BACKGROUND

Research Context

- **Large food and beverage retailer**: 13,000+ domestic stores
- **Distinct category:** Highly perishable, fresh foods



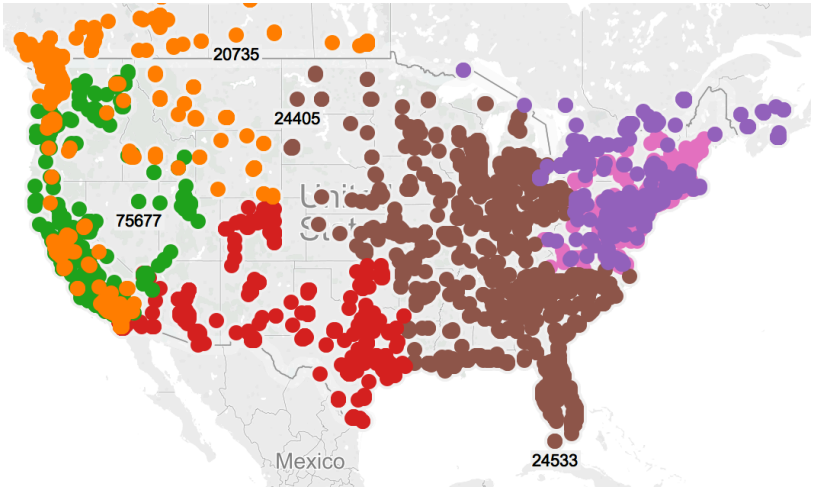

- **Growth expected:** While only 10% of volumes, 3-5x growth predicted in next few years

How should the fresh food supply network be designed to accommodate expected growth?

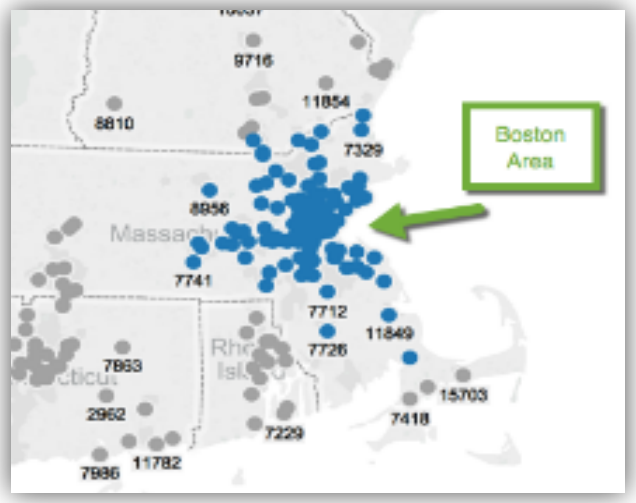
Pictures from: https://www.pexels.com/

Tough Problem

Massive Footprint



Complex Routing



Uncertain Future Conditions

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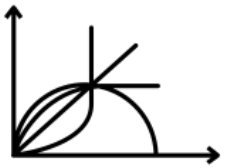
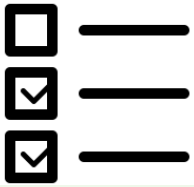
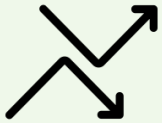
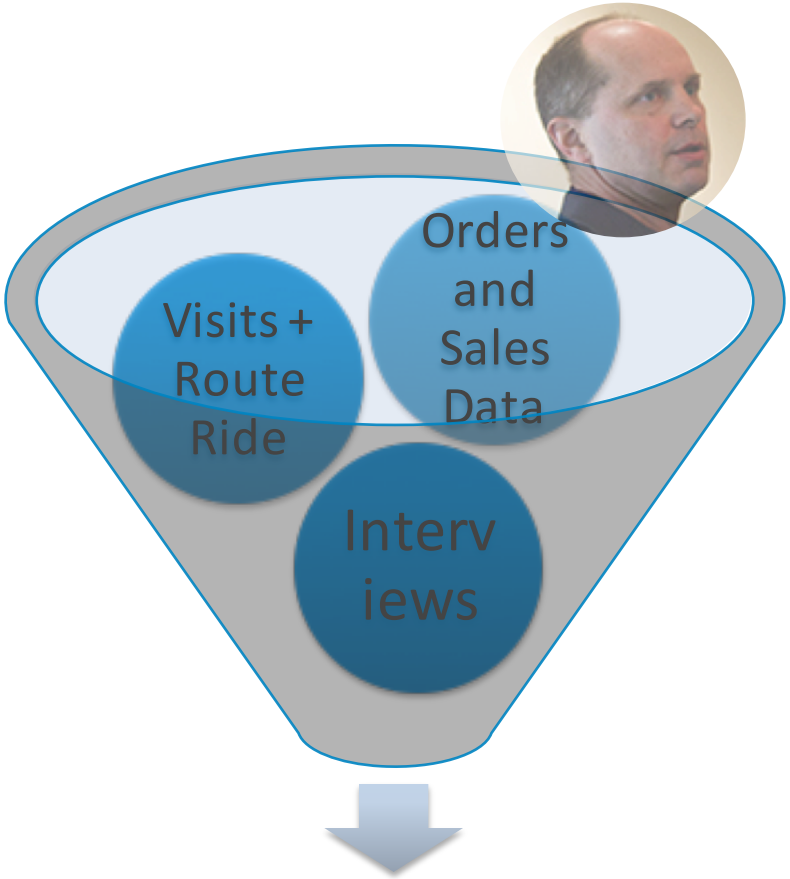
Which Approach to Use?

Methodology	Output	Requirements
Integer Programming or Simulation	Optimal Solution 	Precise Inputs 
Total cost approximation	Insights, and Tradeoffs 	Estimates, ranges 

MODELLING PROCESS

Data Collection / Research



Model Design & Assumptions

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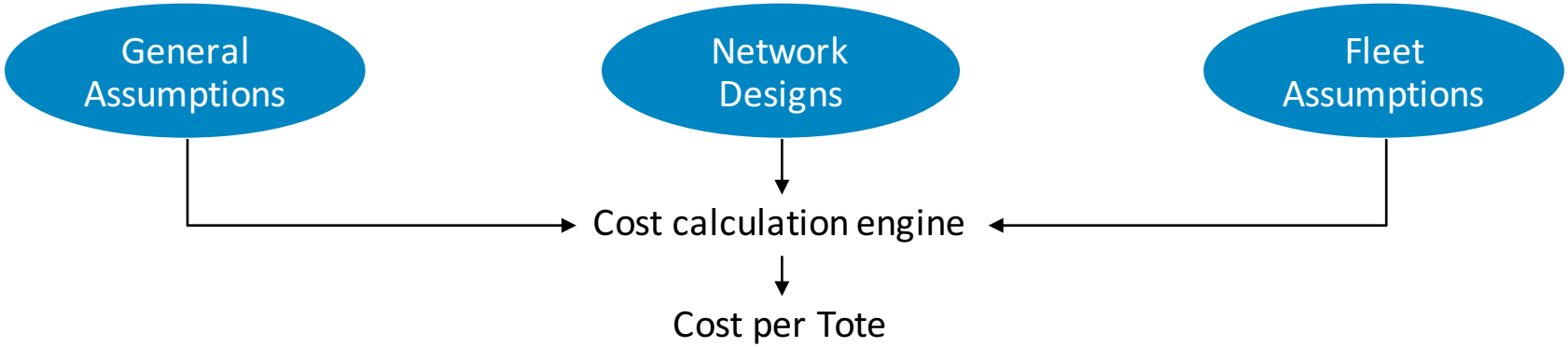
Model Design



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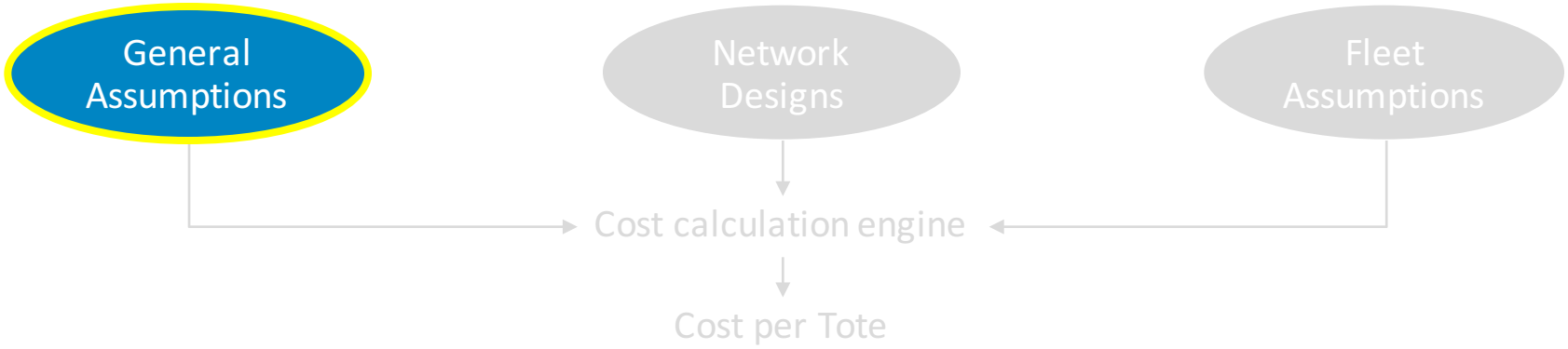
Model Design



Demand assumptions:

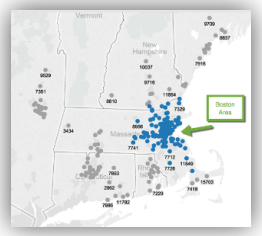
- Fresh food volumes
- Non-fresh food volumes
- Node locations
- Store count
- Delivery intervals
- Fuel, wage, etc. costs

21 Fresh Food Items / Tote

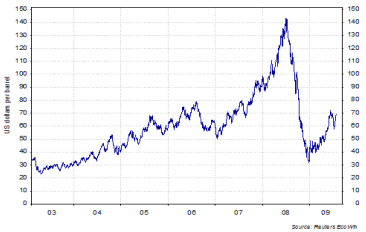
85k Fresh Food Totes / Yr

2-day Delivery Interval

~200 Stores



Diesel $2.1 / Gallon



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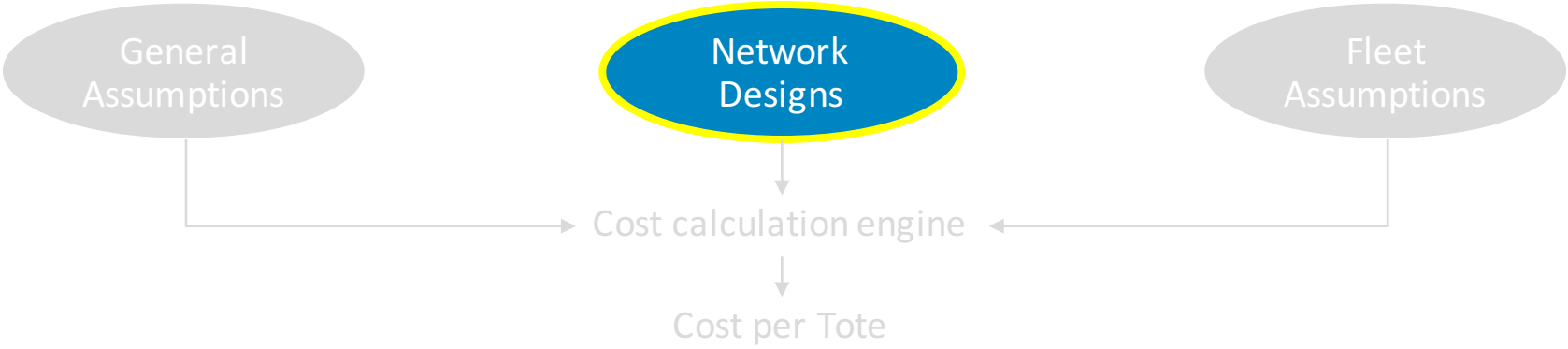
Model Design



1:1 Delivery (Trunk)

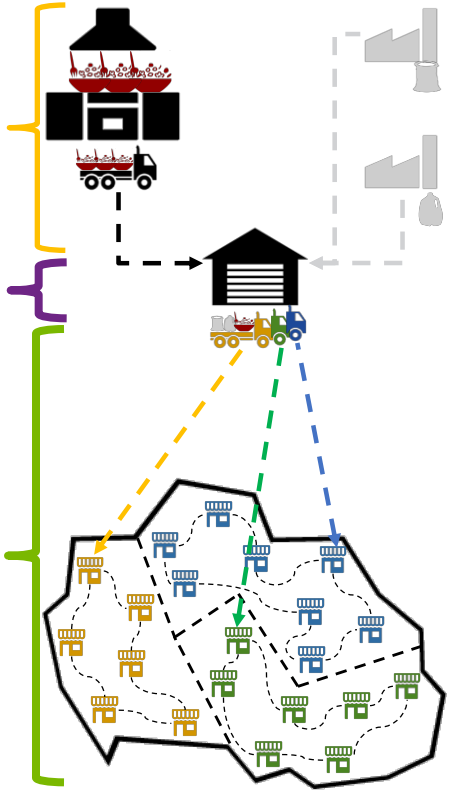
- Trunk Loading
- Trunk Linehaul
- Unloading

Crossdocking (Node)

- Sorting
- Holding

1: Many Delivery

- Branch Loading
- Branch Linehaul
- Store Tour
- Drop Fixed
- Drop FF Variable
- Drop Non-FF Variable



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Model Design

General Assumptions

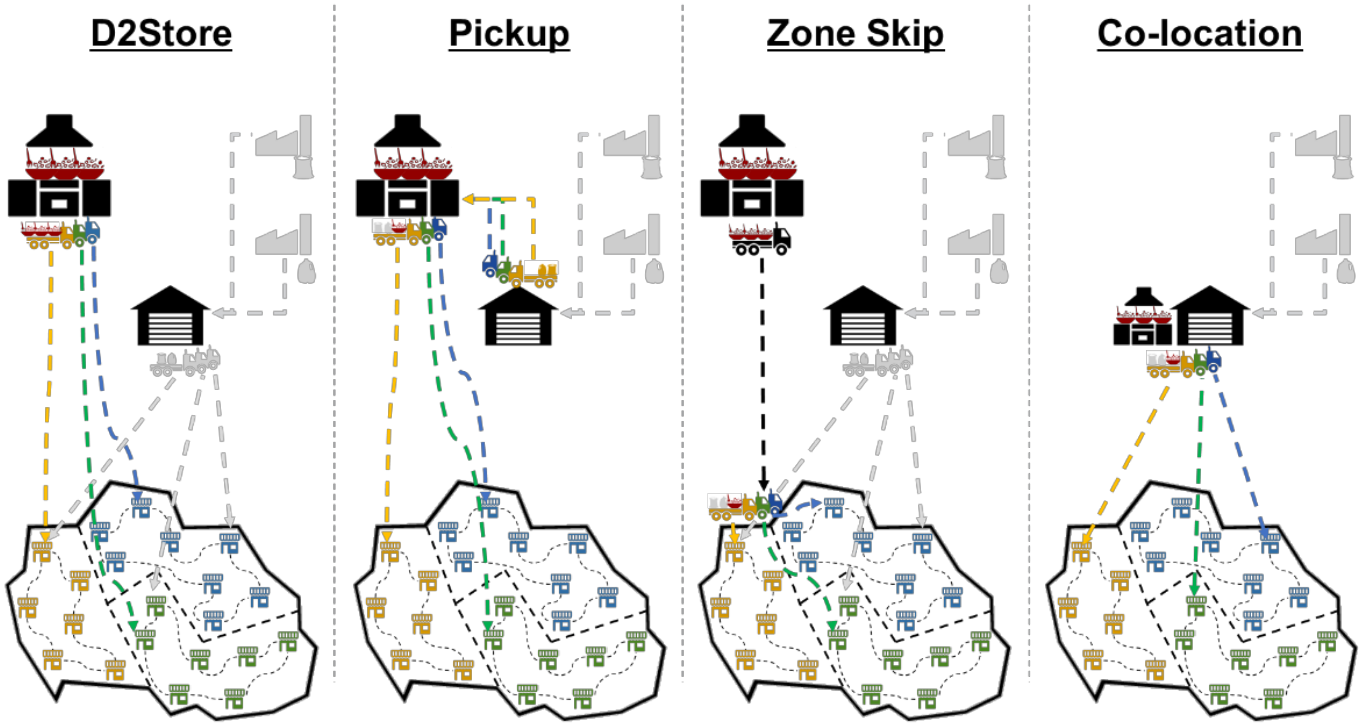
Network Designs

Fleet Assumptions

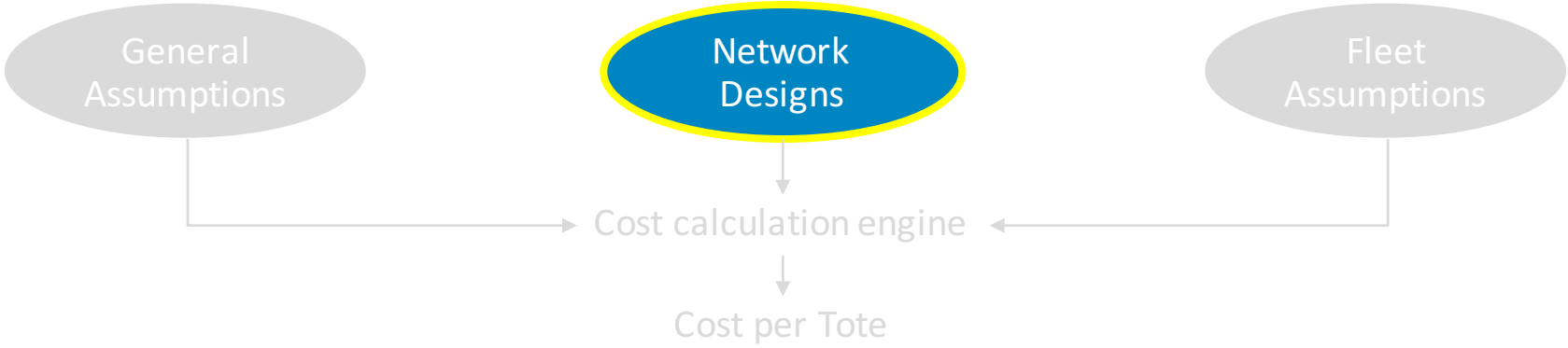
Cost calculation engine

Cost per Tote

Alternative Supply Networks



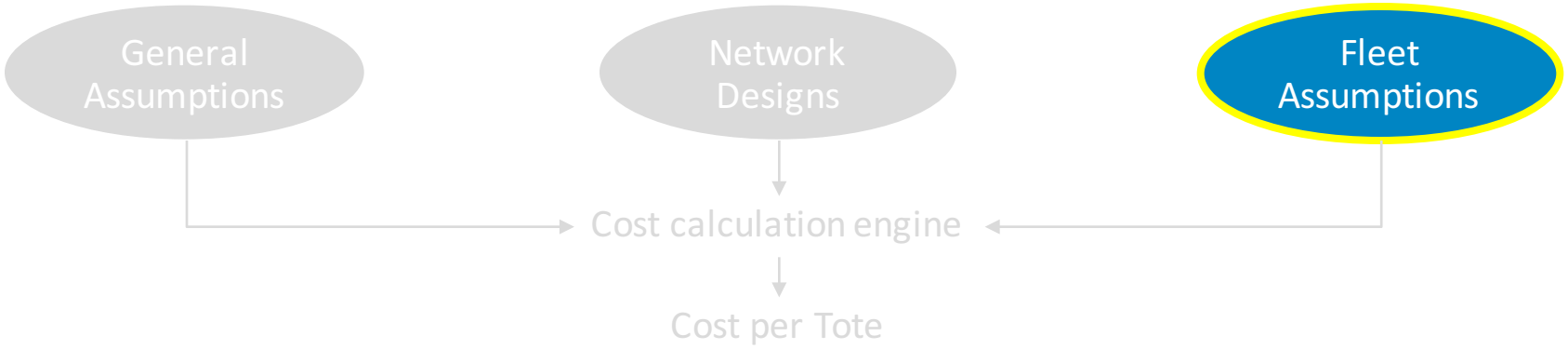
Model Design



Mapping Supply Activities to Network Designs

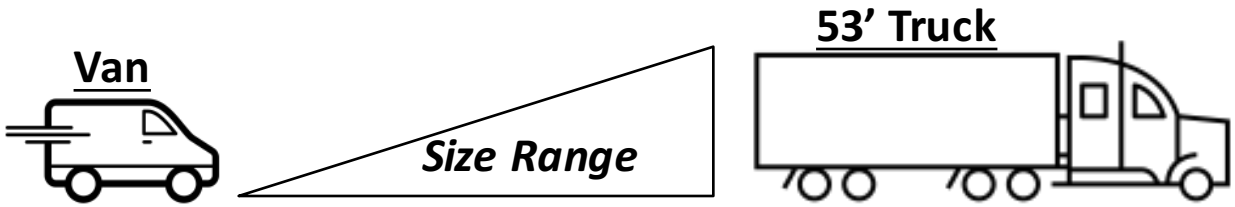
Activities:	Network Design: Current	D2Store	Pick-up	Zone Skip	Co-location
1:1 Delivery (Trunk)					
Trunk Loading	■			■	
Trunk Linehaul	■			■	
Unloading	■			■	
Crossdocking (Node)					
Sorting	■		■		■
Holding	■				
1:∞ Delivery (Branch)					
Branch Loading	■	■	■	■	■
Branch Linehaul	■	■	■		■
Store Tour	■	■	■	■	■
Drop Fixed	■	■	■	■	■
Drop FF Variable	■	■	■	■	■
Drop Non-FF Variable	■		■		■
Savings in Non-FF SC		■		■	

Model Design



Fleet assumptions:

- Range of vehicle options



- Assumptions per vehicle
  - *Tote Capacity*
  - *Driver Count & Wage*
  - *Speed (Hwy & City)*
  - *MPG (Hwy & City)*
  - *Equipment Hire Rate*
  - *Maintenance per mile*
  - *Annual Lease*

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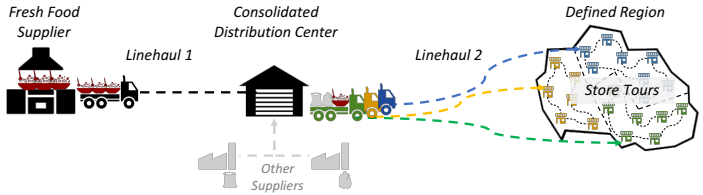
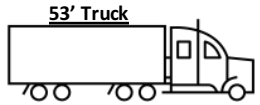
Model Design

General Assumptions

Network Design



Fleet Assumptions



Cost Calculations

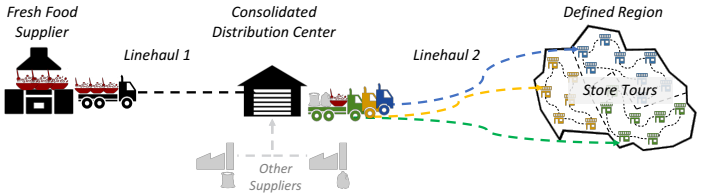
Activities:	Time & Dist Mins	Time & Dist Miles	Costs: Wage *(Time per Tote) * (# of Totes) * ($ per FTE) * (# of FTEs for Activity)*	Costs: Fuel *(Activity Travel Distance) * ($ per Gallon Fuel) * (# of Vehicles)*	Costs: Main *(Activity Travel Distance) * (Maint $ per Vehicle Mile) * (# of Vehicles)*	Costs: Lease *(Activity Travel Distance) * (Maint $ per Vehicle Mile) * (# of Vehicles)*
1:1 Delivery						
Trunk Loading						
Trunk Linehaul						
Unloading						
Crossdocking						
Sorting						
Holding						
1:∞ Delivery						
Branch Loading						
Branch Linehaul						
Store Tour						
Drop Fixed						
Drop FF Variable						
Drop Non-FF Variable						
Savings in Non-FF SC						

MIT Supply Chain MANAGEMENT

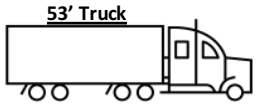
Model Design

General Assumptions

Network Design



Fleet Assumptions



Cost Calculations

Cost Category	Cost Calculation per Activity
Fuel	(Activity Travel Distance) * ($ per Gallon Fuel) * (# of Vehicles)
Wage	(Time per Tote) * (# of Totes) * ($ per FTE) * (# of Vehicles) * (Drivers / Vehicle
Maintenance	(Activity Travel Distance) * (Maint $ per Vehicle Mile) * (# of Vehicles)
Lease	(Activity Travel Distance) * (# of Vehicles) * (Lease $ per mile)

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Model Design: Distance Approximation

Linehaul Distance

Supplier, DC, City Center Coordinates

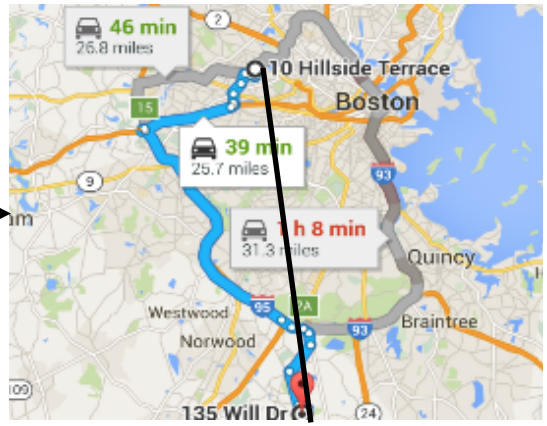
Great Circle Distance

*

Regional Circuity Factor

=

Linehaul Distances



Tour Distance

Sqrt(Stores x Region Area)

*

Travelling salesman factor

=

Total Tour Distance

---

*sqrt[~100 stores daily * 2,500mi2]*

*

0.765

=

350 miles to tour daily stores

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Model Design: Approximating Fleet Size

1. **Volume:** A truck can only carry so many totes.

   Min Trucks Required = Total Daily Demand / Truck Capacity

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= Travel time + Unloading time

*stores * (fixed + variable stopping time)*

*Tour distance * speed*

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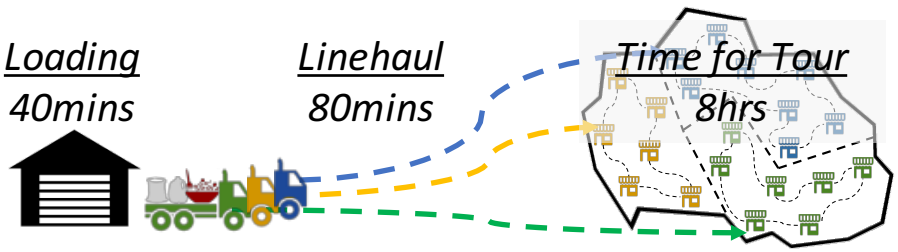
= Travel time + Unloading time

- *stores * (fixed + variable stopping time)*
- *Tour distance * speed*

10hrs – loading – linehaul – backhaul



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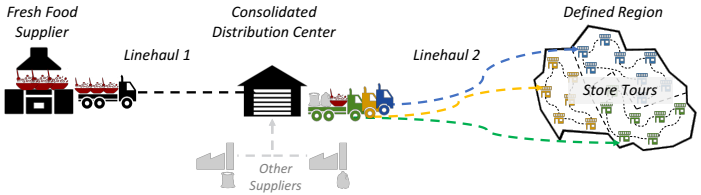
Fleet Size = Larger of Time & Volume Requirements

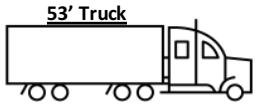
Model Design

General Assumptions

Network Design



Fleet Assumptions

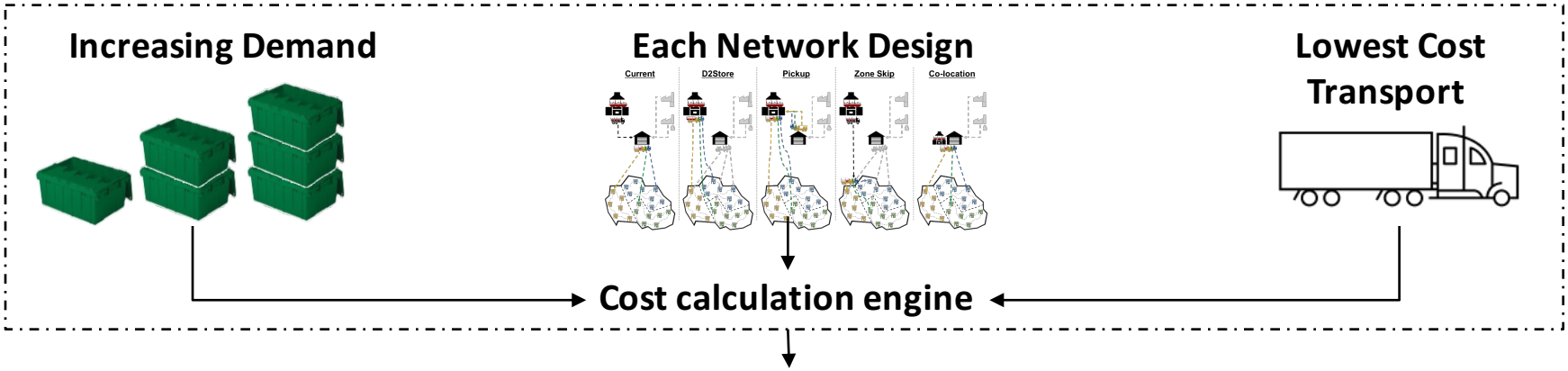


Cost Calculation Engine

	Time & Dist		Costs			
Activities:	**Mins**	**Miles**	**Wage**	**Fuel**	**Main**	**Lease**
			*(Time per Tote) * (# of Totes) * ($ per FTE) * (# of FTEs for Activity)*	*(Activity Travel Distance) * ($ per Gallon Fuel) * (# of Vehicles)*	*(Activity Travel Distance) * (Maint $ per Vehicle Mile) * (# of Vehicles)*	*(Activity Travel Distance) * (Maint $ per Vehicle Mile) * (# of Vehicles)*
1:1 Delivery						
Trunk Loading						
Trunk Linehaul						
Unloading						
Crossdocking						
Sorting						
Holding						
1:∞ Delivery						
Branch Loading						
Branch Linehaul						
Store Tour						
Drop Fixed						
Drop FF Variable						
Drop Non-FF Variable						
Savings in Non-FF SC						

Model Design: Cost per Tote

Light model allows for rapid scenario testing:



Total Cost / Tote

Annual Demand	Current	D2Store	Pick-up	Zone Skip	Co-location
1.0x	$3.15	$7.03	$5.01	$6.50	$1.75
1.5x	$2.71	$4.09	$4.04	$3.95	$1.68
1.6x	$3.70	$3.88	$3.86	$4.71	$1.65
1.7x	$3.13	$3.92	$3.70	$4.16	$1.68
1.8x	$3.02	$3.74	$3.56	$3.96	$1.65
1.9x	$2.93	$3.58	$3.50	$3.78	$1.63
2.0x	$2.84	$3.44	$3.39	$3.63	$1.60
4.4x	$2.30	$2.55	$2.73	$2.48	$1.60
4.5x	$2.28	$2.51	$2.70	$2.44	$1.60
4.6x	$2.29	$2.28	$2.79	$2.18	$1.62
4.7x	$2.66	$2.25	$2.76	$2.50	$1.62
4.8x	$2.64	$2.47	$2.73	$2.72	$1.62
4.9x	$2.62	$2.44	$2.71	$2.68	$1.62
5.0x	$2.46	$2.23	$2.68	$2.29	$1.62

*All assumptions and network designs can be rapidly tested as above to generate key **insights**.*

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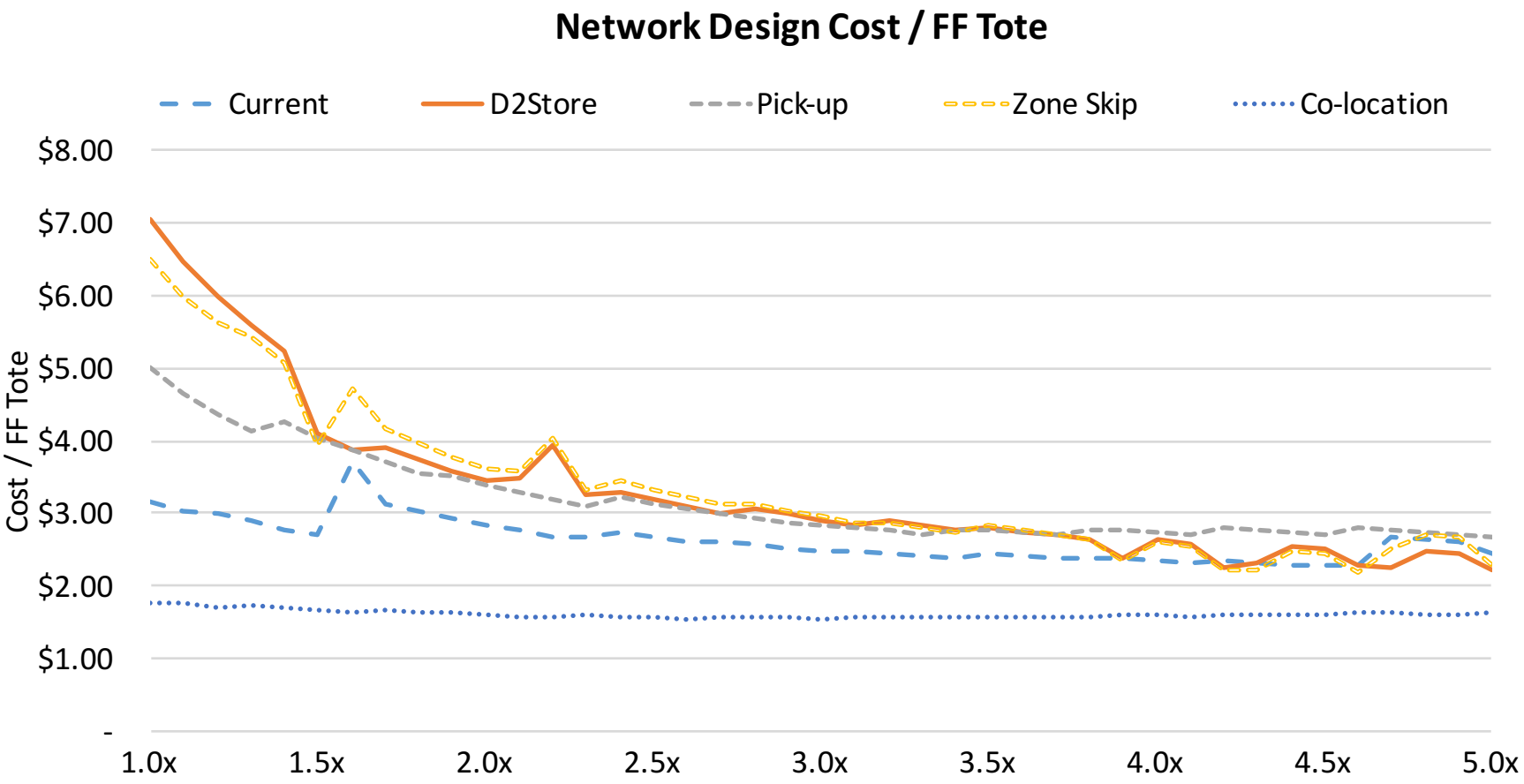
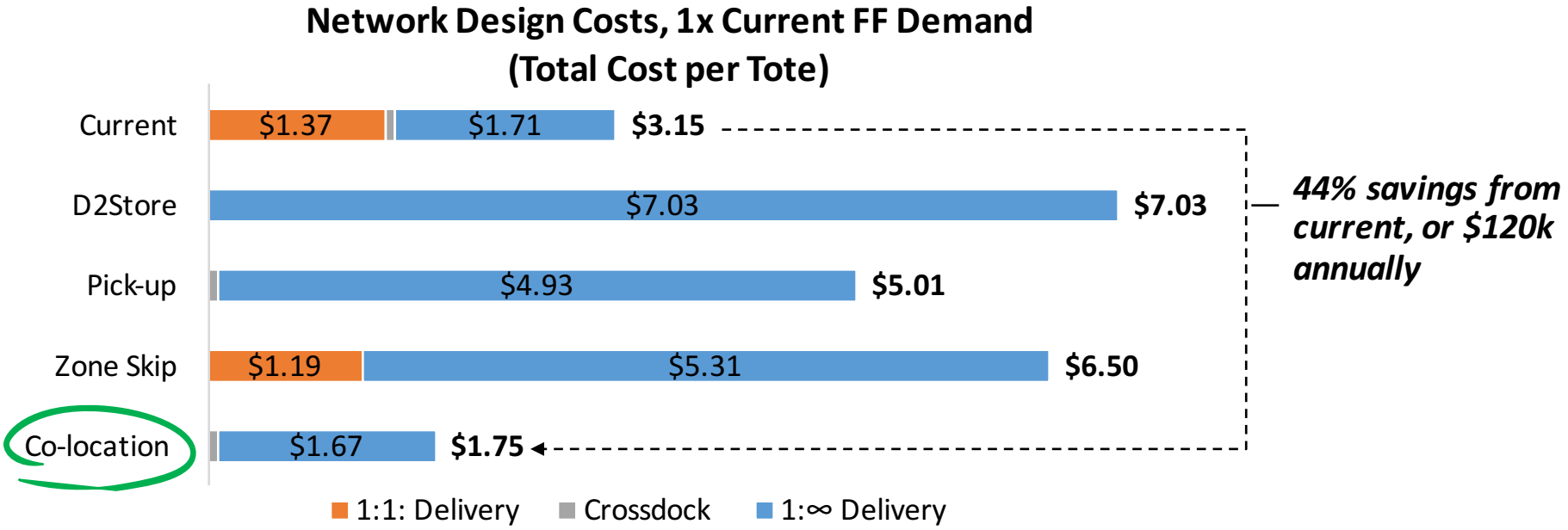
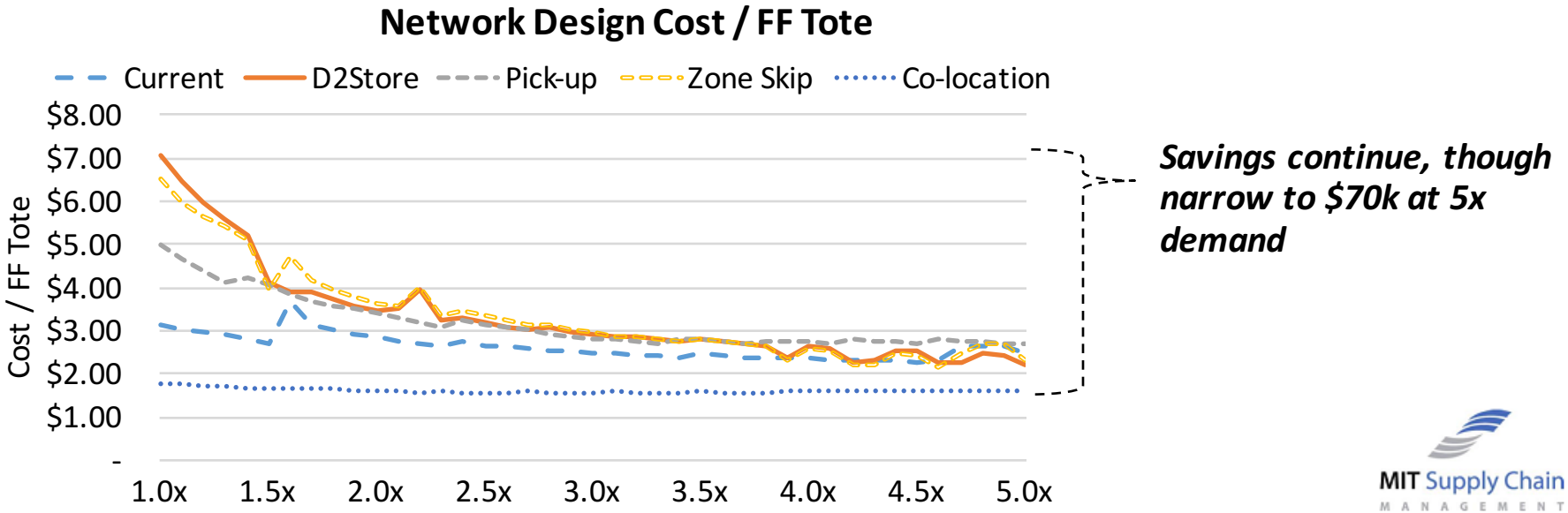
RESULTS & INSIGHTS

High-Level Results: Network Costs with Increasing Demand



Insight 1: Co-Location Saves





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Insight 1: Co-Location Saves

Further points for investigation:

- Over 5 years, the estimated savings of co-location will be ~$425,000…

  ….*Are the costs of moving the supplier to the DC justified?*

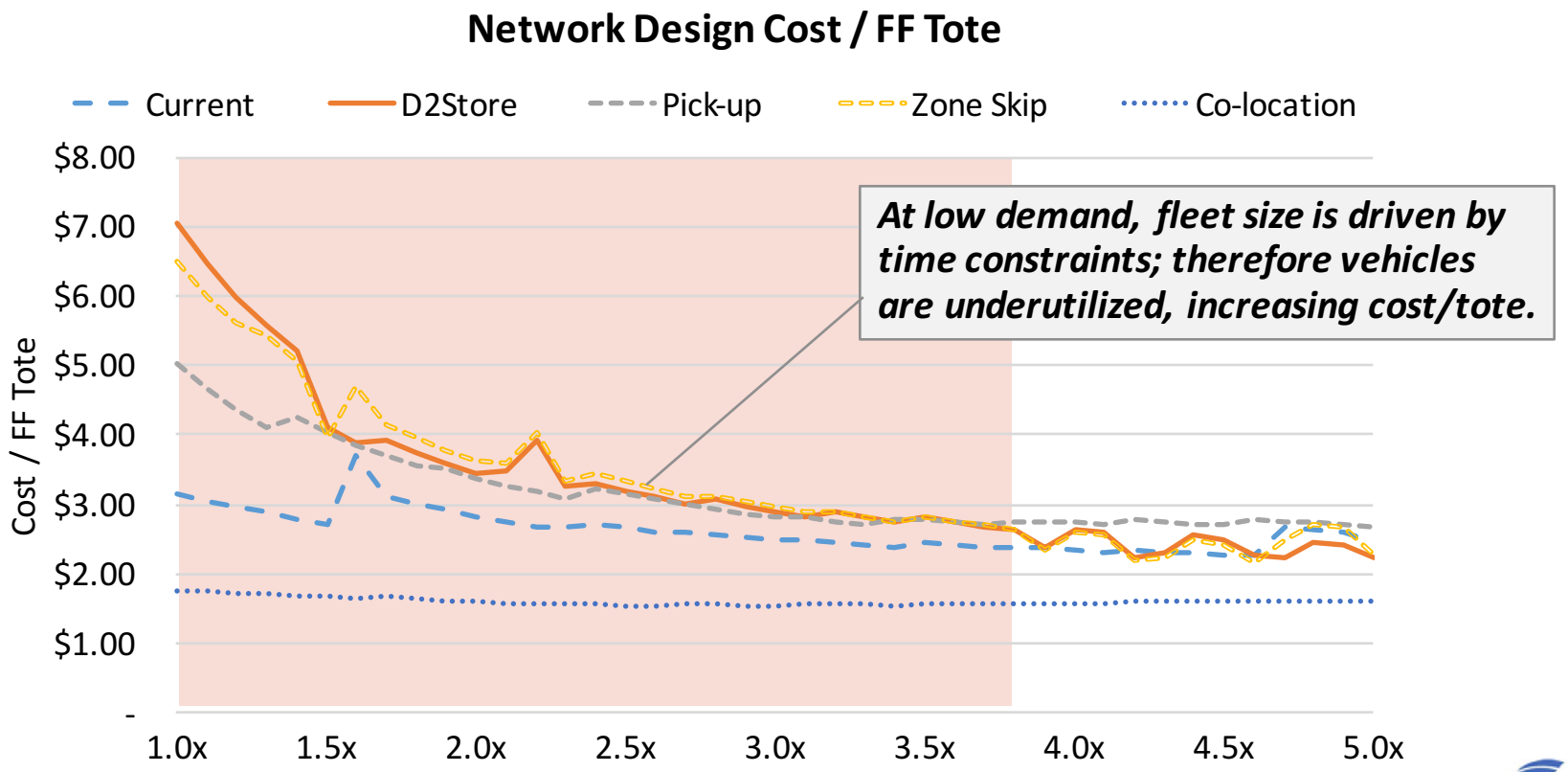
- Supplier co-location with one DC may increase costs to other regional DCs…

  ….*Which regional DC merits co-location?*

Insight 2: Dedicated Supply Networks Lack Economies of Scale

Dedicated supply networks only make financial sense once fresh food demand approaches 4.0x current levels.

Why? Trucks are underutilized at low demand levels:



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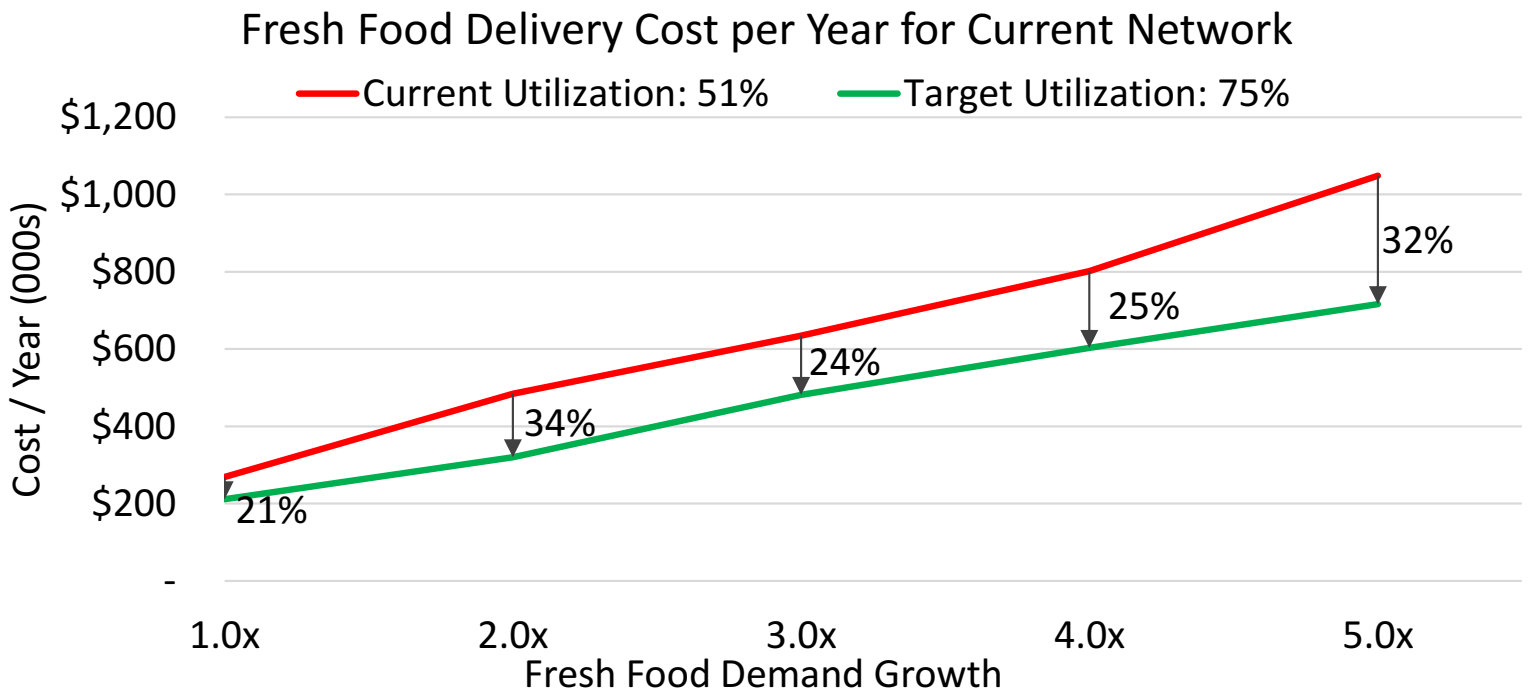
Insight 3: Tote Utilization Impacts Costs

- **At 21 items per tote, average utilization is only 51%**
- **Denser packing and/or smaller tote sizes can achieve savings**



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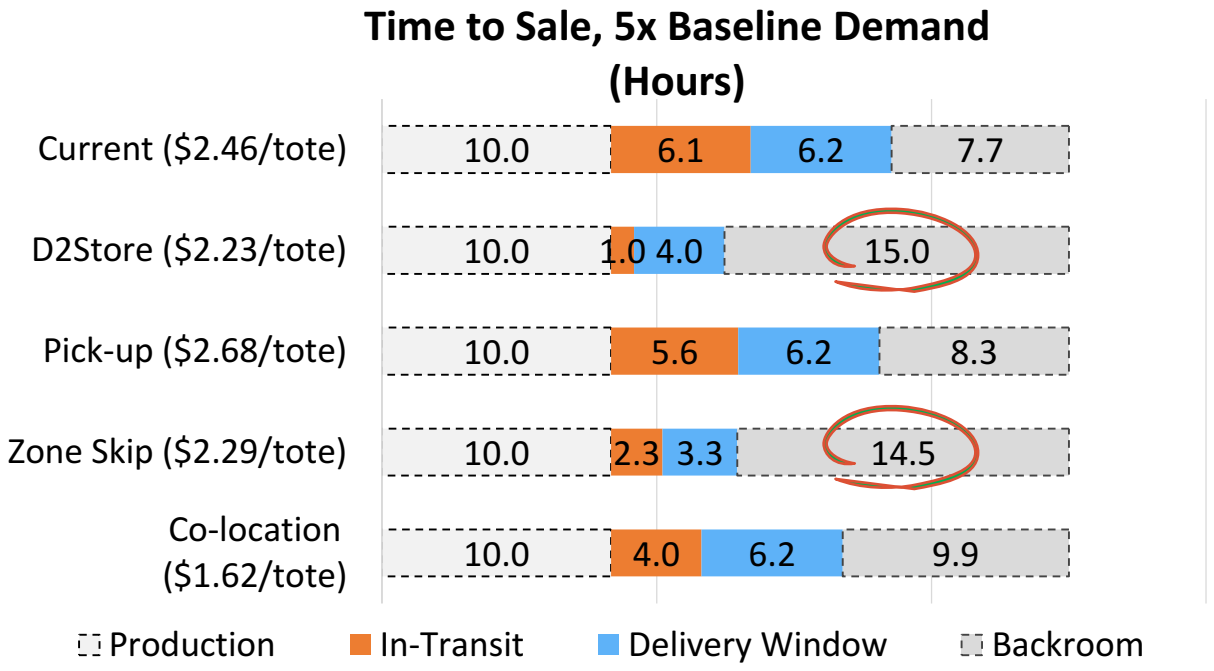
Insight 4: Cost vs Time

Selecting vehicles for speed – instead of cost – can reduce store deliveries by 6 hours at a 15-18% premium.



Does faster mean fresher? Despite faster delivery, time-to-customer will *not* be reduced <u>given current production schedules</u>

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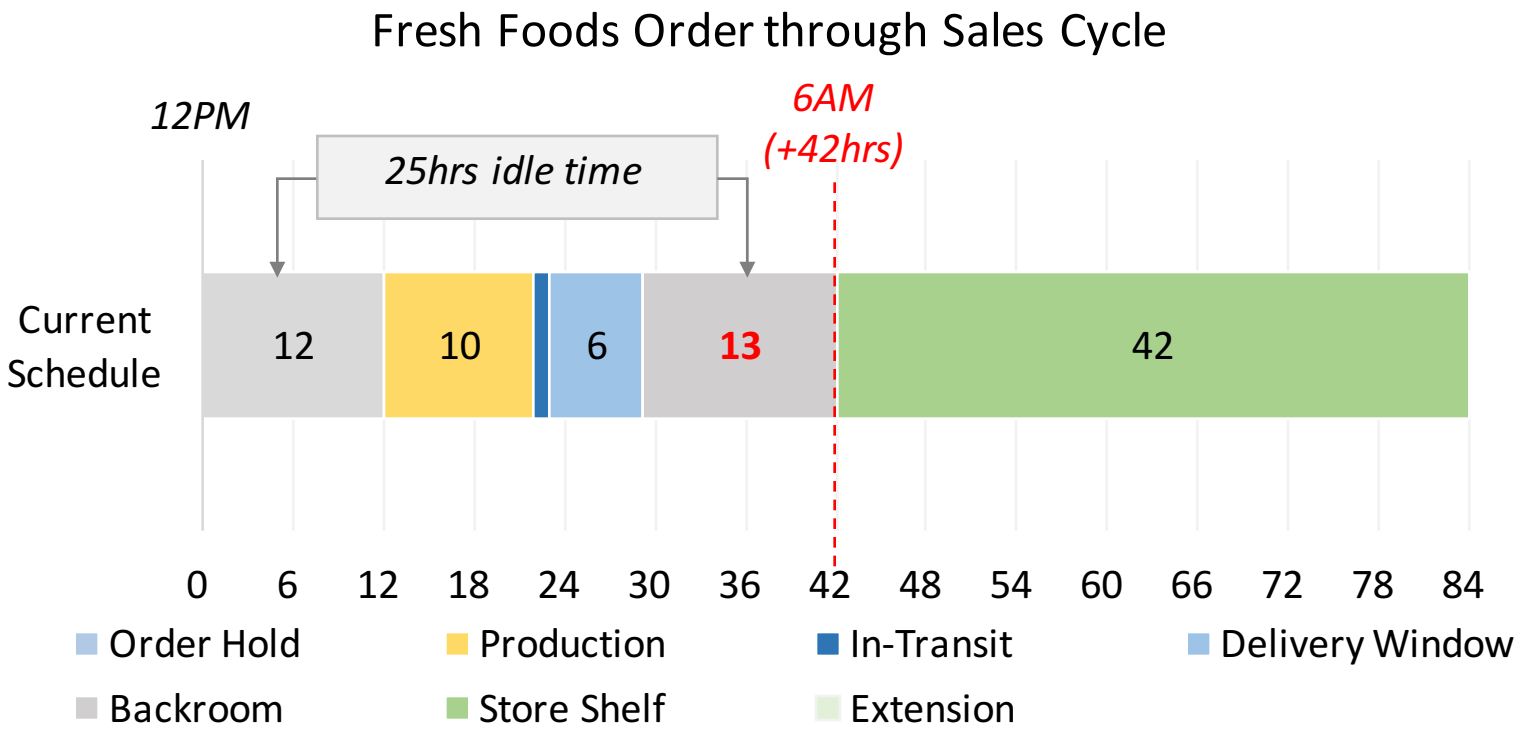
Insight 5: Policy Impacts on Freshness

Current policy to delay production leaves fresh product out of customer reach for up to 13 hours:



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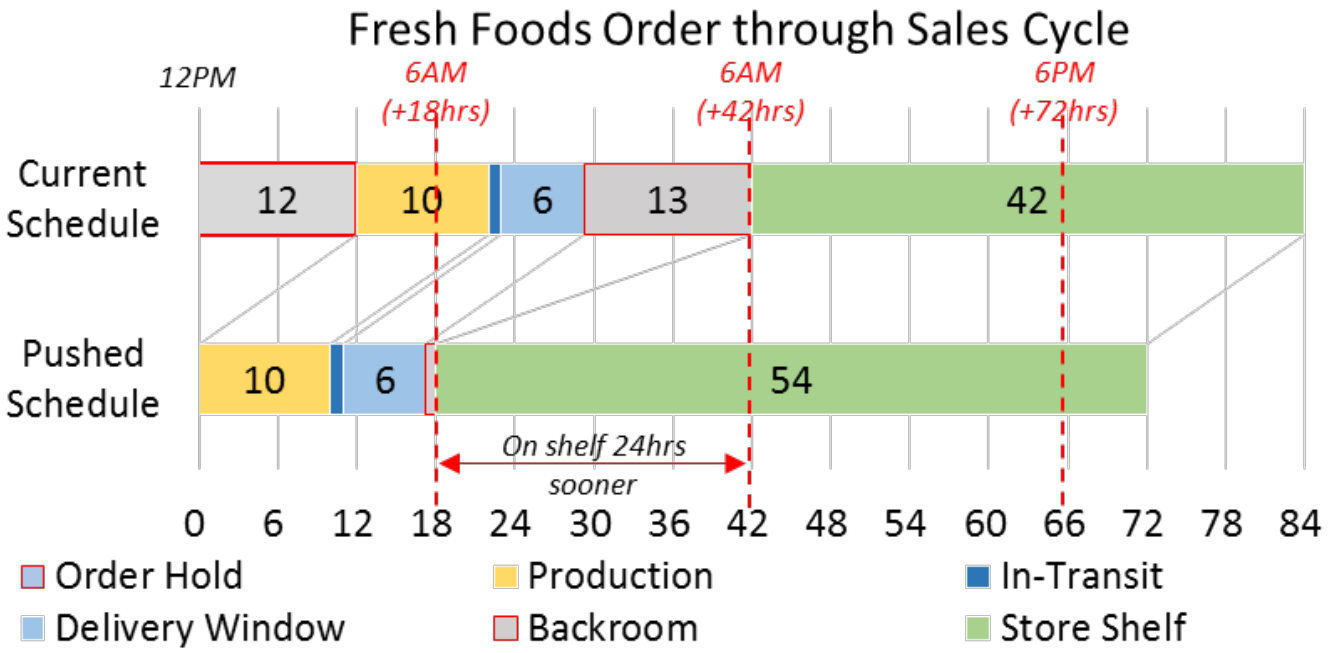
Insight 5: Policy Impacts on Freshness

Rapid delivery + Immediate Production Policy =

- **Product on-shelf 24 hours earlier**
- **13 hours fresher**



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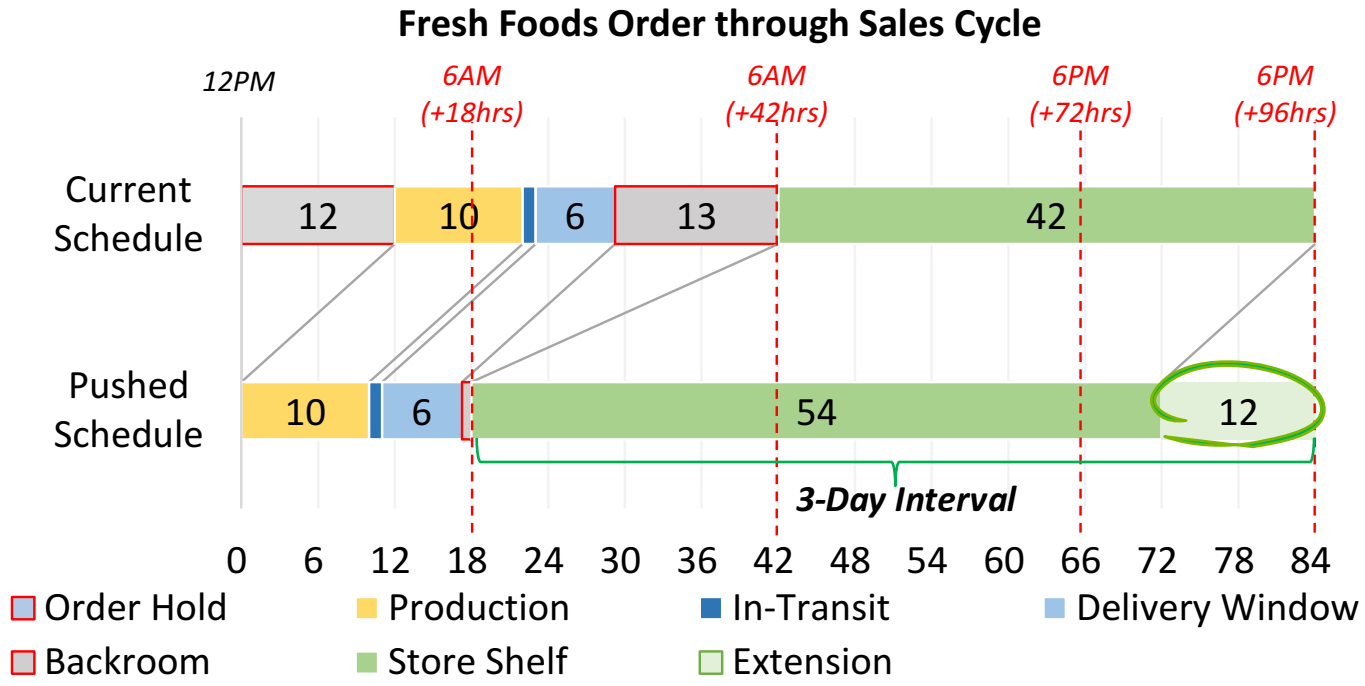
Insight 6: Longer Delivery Intervals are Possible

Rapid delivery + Immediate Production Policy **+ 12-Hour Shelf-life Extension =**

- Product on-shelf 24 hours earlier
- 12 hours fresher
- **3-Day Delivery Interval**



Impact: D2Store comparable to Current network design cost at 3x Demand.

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Conclusion: The Approximation Model

Generates Insights & Trade-Offs:

- Co-Location is the lowest cost option
- Dedicated supply network costs will drop with economies of scale
- Improving tote utilization saves costs
- Speed gains are possible with limited cost increases
- Better freshness is achievable with revised policies
- Delivery intervals can be extended

First-Cut for Further Analysis:

- Optimization methods
- Operational studies
- Pilots

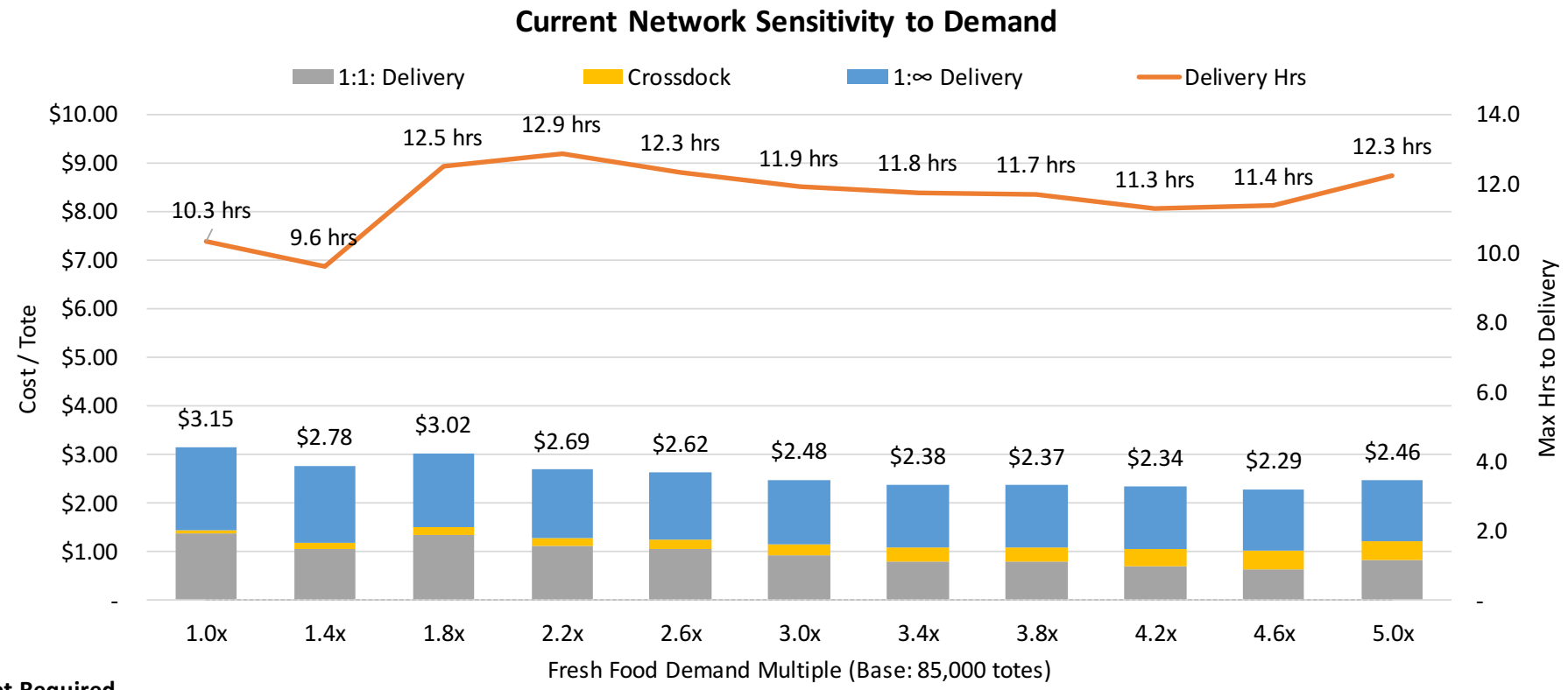
Extendable:

- Additional regions
- Alternative network designs
- Other companies or products

Questions, Comments, Suggestions?
Use the Discussion!

BACK – UP SLIDES

High-Level Results: Current Design



Fleet Required

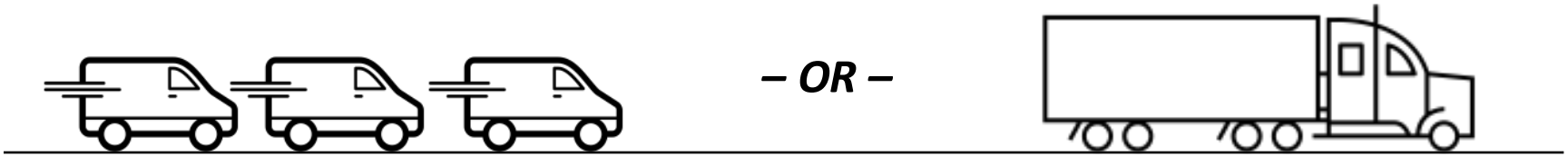
1:1 - # x Size	1 x '36	1 x '48	2 x '26	2 x '26	2 x '36	2 x '36	2 x '36	2 x '48	2 x '48	2 x '48	3 x '36
1:∞ - # x Size	9 x '26	11 x '26	8 x '48	8 x '48	9 x '48	10 x '48	11 x '48	12 x '48	14 x '48	15 x '48	14 x '53

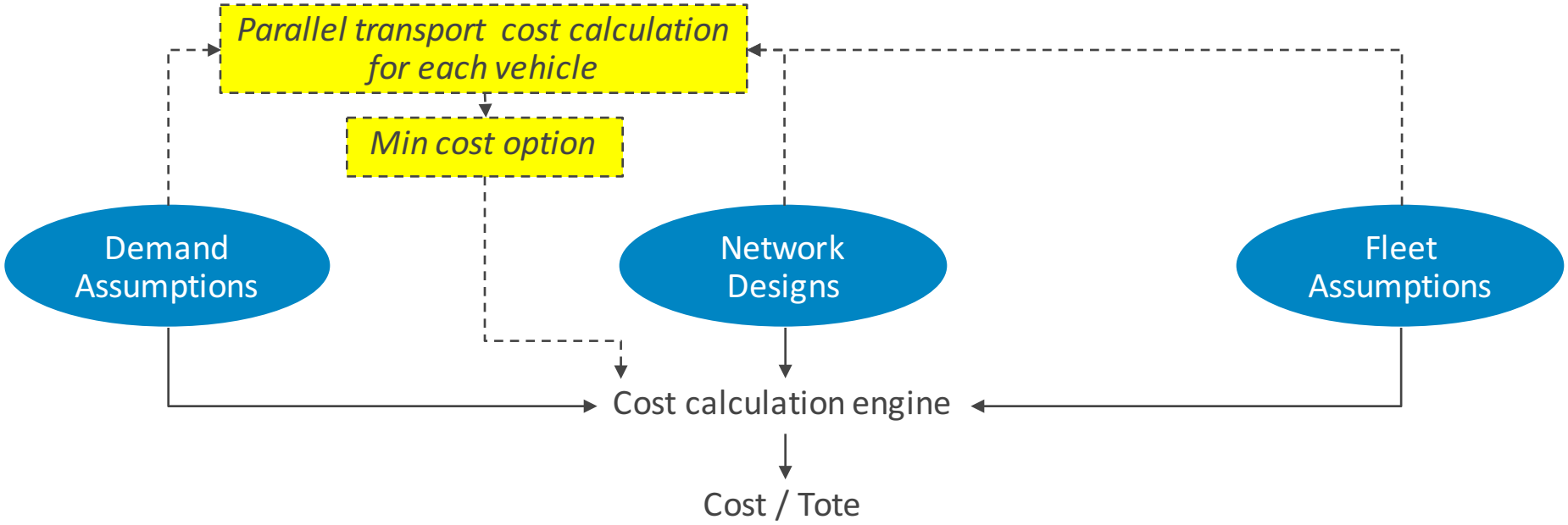
Fleet Assumptions

Equipment		Vans	'26 Truck	'36 Truck	'48 Truck	'53 Truck
Total Pallet Capacity	*pallets / equipment*	2.9	12.0	18.0	24.0	26.0
Tote Capacity	*totes / equipment*	86	360	540	720	780
Drivers	*per equipment*	2.0	2.0	2.0	2.0	2.0
Driver Wage	*$ / hour*	$12.0	$16.0	$18.0	$18.0	$18.0
Highway Speed	*miles / hr*	50.0	50.0	50.0	50.0	50.0
City Speed	*miles / hr*	20.0	20.0	15.0	15.0	15.0
Fuel Consumption (Hwy)	*miles / gallon*	16.7	7.7	7.1	6.7	6.7
Fuel Consumption (City)	*miles / gallon*	16.7	7.7	7.1	6.7	6.7
Equipment Hire Rate	*$ / mile*	$3.0	$8.5	$10.0	$10.0	$10.0
Vehicle Maintenance	*$ / mile*	$1.0	$1.0	$1.0	$1.0	$1.0
Vehicle Annual Lease	*$ / equipment*	$13,333.3	$60,000.0	$70,000.0	$80,000.0	$90,000.0

Model Design: Vehicle Selection using Parallel Calculation

Which option is most efficient?





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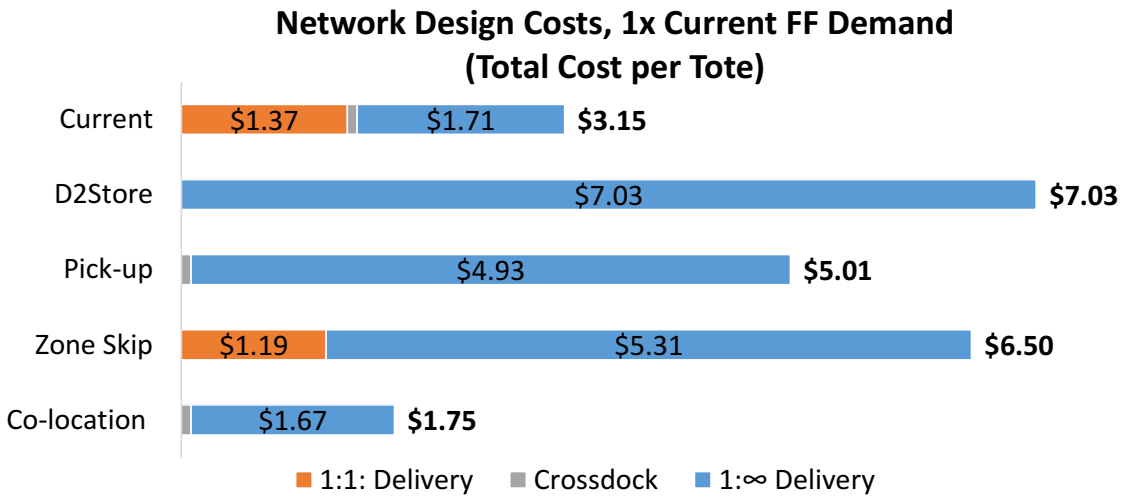
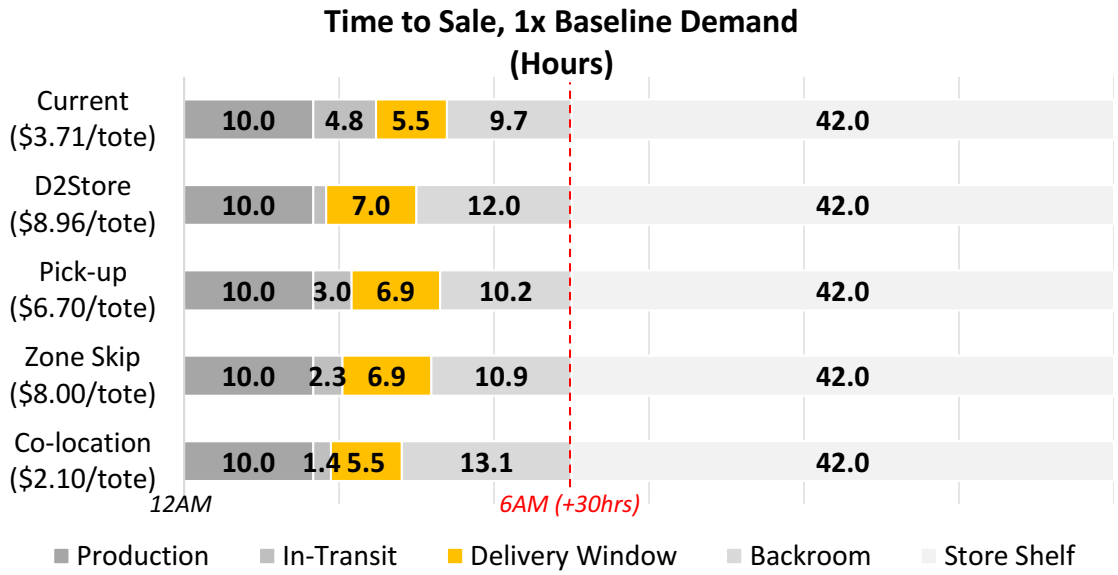
Results under Baseline Conditions





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