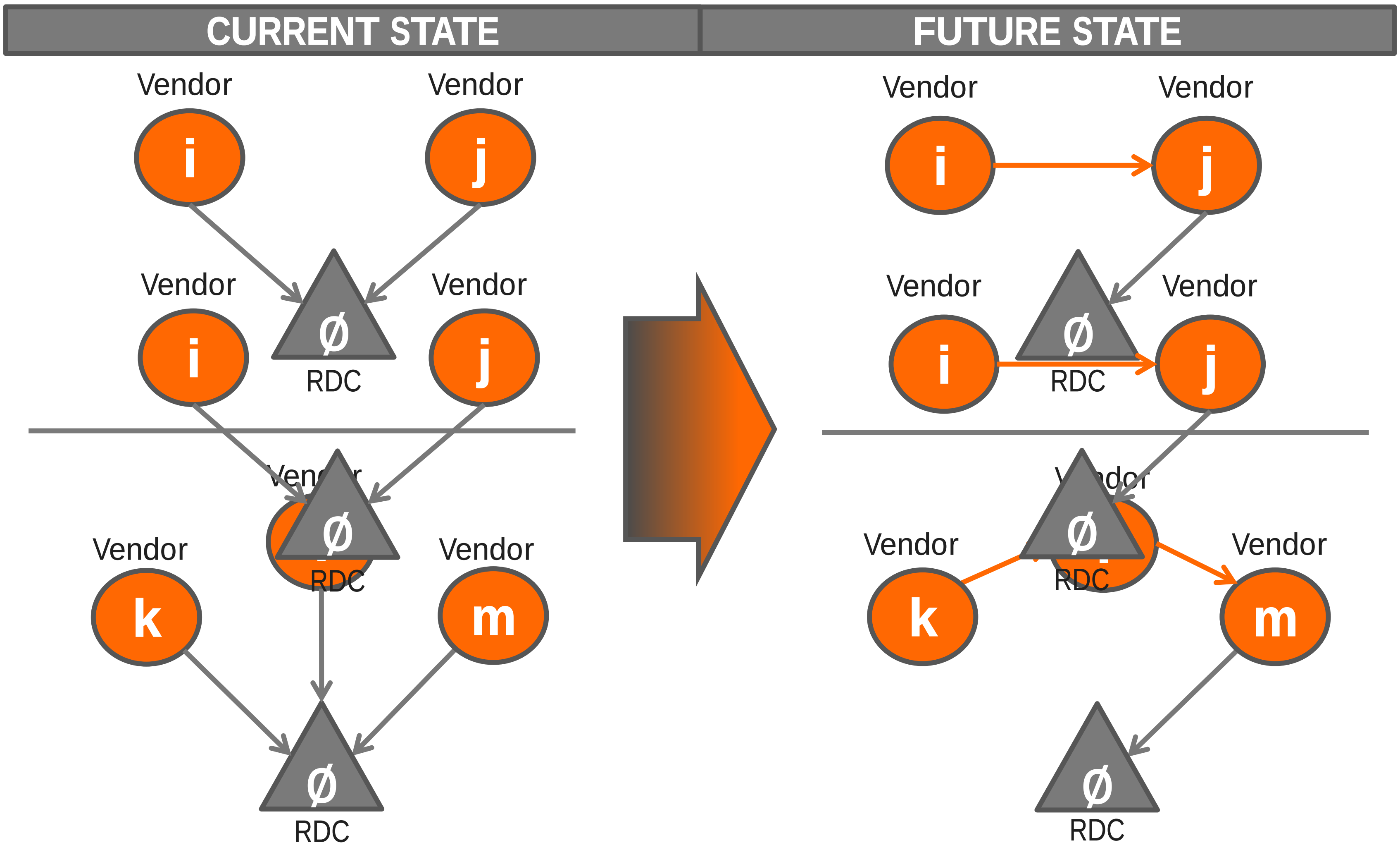
INBOUND TRANSPORTATION NETWORK



18 Rapid Deployment Centers (RDCs) & 633 Vendors

PROBLEM



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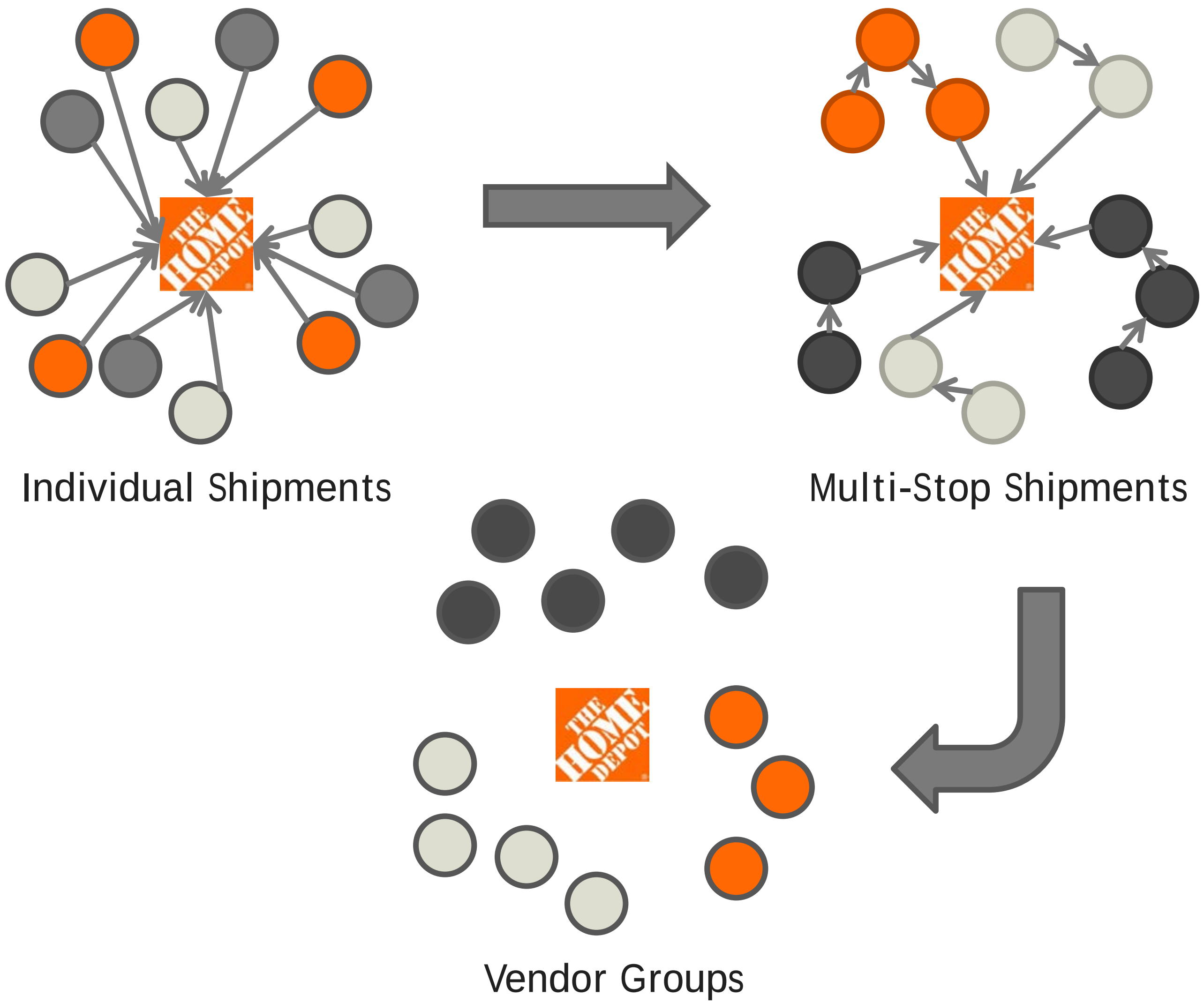
PROJECT FLOW



DATA

- Bid Rate
- Mode of Transportation
- Shipment Date
- Total Cost
- Volume
- Weight

Bid Rate from Boston to Los Angeles

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DESIGN STRATEGY

Objective

Maximize cost savings via multi-stop pickup coordination

Pre-processing

Create all feasible pairs and triplets

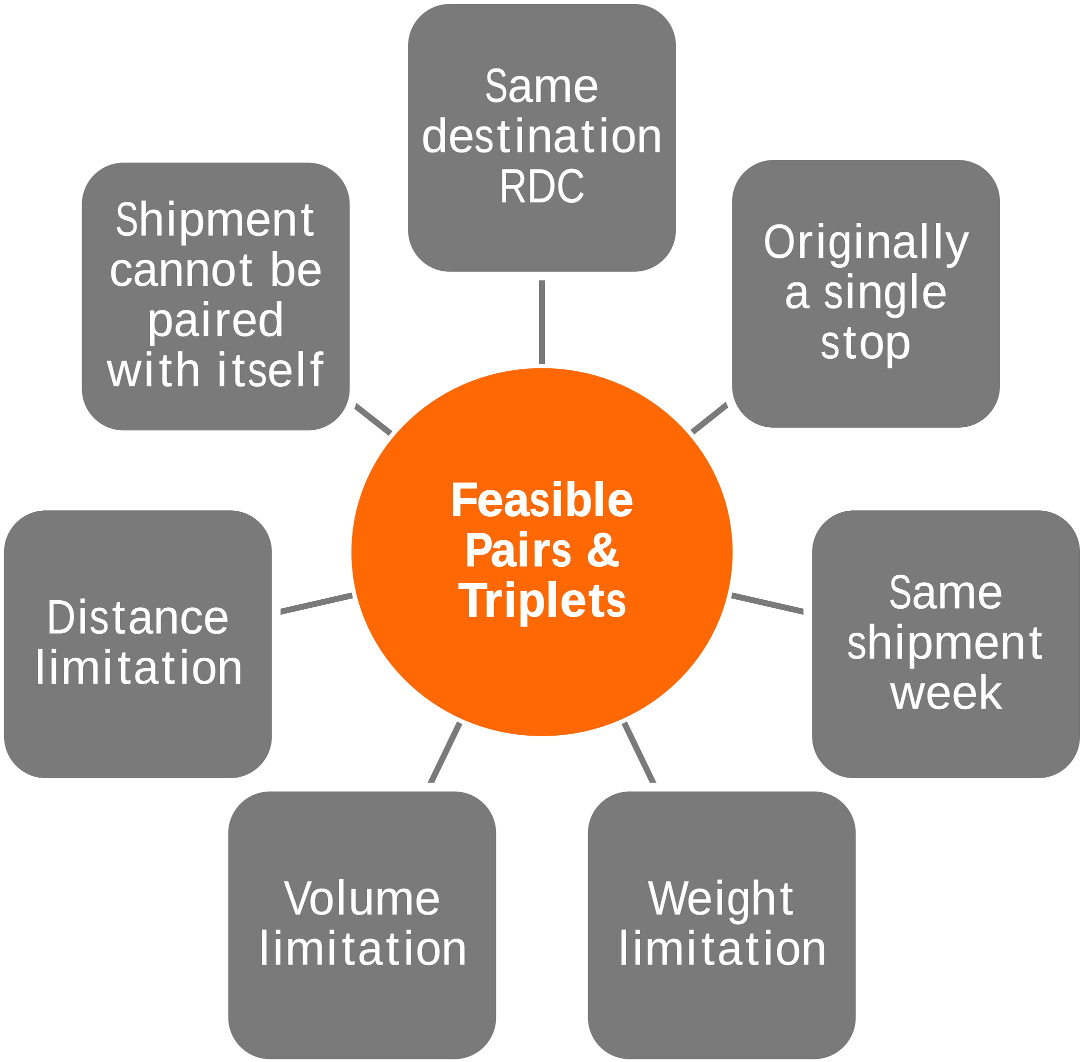
Optimization

Integer Programming via FICO® Xpress Optimization Suite

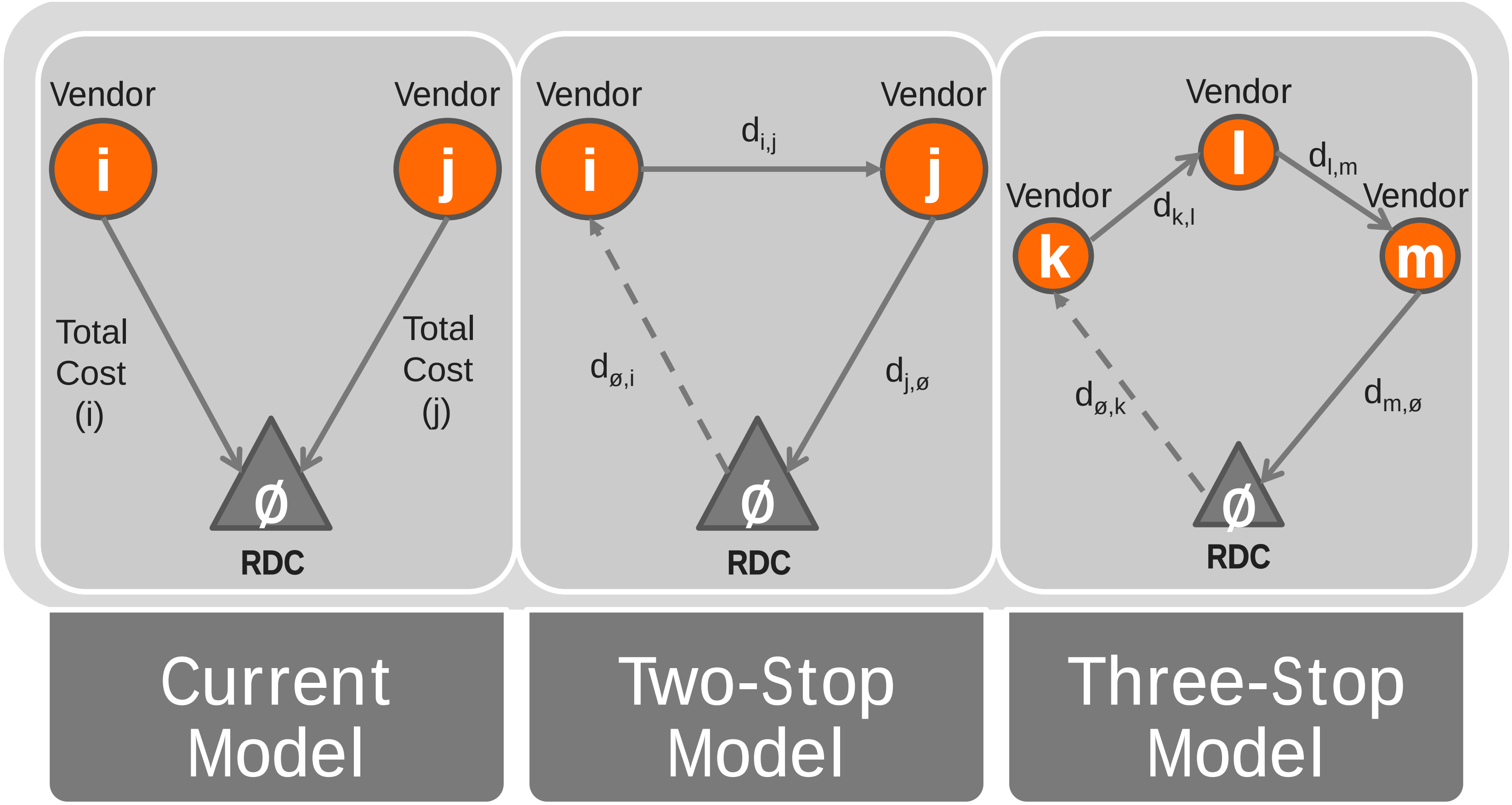
Post-processing

Create vendor groups from combined shipments

MATLAB PRE-PROCESSING



COST MODEL



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OPTIMIZATION MODEL & CONSTRAINTS

- Objective Function

$$max\left\{\sum_i\sum_j s_{i,j}x_{i,j} + \sum_k\sum_l\sum_m s_{k,l,m}x_{k,l,m}\right\}$$

s.t.

1) $\left[\frac{ORM_{i,j}}{50} + 2.5\right] * x_{i,j} \leq 11$

2) $\left[\frac{ORM_{k,l,m}}{50} + 2.5\right] * x_{k,l,m} \leq 11$

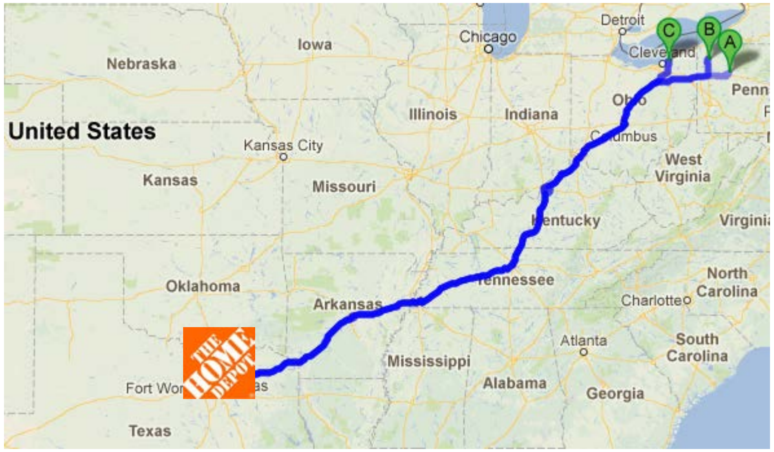
3) $\sum_i\sum_j x_{i,j,k} + \sum_j\sum_l x_{j,k,l} + \sum_l\sum_m x_{k,l,m} + \sum_j x_{j,k} + \sum_l x_{k,l} \leq 1, \forall k$

4) $x_{i,j} \in \{0,1\}$

5) $x_{k,l,m} \in \{0,1\}$

OPTIMIZATION OUTPUT SAMPLE

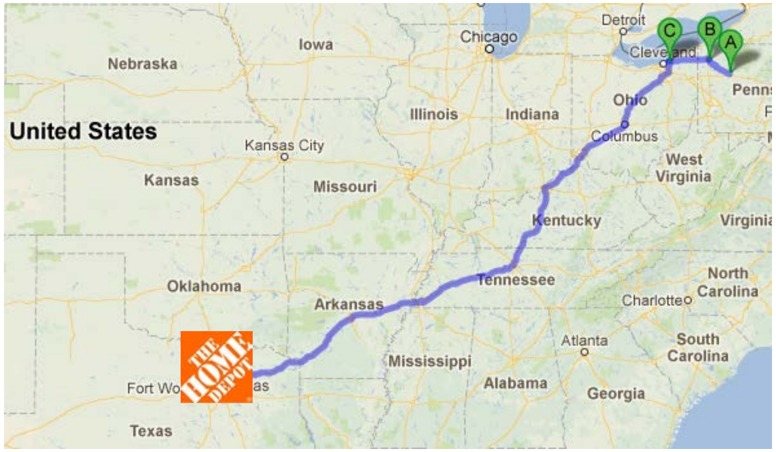
Independent Routes



Total Distance: 3,748.96 miles

Total Cost: $2,751.79

Combined Routes

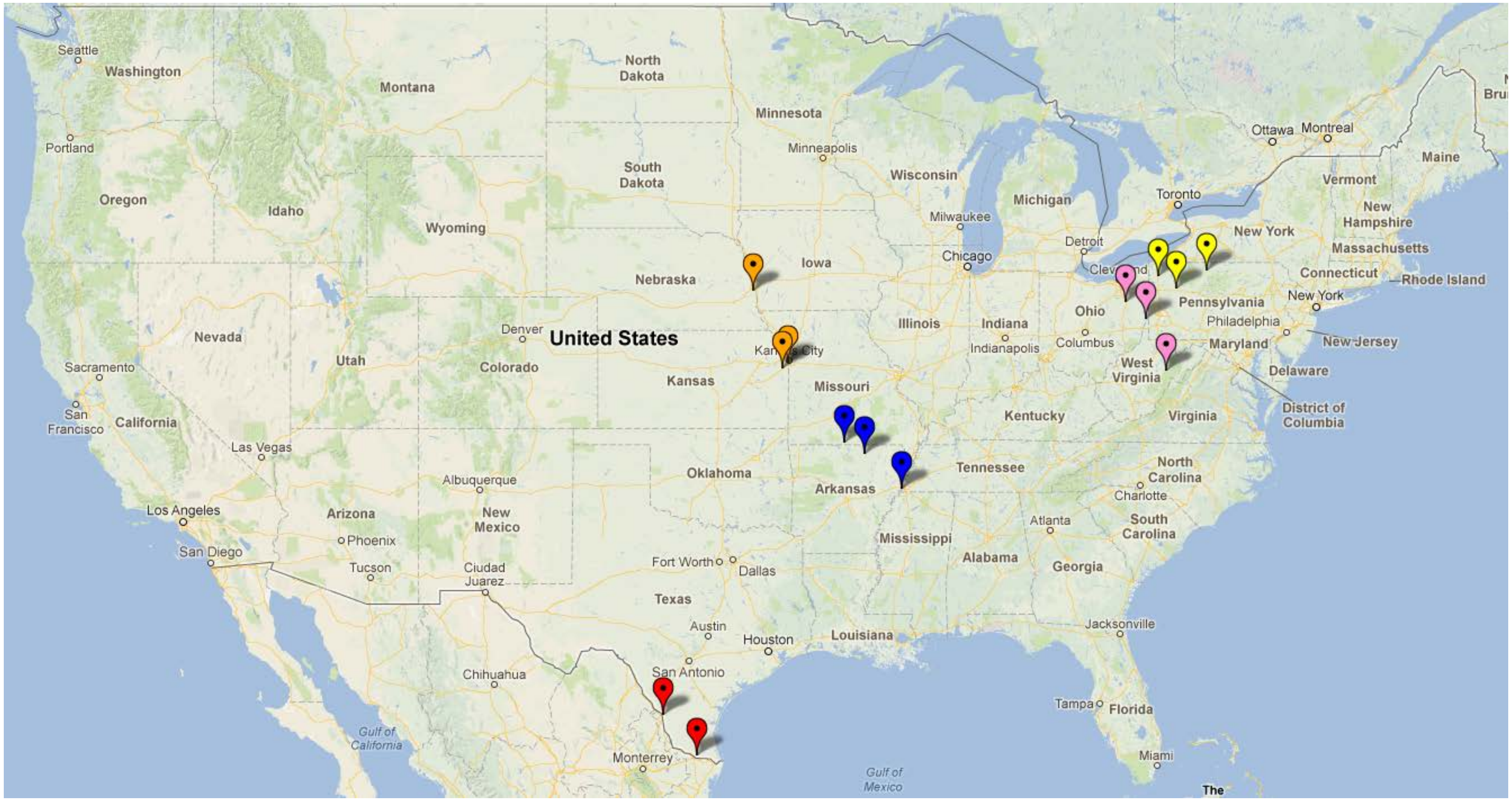


Total Distance: 1,321.17 miles

Total Cost: $1,681.30

Savings: $890.49

POST PROCESSING OUTPUT SAMPLE



Five Most Frequently Combined Vendor Groups for all RDCs

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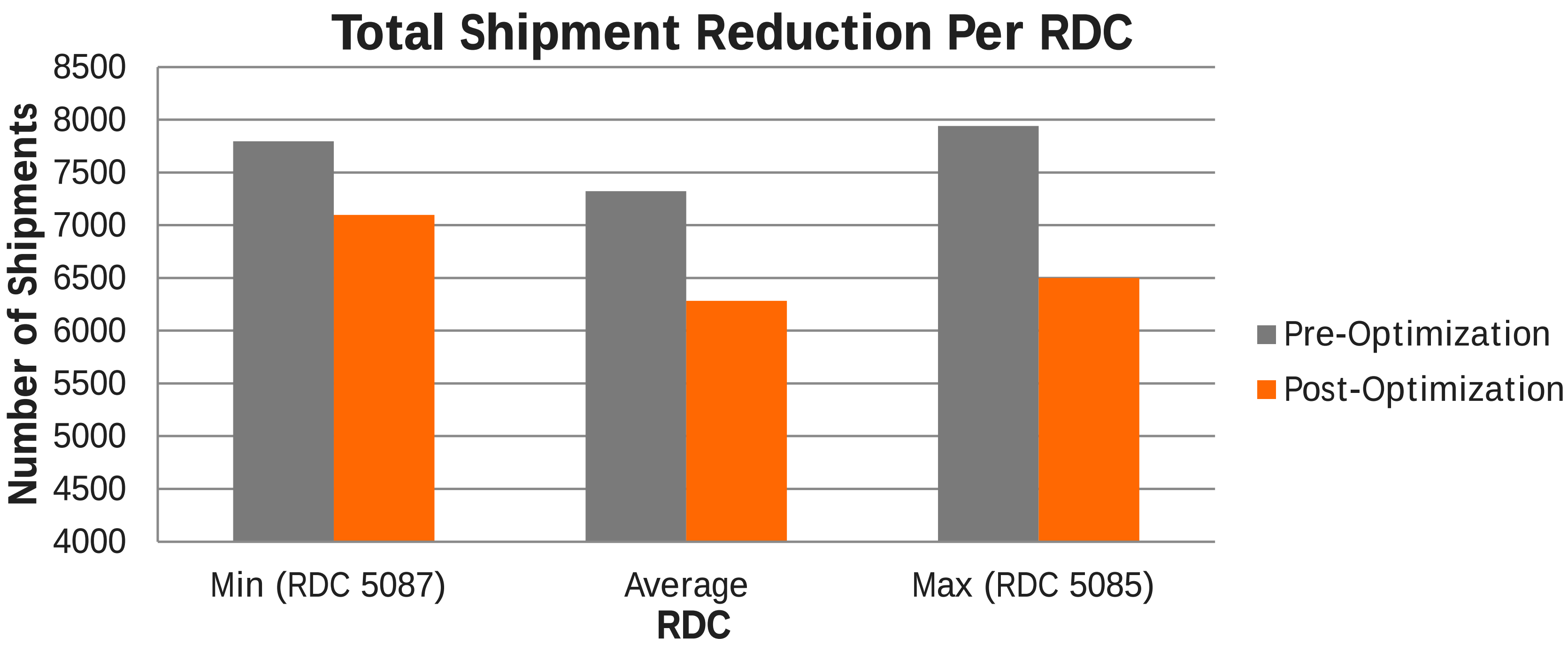
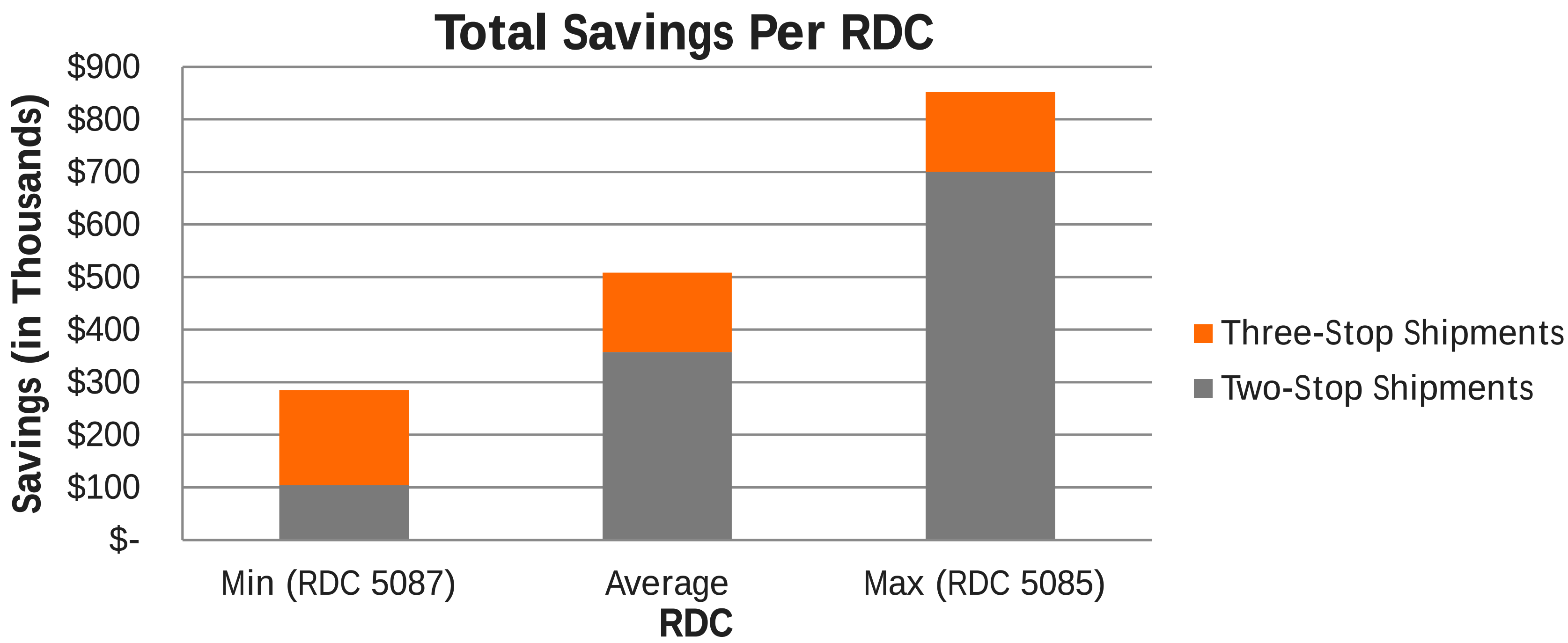
ANALYSIS



Number of Multi-Stop Pickups Per RDC

	2-Stops	3-Stops
Minimum	208	161
Average	620	209
Maximum	1121	309

ANALYSIS



Vendor Group Sizes Per RDC

	Groups of 3	Groups of 4	Groups of 5
Average	52	13	3
Total	940	240	53

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DELIVERABLE

State: **MO** | Vendor: **327123MO001**| RDC: **5023**

Inbound Vendor Coordination

State: **MO**

Vendor ID: **327123MO001** RDC: **5023**

Run Clear

Vendor Pairs and Triplets

A	B	C	Frequency	Savings
327123MO001	50920MO001	6366820KS001	12	$ 10,029.23
327123MO001	576006MO001	6366820KS001	5	$ 3,211.14
327123MO001	50920MO001	73755MO001	5	$ 5,725.12
14894KS001	327123MO001	6366820KS001	3	$ 1,111.71
327123MO001	50920MO001	801613MO001	3	$ 4,170.23
327123MO001	50920MO001	689130MO001	3	$ 1,986.08
-	327123MO001	6366820KS001	3	$ 1,679.69
-	10618NE001	327123MO001	2	$ 990.86

Vendor Groups

A	B	C	D	E	Group Size
327123MO001	50920MO001	6366820KS001	689130MO001	801613MO001	5
-	327123MO001	50920MO001	576006MO001	6366820KS001	4
-	327123MO001	50920MO001	6366820KS001	73755MO001	4
-	14894KS001	327123MO001	6366820KS001	689130MO001	4
-	-	10618NE001	327123MO001	801613MO001	3
-	-	327123MO001	689130MO001	817880MO002	3

SUMMARY

Problem:
< 2% of shipments are part of multi-stops

Design Strategy:
IP optimization model

Deliverable:
Excel tool of 1,233 vendor groups

Project Value:
14% of shipments are part of multi-stops
$9.1M in transportation cost savings

QUESTIONS

APPENDIX

MATLAB DATA PRE-PROCESSING

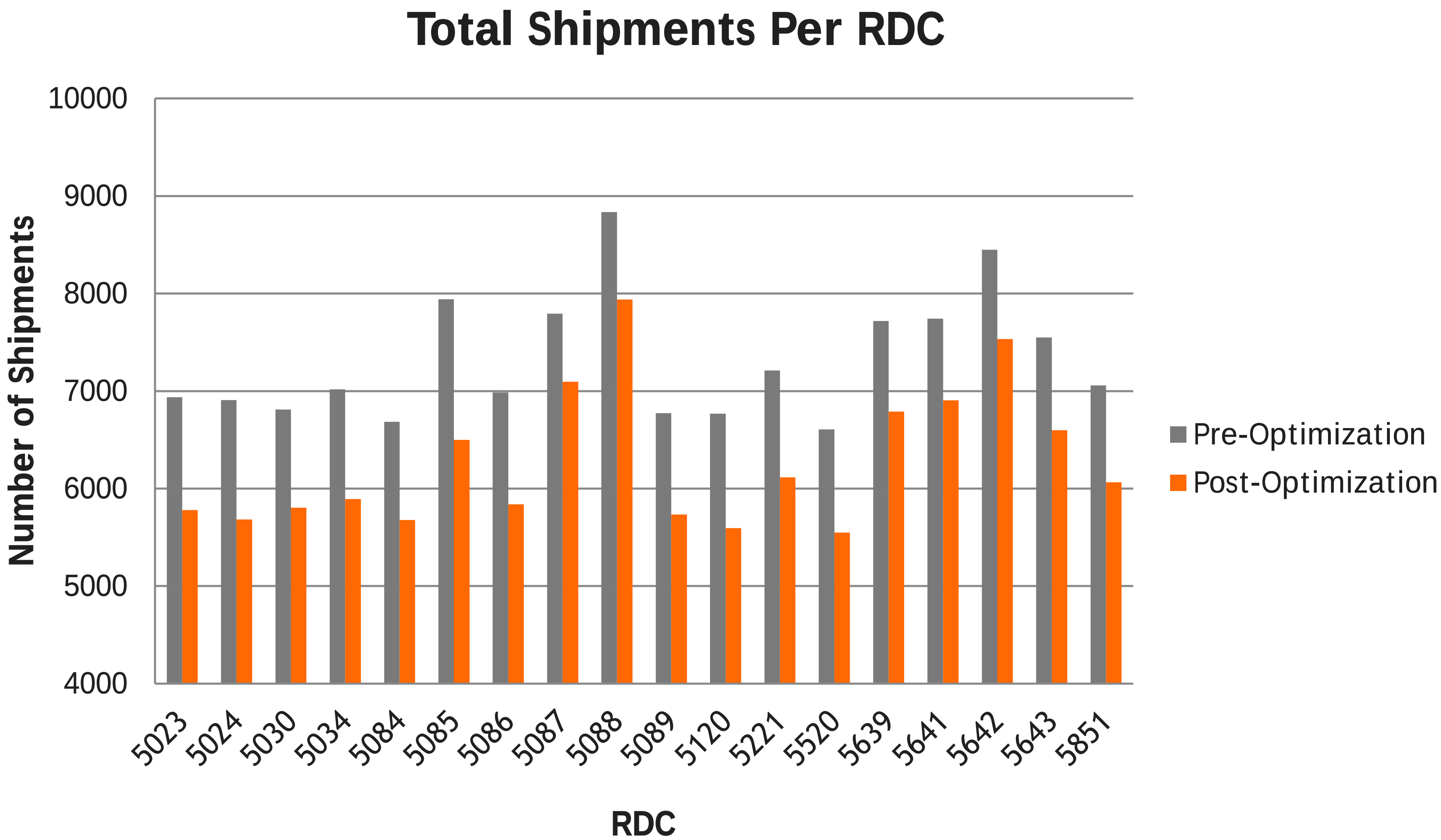
1. The distance between vendors that are combined is limited to 225 miles.
   a) For a two-stop from i to j: $distance_{i,j} < 225$
   b) For a three-stop from i to j and j to k: $distance_{i,j} + distance_{j,k} < 225$
2. The maximum weight that a 53-foot container can withstand is 42,000 pounds.
   a) For a two-stop combining shipments i and j: $weight_i + weight_j \leq 42{,}000$
   b) For a three-stop combining shipments i, j, and k: $weight_i + weight_j + weight_k \leq 42{,}000$
3. The maximum volume that a 53-foot container can withstand is 3,000 cubic feet.
   a) For a two-stop combining shipments i and j: $volume_i + volume_j \leq 3{,}000$
   b) For a three-stop combining shipments i, j, and k: $volume_i + volume_j + volume_k \leq 3{,}000$
4. The shipment date can move within the same calendar week as it is currently scheduled.
   a) For a two-stop combining shipments i and j:
      i. $week_i = week_j$
      ii. $year_i = year_j$
   b) For a three-stop combining shipments i, j, and k:
      i. $week_i = week_j = week_k$
      ii. $year_i = year_j = year_k$

OPTIMIZATION VARIABLES

- Data parameters
  - i = j = k = l = m = {shipments}
  - Ø = {RDC}
  - $s_{i,j}$: cost savings per truck if shipments i and j are combined
  - $s_{k,l,m}$: cost savings per truck if shipments k, l, and m are combined
  - $ORM_{i,j}$: $distance_{Ø,j} + distance_{i,j} – distance_{Ø,I}$
  - $ORM_{k,l,m}$: $distance_{Ø,m} + distance_{l,m} + distance_{k,l} – distance_{Ø,k}$

- Decision variables
  - $x_{i,j}$ = 1, if a truck drives directly from shipment i to shipment j
    0, otherwise
  - $x_{k,l,m}$ = 1, if a truck drives from the origin of shipment k to shipment m to shipment l
    0, otherwise

ANALYSIS



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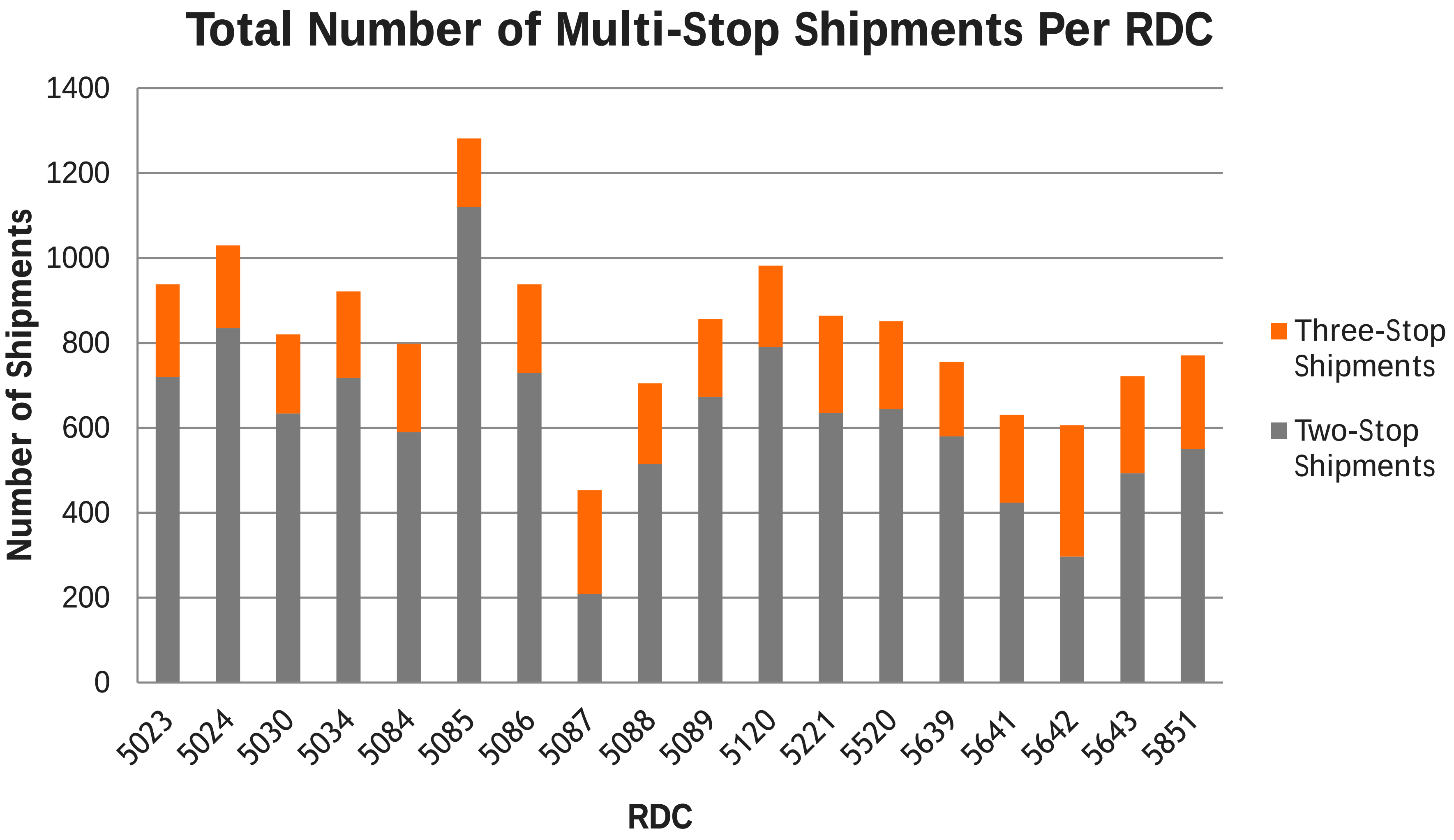
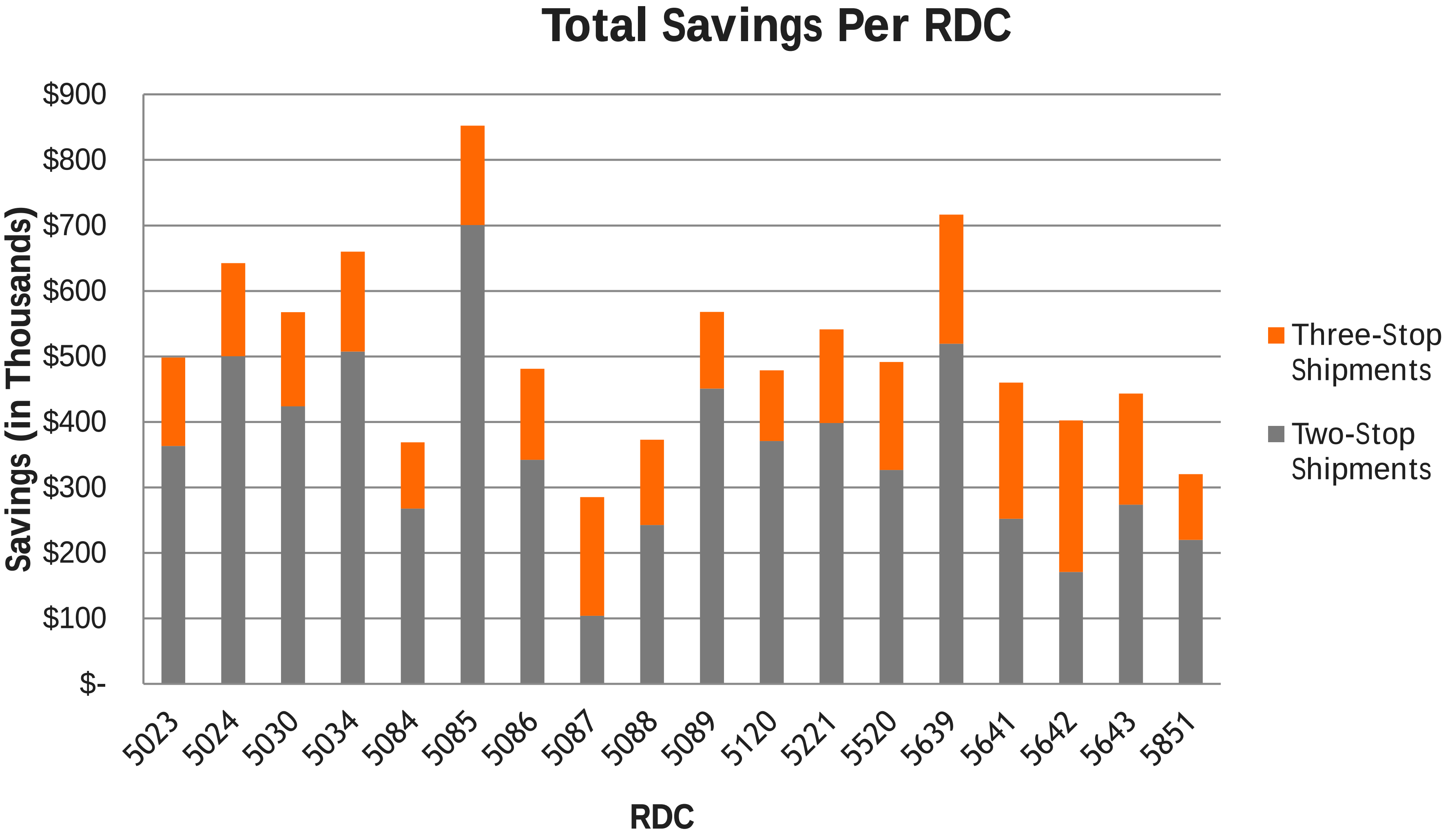


Total Number of Multi-Stop Shipments Per RDC
Number of Shipments
1400
1200
1000
800
600
400
200
0
5023
5024
5030
5034
5084
5085
5086
5087
5088
5089
5120
5221
5520
5639
5641
5642
5643
5851
RDC
Three-Stop Shipments
Two-Stop Shipments

ANALYSIS



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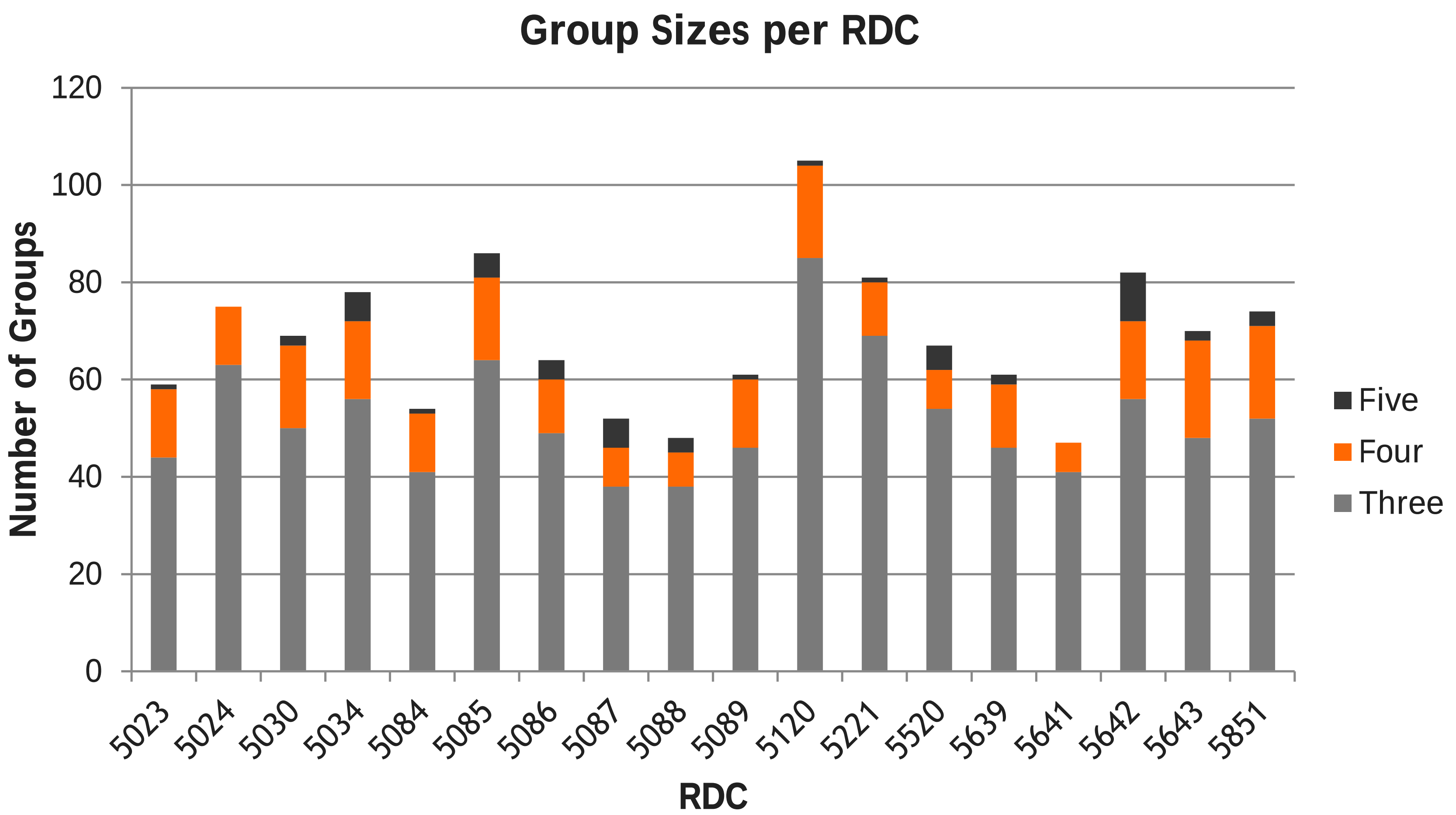
ANALYSIS



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HIGH FREQUENCY OPTIMIZATION MODEL

$$max\left\{\left(\sum_i\sum_j s_{i,j}x_{i,j} - \lambda_1 * \sum_a\sum_b y_{a,b}\right) + \left(\sum_k\sum_l\sum_m s_{k,l,m}x_{k,l,m} - \lambda_2 * \sum_c\sum_d\sum_e y_{c,d,e}\right)\right\}$$

s.t.

$$\sum_i\sum_j x_{i,j,k} + \sum_j\sum_l x_{j,k,l} + \sum_l\sum_m x_{k,l,m} + \sum_j x_{j,k} + \sum_l x_{k,l} \leq 1\forall k \qquad (1)$$

$$\sum_{\substack{i \\ v(i)=a}}\sum_{\substack{j \\ v(j)=b}} x_{i,j} + \sum_{\substack{i \\ v(i)=b}}\sum_{\substack{j \\ v(j)=a}} x_{i,j} \leq c_1 * y_{a,b} \qquad (2)$$

$$\sum_{\substack{k \\ v(k)=c}}\sum_{\substack{l \\ v(l)=d}}\sum_{\substack{m \\ v(m)=e}} x_{k,l,m} + \sum_{\substack{k \\ v(k)=c}}\sum_{\substack{l \\ v(l)=e}}\sum_{\substack{m \\ v(m)=d}} x_{k,l,m} + \sum_{\substack{k \\ v(k)=d}}\sum_{\substack{l \\ v(l)=c}}\sum_{\substack{m \\ v(m)=e}} x_{k,l,m} + \cdots$$

$$\sum_{\substack{k \\ v(k)=d}}\sum_{\substack{l \\ v(l)=e}}\sum_{\substack{m \\ v(m)=c}} x_{k,l,m} + \sum_{\substack{k \\ v(k)=e}}\sum_{\substack{l \\ v(l)=c}}\sum_{\substack{m \\ v(m)=d}} x_{k,l,m} + \sum_{\substack{k \\ v(k)=e}}\sum_{\substack{l \\ v(l)=d}}\sum_{\substack{m \\ v(m)=c}} x_{k,l,m} \leq c_2 * y_{c,d,e} \qquad (3)$$

$$x_{i,j} \in (0,1) \qquad (4)$$

$$x_{k,l,m} \in (0,1) \qquad (5)$$

$$y_{a,b} \in (0,1) \qquad (6)$$

$$y_{c,d,e} \in (0,1) \qquad (7)$$