MIT Supply Chain
MANAGEMENT

Intermodal vs. Truckload

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MIT SCM RESEARCH FEST

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Agenda

1. Context & Scope
2. Methodology
3. Results
4. Simplifying the model
5. Generalizing the model
6. Key Takeaways

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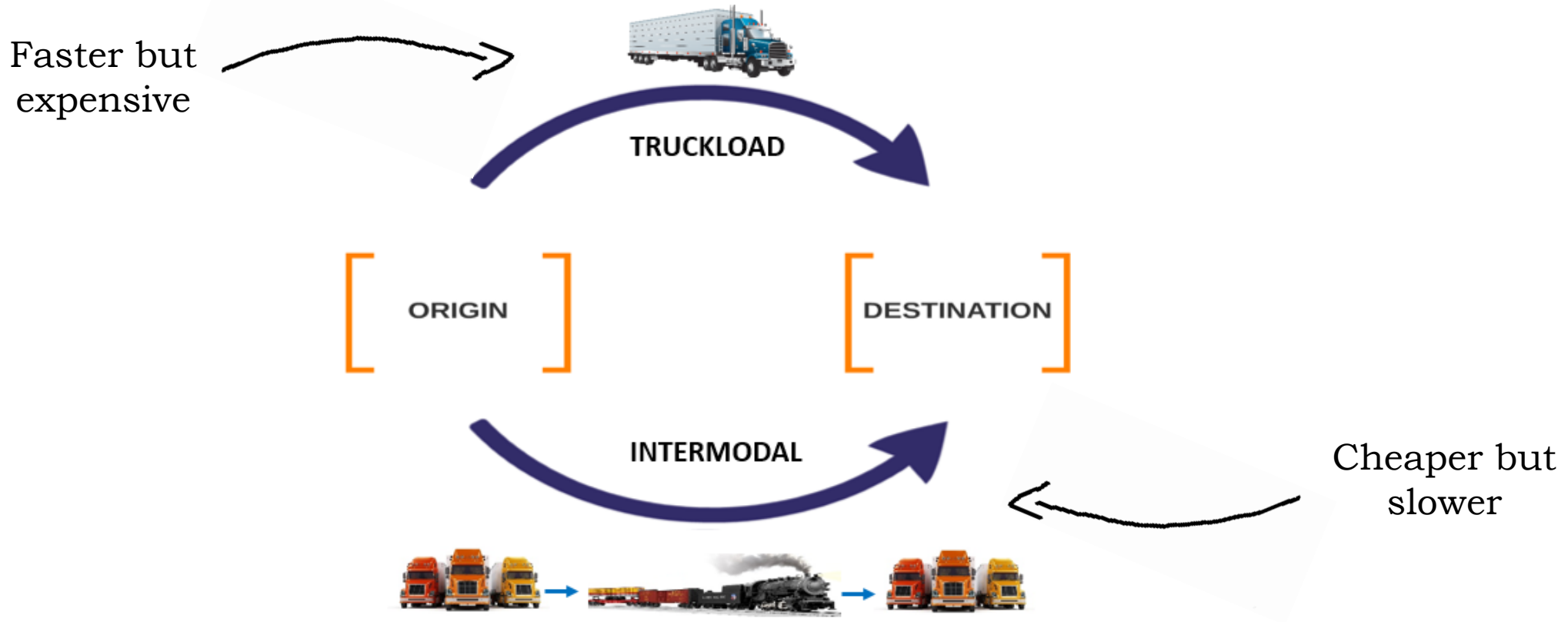
Two transportation mode options for inbound logistics



Motivation for the research

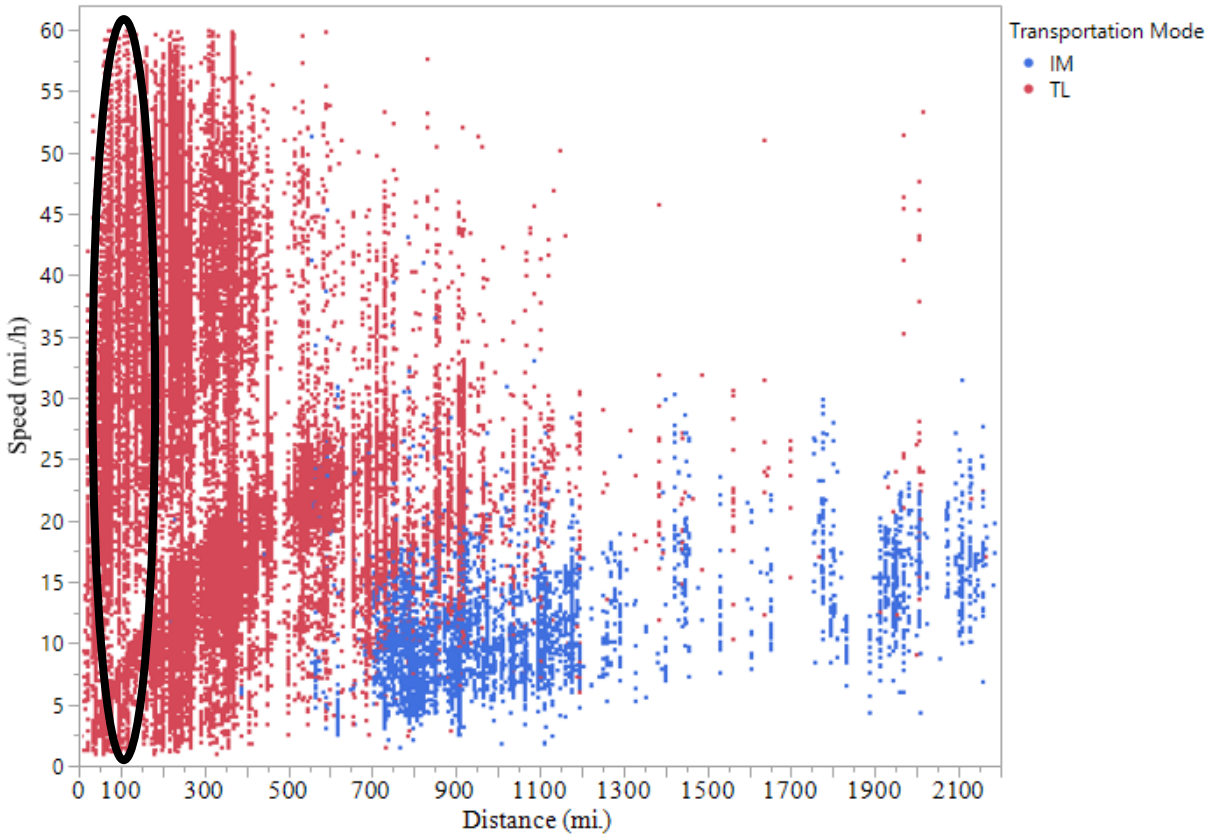


Figure 1: Speed vs. Distance

- High variability speed of loads shipped on similar-distance lanes.
- Different speed variability of each transportation mode.

Research question

- How to incorporate this transit variability into the calculation of the total logistics cost for each transportation mode (Truckload, Intermodal)?

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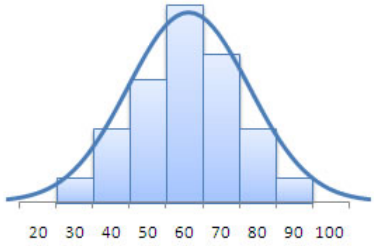
Methodology

Step 1

Data Profiling

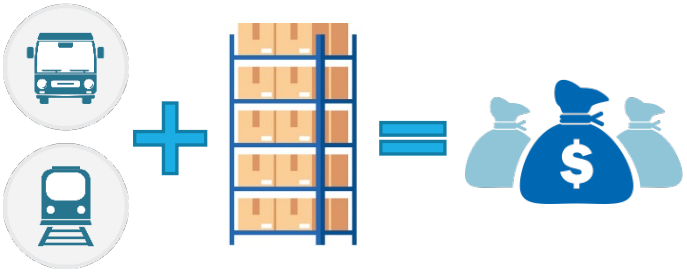
Step 2

Time/Distance Probability Distribution



Step 3

Total Cost Function



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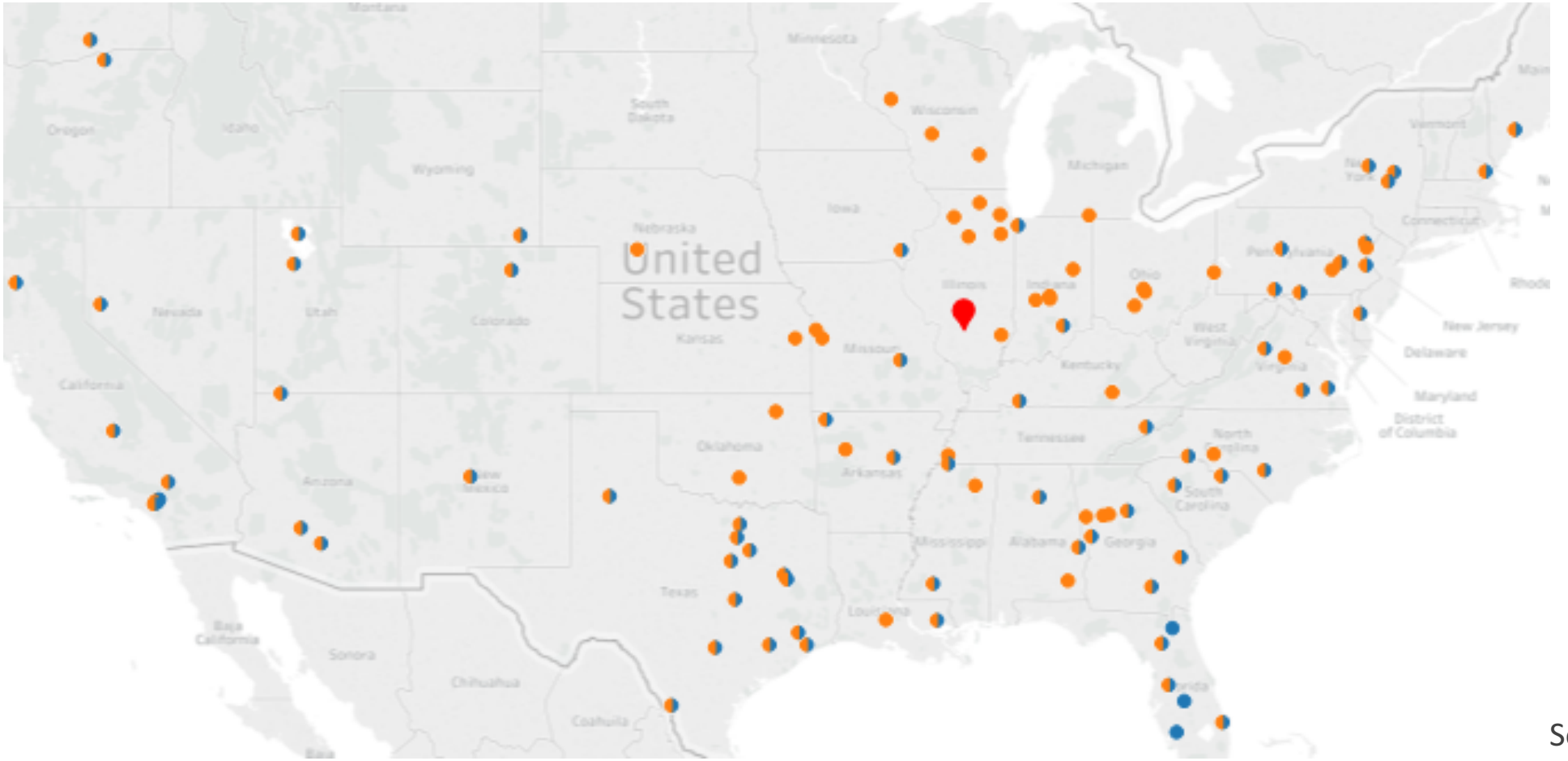
Geographic Scope



Source: ABC Stores

Data Profiling: Transit Time

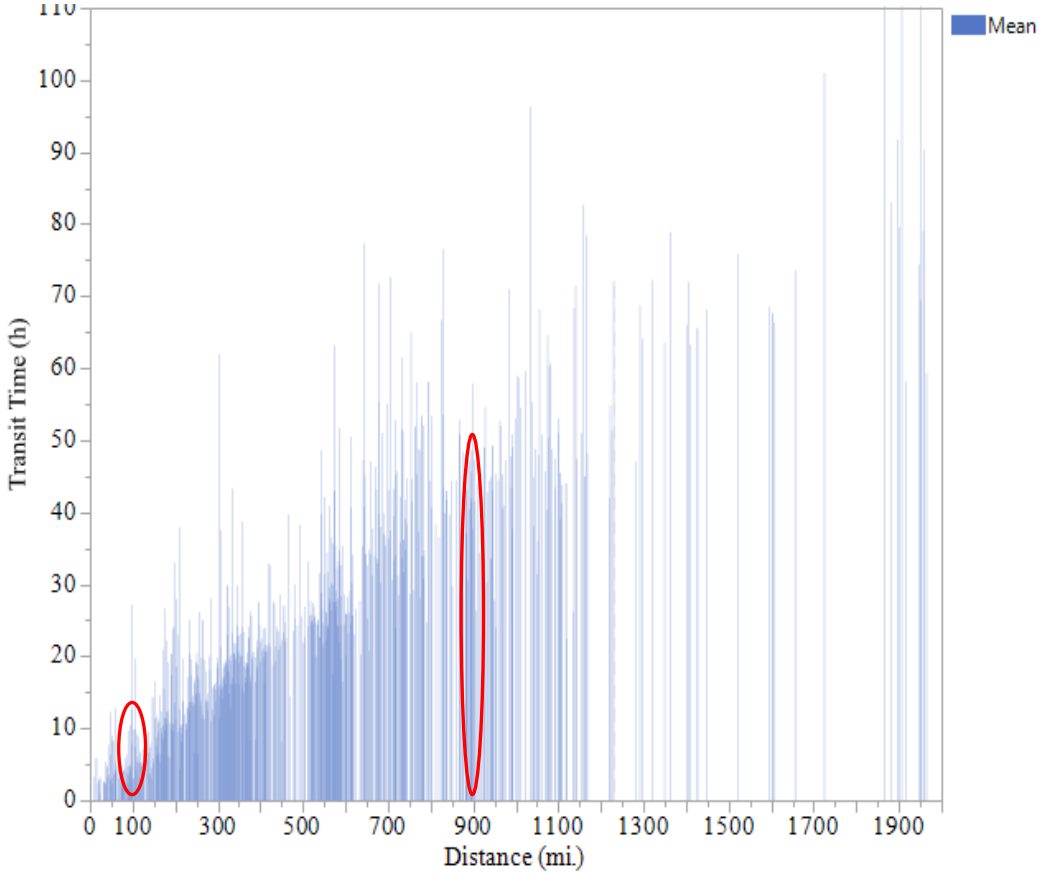


Figure 2: Average Transit Time vs. Distance - Truckload

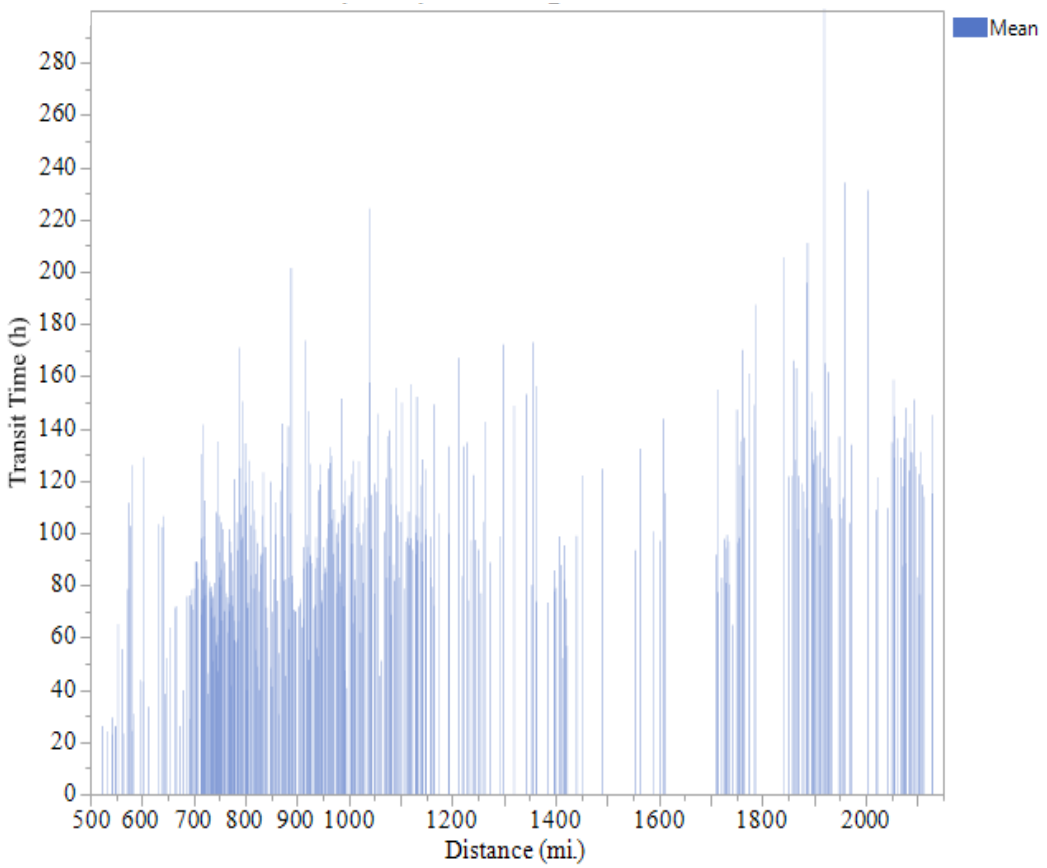


Figure 3: Average Transit Time vs. Distance - Intermodal

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Time/Distance Distribution

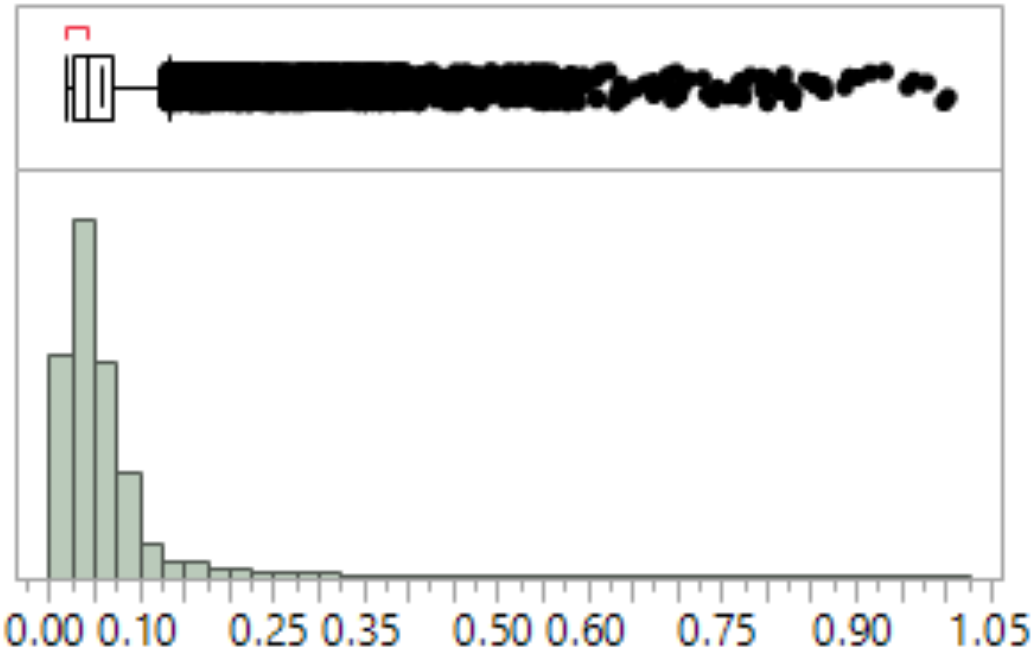

Figure 4: Histogram of Time/Distance (h/ mi.) - Truckload

Mean: 0.0568 h/ mi.
Standard deviation: 0.0561 h/mi.

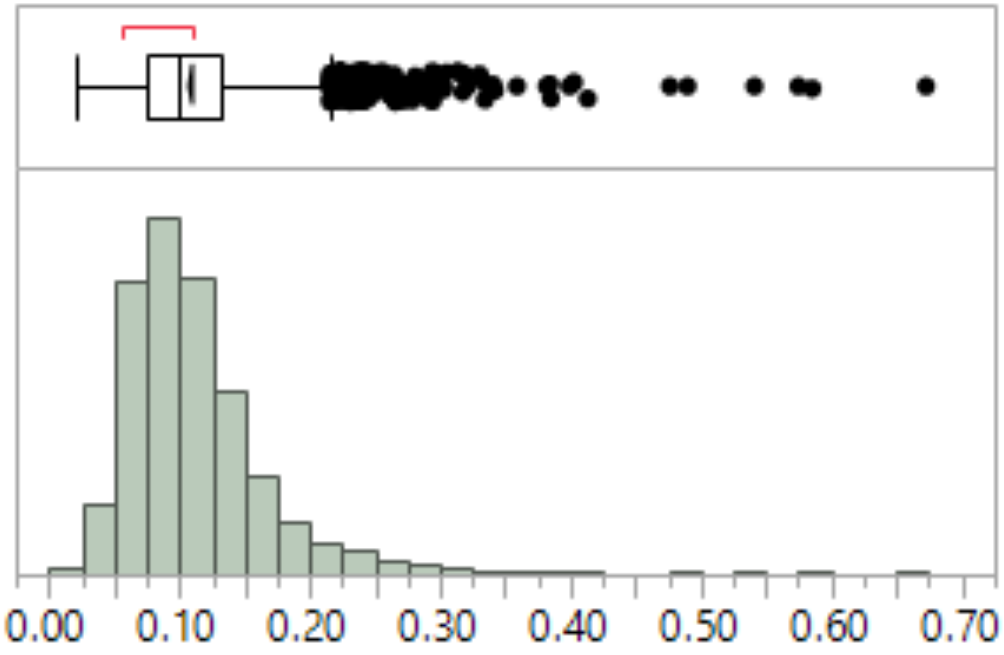

Figure 5: Histogram of Time/Distance (h/ mi.) - Intermodal

Mean: 0.1086 h/ mi.
Standard deviation: 0.0504 h/mi.

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Total Logistics Cost

$$Total\ Cost = \underbrace{[CPL \times D]}_{\text{Transportation Cost}} + \underbrace{\left[\frac{h}{8760} \times C \times D \times d \times t(\mu, \sigma, service\ level)\right]}_{\text{Inventory Cost}}$$

- Where:
  - *CPL*= Carrier cost per load ($/l).
  - *D* = Annual demand of the lane in number of loads (l).
  - $\frac{h}{8760}$ = Inventory holding rate ($/$/h).
  - *C* = Value of the load ($/l).
  - *d* = Distance (mi.).
  - $t(\mu, \sigma, service\ level)$ = Time/Distance for a given service level (h/mi.).

Inventory Cost

$$Inventory\ Cost = \frac{h}{8760} \times C \times D \times d \times t(\mu, \sigma, service\ level)$$

Where:

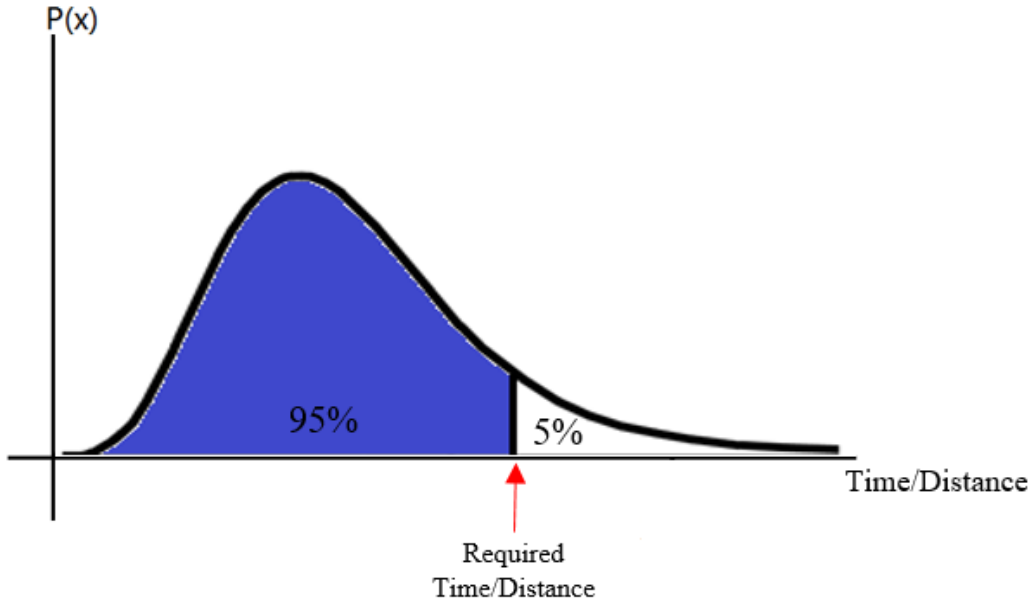
$\frac{h}{8760}$ = *Inventory holding rate ($/$/h).*

C = Value of the load ($/l).

D = Annual demand (l).

d = Distance (mi.).

$t(\mu, \sigma, service\ level)$ = *Required Time/Distance (h/mi.).*



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3. **Results**
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Initial results

		Model Recommendation		
		TL	IM	TOTAL
ABC Stores Choice	TL	60%	4%	65%
	IM	21%	14%	35%
	TOTAL	81%	19%	100%

- ✓ The model's recommendation coincides with ABC Store's mode choice on about 74% of the lanes.

Sensitivity Analysis

Load Value

Volume

Service level

$$Total\ Cost = [CPL \times D] + \left[\frac{h}{8760} \times C \times D \times d \times t(\mu, \sigma, service\ level)\right]$$

Impact of changes in Load Value

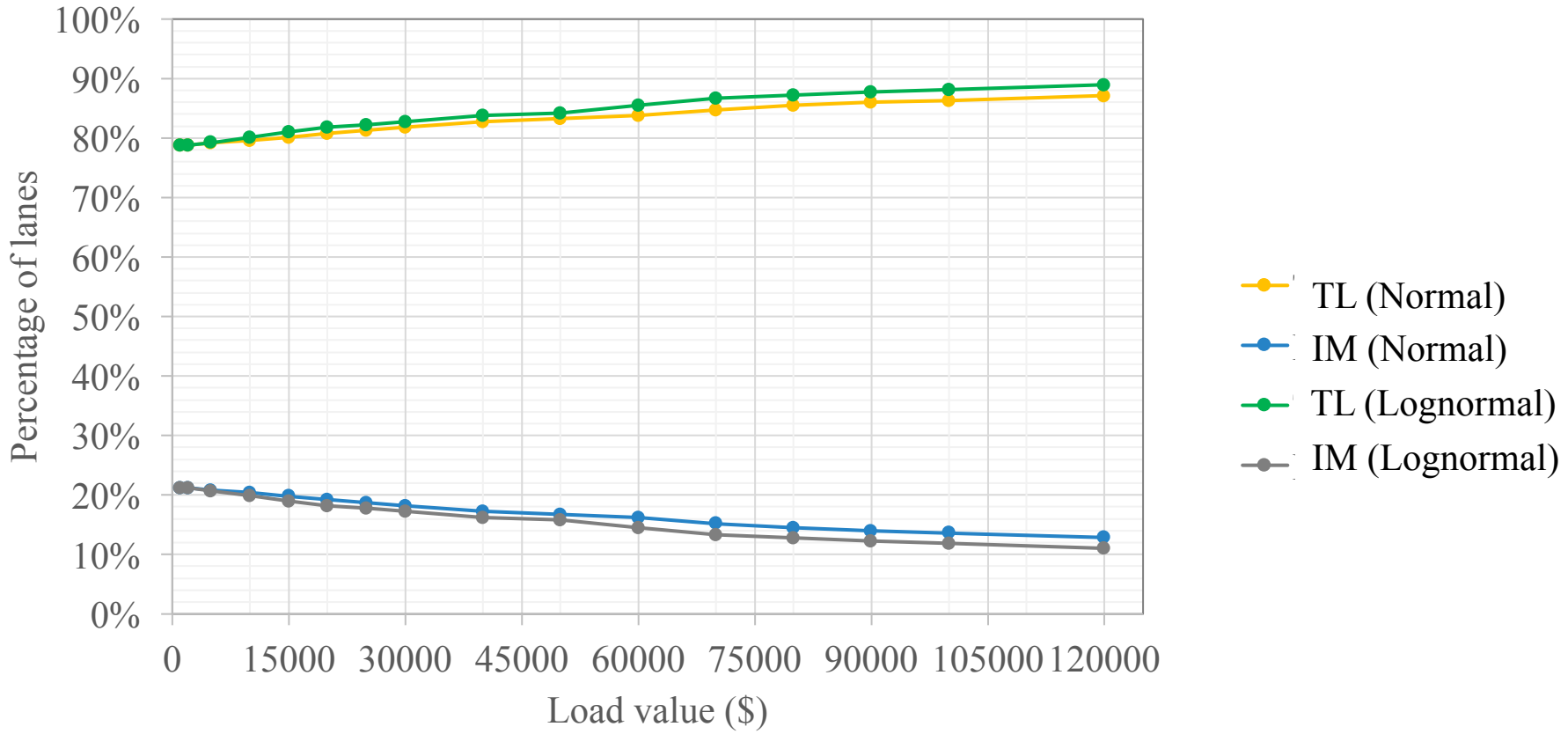

Figure 6: Sensitivity Analysis based on Load Value

Impact of changes in Volume

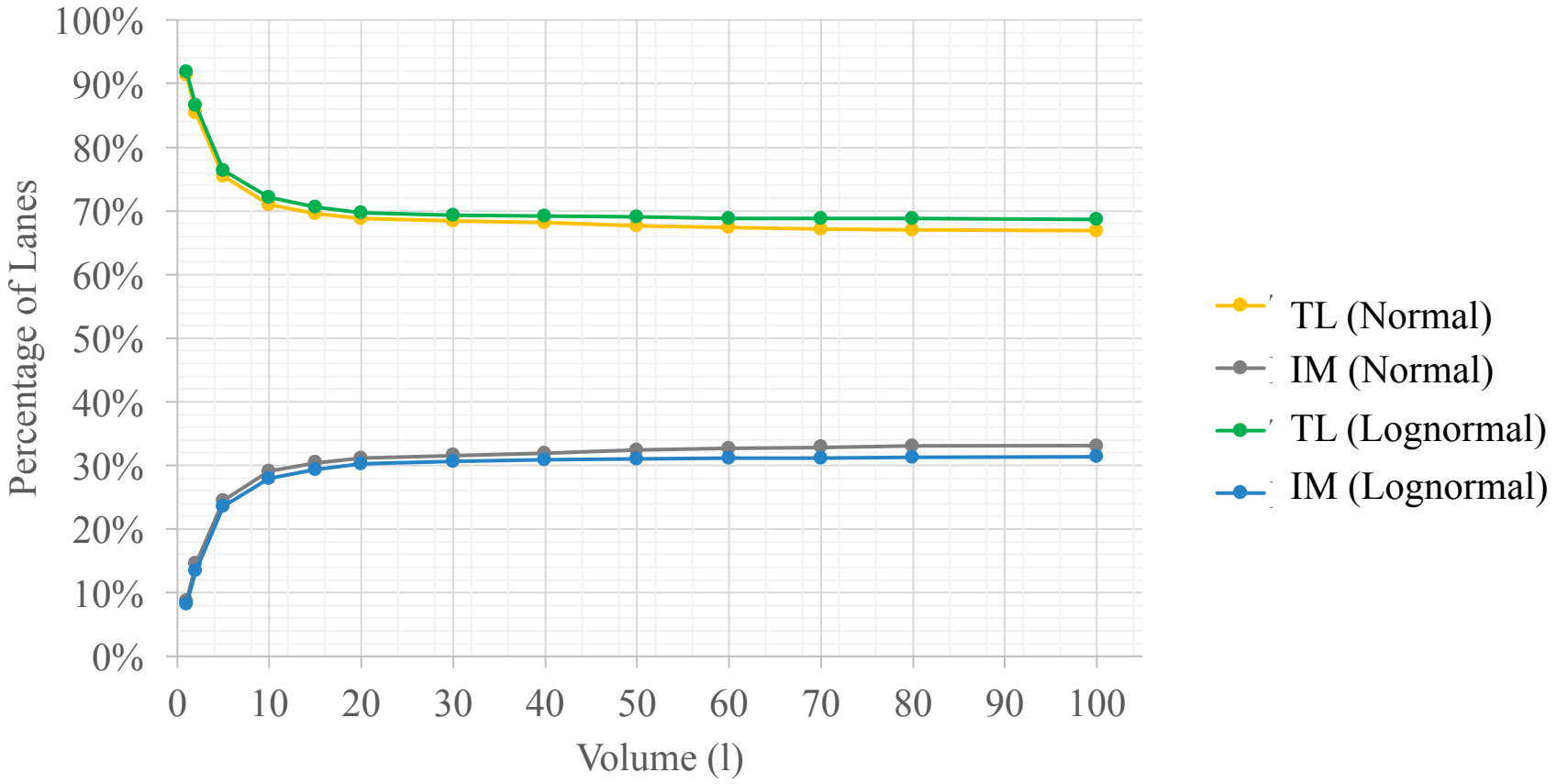

Figure 7: Sensitivity Analysis based on Volume

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Impact of changes in Service Level

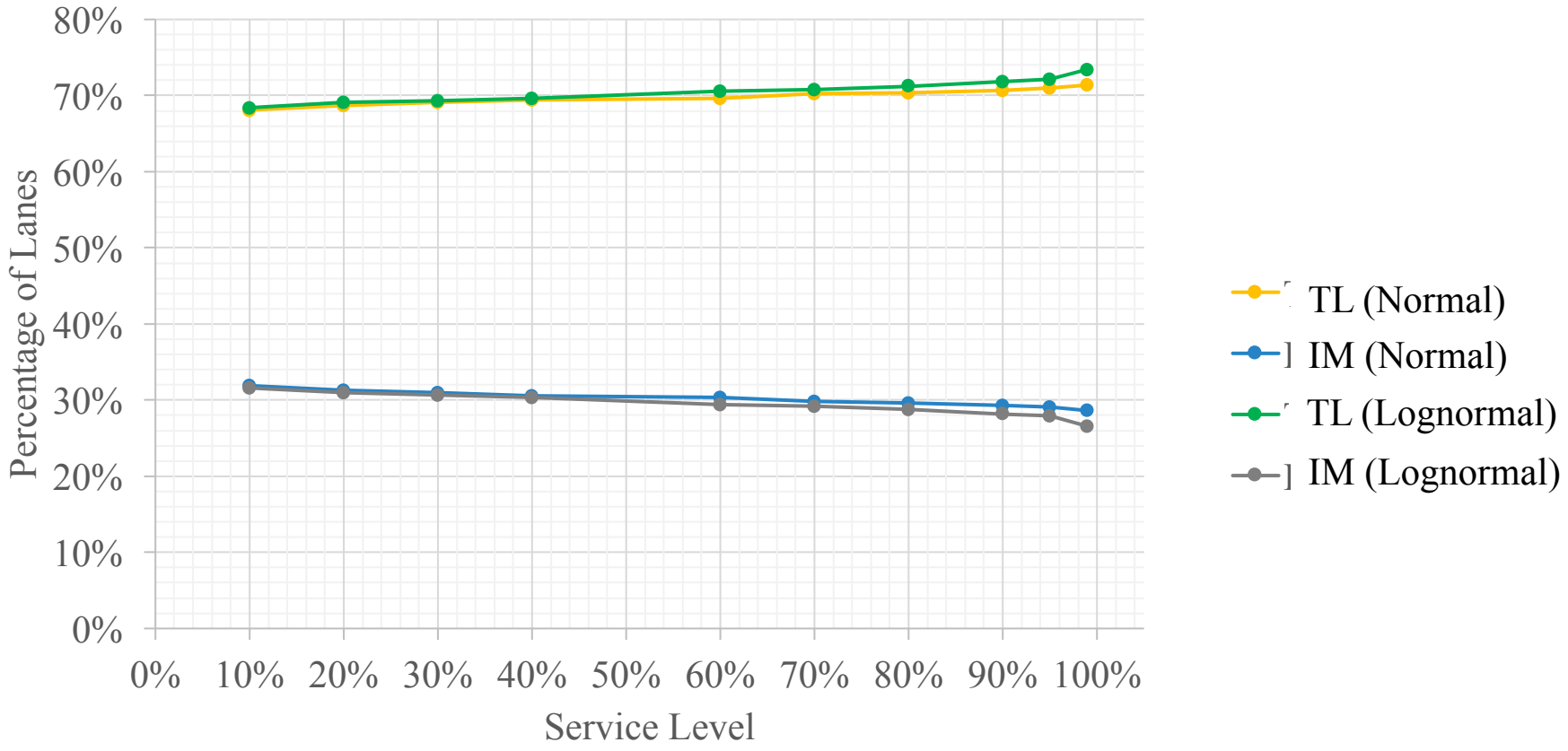

Figure 8: Sensitivity Analysis based on Service Level

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Two ways of simplifying the model

Initial model

- Time/Distance Distribution: Normal and Lognormal
- Multiple set of parameters for each transportation mode

Final model

- Time/Distance Distribution: Normal
- One set of parameters for each transportation mode

$$Total\ Cost = [CPL \times D] + \left[\frac{h}{8760} \times C \times D \times d \times t(\mu, \sigma, service\ level)\right]$$

Two ways of simplifying the model

$$Total\ Cost = [CPL \times D] + \left[\frac{h}{8760} \times C \times D \times d \times t(\mu, \sigma, service\ level)\right]$$

Initial model

Distance (mi.)	Number of observations	Lognormal Distribution		Normal Distribution	
		Scale	Shape	Mean	Stdev
		(h/ mi.)			
<100	11,913	(3.1926)	0.7979	0.0635	0.0867
100 - 200	13,869	(3.1353)	0.6885	0.0568	0.0535
200 - 300	15,619	(3.0740)	0.6636	0.0589	0.0534
300 - 400	13,027	(3.1263)	0.5337	0.0511	0.0363
400 - 500	1,912	(3.0352)	0.4299	0.0532	0.0310
500 - 600	2,353	(3.0727)	0.3487	0.0496	0.0233
600 - 700	1,348	(2.9644)	0.3722	0.0558	0.0278
700 - 800	997	(3.0034)	0.3905	0.0543	0.0342
800 - 900	1,284	(3.0340)	0.3102	0.0506	0.0181
900 - 1000	152	(3.0962)	0.3031	0.0474	0.0152
1000 - 1100	234	(3.0518)	0.3458	0.0504	0.0207
1100 - 1200	81	(2.9697)	0.4789	0.0584	0.0340
>1200	115	(3.1276)	0.3365	0.0463	0.0157

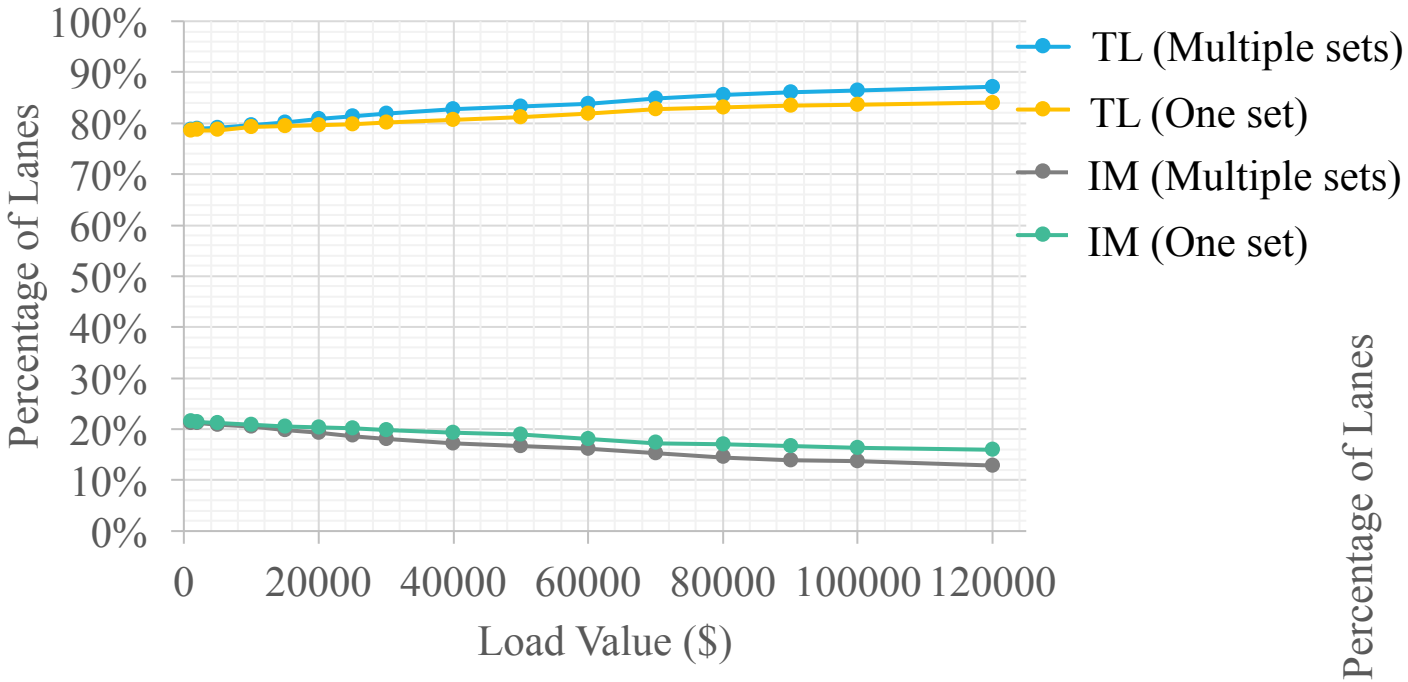
al

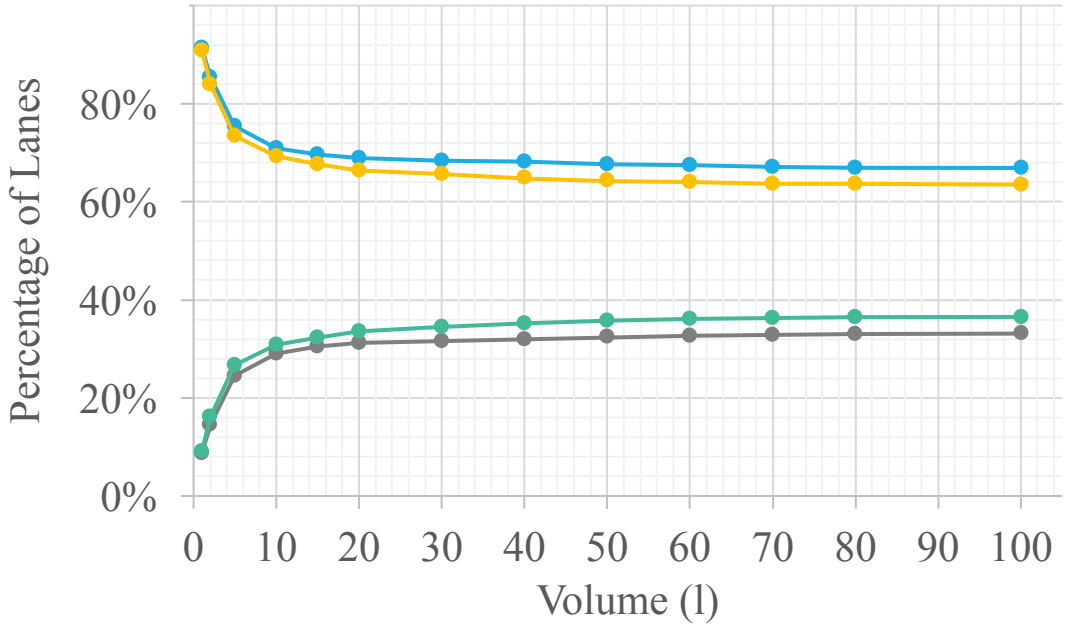
ution	Normal Distribution	
ape	Mean	Stdev
(h/ mi.)		
0.7529	0.0913	0.0645
0.5868	0.1534	0.0791
0.3832	0.1246	0.0517
0.4193	0.1287	0.0557
0.3261	0.1048	0.0394
0.3143	0.0993	0.0348
0.3097	0.0920	0.0303
0.4330	0.0751	0.0352
0.3103	0.0685	0.0217
0.2840	0.0803	0.0216
0.2990	0.0751	0.0239
0.2748	0.0676	0.0234
0.2245	0.0632	0.0143
0.2438	0.0601	0.0187

Final model

Transportation Mode	Normal Distribution	
	Mean	Stdev
Truckload	0.0568	0.0561
Intermodal	0.1086	0.0504

Sensitivity Analysis – Load Value & Volume





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Generalizing the model

$$Total\ Cost = [CPL \times D] + \left[\frac{h}{8760} \times C \times D \times d \times t(\mu, \sigma, service\ level)\right]$$

Truckload

- Annual transportation cost = $15,000
- μ = 0.0568 σ = 0.0561

Intermodal

- Annual transportation cost = $13,500
- μ = 0.1086 σ = 0.0504

- Annual holding rate (h) = 0.10
- Volume (D) = 25 loads per year
- Distance (d) = 900 miles
- Different values of load value (C) and service level were tested.

Total Cost comparison – Load Value

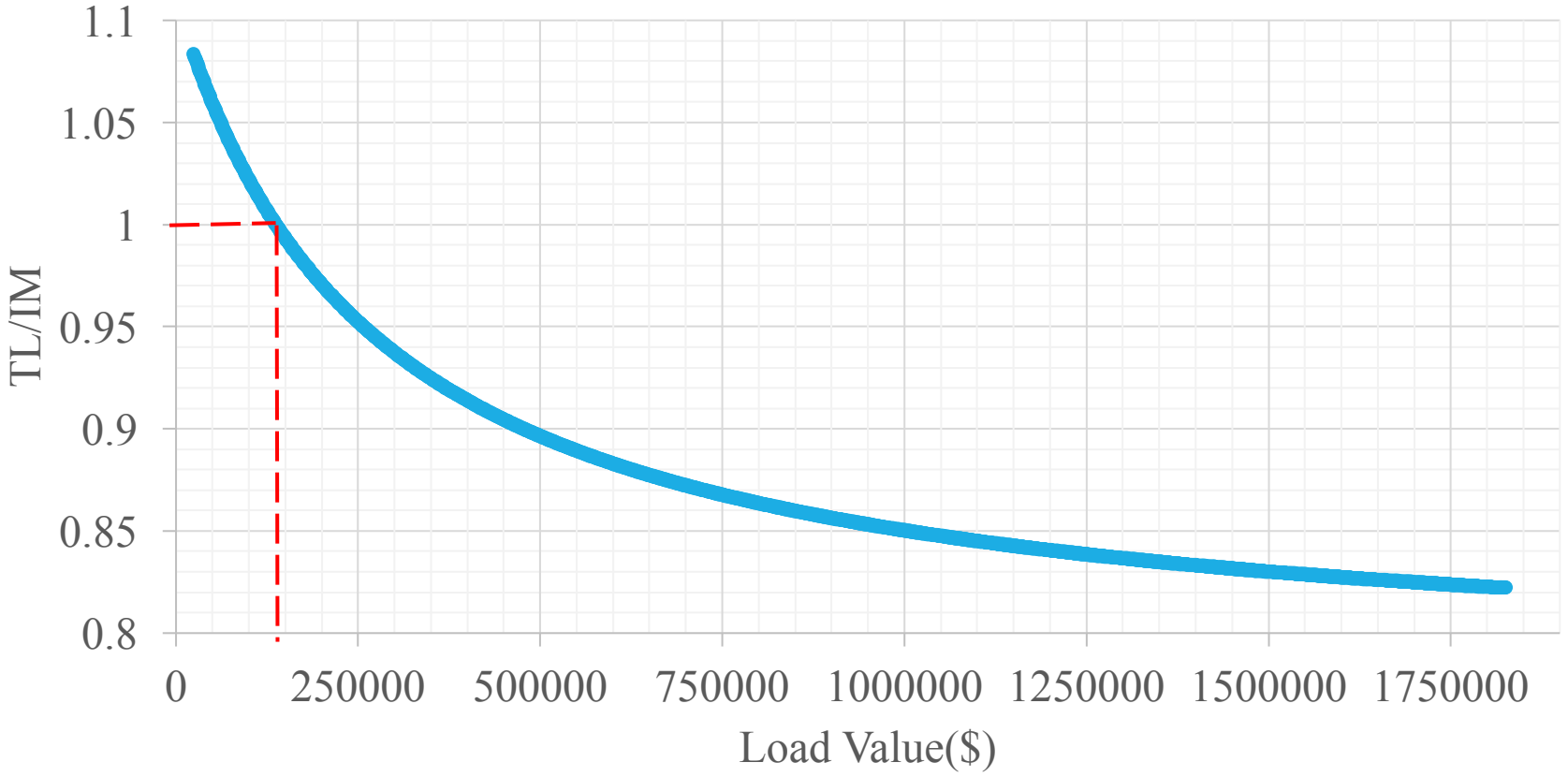

Figure 11: Total cost of Truckload/ Total cost of Intermodal by load value

Total Cost comparison – Service Level

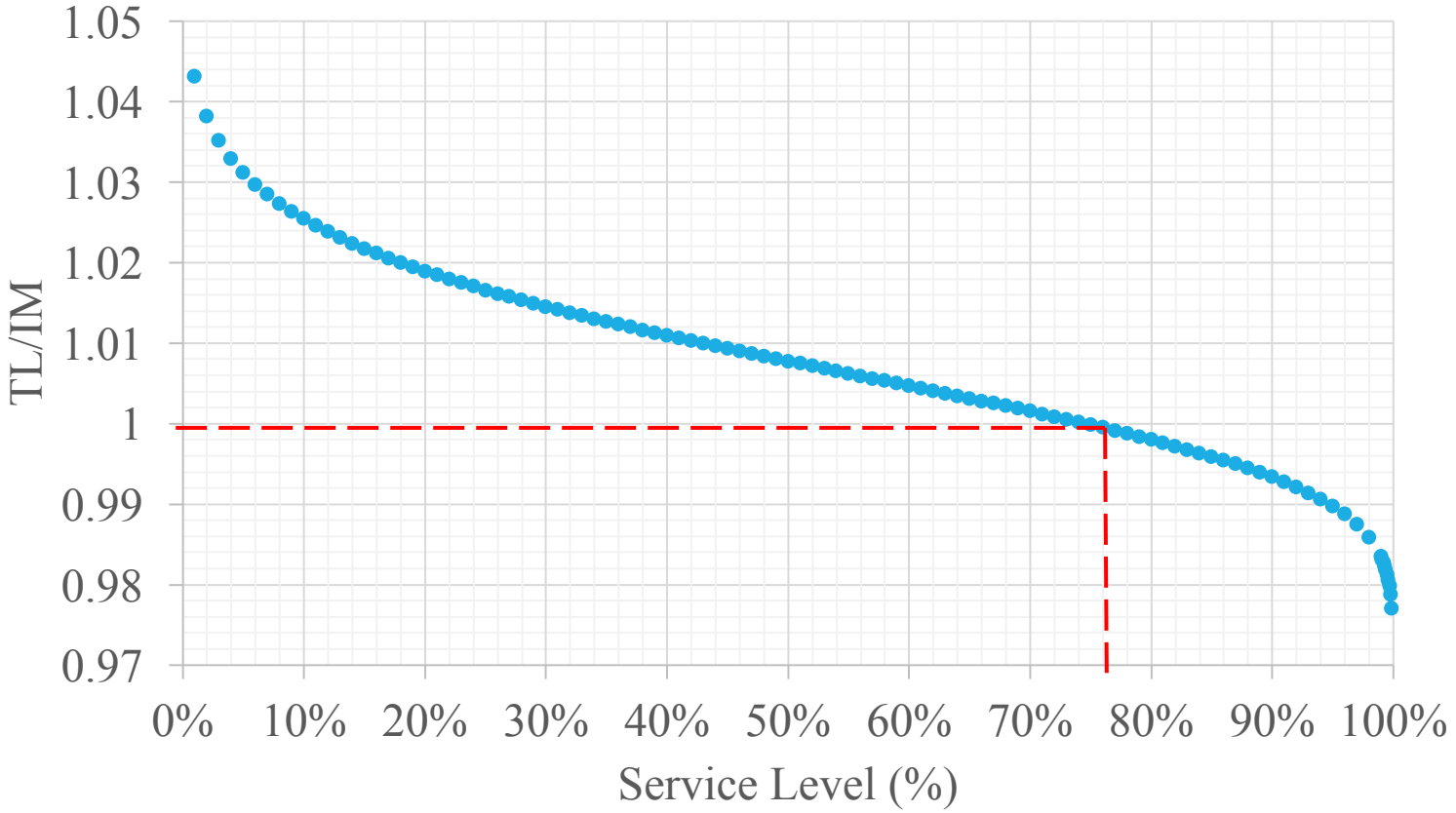

Figure 12: Total cost of Truckload/ Total cost of Intermodal by service level

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Key Takeaways

- ✓ Both normal and lognormal distributions can be used to transit time per mile.
- ✓ The expected transit time of truckload is shorter than the expected transit time of intermodal.
- ✓ The variability of transit time is lower for intermodal than for truckload.

Future Research

- Geographic Impact
- Demand Variability
- Carrier capacity

Q&A

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Thank You

Appendix

Appendix 1

- To convert the scale and shape (lognormal parameters) to mean and standard deviation, respectively, we applied the following formulas:

$$\mu = e^{\nu+\frac{\lambda^2}{2}} \qquad \sigma = \sqrt{(e^{2\nu+\lambda^2})\times(e^{\lambda^2}-1)}$$

Appendix 2: Why multiple sets?

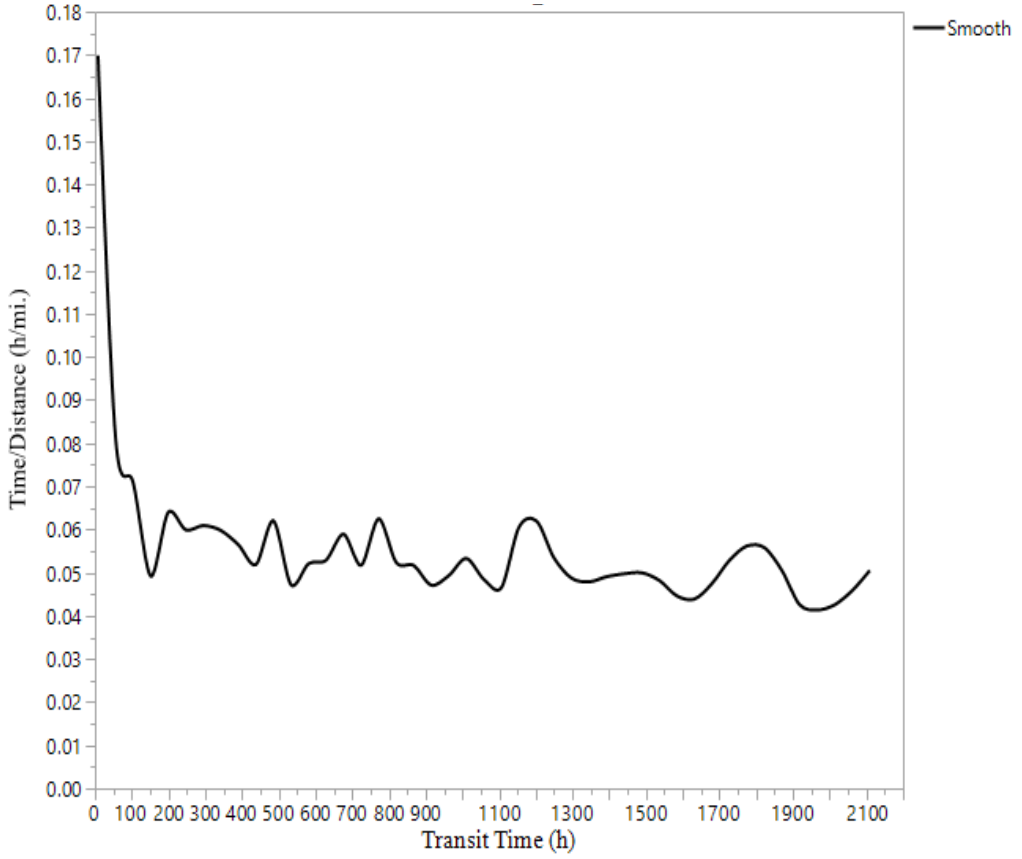

Figure 25: TL Time/Distance vs. Transit Time

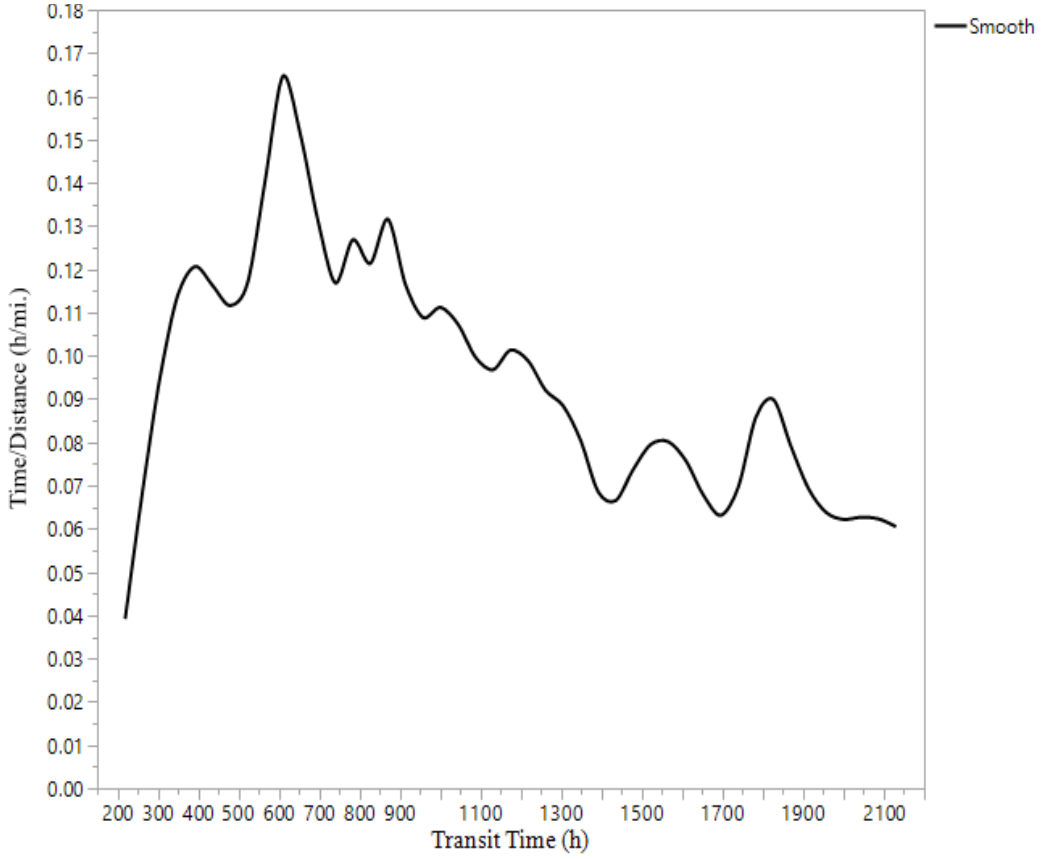

Figure 26: TL Time/Distance vs. Transit Time