Transportation

General Concepts

Lecture 15
ESD.260 Fall 2003

Caplice

Transportation Operations

Consolidated operations (CO)

- Bus/rail transit
- LTL
- Rail
- Airlines
- Ocean carriers/liner service
- Package delivery

Direct operations (DO)

- Taxi
- TL
- Unit trains
- Charter/private planes
- Tramp services
- Courier

DO conveyances on CO carriers (sub-consolidation)

- Rail cars
- Ocean containers
- Air "igloos"

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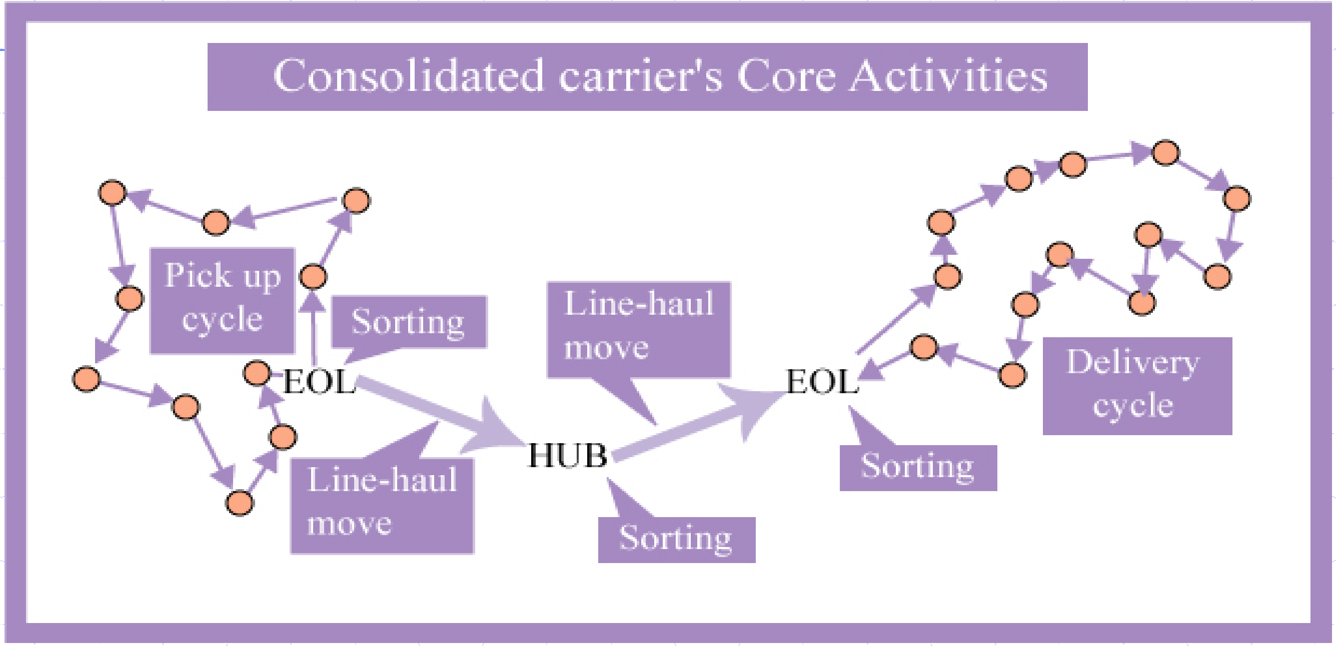
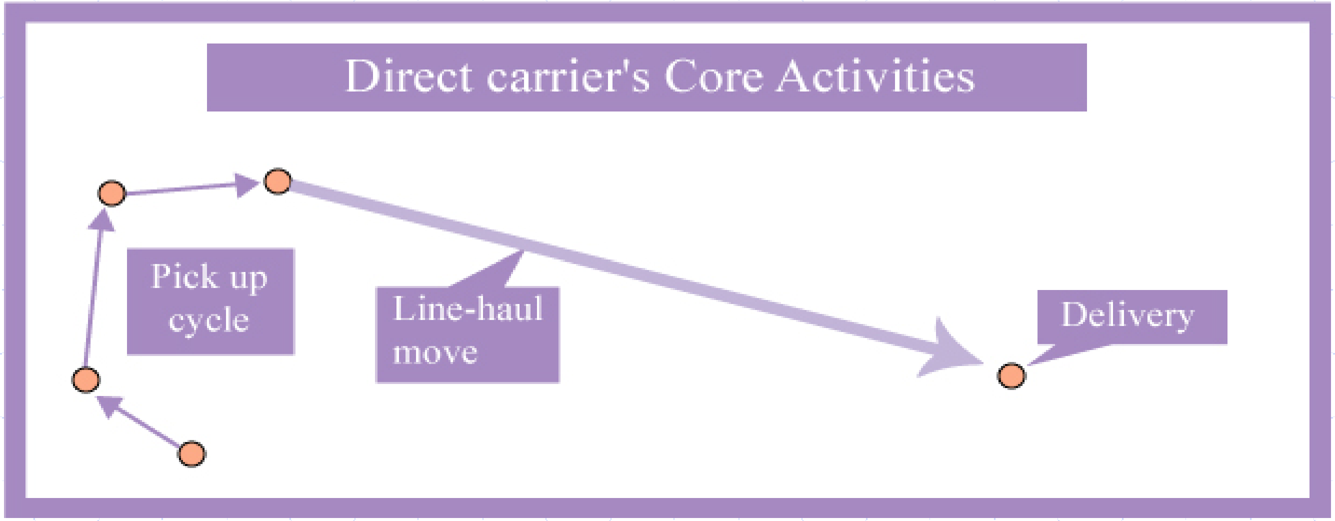
Core Transportation Activities





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Types of Transportation Systems

- Based on Consolidation Used
  - w/o Transhipment Point
    - One to One
    - One to Many
    - Many to One
    - Many to Many
  - With Transhipment Point
    - One to Many
    - Many to One
    - Many to Many
  - Other Issues
    - Dynamic Transhipment Points
    - Interleavened trips
    - Planning versus Execution

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Solutions Approach

- Math Programming Approach
  - Develop detailed objective function and constraints
  - Requires substantial data
  - Solve MILP to optimality
- Simulation Approach
  - Develop detailed rules and relationships
  - Simulate the expected demand patterns
  - Observe results and rank different scenarios
- Continuous Approximation Approach
  - Develop a Logistics Cost Function (LCF) that incorporates the relevant decision variables
  - Obtain reasonable results with as little information as possible in order to gain insights
  - Detailed data can actually make the optimization process harder

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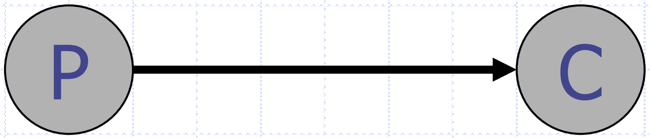
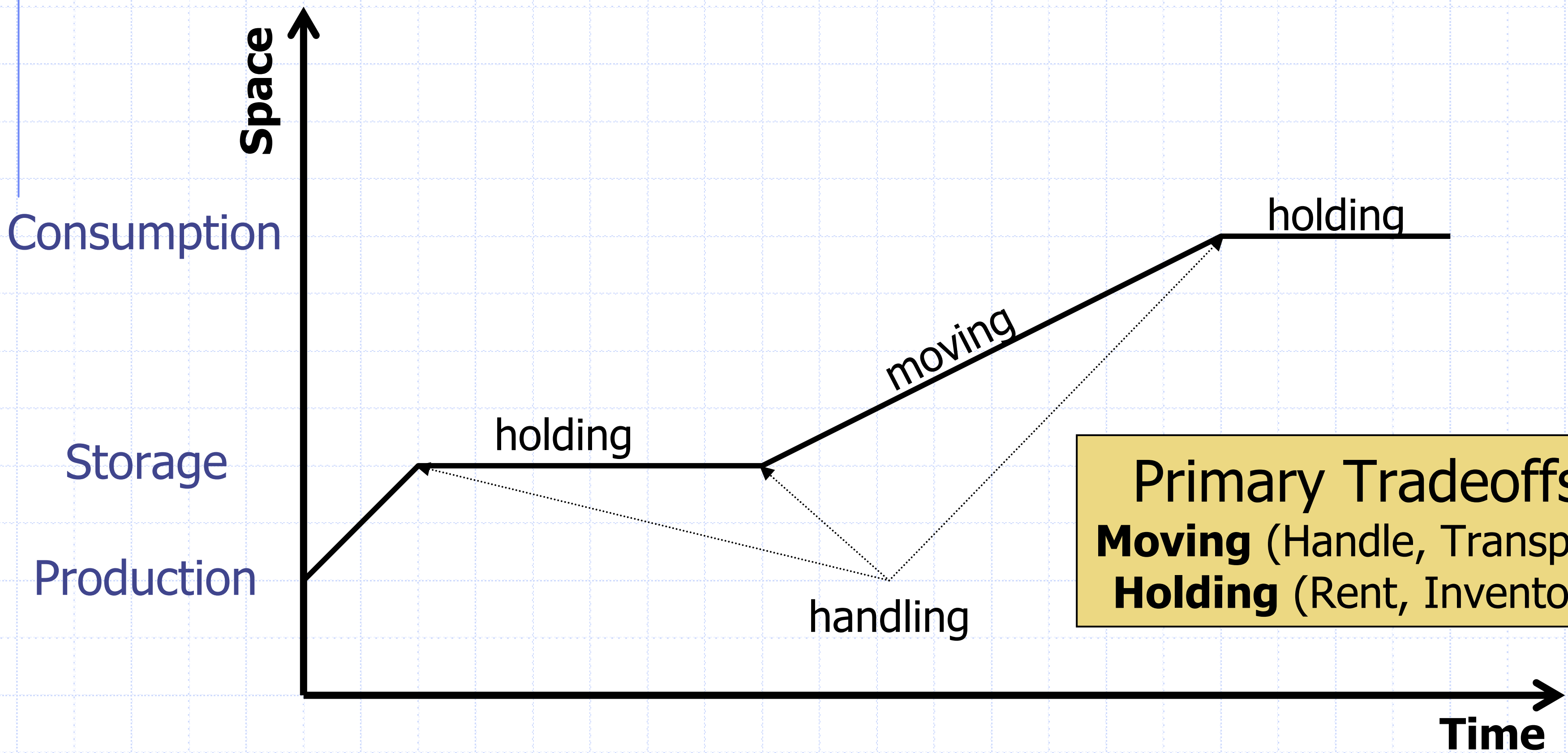
Time Space Diagram

Consider a simple Product to Consumption Network





Primary Tradeoffs:

Moving (Handle, Transport)

Holding (Rent, Inventory)

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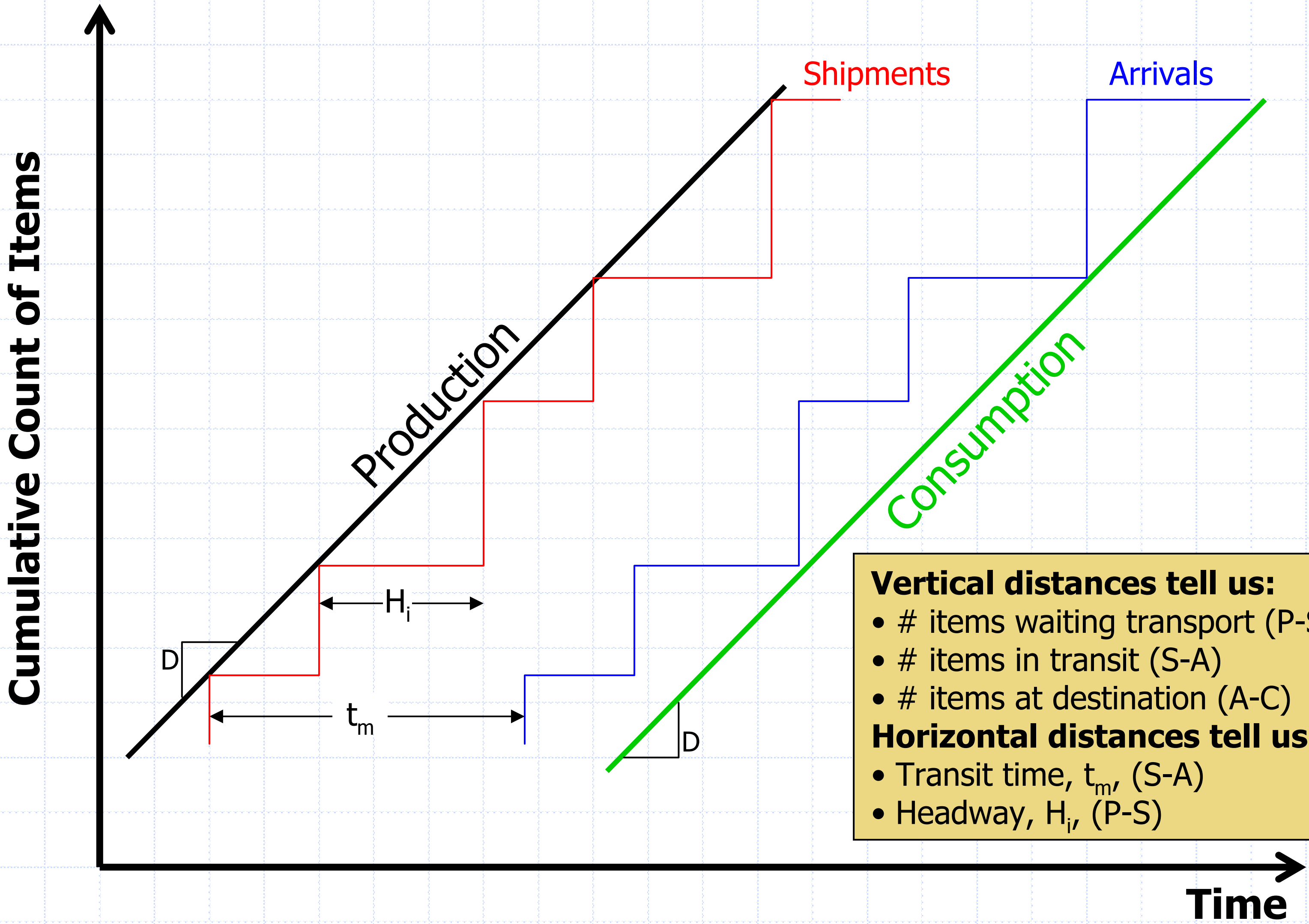
Cumulative Count Curve



Vertical distances tell us:
- # items waiting transport (P-S)
- # items in transit (S-A)
- # items at destination (A-C)

Horizontal distances tell us:
- Transit time, t_m, (S-A)
- Headway, H_i, (P-S)

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Logistics Cost Function

LC (per item) = Holding Costs + Moving Costs

= (Rent Cost + Inventory Cost) + (Transport Cost + Handling Cost)

= R + I + T + H

Nomenclature

- D = Annual demand (items/time)
- c_r = Rent cost ($/item-time)
- c_i = Inventory cost ($/item-time)
- c_f = Fixed transport cost ($/shipment)
- c_v = Variable transport cost (#/item)
- H_{MAX} = Maximum headway (time)
- v = Shipment size (items)
- V = Total number of units shipped$=\Sigma v$
- v_{MAX} = Maximum capacity for transport mode (items)
- c_s = Fixed cost per stop ($/stop)
- c_d = Cost per distance ($/distance)
- c_{vd} = Marginal cost per item per distance
- c_{vs} = Marginal cost per item per stop
- n_s = Number of <u>delivery</u> stops
- c_{vh} = Variable handling costs ($/item)
- c_{fh} = Fixed handling costs ($/pallet)
- v_{hMAX} = Maximum capacity for pallet or box (items)

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Holding Costs = R + I

- Rent Cost ($/item)
  - f(max inventory)
  - Captures facility costs
  - Not affected by the item by item flow

$$AnnualRentCost = c_r D H_{MAX}$$
$$R = c_r H_{MAX}$$

- Inventory Cost ($/item)
  - f(delay to items)
  - Captures capital costs, insurance, etc.
  - Implies that each time period matters equally
  - Constant to each time period (linear)

$$AnnualInventoryCost = c_i D\left(H_{MAX} + t_m\right)$$
$$I = c_i\left(H_{MAX} + t_m\right) = c_i H_{MAX} + c_i t_m$$

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Move Costs = T + H

- Transport Cost ($/item)
  - Fixed and variable components on shipment basis
  - Ignores when and what each shipment contained
  - T decreases with increase in avg shipment size
  - But this is missing some key drivers . . .

$$ShipmentCost = c_f + c_v v$$

$$n\_ShipmentCosts = \sum_{i=1}^{n}\left(c_f + c_v v_i\right) = nc_f + c_v V$$

$$T = c_f\left(\frac{n}{V}\right) + c_v = \left(\frac{c_f}{\bar{v}}\right) + c_v$$

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Transport Costs

- **Relation to Headways**
  - Recall that V=n(Avg H)(D)
  - T decreases w/ increase in Avg H
  - I decreases with H_{MAX}

$$T = \left(\frac{c_f}{D\bar{H}} \right) + c_v$$

- **Relation to Distance**
  - "Fixed" costs are variable wrt stops and distance
  - Marginal cost of an additional item – per stop and per distance – ignore c_{vd}

$$c_f = c_s\left(1+n_s\right) + c_d d$$

$$c_v = c_{vs} + c_{vd} d$$

$$n\_ShipmentCost = nc_f + Vc_v$$

$$T = c_s\left(\frac{1+n_s}{\bar{v}}\right) + c_d\left(\frac{d}{\bar{v}}\right) + c_{vs} + c_{vd} d$$

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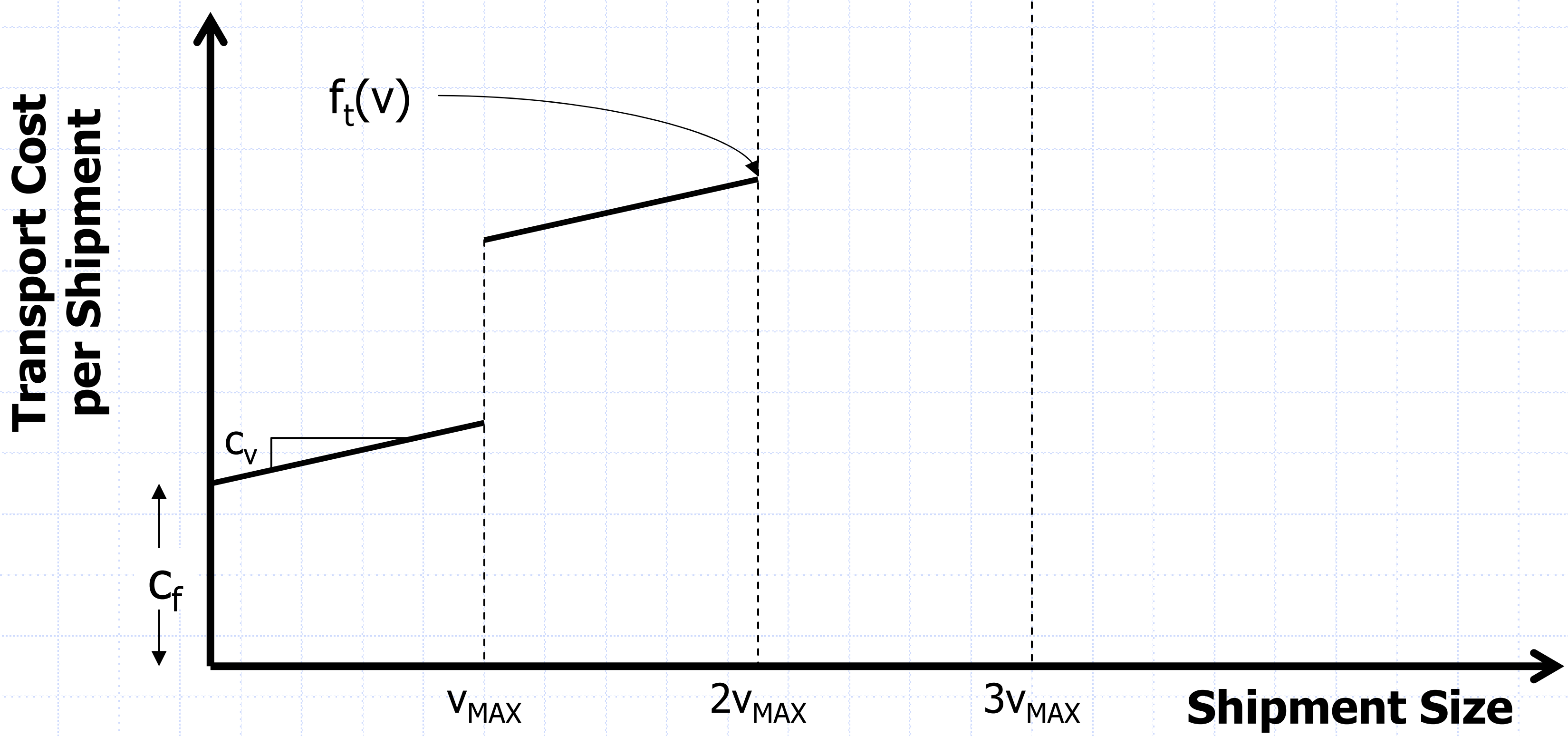
Transport Costs

Relation to Capacity

- $f_t(v)$ is sub-additive: $f_t(v_1+v_2) \leq f_t(v_1)+f_t(v_2)$
- $c_v v_{MAX} << c_f$



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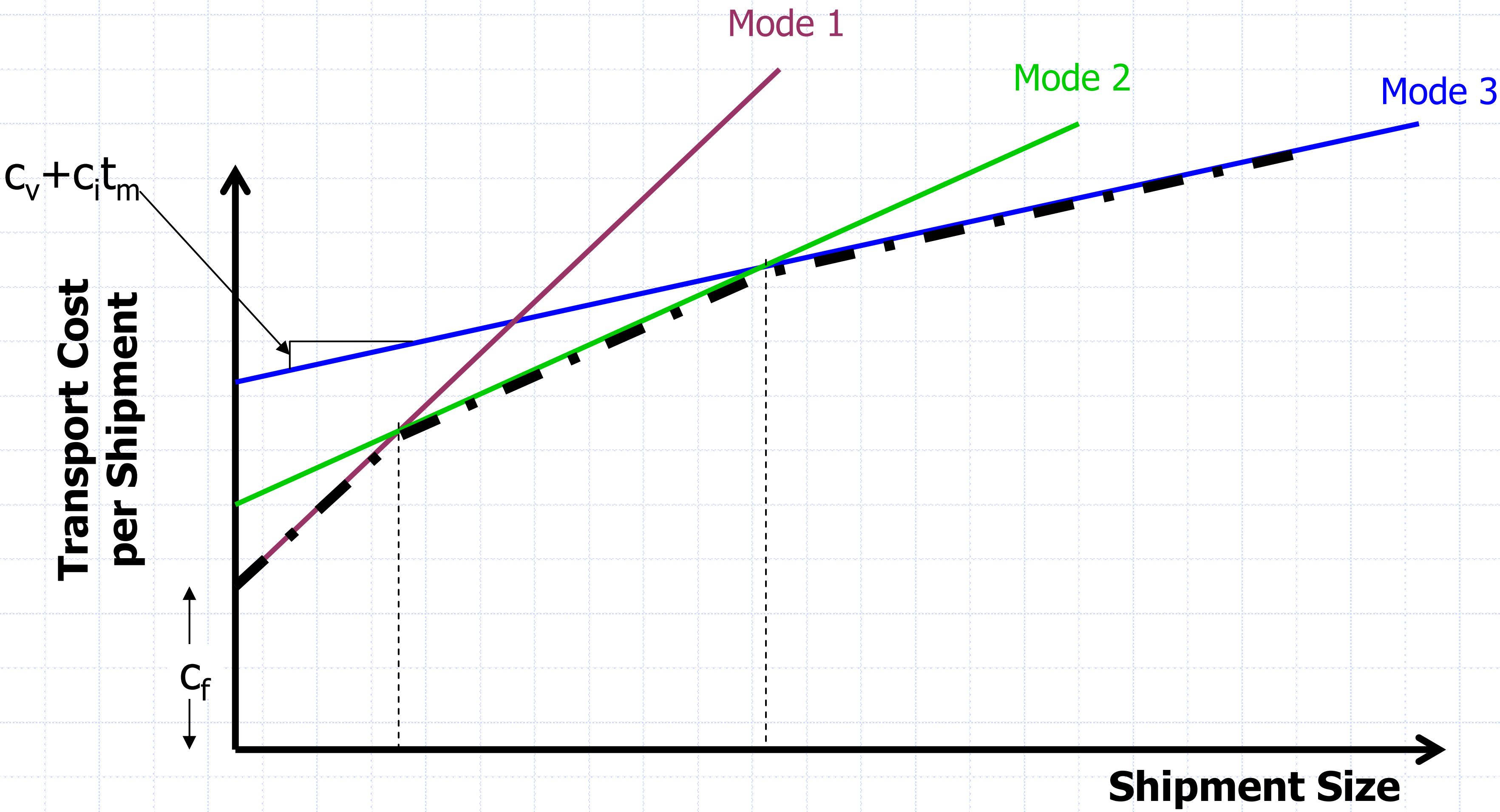
Transport Costs

- Multiple Modes



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Handling Costs

- Handling Costs ($/item)
  - Loading items into boxes, pallets, containers, etc.
  - If handled individually – linear with each item
  - If handled in batches – fixed & variable components
  - Generally subsumed w/in transportation (move) costs as long as $v >> v_{hMAX}$ (total shipment size is greater than pallet)

$$HandlingCost = c_{fh} + c_{vh} v_h$$

$$MovementCost = c_f + \left(c_v + c_{vh} + \frac{c_{fh}}{v_{hMAX}} \right) V$$

$$T + H = c_s \left(\frac{1 + n_s}{\bar{v}} \right) + c_d \left(\frac{d}{\bar{v}} \right) + \left[c_{vs} + c_{vh} + \frac{c_{fh}}{v_{hMAX}} \right]$$

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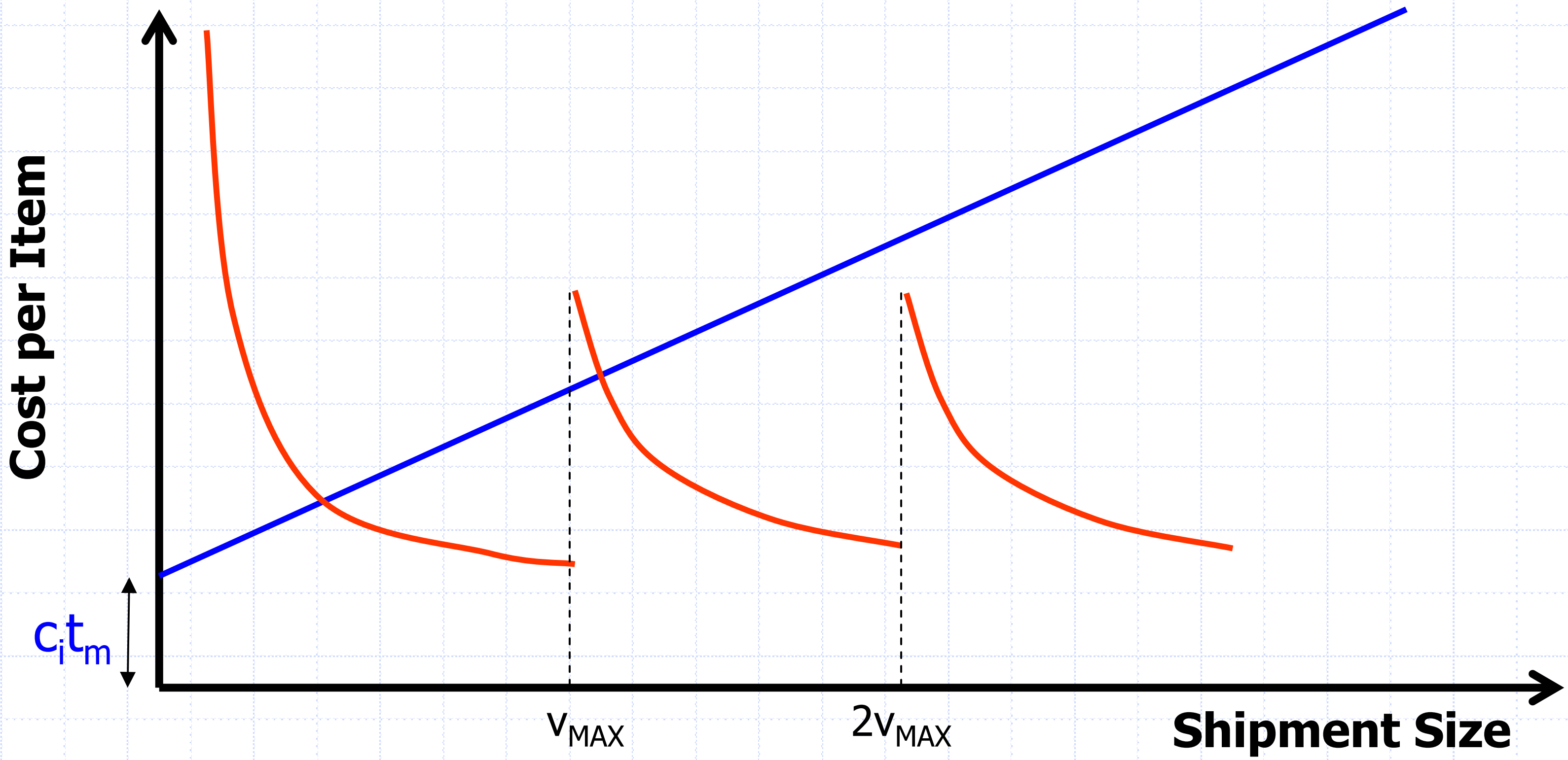
Total Logistics Cost Function

$$LC(\$/item) = c_r H_{MAX} + c_i H_{MAX} + c_i t_m + c_s\left(\frac{1+n_s}{\bar{v}}\right) + c_d\left(\frac{d}{\bar{v}}\right) + c_{vs}$$



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