



P11

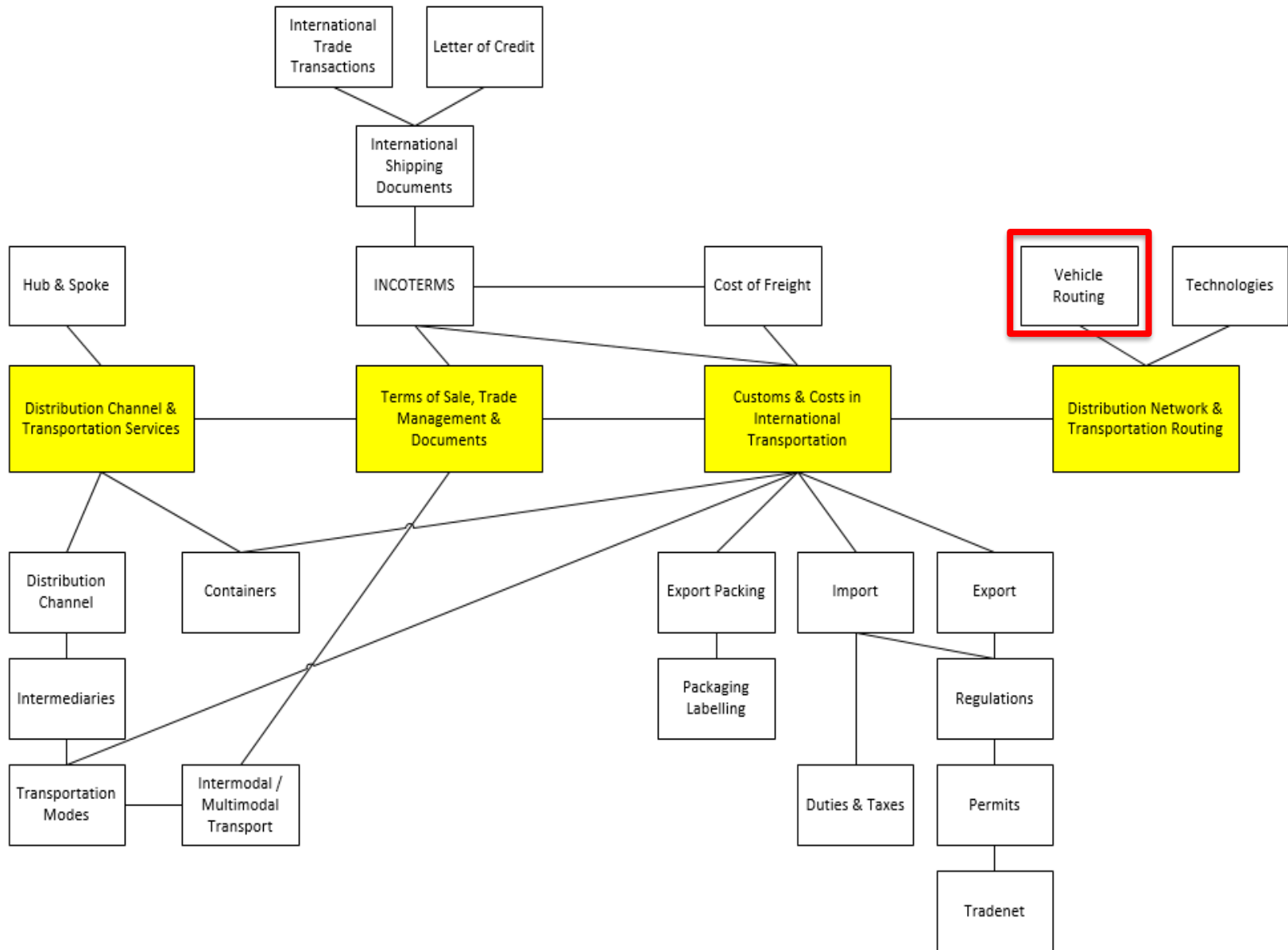
How to Deliver

- Explain Vehicle Routing Problem (VRP)
- Apply the principles of good routing
- Recommend technologies to enhance vehicle routing
- Solve a real-life vehicle routing problem



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E216 Distribution
&Transportation

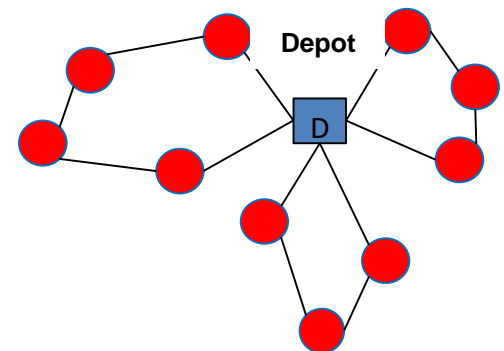
E216 Distribution & transportation - Topic Tree



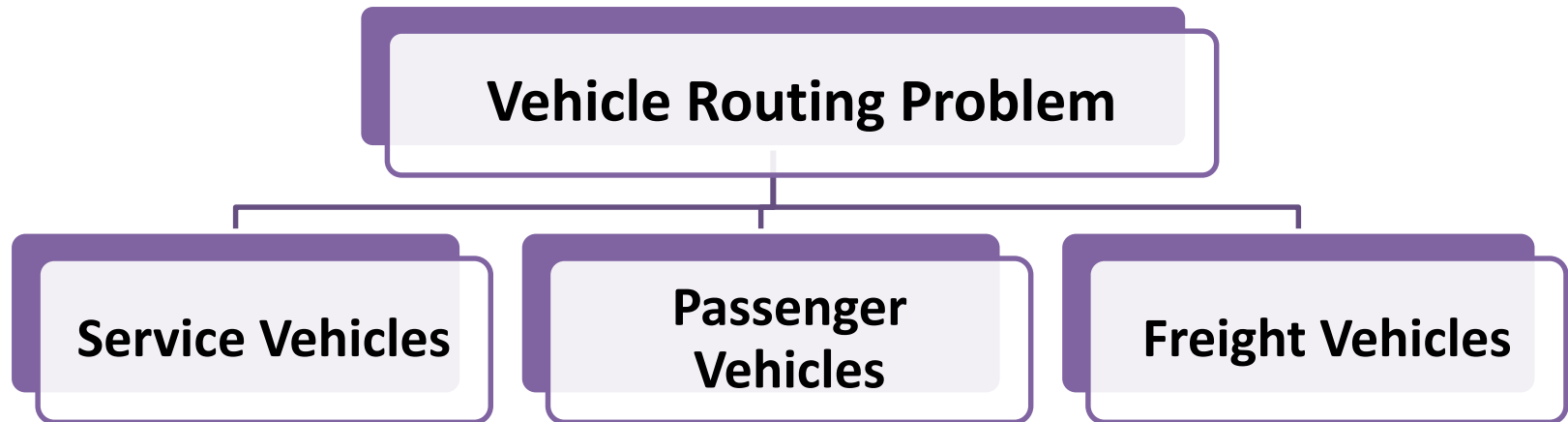
Vehicle Routing Problem (VRP)



- Fleet of vehicle is available at a:
 - Single terminal to serve a set of stops with;
 - Shipment size associated with each stop and;
 - A cost is associated with each ordered pair of stops
- The objective is to deliver shipments to all stops at **minimum cost** in a set of cycles **without violating vehicle capacity**

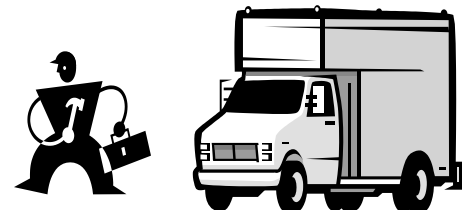


Vehicle Routing Problem (VRP)



Service Vehicles

- Service vehicles do not move things or people from place to place; support jobs in the field (e.g. vans for repairman)
- Service routes are not constrained by shipment sizes and vehicle capacity; constrained only by the **time in the driver's day or shift**



Vehicle Routing Problem (VRP)



Passenger Fleets

- Also known as “carriers”; they carry something from one place to another
- Length of routes are **constrained by the number of seats** (or combination of standing and sitting room)

Freight Vehicles

- Carriers: ships, trucks, rail or air
- Are **capacity limited**
- Commercial software is clearly targeted at the trucking segment



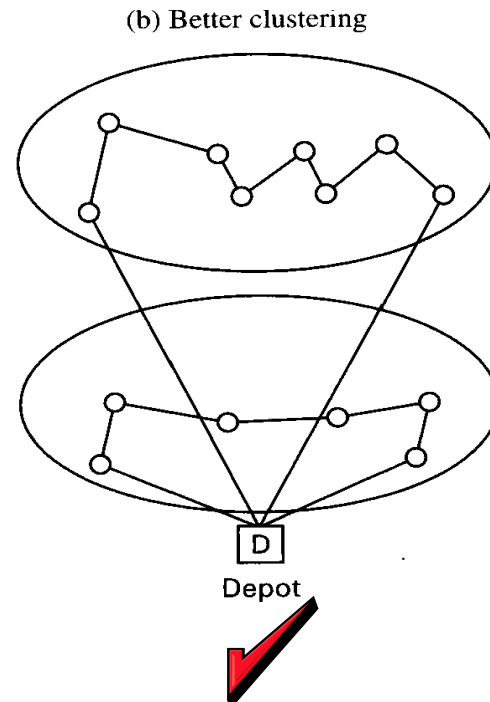
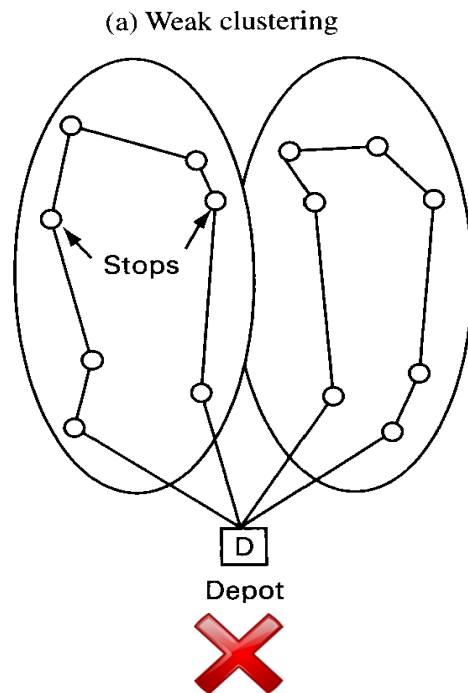
Principles of Good Routing



(Note: You may consider adopting some of these principles during transportation routing problem)

Load trucks with stop points closest to each other

- Minimize the inter-stop travel between stops → Minimize the total travel time on the route

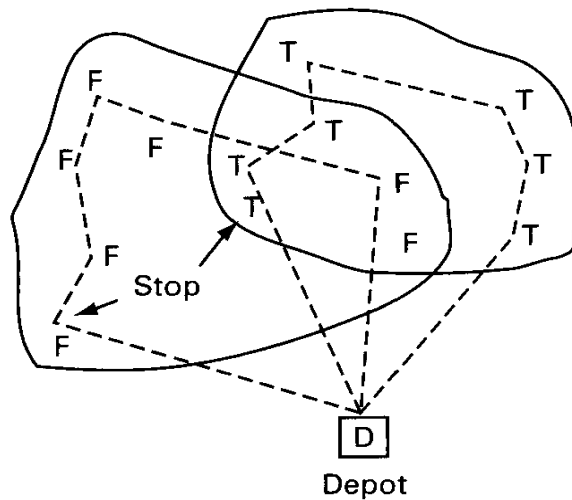


Principles of Good Routing

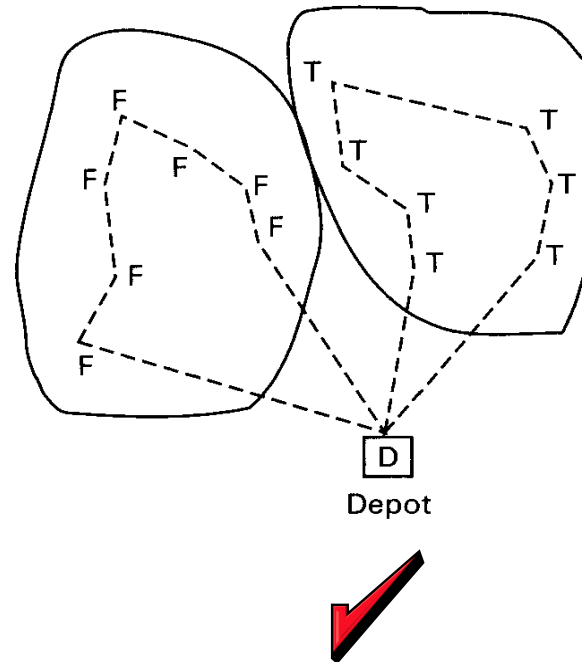


Stops on different days should be arranged to minimize travel time and distance

(a) Weak clustering—routes cross



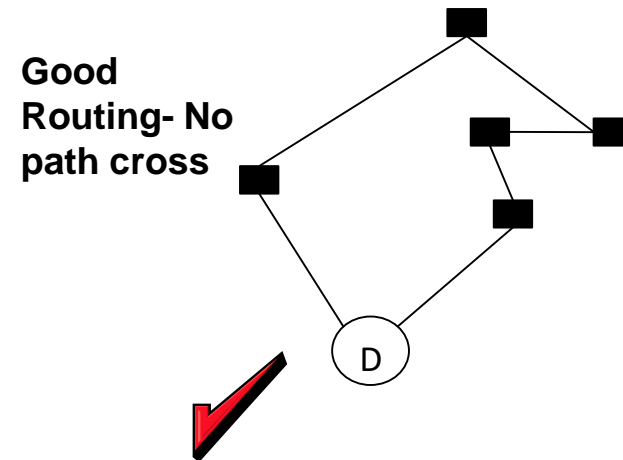
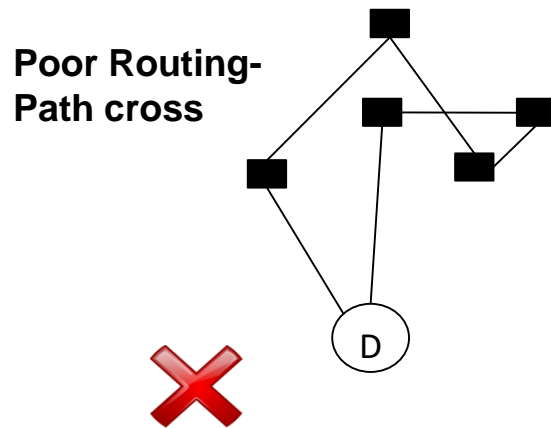
(b) Better clustering



Principles of Good Routing



Stops should be sequenced so that no path cross each other



Pickup should be mixed into delivery routes rather than assigned to the end of the routes

- Pickups should be made as much as possible during the courses of deliveries to minimize the amount of path crossing

Principles of Good Routing



Most efficient routes are built using the largest vehicles available

- Using a vehicle large enough to handle all stops in one route will minimize total distance/time traveled to serve the stops

For a stop that is far from a route cluster, alternate means of transport can be explored

- Using small trucks or for-hire transportation service as alternative

Avoid short stop time windows

- Narrow stop time window can force stop sequencing away from ideal patterns
- Renegotiate for widened time window limits

What is a good VRP application?



A good vehicle routing application should:

- Integrate with fleet management system
- Integrate with vehicle tracking system
- Integrate with inventory management system
- Have user friendly graphic user interface (GUI)
- Generate routes based on road network data
- Be able to react to real-time road traffic condition
- Consider delivery time windows, vehicle capacity,
- Handle vehicles with different capacities
- Balance the truck operation cost and driver's overtime cost
- Consider multiple depots
- Consider pickup and delivery sequence and vehicle capacity
- Consider variation of delivery time

Technologies to Enhance Vehicle Routing



- Technology is what truly makes automated practices practical today.
- Some examples of technologies that may be used to enhance vehicle routing are:

On-Board Trip Recorder / camera

- Devices both record vehicle speeds and engine vital signs and record drivers to create hours-of-services logs
- Can also display route instructions to drivers and upload actual route lengths at the end of the day to compare software estimates against actual.

In-Vehicle Navigation System / Global Positioning Systems (GPS) Receivers

- Provide turn-by-turn instructions to destinations through use of GPS receivers, map databases and shortest path algorithms
- Voice synthesizers and recognition systems provide back-seat drivers to know where he is going
- Greater flexibility to reassign drivers on a day-to-day (or minute-by-minute) basis (No longer be constrained to sending drivers into unfamiliar territory)



Technologies to Enhance Vehicle Routing



Cell Phones/ Smart Phones

- “Affordable GPS real-time tracking & reporting” — Routing and scheduling transformed by the ability to track and communicate with drivers via inexpensive cell phones (or smart phones) and personal digital assistants (PDAs)
- Embedded Global Positioning System (GPS) chips in cell phones, sometimes augmented by triangulation among cell phone towers



Transportation Management Software (TMS)



Example: V3 Transplanner

Create Order/Plan

Add New Order Item Record

Qty	Length (cm)	Width (cm)	Height (cm)	Weight/Unit (kg)	Chargeable Weight Calc	Chargeable Weight (kg)
20	75	25	50	5	6000	3126
Total Volume :		1.88	(m ³)	Total Weight :		0.00 (kg)
				Total Chargeable Weight :		31260

Submit Cancel

Order

*CustomerId : E77C

Customer Ref. No. :

*Activity Type : Deliver

MAWB :

HAWB :

Search Consignee :

Consignee : --Select Consignee--

Consignee Address :

*Receipt Date : 2008/10/07

Remarks :

Ext. Order No. :

*Start Time(Pick/Drop) : 2008/10/07 11:00 M

*End Time(Pick/Drop) : 2008/10/07 22:00 M

*Item : 20

Total Chargeable Weight : 31260 [kg]

Total Gross Weight : 100.00 [kg]

Total Volume : 1.88 m³

Customer DO. No. :

Search Shipper :

Shipper : Hougang Mall

Shipper Address : Hougang Mall

Category : GP

Add Clear

Route Plan

3. Vehicle Type : big

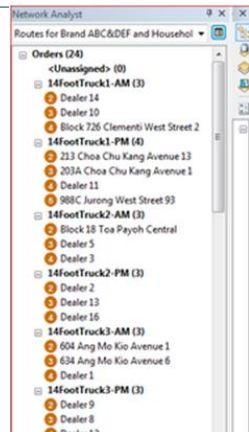
3.1. Vehicle 1:Assign --Select Vehicle-- assign

Capacity :6000.0(kg)---->Used:415.0(kg)

Volume:30(m³)---->Used:10.998(m³)

Location	Arrive at	Process begin at	Leave at	Order	Item
RP Toys Ltd	08:00:00	08:00:00	08:00:00	--	--
Causeway Point	08:02:08	08:02:08	08:35:28	ISN00000117	Detail
West Mall	08:49:33	08:49:33	09:09:33	ISN00000125	Detail
Jurong Point	09:15:22	09:15:22	09:40:22	ISN00000127	Detail
Takashimaya	09:57:19	09:57:19	10:37:19	ISN00000121	Detail
United Square	10:41:06	10:41:06	11:01:06	ISN00000119	Detail
RP Toys Ltd	11:19:31	11:19:31	11:19:31	--	--

Example: ArcGIS



Today's Problem



Determine the **postal codes** of the locations

E.g. Google Maps, singpost.com, streetdirectory.com, gothere.sg

No.	Locations	Postal Codes
1	9 Woodlands Ave 9 (Brown Cookies)	738964
2	Hougang Mall	538766
3	Tampines Mall	529510
4	East Coast Seafood Center	449883
5	Causeway Point	738099
6	United Square	307591
7	Ngee Ann City	238873
8	Ang Mo Kio Hub	569933
9	Jurong Point	648886
10	Changi International Airport	819642
11	Thomson Plaza	574408
12	White Sand Shopping Centre	518457
13	Tanjong Katong Complex	400845
14	National University of Singapore	119077
15	North Point Shopping Centre	769098

Google maps Find businesses, addresses and places of interest.

[Get Directions](#) [My Maps](#)

Narrow by: [User Rating](#)

Hougang Mall

Categories: [Travel Service](#), [Cash Machine](#)

Did you mean: [Hougang Mall near United States](#)

Posb - Hougang Mall [more info](#)

POSB - Hougang Mall, 90 Hougang Avenue 10 538766, Singapore - 6487 4155 [Write a review](#)

FIND POSTAL CODE

To find a postal code, please use one of the following search options, then click 'find it'

Result

building/block/house no. : 90
street name : HOUGANG AVENUE 10
building/estate name : HOUGANG MALL
building type : BLOCK
Postal Code : 538766

[MAP](#)

Today's Problem



Step 2: Determine the **distance between locations**

E.g. Google Maps, streetdirectory.com, gothere.sg

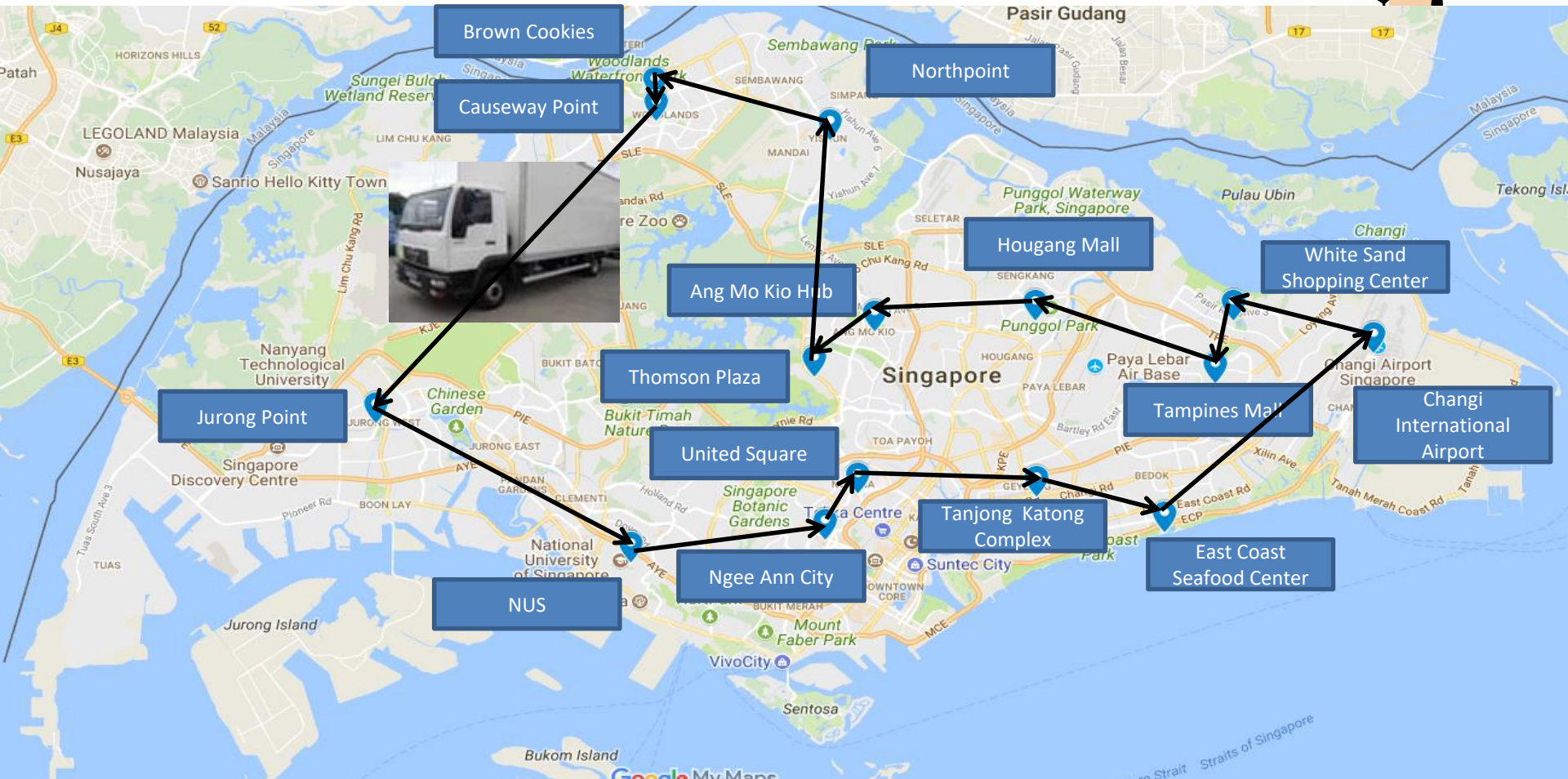
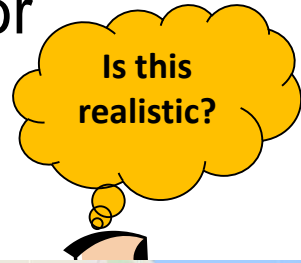
Distance between Locations	9 Woodlands Ave 9	Hougang Mall	Tampines Mall	Causeway Point	United Square	Ngee Ann City	Ang Mo Kio Hub	Jurong Point	Changi International Airport	East Coast Seafood Centre	Thomson Plaza	White Sands Shopping Centre	Tanjong Katong Complex
9 Woodlands Ave 9		18.7	25.4	1.3	19.5	21	12.7	19.1	30.6	31.7	18.3	24	24.7
Hougang Mall	18.7		11.5	19.2	13.7	14.6	6.8	29.7	17.2	13.7	12.4	10.1	9.7
Tampines Mall	25.4	11.5		24.4	16.1	17	17.7	31.5	9.4	7.1	16.3	3.8	8.9
Causeway Point	1.3	19.2	24.4		19	20.4	12.1	19.2	30.6	31.1	17.7	23.4	24.1
United Square	19.5	13.7	16.1	19		2.8	6.6	18.8	22.3	13.4	3	21.4	9.6
Ngee Ann City	21	14.6	17	20.4	2.8		8.9	20.1	22.5	13.6	4.3	22.4	8.2
Ang Mo Kio Hub	12.7	6.8	17.7	12.1	6.6	8.9		26.6	23	18.5	8.1	14.8	11.4
Jurong Point	19.1	29.7	31.5	19.2	18.8	20.1	26.6		37.3	32.4	19	37.1	25.4
Changi International Airport	30.6	17.2	9.4	30.6	22.3	22.5	23	37.3		9.3	22.1	9.6	14.4
East Coast Seafood Centre	31.7	13.7	7.1	31.1	13.4	13.6	18.5	32.4	9.3		15.3	14.1	5.8
Thomson Plaza	18.3	12.4	16.3	17.7	3	4.3	8.1	19	22.1	15.3		18.9	11.4
White Sands Shopping Centre	24	10.1	3.8	23.4	21.4	22.4	14.8	37.1	9.6	14.1	18.9		13.1
Tanjong Katong Complex	24.7	9.7	8.9	24.1	9.6	8.2	11.4	25.4	14.4	5.8	11.4	13.1	
National University of Singapore	20.3	25.5	27.9	19.7	14	10.5	22.5	11.7	31	24.2	15.5	32.7	20.1
North Point Shopping Centre	7.5	15.7	19.6	7.7	14.1	19.7	8.1	25.4	26.6	26.1	10.3	20.1	20.1

Today's Problem



Step 3: Use a known method (E.g. Nearest Neighbor technique) to **determine the vehicle routing**

Assumptions: One truck delivers to all locations. There are no capacity constraint .

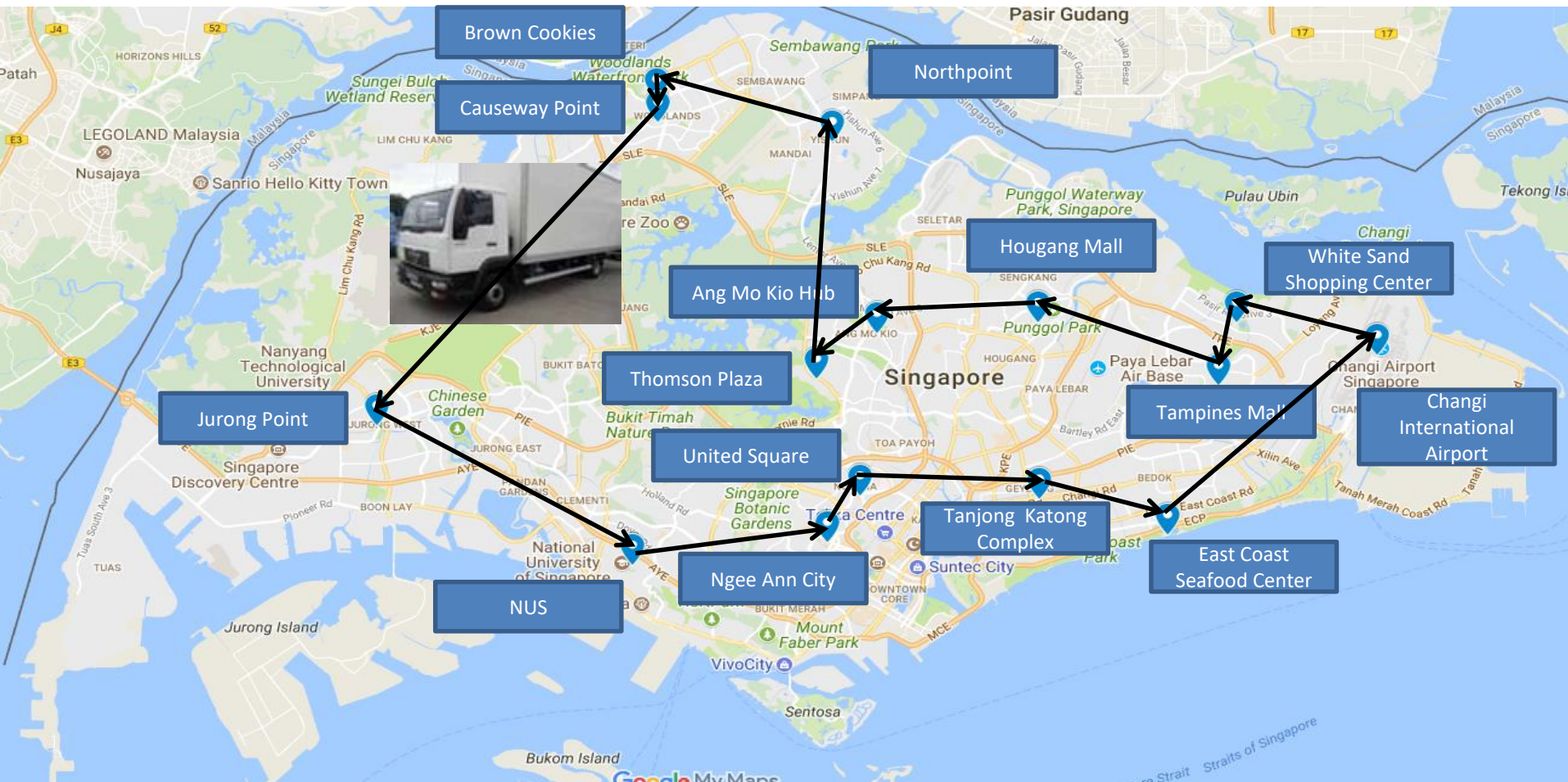


Today's Problem



- Brown Cookies uses container trucks (capacity= 33.3m^3) for transportation. (Capacity constraint introduced). Demand (volume) of each location is given in the figure below.

Total Volume= 38m^3 , is one truck possible?



Suggested Routing (with Volume)



Routings (Destinations)	Postal Codes	Route A	Route B	Demand Volume (cbm)
9 Woodlands Ave 9 (Republic Pastries Pte Ltd)	738964	start/end	start/end	
Causeway Point	738099		B1	4
North Point Shopping Centre	769098	A1		3
Ang Mo Kio Hub	569933	A2		3
Hougang Mall	538766	A3		2
Tanjong Katong Complex	400845	A5		2
East Coast Seafood Centre	449883	A6		2
Tampines Mall	529510	A9		2
White Sand Shopping Centre	518457	A8		2
Changi International Airport	819642	A7		3
United Square	307591		B3	4
Ngee Ann City	238873		B4	3
Thomson Plaza	574408		B2	3
National University of Singapore	119260		B5	2
Jurong Point	648886		B6	3
Republic Pastries Pte Ltd	738964			

Routings (Destinations)	Postal Codes
Causeway Point	738099
North Point Shopping Centre	769098
Ang Mo Kio Hub	569933
Hougang Mall	538766
Tanjong Katong Complex	400845
East Coast Seafood Centre	449883
Tampines Mall	529510
White Sand Shopping Centre	518457
Changi International Airport	819642
United Square	307591
Ngee Ann City	238873
Thomson Plaza	574408
National University of Singapore	119260
Jurong Point	648886
	Total

Truck B (Total Volume= 19m³)

- “West Cluster”
- Deliver to locations with largest volume first when possible
- Ensure no path cross each other
- Apply nearest neighbor principle when possible

Truck A (Total Volume= 19m³)

- “East Cluster”
- Deliver to locations with largest volume first when possible
- Ensure no path cross each other
- Apply nearest neighbor principle when possible

Today's Problem



- Some stores (at certain locations) have **time windows** for delivery. E.g. opening hours, off-peak period
→ **Time constraint introduced**
- Determine the transportation time to each location (E.g. Google Maps timing or perform some simple calculation with distance)
- Determine the total time taken including unloading time
 - Assumptions: Unloading time for 2m^3 , 3m^3 & 4m^3 are taken to be 2 min, 3 min & 5 min respectively
- Adjust routing accordingly, taking into consideration the time constraints

Suggested Routing (with time window)



Location	Postal Code	Capacity Demand (cbm)	Distance to (km)	Time Taken (Min) (Assuming car speed at 60km/h)	Loading/ Unloading time (assumption)	Time Taken (including unloading)	Time (Start at 0900hrs)
Causeway Point	738099	4	1.3	1.3	5	6.3	907
Thomson Plaza	574408	3	17.7	17.7	5	22.7	930
United Square	307591	4	3	3	5	8	938
Ngee Ann City	238873	3	2.8	2.8	3	5.8	944
National University of Singapore	119260	2	10.5	10.5	2	12.5	957
Jurong Point	648886	3	11.7	11.7	3	14.7	1012
9 Woodlands Avenue 9	738964		19.1	19.1			1032
		19	66.1	66.1	23	70	

Truck A / Route 1

- Same route (as earlier) still applicable after checking against the time windows
- Truck expected to be back at factory at about 1032hrs

Suggested Routing (with time window)



Location	Postal Code	Capacity Demand (cbm)	Distance to (km)	Time Taken (Min) (Assuming car speed at 60km/h)	Loading/ Unloading time (assumption)	Time Taken (including unloading)	Time (Start at 0900hrs)	Time Windows
North Point Shopping Centre	769098	3	7.5	7.5	5	12.5	913	0900-1100
Ang Mo Kio Hub	569933	3	8.1	8.1	3	11.1	925	0900-1200
Hougang Mall	538766	2	6	6	2	8	933	No time window stated
Tanjong Katong Complex	400845	2	5	5	3	8	941	0800-1100
East Coast Seafood Centre	449883	2	5.8	5.8	3	8.8	950	0900-1100
Tampines Mall	529510	2	7.1	7.1	2	9.1	1000	0930-1200
White Sand Shopping Centre	518457	2	3.8	3.8	2	5.8	1006	0800-1030
Changi International Airport	819642	3	9.6	9.6	5	14.6	1021	No time window stated
9 Woodlands Avenue 9	738964		30.6	30.6			1052	
		19	83.5	83.5	25	77.9		

Truck B / Route 2

- Same route (as earlier) still applicable after checking against the time windows
- Truck expected to be back at factory at about 1052hrs

Conclusion



- Assumptions made include: there is no traffic jam, trucks do not skip roads with ERP, there are no other delays etc.
- Objective is to minimize total transportation cost
 - Other cost can be added if more information is provided (e.g. petrol price, driver's wage)
- With proper planning, Brown Cookie is able to satisfy both the capacity constraints & time windows
 - There is no one fix method for doing VRP
 - Both knowledge (best practices) & experiences are important for a good Vehicle Routing
- With the help of technology, Brown Cookie is able to:
 - Update the driver real time if there are any emergencies
 - Determine the locations of the trucks via maps and planning tools
 - **TMS software**



Going Further... Last Mile Delivery



- It is the final transportation of goods from the hub (fulfilment centre) to the final destination (the customer).
 - It is literally **the face** of one's business, as far as the customer is concerned.
- The efficiency of the last-mile and the experience of the customer at this stage go a long way in determining the common perception of the business, which flutters about the market in the form of reviews, gossip and even competition.



Going Further... Last Mile Delivery



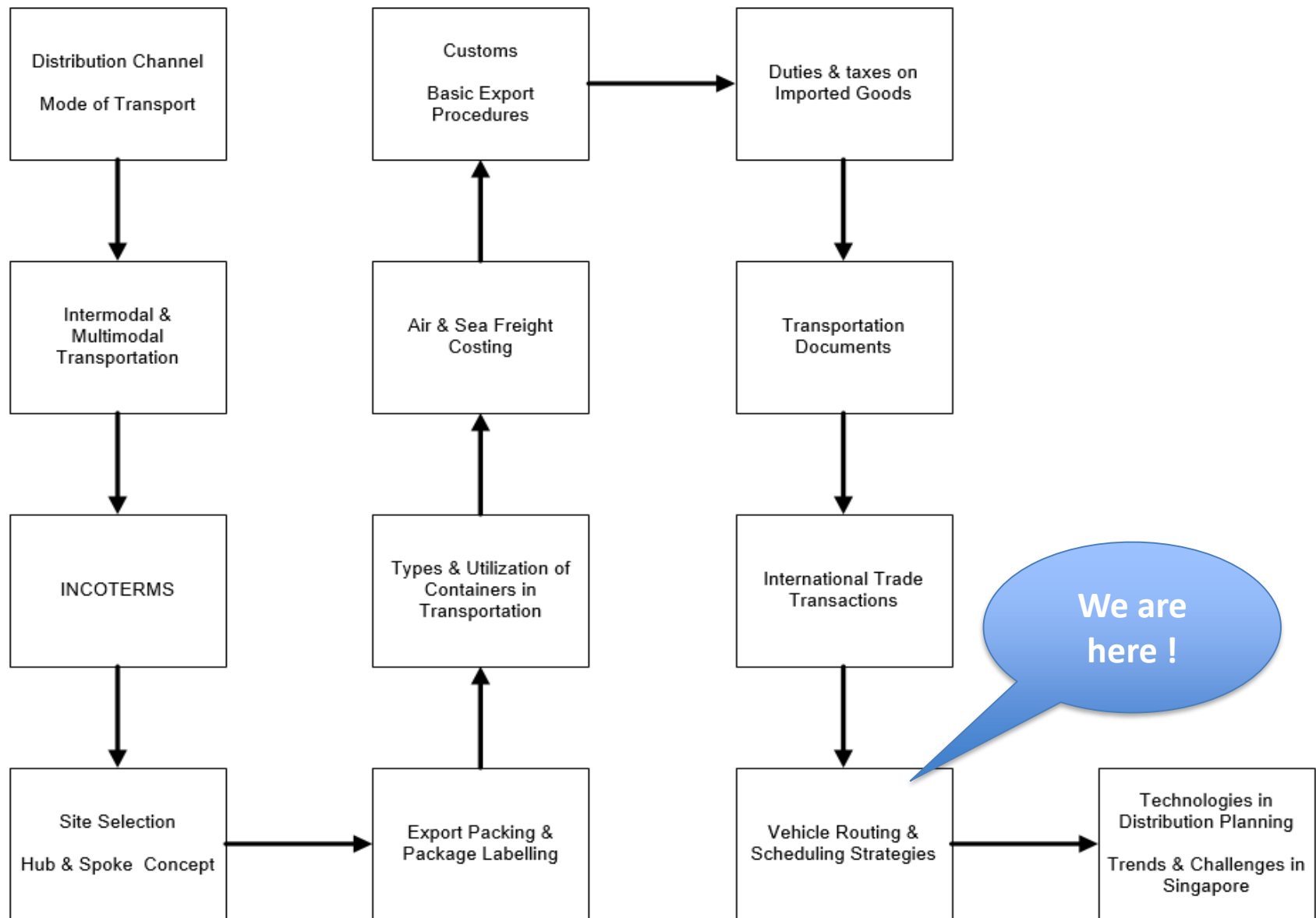
- Last-mile delivery is a complex task.
- Poor Infrastructure (especially in developing countries)
 - Poor transportation infrastructure means long journeys, inefficient routes, inefficient transportation technology, etc.
 - Translates into woeful costs and time lags.
- B2B vs B2C Deliveries:
 - For B2B delivery, the extra costs and wasted time worth it compared to B2C deliveries, in which the costs of fuel and time wastage must be borne for just one package.
- Types of Goods:
 - The type of goods add to the challenges of last mile delivery. E.g. toxic, fragile, perishable or flammable items, which needs for more planning.

Going Further... Last Mile Delivery Challenges



- Customer nuisance:
 - The biggest challenge to the last-mile
 - E.g. incorrect address, remote locations, cramped locations, absence of the customer to receive the package, last minute cancellations of orders, returning orders, etc.
- These challenges ensure that the factors affecting potential costs of the last-mile cannot be accurately anticipated.
- In the ultra-competitive e-commerce industry, this can compound into critical difference.

E216 Distribution & transportation - Topic Flow



Learning Outcome



- Explain Vehicle Routing Problem (VRP)
- Apply principles of good routing
- Recommend technologies to enhance vehicle routing
- Solve a real life vehicle routing problem

