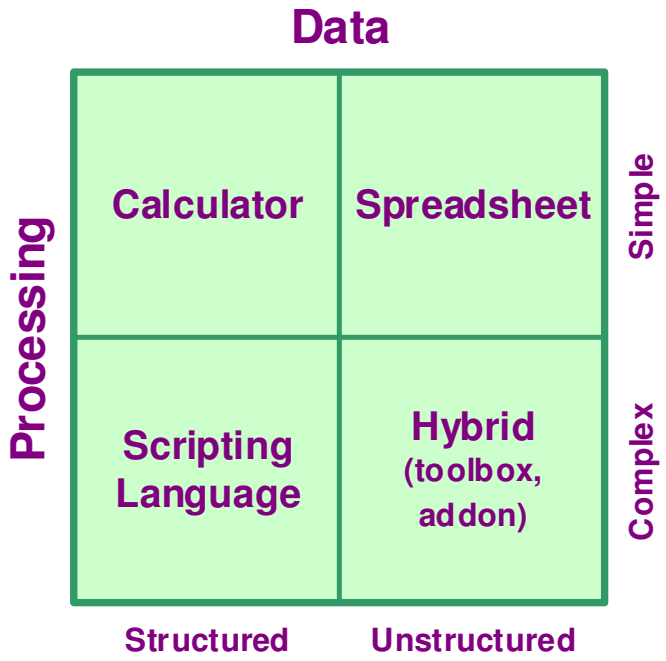
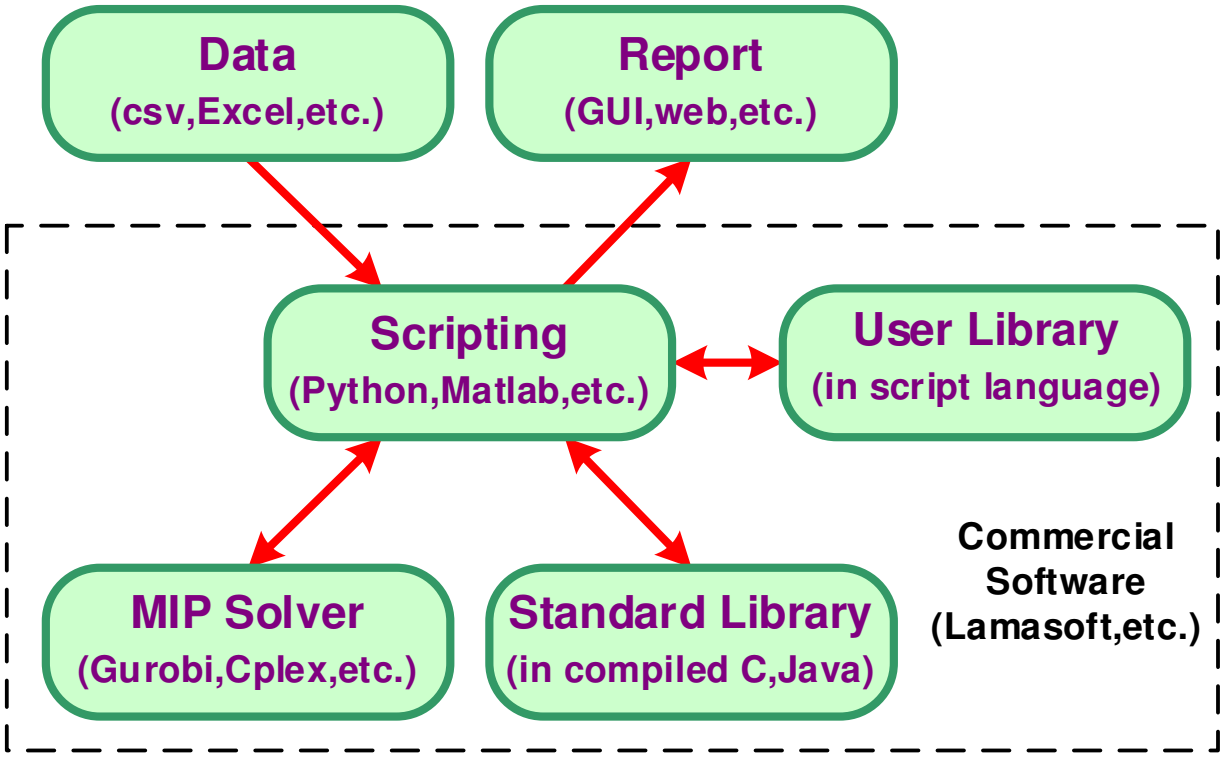
Computational Tools



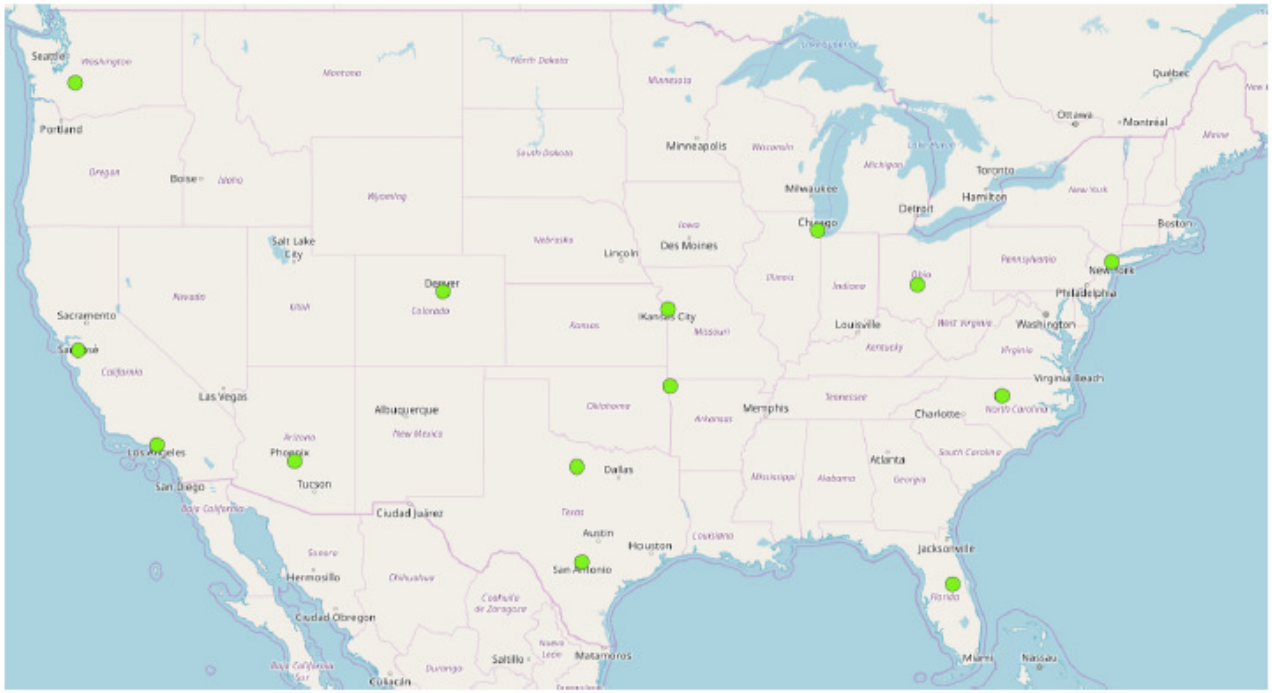
Logistics Software Stack



- New *Julia* (1.0) scripting language
  - (almost?) as fast as C and Java (but not FORTRAN)
  - does not require compiled standard library for speed
  - uses *multiple dispatch* to make type-specific versions of functions

PharmaCo Case Study

Exhibit A: Map of PharmaCo DC locations



2. Last year's P&L showed distribution operating costs of $109.3 million annually, subdivided into fixed DC operating, variable DC operating, and freight.

Exhibit B: Supply Chain Cost Profile

Supply Chain Costs (millions)				
Fixed Operating	Variable Operating	Transport-ation	Inventory Carrying	Total Supply Chain
$34.9	$42.0	$6.7	$25.7	**$109.3**

Logistics Engineering Design Constants

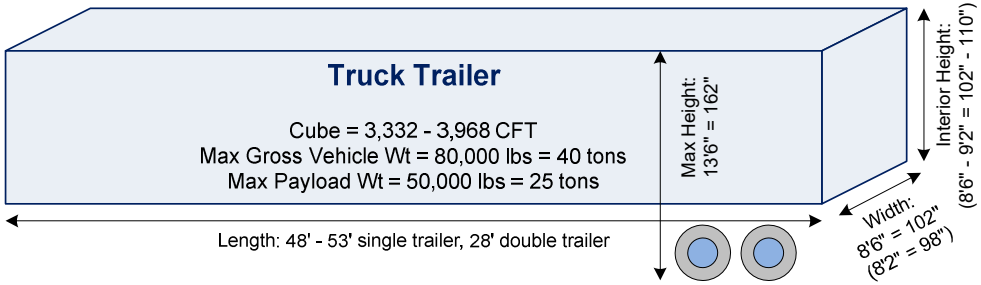
1. Circuity Factor: 1.2 (g)
   - 1.2 × GC distance ≈ actual road distance
2. Local vs. Intercity Transport:
   - Local: < 50 mi ⇒ use actual road distances
   - Intercity: > 50 mi ⇒ can estimate road distances
     - 50-250 mi ⇒ return possible (11 HOS)
     - > 250 mi ⇒ always one-way transport
     - > 500-750 mi ⇒ intermodal rail possible
3. Inventory Carrying Cost (h) = funds + storage + obsolescence
   - 16% average (no product information, per U.S. Total Logistics Costs)
     - (16% ≈ 5% funds + 6% storage + 5% obsolescence)
   - 5-10% low-value product (construction)
   - 25-30% general durable manufactured goods
   - 50% computer equipment
   - >> 100% perishable goods (produce)

Logistics Engineering Design Constants

4. $\dfrac{\text{Value}}{\text{Transport Cost}} \gg 1: \quad \$1\ \text{ft}^3 \approx \dfrac{\$2{,}620\ \text{Shanghai-LA/LB shipping cost}}{2{,}400\ \text{ft}^3\ 40\text{'}\ \text{ISO container capacity}}$

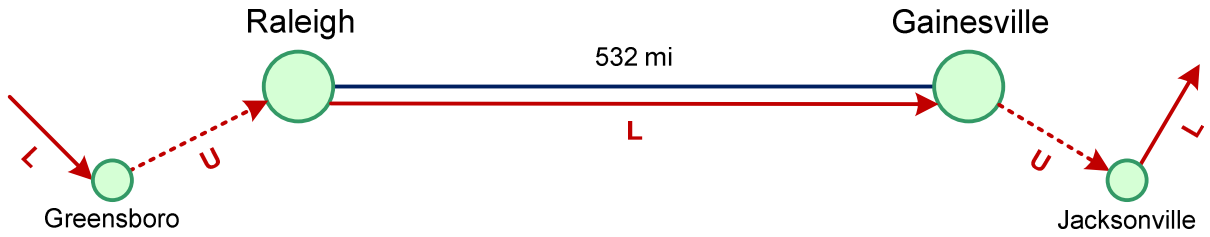
5. TL Weight Capacity: 25 tons (K_{wt})
   - (40 ton max per regulation) – (15 ton tare for tractor-trailer) = 25 ton max payload
   - Weight capacity = 100% of physical capacity

6. TL Cube Capacity: 2,750 ft³ (K_{cu})
   - Trailer physical capacity = 3,332 ft³
   - Effective capacity = $3{,}332 \times 0.80 \approx 2{,}750\ \text{ft}^3$
   - Cube capacity = 80% of physical capacity



Logistics Engineering Design Constants

7. TL Revenue per Loaded Truck-Mile: $2/mi in 2004 (r)
   - TL revenue for the carrier is your TL cost as a shipper



$$15\%, \quad \text{average deadhead travel}$$

$$\$1.60, \quad \text{cost per mile in 2004}$$

$$\frac{\$1.60}{1-0.15} = \$1.88, \quad \text{cost per loaded-mile}$$

$$6.35\%, \quad \text{average operating margin for trucking}$$

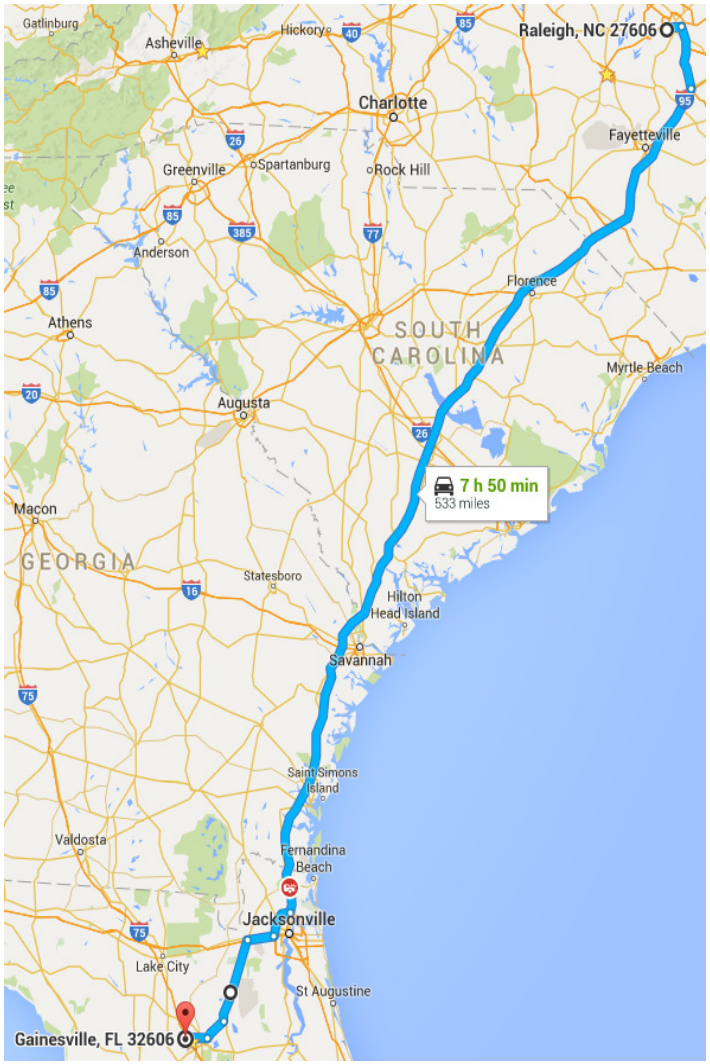
$$\frac{\$1.88}{1-0.0635} \approx \$2.00, \quad \text{revenue per loaded-mile}$$

One-Time vs Periodic Shipments

- **One-Time Shipments** (*operational* decision): know shipment size q
  - Know when and how much to ship, need to determine if TL and/or LTL to be used
  - Must contact carrier or have agreement to know charge
    - Can/should estimate charge before contacting carrier
- **Periodic Shipments** (*tactical* decision): know demand rate f, must determine size q
  - Need to determine how often and how much to ship
  - Analytical transport charge formula allow "optimal" size (and shipment frequency) to be estimated
    - U.S. Bureau of Labor Statistic's *Producer Price Index* (PPI) for TL and LTL used to estimate transport charges

Truck Shipment Example

- Product shipped in cartons from Raleigh, NC (27606) to Gainesville, FL (32606)
- Each identical unit weighs 40 lb and occupies 9 ft^3 (its *cube*)
  - Don't know linear dimensions of each unit for TL and LTL
- Units can be stacked on top of each other in a trailer
- Additional info/data is presented only when it is needed to determine answer



Truck Shipment Example: One-Time

1. Assuming that the product is to be shipped P2P TL, what is the maximum payload for each trailer used for the shipment?

$$q_{\max}^{wt} = K_{wt} = 25 \text{ ton}$$

$$K_{cu} = 2750 \text{ ft}^3$$

$$s = \frac{40 \text{ lb/unit}}{9 \text{ ft}^3/\text{unit}} = 4.4444 \text{ lb/ft}^3$$

$$K_{cu} = \frac{q_{\max}^{cu}}{\left(\frac{s}{2000}\right)} \Rightarrow q_{\max}^{cu} = \frac{s K_{cu}}{2000}$$

$$q_{\max} = \min\left\{q_{\max}^{wt}, q_{\max}^{cu}\right\} = \min\left\{K_{wt}, \frac{s K_{cu}}{2000}\right\}$$

$$= \min\left\{25, \frac{4.4444(2750)}{2000}\right\} = 6.1111 \text{ ton}$$

Truck Shipment Example: One-Time

2. On Jan 10, 2018, 320 units of the product were shipped. How many truckloads were required for this shipment?

$$q = 320\frac{40}{2000} = 6.4 \text{ ton}, \quad \left\lceil \frac{q}{q_{\max}} \right\rceil = \left\lceil \frac{6.4}{6.1111} \right\rceil = 2 \text{ truckloads}$$

3. Before contacting the carrier (and using Jan 2018 PPI), what is the estimated TL transport charge for this shipment?

$$d = 532 \text{ mi}$$

$$r_{TL} = \frac{PPI_{TL}^{\text{Jan 2018}}}{PPI_{TL}^{2004}} \times r_{2004} = \frac{PPI_{TL}}{102.7} \times \$2.00/\text{mi}$$

$$= \frac{131.0}{102.7} \times \$2.00/\text{mi} = \$2.5511/\text{mi}$$

$$c_{TL} = \left\lceil \frac{q}{q_{\max}} \right\rceil r_{TL} d = \left\lceil \frac{6.4}{6.1111} \right\rceil (2.5511)(532) = \$2,714.39$$

Truck Shipment Example: One-Time

Databases, Tables & Calculators by Subject

Change Output Options: From: 2008 To: 2018 include graphs include annual averages

Data extracted on: September 5, 2018 (4:22:19 PM)

PPI Industry Data

```
Series Id:      PCU484121484121
Series Title:   PPI industry data for General freight trucking, long-distance TL, not seasonally adjusted
Industry:       General freight trucking, long-distance TL
Product:        General freight trucking, long-distance TL
Base Date:      200312
```

Download: xlsx

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008	116.0	115.9	116.5	117.8	120.5	123.0	124.0	124.0	121.8	121.3	117.8	115.1
2009	113.2	112.1	110.4	109.7	109.8	110.1	111.4	111.0	111.7	110.8	111.5	110.9
2010	110.8	111.0	111.9	112.2	113.2	113.5	113.4	113.7	113.8	114.4	115.8	116.1
2011	116.5	117.4	119.3	121.0	121.7	121.4	121.3	121.2	122.0	122.0	123.2	123.3
2012	124.0	124.6	126.2	126.7	127.0	125.8	125.6	126.8	127.4	127.2	126.9	127.0
2013	126.7	127.2	128.0	127.5	127.8	127.6	127.6	127.6	127.1	127.2	127.6	127.4
2014	127.9	128.2	128.7	129.5	130.6	130.8	130.3	130.4	130.4	129.7	129.8	128.9
2015	126.7	126.0	126.0	126.2	126.3	127.1	126.9	126.2	125.9	125.5	125.8	124.8
2016	124.6	123.4	123.2	123.6	122.8	122.7	123.0	123.0	123.3	124.1	124.1	124.2
2017	124.4	124.7	124.2	124.3	124.0	124.2	124.2	125.9	126.6	126.6	128.5	130.3
2018	131.0	132.0	132.0	132.6(P)	133.6(P)	135.9(P)	138.6(P)					

P : Preliminary. All indexes are subject to revision four months after original publication.

Truck Shipment Example: One-Time

4. Using the Jan 2018 PPI LTL rate estimate, what was the transport charge to ship the fractional portion of the shipment LTL (i.e., the last partially full truckload portion)?

$$q_{\text{frac}} = q - q_{\max} = 6.4 - 6.1111 = 0.2889 \text{ ton}$$

$$r_{LTL} = PPI_{LTL}\left[\frac{\frac{s^2}{8}+14}{\left(q_{\text{frac}}^{\frac{1}{7}} d^{\frac{15}{29}} - \frac{7}{2}\right)\left(s^2+2s+14\right)}\right]$$

$$= 177.4\left[\frac{\frac{4.44^2}{8}+14}{\left(0.2889^{\frac{1}{7}} 532^{\frac{15}{29}} - \frac{7}{2}\right)\left(4.44^2+2(4.44)+14\right)}\right] = \$3.8014 / \text{ton-mi}$$

$$c_{LTL} = r_{LTL}\, q_{\text{frac}}\, d = 3.8014(0.2889)(532) = \$584.23$$

Truck Shipment Example: One-Time

5. What is the change in total charge associated with the combining TL and LTL as compared to just using TL?

$$\Delta c = c_{TL} - \left(c_{TL-1} + c_{LTL}\right)$$

$$= \left\lceil \frac{q}{q_{\max}} \right\rceil r_{TL} d - \left(\left\lfloor \frac{q}{q_{\max}} \right\rfloor r_{TL} d + r_{LTL}\, q_{\text{frac}}\, d \right)$$

$$= \$772.96$$

Truck Shipment Example: One-Time

6. What would the fractional portion have to be so that the TL and LTL charges are equal?

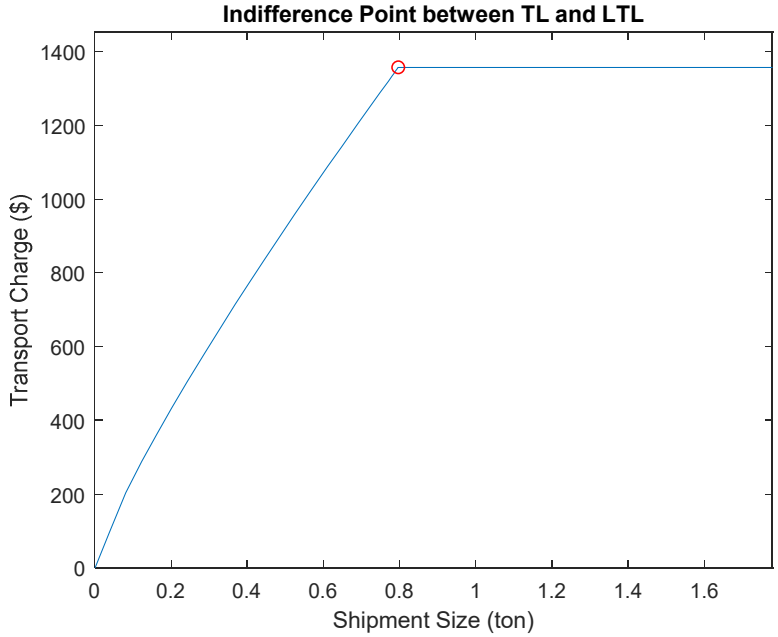
$$c_{TL}(q) = \left\lceil \frac{q}{q_{\max}} \right\rceil r_{TL} d$$

$$r_{LTL}(q) = PPI_{LTL}\left[\frac{\frac{s^2}{8} + 14}{\left(q^{\frac{1}{7}} d^{\frac{15}{29}} - \frac{7}{2} \right)\left(s^2 + 2s + 14 \right)} \right]$$

$$c_{LTL}(q) = r_{LTL}(q)\, q d$$

$$q_I = \arg\min_q \left(\left\| c_{TL}(q) - c_{LTL}(q) \right\| \right)$$

$$= 0.7960 \text{ ton}$$



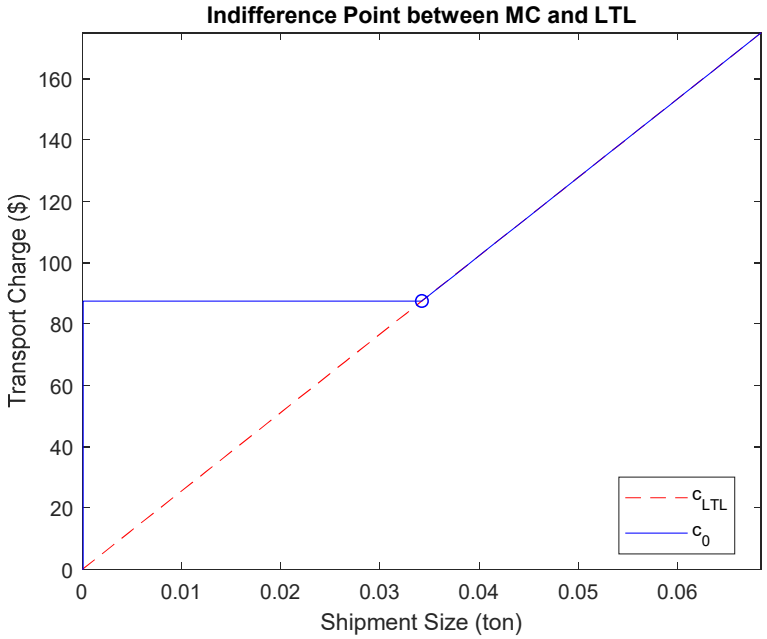
Truck Shipment Example: One-Time

7. What are the TL and LTL minimum charges?

$$MC_{TL} = \left(\frac{r_{TL}}{2}\right)45 = \$57.40$$

$$MC_{LTL} = \left(\frac{PPI_{LTL}}{104.2}\right)\left(45 + \frac{d^{\frac{28}{19}}}{1625}\right)$$

$$= \left(\frac{177.4}{104.2}\right)\left(45 + \frac{532^{\frac{28}{19}}}{1625}\right) = \$87.51$$



- Why do these charges not depend on the size of the shipment?
- Why does only the LTL minimum charge depend of the distance of the shipment?

Truck Shipment Example: One-Time

- Independent Transport Charge ($):

$$c_0(q) = \min\left\{\max\left\{c_{TL}(q), MC_{TL}\right\}, \max\left\{c_{LTL}(q), MC_{LTL}\right\}\right\}$$

Truck Shipment Example: One-Time

- **PX: Package Express**
  - (Undiscounted) charge c_{PX} based rate tables, R, for each service (2-day ground, overnight, etc.)
  - Rate determined by on *chargeable weight*, wt_{chrg}, and *zone*
  - All PX carriers (FedEX, UPS, USPS, DHL) use *dimensional weight*, wt_{dim}
  - wt_{dim} > 150 lb is prorated per-lb rate
  - Actual weight 1–70 lb (UPS, FedEx home), 1–150 lb (FedEx commercial)
  - Carrier sets a *shipping factor*, which is min cubic volume per pound
  - Zone usually determined by O-D distance of shipment
  - Supplemental charges for home delivery, excess declared value, etc.

$$c_{PX} = R\left(wt_{\text{chrg}}, zone\right)$$

$$wt_{\text{chrg}} = \left\lceil \max\left\{wt_{\text{act}}, wt_{\text{dim}}\right\} \right\rceil \text{ (lb)}$$

$$wt_{\text{act}} = \text{actual weight (1 to 150 lb)}$$

$$wt_{\text{dim}} = \frac{l \times w \times d \text{ (in}^3\text{)}}{sf \text{ (in}^3\text{/lb)}} \text{ (lb)}$$

$$l, w, d = \text{length, width, depth (in)}$$

$$l \geq w, \quad l \times w \times d \geq \text{actual cube}$$

$$sf = \text{shipping factor (in}^3\text{/lb)}$$

$$= 12^3 / s, \text{ inverse of density}$$

$$= 139 \text{ FedEx (2019)}$$

$$\Rightarrow s = 12.43 \text{ lb/ft}^3 \text{ (Class 85)}$$

$$= 194 \text{ USPS} \Rightarrow s = 8.9 \text{ lb/ft}^3$$

Truck Shipment Example: One-Time

- (Undisc.) charge to ship a single carton via FedEx?

$$wt_{\text{act}} = 40 \text{ lb}, cu = 9 \text{ ft}^3$$

$$d = 532 \text{ mi} \Rightarrow zone = 4$$

$$\text{carton} \Rightarrow l \times w \times d = \text{actual cube} \Rightarrow$$

$$l \times w \times d = 9 \times 12^3 = 15{,}552 \text{ in}^3 = 32 \times 27 \times 18$$

$$wt_{\text{dim}} = \frac{l \times w \times d}{sf} = \frac{15{,}552}{139} = 111.9 \text{ lb}$$

$$wt_{\text{chrg}} = \left\lceil \max\left\{wt_{\text{act}}, wt_{\text{dim}}\right\} \right\rceil$$

$$= \left\lceil \max\left\{40, 111.9\right\} \right\rceil = 112 \text{ lb}$$

$$c_{PX} = R\left(wt_{\text{chrg}}, zone\right)$$

$$= R(112, 4) = \$64.27$$

FedEx Standard List Rates (eff. Jan. 7, 2019)

Service		FedEx Ground® and FedEx Home Delivery® (up to 70 lbs.)						
Delivery Commitment		1–5 days based on distance to destination						
Zones[1]		2	3	4	5	6	7	8
		0–150 miles	151–300 miles	301–600 miles	601–1,000 miles	1,001–1,400 miles	1,401–1,800 miles	1,801-plus miles
Maximum Weight in Lbs.	1 lb.	$ 7.85	$ 8.23	$ 8.96	$ 9.36	$ 9.68	$ 9.80	$ 9.96
	2 lbs.	[illegible]	9.48	10.15	10.37	10.82	11.24	11.43
	3	8.87	[illegible]	10.70	11.14	11.59	11.98	12.57
	4	9.13	[illegible]	[illegible]	11.75	12.08	12.87	13.47
	5	9.37	[illegible]	[illegible]	[illegible]	[illegible]	13.46	14.22
	6	9.68	[illegible]	[illegible]	[illegible]	[illegible]	13.81	14.48
	7	10.23	[illegible]	[illegible]	[illegible]	[illegible]	14.18	15.18
	8	10.43	[illegible]	[illegible]	[illegible]	[illegible]	14.61	15.69
	9	10.59	11.40	12.48	13.39	14.04	15.21	16.52
	10	10.84	11.51	12.60	13.76	14.33	16.10	17.62
	111	59.41	59.89	64.26	67.20	75.20	82.60	92.25
	112	60.62	61.13	64.27	67.21	75.84	83.31	92.36
	113	60.68	61.18	64.98	67.83	76.52	84.00	94.04
	114	61.32	62.45	66.33	69.15	77.81	85.41	94.65
	115	61.99	63.16	66.34	69.33	77.82	85.42	94.66
	146	82.51	84.98	88.95	89.15	98.04	105.96	118.85
	147	83.66	85.00	89.66	89.86	98.74	106.69	119.66
	148	84.68	85.63	90.61	90.62	100.20	107.40	120.46
	149	84.84	86.38	91.26	91.28	100.42	108.08	121.81
	150[2]	84.85	87.16	92.76	94.33	100.95	108.83	122.60

Note: No Zone 1 (usually < 50 mi local)