
Managing Transportation in a Supply Chain

Chapter 14

Sections 4.3, 4.4 and 4.5

Outline

- ◆ **Key modes of transport and major issues**
- ◆ **Transportation System Design**
- ◆ **Tradeoffs in transportation design**
 - **Transportation and service**
- ◆ **Vehicle Routing**

Parties Involved in Transportation

Carriers care about

- ◆ Vehicle related costs
- ◆ Fixed operating costs
- ◆ Trip related costs
- ◆ Quantity related cost
- ◆ Overhead cost

◆ Shippers care about

- ◆ Transportation cost
- ◆ Inventory cost
- ◆ Facility cost
- ◆ Processing cost

- ◆ Service levels and fast delivery.

14.3: Transportation Modes

- ◆ Trucks
 - TL
 - LTL
- ◆ Rail
 - Carload
 - Intermodal
- ◆ Air
- ◆ Package Carriers
- ◆ Water
- ◆ Pipeline

Truckload (TL)

- ◆ **Average revenue per ton mile (1996) = 9.13 cents**
- ◆ **Average haul = 274 miles**
- ◆ **Average Capacity = 42,000 - 50,000 lb.**
- ◆ **Low fixed and variable costs**
- ◆ **Major Issues**
 - **Utilization**
 - **Consistent service among different companies**
 - **Backhauls**

Less Than Truckload (LTL)

- ◆ **Average revenue per ton-mile (1996) = 25.08 cents**
- ◆ **Average haul = 646 miles**
- ◆ **Higher fixed costs (terminals) and low variable costs**
- ◆ **Major Issues**
 - **Location of consolidation facilities**
 - **Utilization**
 - **Vehicle routing**
 - **Customer service**

Rail

- ◆ **Average revenue / ton-mile (1996) = 2.5 cents**
- ◆ **Average haul = 720 miles**
- ◆ **Average load = 80 tons**
- ◆ **Key Issues**
 - **Scheduling to minimize delays / improve service**
 - **Off track delays (at pick up and delivery end)**
 - **Yard operations**
 - **Variability of delivery times**

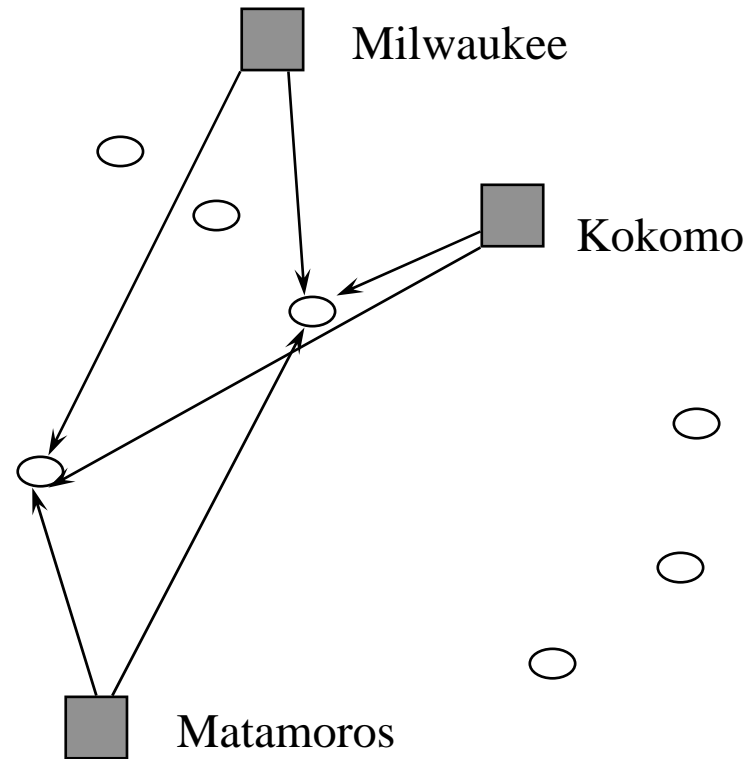
Air

- ◆ **Key Issues for Passenger Airlines, \$250 B /year**
 - **Location/Number of hubs**
 - **Location of fleet bases / crew bases**
 - **Schedule optimization**
 - **Fleet assignment**
 - **Crew scheduling, leg based**
 - **Yield management**
- ◆ **Cargo Airlines, \$40 B /year**
 - **Shape, weight, volume of the cargo**
 - **Cargo shippers, consolidators**
- ◆ **Service supply chains deal heavily with airline issues**

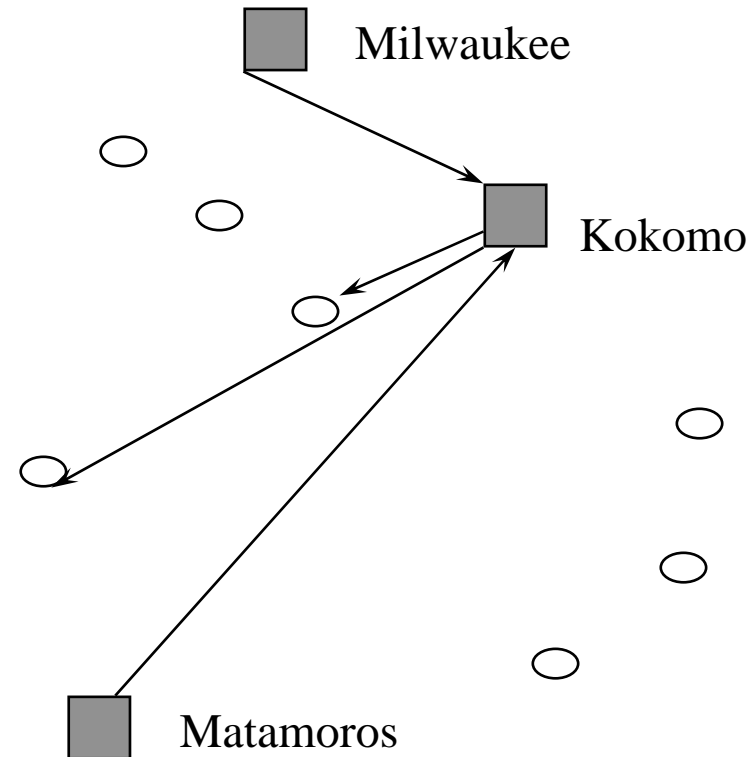
14.4: Transportation System Design

- ◆ **AC Delco: Very high value low volume parts**
 - **Three plants: Milwaukee(Wisc), Kokomo(Ind), Matamoros(Mex)**
 - **21 assembly plants (customers for above plants)**
- ◆ **ACs, batteries, hoses, brakes, belts, etc.**
- ◆ **What are the distribution options? Which one to select?
On what basis?**

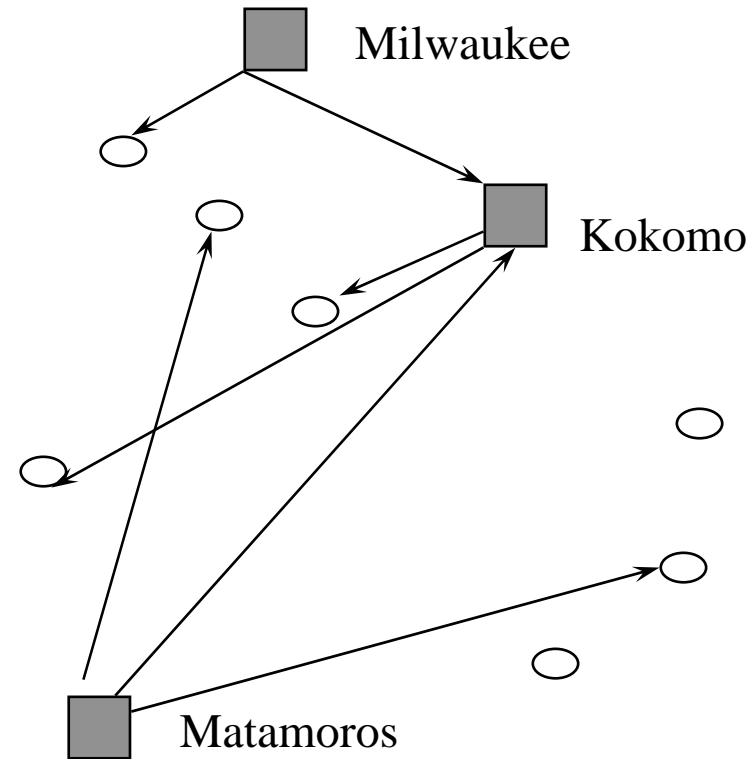
All Shipments Direct



All Shipments Via Kokomo (with or without cross dock)

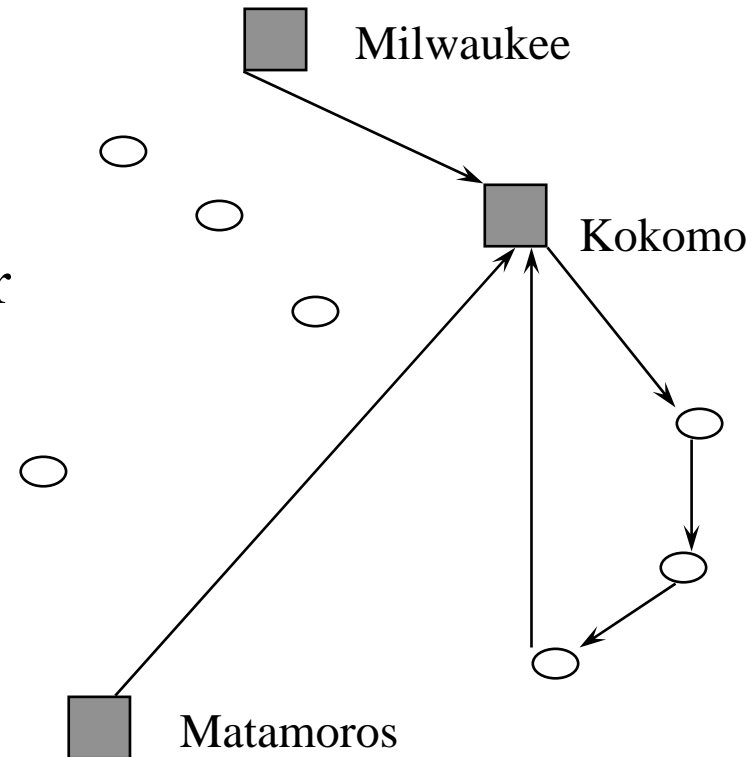


Some Shipments Direct, Others Via Kokomo

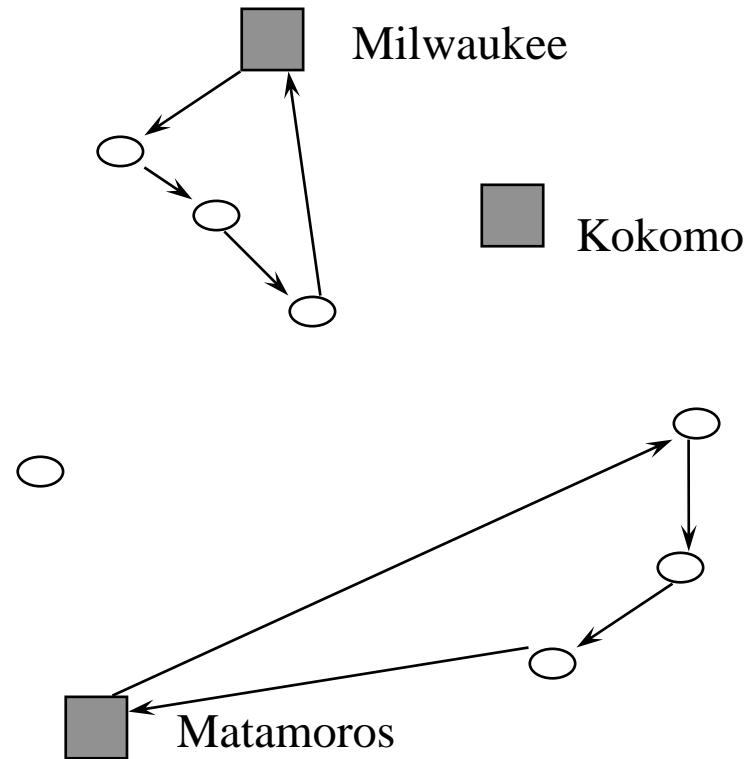


Milk Runs From Kokomo

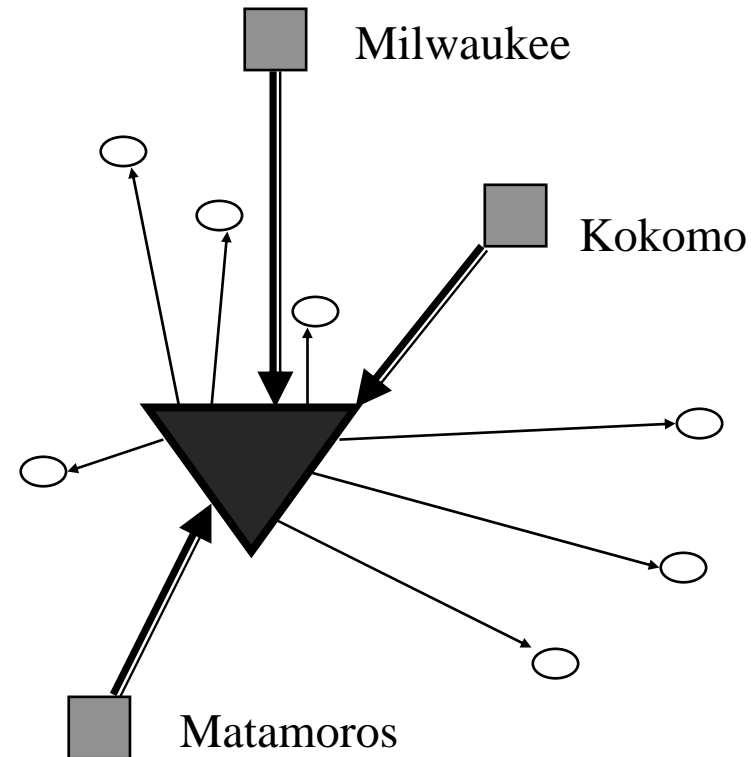
Milk run is loop that contains either single supplier or single customer.



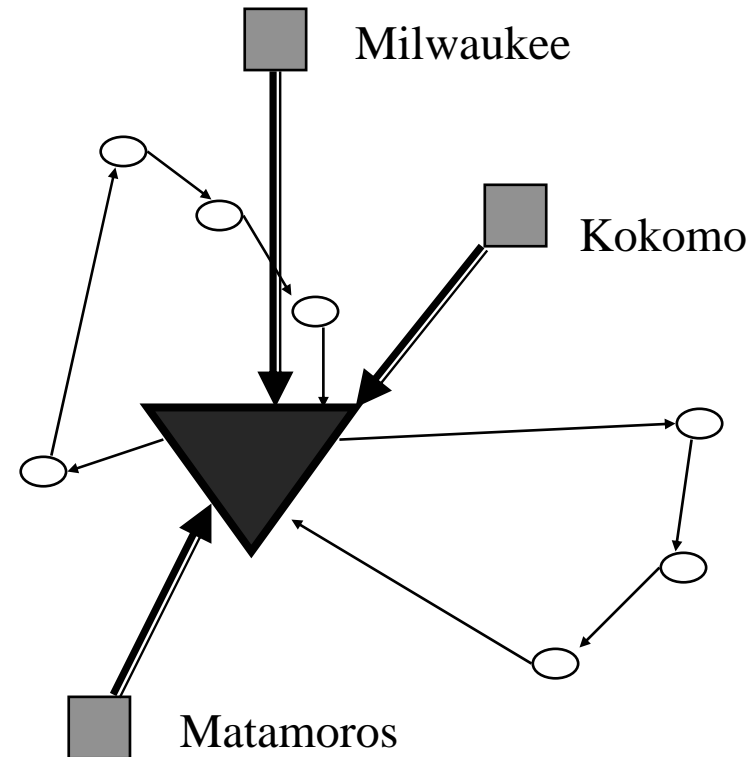
Milk Runs From Plants



Shipments via Central Warehouse



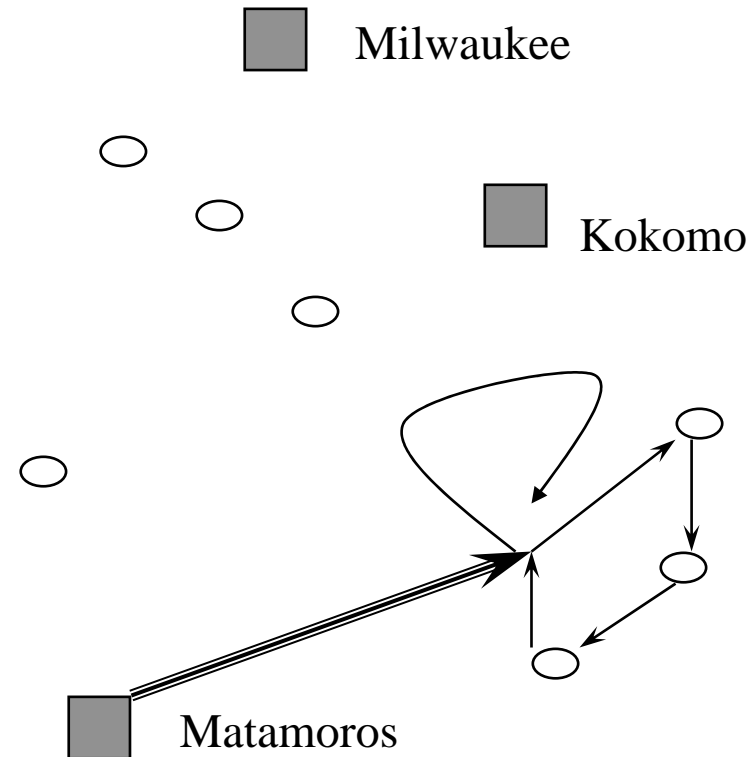
Shipments via Central Warehouse Using Milk Runs



Cross Docking

This approach is useful if deliveries are time sensitive and there are several dropoffs in proximity, not all of which can be delivered on a single truck.

Items are shifted from one truck to another without going to storage. Timing of truck arrivals/departures is very crucial.

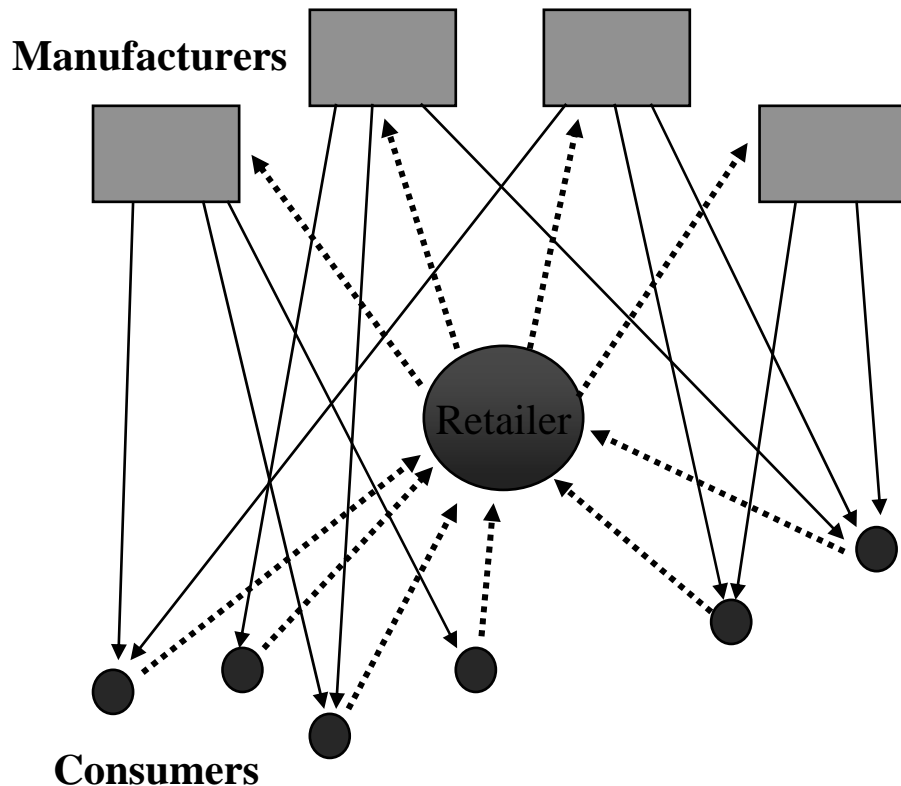


Total Costs

<i>Routes</i>	<i>Transport</i>	<i>Inventory</i>	<i>Total</i>
Direct, Full Load	2.0	17.5	19.5
Direct, Optimal Load	4.0	5.6	9.6
Via Kokomo, Full Load	2.1	9.7	11.8
Via Kokomo, Optimal Load	3.0	7.2	10.2
Direct + Kokomo	3.7	5.8	9.5
Milk run from Kokomo	2.4	7.2	9.6
Milk run from Plants	3.5	4.6	8.1

Section 4.3: Design Options for Distribution

4.3.1: Drop-Shipping or Direct Shipping to Consumer



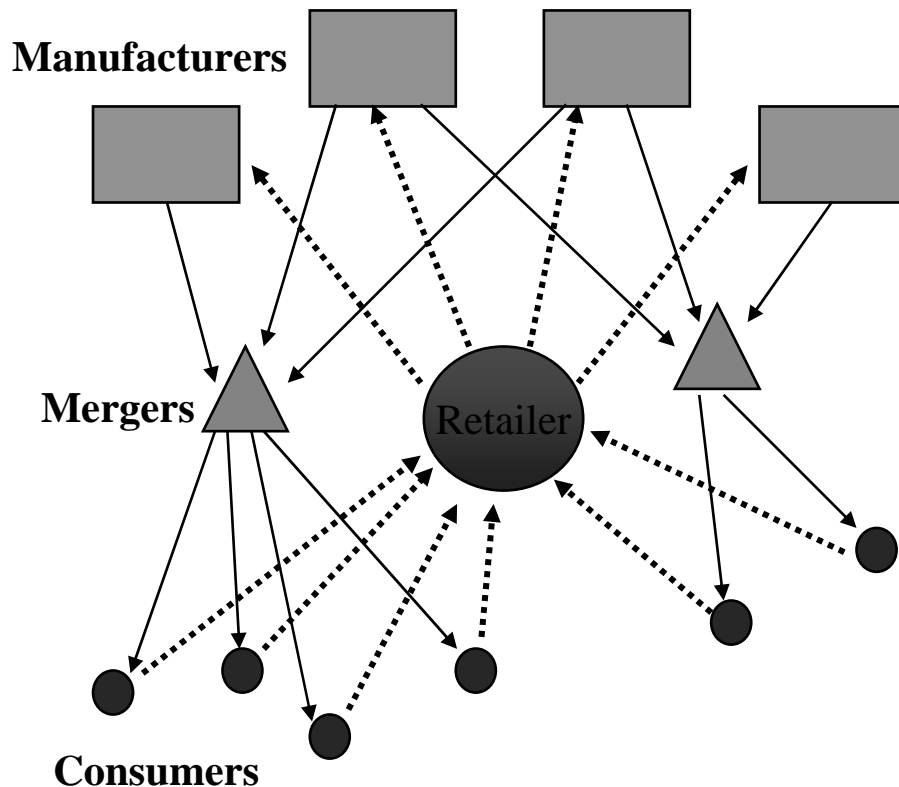
- ◆ Products are shipped directly to the consumer from the manufacturer
- ◆ Manufacturer often uses package carriers for delivery
- ◆ Retailer picks consumer orders from customers and passes them to the manufacturers
- ◆ Retail does not hold product inventory, rather it is purely for order generation (naturally or via promotions, ads)
- ◆ Examples: Dell, Nordstrom

Drop shipping for high-value and low unpredictable demand items

- ◆ All consumers' needs for a particular product is satisfied from a manufacturer: All finished goods inventory for a product reside at one manufacturer. Finished goods inventory is aggregated over different consumers.
 - Aggregated demand often has smaller standard deviation than the sum of the standard deviations of the individual demands in the aggregation because extremes cancel out.
- ◆ Manufacturers postpone customization of products until order is placed. Component and sub-assembly inventory is aggregated over different products.
- ◆ A wide range of products can be provided at a low cost due to postponement.
 - e.g. Dell uses postponement very effectively.
- ◆ Direct shipment simplifies retailers' functions but complicates manufacturers'. Can manufacturer's handle shipping units one by one to the consumers? Manufacturers and retailers must coordinate their actions using an integrated information systems.
- ◆ Product returns are harder to handle.
- ◆ Response times to consumer orders are longer with direct shipping.
- ◆ Direct shipping increases shipment costs.

How to reduce shipment costs for medium demand?

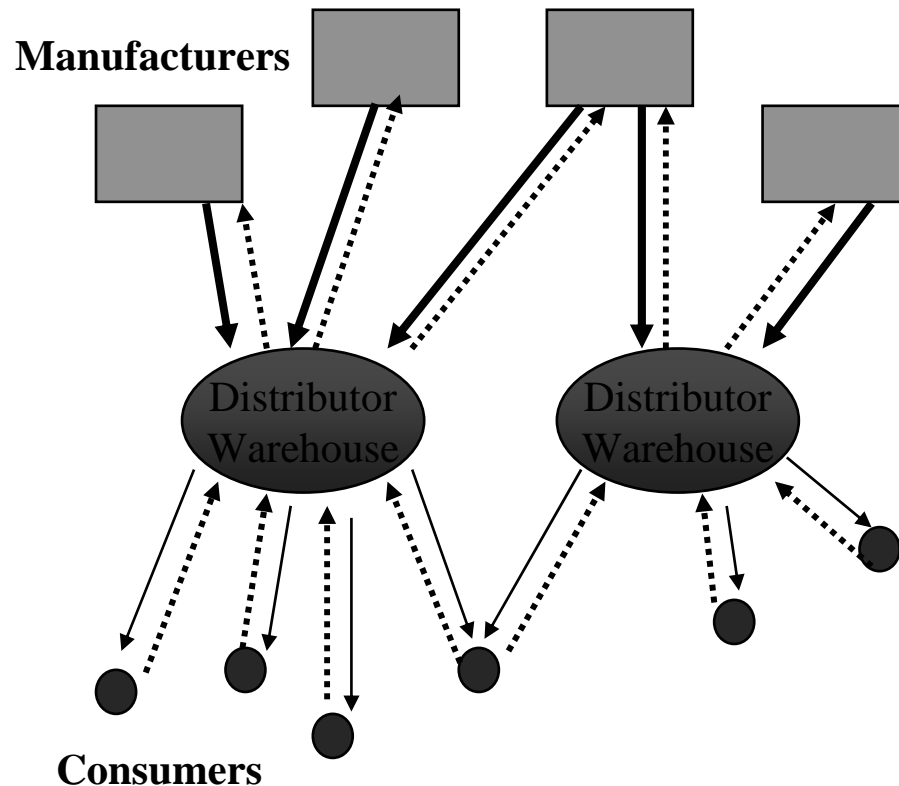
4.3.2: In-Transit Merge



- ◆ The distribution network is too extensive with direct shipping and economies of scale in transportation costs cannot be achieved.
- ◆ Consider merging shipments at Mergers. Shipments to Mergers are larger so economies of scale is achieved.
- ◆ Mergers increase facility costs.
- ◆ Mergers can be done within trucks: Cross-docking becomes useful.
- ◆ Response time may go up.
- ◆ Example:
 - Furniture retailers merge couches and coffee tables produced by different manufacturers
 - Dell merges a Dell PC with a Sony flat screen

How to reduce transportation costs and response times further?

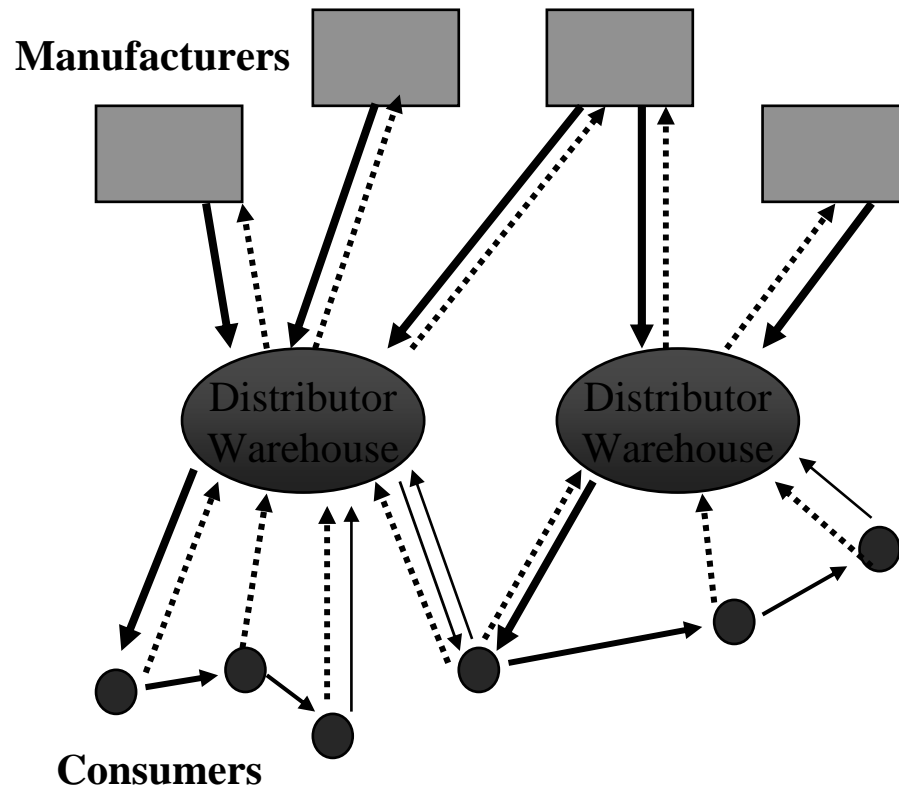
4.3.3: Distributor Storage with Carrier Delivery



- ◆ Keep finished goods inventory at a warehouse which ships to consumers using carriers.
- ◆ Shipments from manufacturers to warehouses are in TL or LTL to exploit economies of scale.
- ◆ Warehouses are physically closer to consumers which leads to
 - Shorter order fulfillment time
 - Shorter distance to cover with package carriers.
- ◆ With respect to In-Transit Merge
 - Inventory aggregation is less
 - Facility costs are higher
- ◆ Easier to run. Warehouse meets the demands so infrequent orders from manufacturers to warehouses.
- ◆ Less information to keep track of. Only warehouses need real time demand/order status information.
- ◆ Example: Amazon

How to provide more delivery service?

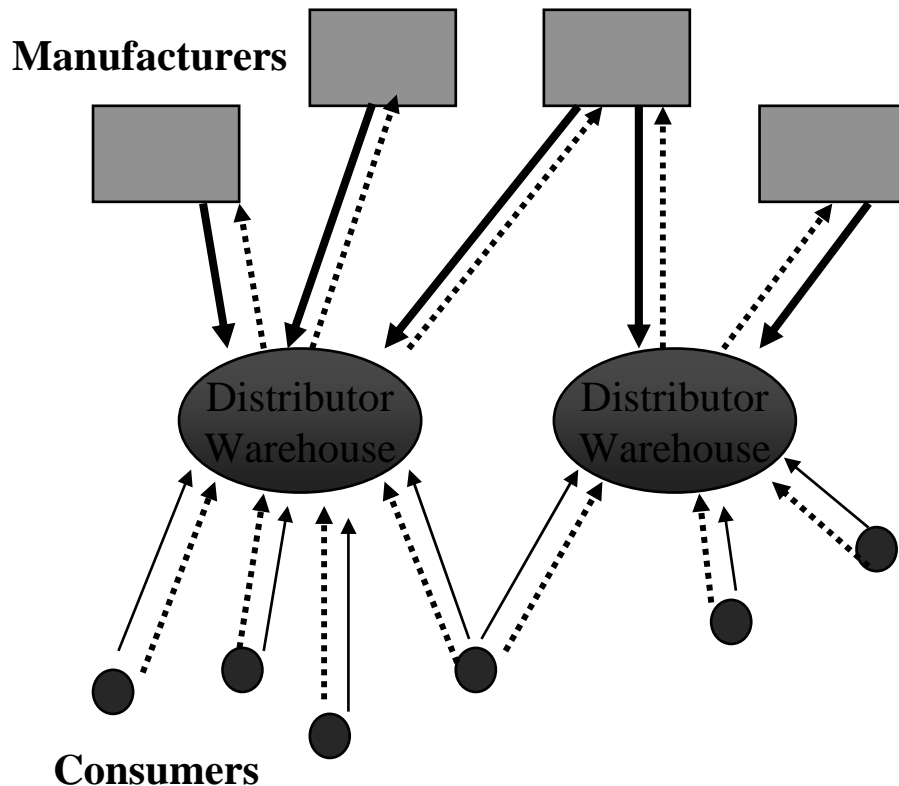
4.3.4: Distributor Storage with Last Mile Delivery



- ◆ Very similar to Distributor Storage with Carrier Delivery except that the warehouse delivers to the consumers using Milk Runs.
- ◆ Transportation costs go up because warehouses are not as effective as package carriers in aggregating loads to have economies of scale.
- ◆ Warehouse may need to own a trucking fleet so the physical infrastructure costs are higher. Products must be flowing fast to justify the infrastructure.
- ◆ The cost for drivers and load handlers are high. Last mile delivery can be a sound option if labor costs are relatively small with respect to the premium consumers are willing to pay for home delivery.
- ◆ Response times are shorter
 - Warehouses are located closer to consumers
 - A private fleet of trucks can deliver faster than package carriers.
- ◆ Home delivery is high customer service; appreciated by the customers for bulky products, e.g. a washer
- ◆ Consumer must pay for delivery costs.
 - Peapod charged \$9.95/delivery
 - Delivery costs can depend on the time of the day
- ◆ Example: Milk delivery, Grocery delivery

How to reduce eliminate consumer's delivery cost?

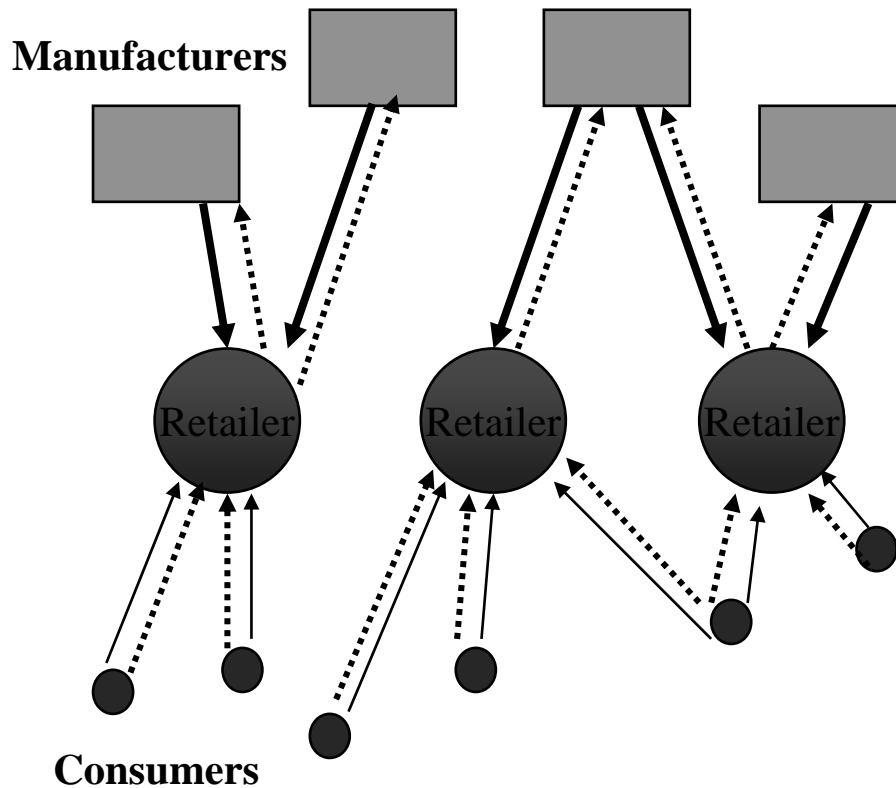
4.3.5: Manufacturer or Distributor Storage with Consumer Pickup



- ◆ If consumers are willing to pick up the products easily, let them do so. Otherwise, they would be charged for the delivery costs.
- ◆ This is very similar to Last Mile Delivery except that the consumers come to pick up sites (warehouse, retailer) to get the products.
- ◆ Order tracking is crucial. Consumers must be alerted when their order is ready for pick up. Once a consumer arrives at the pick up site, the products must be quickly located.
- ◆ Significant amount of information is required to run.
- ◆ Example: 7dream.com of Japanese 7-Eleven
 - Check it out but it is in Japanese

How to push products closer to consumers?

4.3.5: Retail Storage with Consumer Pickup



- ◆ Consumers can also pick up from retailers. This is the most common form of shopping.
- ◆ This is very similar to consumer pick up from warehouses except that now the consumers go to retailers which are closer to consumers and more conveniently located for pick ups.
- ◆ Inventories at warehouses are aggregated over consumers. Typically a single warehouse serves many more consumers than a single retailer would. Inventory aggregation happens at a greater extent when consumers pick up from the warehouses.
- ◆ Order tracking may not exist. If the product is available at the retailer, the consumer buys. Otherwise goes to another retailer
- ◆ Example: All the retail stores. Wal-Mart, Albertson's, Van Heusen Shirts, JCPenny₂₅

There are many distribution options but which are suitable for a given circumstance?

	Drop Ship	In-Transit Merge	Package Carrier Delivery	Last Mile Delivery	Pickup from Warehouse	Pickup from Retailer
High-demand						
Medium-demand						
Low-demand						
Very low-demand						
Many product resources						
High product value						
Quick desired response						
High product variety						
Low customer effort						

Red very suitable; Magenta somewhat suitable.

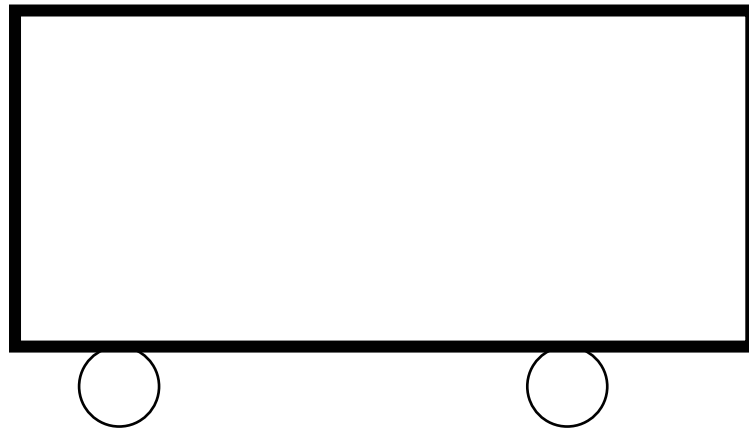
What value do distributors add to SCs?

- ◆ Economies of scale in inbound transportation costs to distributors
- ◆ Economies of scale in outbound transportation costs from distributor to retailers by combining shipments coming from several manufacturers and going to the same retailer.
- ◆ Inventory aggregation at the distributor as opposed to individual retailer inventories
- ◆ Smooths out orders coming from retailers and going to manufacturers. This is a side effect of aggregation.
- ◆ Distributors provide a compromise strategy, for keeping inventories in the SCs, between
 - Storage at the manufacturer with direct shipments
 - » Low inventory cost but high transportation cost
 - Storage at the retailer with customer pickups
 - » High inventory cost but low transportation cost
- ◆ By specializing on distribution, distributors do a better job in logistics of shipments:
 - On time deliveries
 - Breaking bulk shipments
 - Shipment tracking

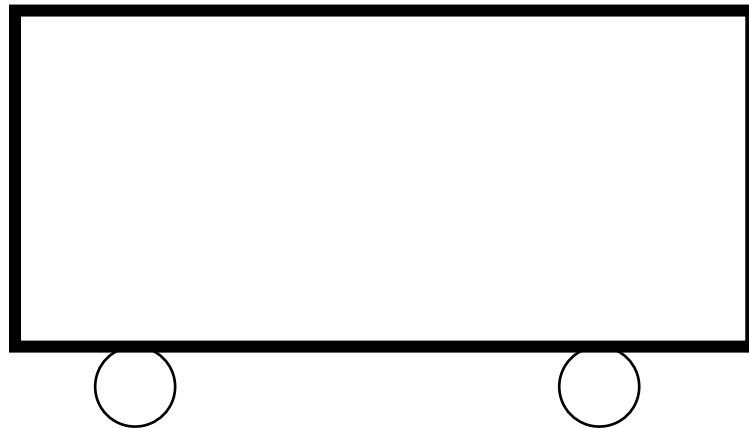
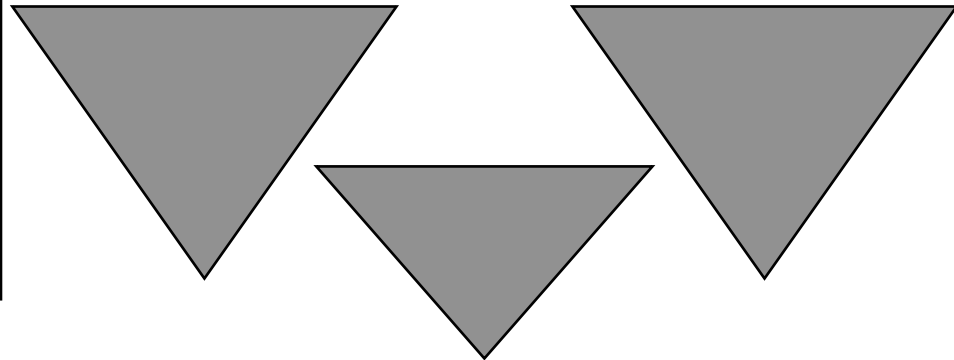
14.5: Tradeoffs in Transportation Design

- ◆ Transportation, facility, and inventory cost tradeoff
 - Choice of transportation mode (later)
 - Inventory aggregation (later)
- ◆ Transportation cost and responsiveness tradeoff
 - Temporal aggregation leads to economies of scale
 - Temporal aggregation decreases responsiveness
 - See Table 14.8 for Alloy Steel

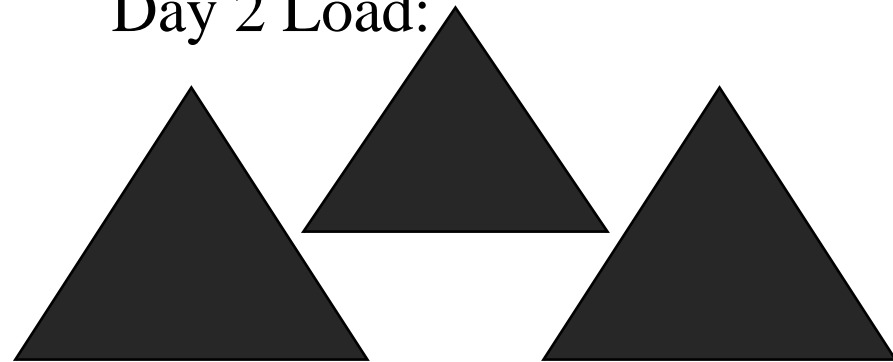
Temporal aggregation: Extremes cancel out



Day 1 Load:



Day 2 Load:



2 trucks at the end of each day or 2 trucks at the end of the 2. day?

14.6: Tailored Transportation

- ◆ By product characteristics
- ◆ By customer density and distance
 - High density, short distance: private fleet, milk runs
 - » Milkman, 7-Eleven Japan
 - Low density, high distance: package carrier
 - » Amazon
- ◆ By customer size
 - Various frequencies of deliveries
 - Delivery on Even days to (L,H), on Odd days to (H)
- ◆ By value and volume
 - If High value, use fast transportation; semiconductor chips
 - If High volume, can afford to disaggregate inventories that is use several warehouses; Wal-Mart DCs
 - If High cube, ?

Routing and Scheduling in Transportation

◆ Clustering

- Assignment of trucks to demand points

◆ Routing

- Sequencing demand points
- Trucks use these sequences to visit demand points

◆ Scheduling

- Exact time of visits/loading and unloading

Classification: Vehicle Routing Problems

- ◆ Demand uncertainty
 - Repair operations, spare parts demand for Xerox customers
- ◆ The nature of operations: pick up / load
- ◆ Planning periods: Single vs. Multiple
- ◆ Static vs. Dynamic, extent real time info used
 - Wireless technologies can help
- ◆ Fleet capacity, known? Strategic vs Operational.
- ◆ Delivery time windows.
 - I want my paper in the morning
- ◆ Objective: transportation costs, inventory costs, crew costs

Two-phase VRP heuristics

- ◆ Clustering
 - Saving matrix method
 - Generalized assignment method
- ◆ Sequencing
 - Route sequencing
 - Route improvement
- ◆ We provide a brief discussion. More detailed discussion is in
 - OPRE 6370: Logistics and Distribution

Clustering: Saving matrix method

- ◆ Distances are Euclidean or Rectilinear
- ◆ Savings of consolidating two customers x, y :
 - Eliminating going from DC to x and
 - Eliminating going from DC to y
 - But adding going from x to y

$$S(x,y) = \text{Dist}(\text{DC},x) + \text{Dist}(\text{DC},y) - \text{Dist}(x,y)$$

$S(x,y) < 0$, when is this possible if ever?

Clustering Example

	X-Coordinate	Y-Coordinate	Demand
Warehouse	0	0	
Customer 1	0	12	48
Customer 2	6	5	36
Customer 3	7	15	43
Customer 4	9	12	92
Customer 5	15	3	57
Customer 6	20	0	16
Customer 7	17	-2	56
Customer 8	7	-4	30
Customer 9	1	-6	57
Customer 10	15	-6	47
Customer 11	20	-7	91
Customer 12	7	-9	55
Customer 13	2	-15	36

Clustering: Distance Matrix

	Whse	Cust 1	Cust 2	Cust 3	Cust 4	Cust 5	Cust 6	Cust 7	Cust 8	Cust 9	Cust 10	Cust 11	Cust 12	Cust 13
Whse	0													
Cust 1	12	0												
Cust 2	8	9	0											
Cust 3	17	8	10	0										
Cust 4	15	9	8	4	0									
Cust 5	15	17	9	14	11	0								
Cust 6	20	23	15	20	16	6	0							
Cust 7	17	22	13	20	16	5	4	0						
Cust 8	8	17	9	19	16	11	14	10	0					
Cust 9	6	18	12	22	20	17	20	16	6	0				
Cust 10	16	23	14	22	19	9	8	4	8	14	0			
Cust 11	21	28	18	26	22	11	7	6	13	19	5	0		
Cust 12	11	22	14	24	21	14	16	12	5	7	9	13	0	
Cust 13	18	28	19	28	25	15	13	10	11	14	6	8	8	0

Clustering

	Truck	Cust 1	Cust 2	Cust 3	Cust 4	Cust 5	Cust 6	Cust 7	Cust 8	Cust 9	Cust 10	Cust 11	Cust 12	Cust 13
Cust 1	1	0												
Cust 2	2	11	0											
Cust 3	3	21	15	0										
Cust 4	4	18	15	28	0									
Cust 5	5	10	14	18	19	0								
Cust 6	6	9	13	17	19	29	0							
Cust 7	7	7	12	14	16	27	33	0						
Cust 8	8	3	7	6	7	12	14	15	0					
Cust 9	9	0	2	1	1	4	6	7	8	0				
Cust 10	10	5	10	11	12	22	28	29	16	8	0			
Cust 11	11	5	11	12	14	25	34	32	16	8	32	0		
Cust 12	12	1	5	4	8	12	15	16	14	10	18	19	0	
Cust 13	13	2	7	7	8	18	25	25	15	10	28	31	21	0

Infeasible if total load is over truck capacity of 200.

Already in the route.

Clustering with savings matrix

- ◆ Attempt to combine different routes with the highest available saving
 - If load is over capacity, reject the combination
 - Else accept the combination and make savings unavailable

Truck routes: {1,3,4}, {2,9}, {6,7,8,11} (=fills truck by 193/200) and {5,10,12,13}

Clustering: Generalized Assignment Method

- ◆ Assign seed points for each route
 - Seeds
 - Sweep clockwise by θ to obtain cones to assign seeds
 - Seed is at $(d_{\max}, \theta / 2)$ where d_{\max} is the distance from origin to the furthest demand point in the cone
- ◆ Evaluate insertion cost for each customer i and seed k
 - $c_{ik} = \text{Dist}(\text{DC}, i) + \text{Dist}(i, S_k) - \text{Dist}(\text{DC}, S_k)$
- ◆ Assign customers to routes with an Integer Program

How Much to Sweep

- ◆ For every cone sweep as much as possible before going over the transportation capacity b_k
- ◆ What if for same demand point i :
 - If i is not included, below capacity and if i is included above capacity
 - » Use the ArcTan method of the book
 - » Decide ad hoc, remember you are not making the final call here. The final assignments and cluster construction is by the Integer Program.

Assign Customers to Routes

$$\text{Min} \sum_{k=1}^K \sum_{i=1}^n c_{ik} y_{ik}$$

ST:

$$\sum_{k=1}^K y_{ik} = 1 \quad \text{For all customer } i \text{'s}$$

$$\sum_{i=1}^n a_i y_{ik} \leq b_k \quad \text{For all truck } k \text{'s}$$

$$y_{ik} \in \{0,1\}$$

Using either savings matrix or generalized assignment we obtain the clustering.

Routing by Construction

- ◆ Traveling Salesman Problem, construction heuristics:
 - Farthest insert: Given a trip and customers to be inserted, obtain the best way to insert each customer. Insert the customer giving the longest trip.
 - Nearest insert: Exactly the same as farthest insert, except that the customer giving the shortest trip is inserted.
 - Nearest neighbor: Insert the nearest neighbor.
 - Sweep: Insert in the order of a sweep.
- ◆ Sweep needs a picture

Routing by Improvement

- ◆ Traveling Salesman problem, route improvement
 - 2-Opt, cuts into two paths, how many ways to join?
 - 3-Opt, cuts into three paths, how many ways to join?
 - Both needs a route to begin with. They cut and paste pieces of routes to improve the total length of the tour.

Summary of Learning Objectives

- ◆ Strengths and weaknesses of transport modes
- ◆ Choices of transportation networks
- ◆ Tradeoffs in transportation network design
- ◆ Tailored transportation networks
- ◆ Heuristics for Clustering and Sequencing