P13
Route Plan

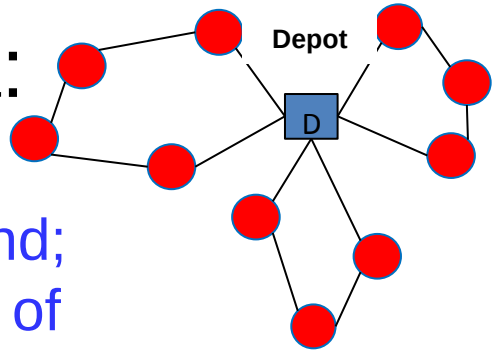
- Vehicle Routing Problem (VRP)
- Principles of Good Routing
- Technologies to enhance Vehicle Routing
- Real-Life Application of Vehicle Routing

SCHOOL OF ENGINEERING

E216 Distribution &Transportation

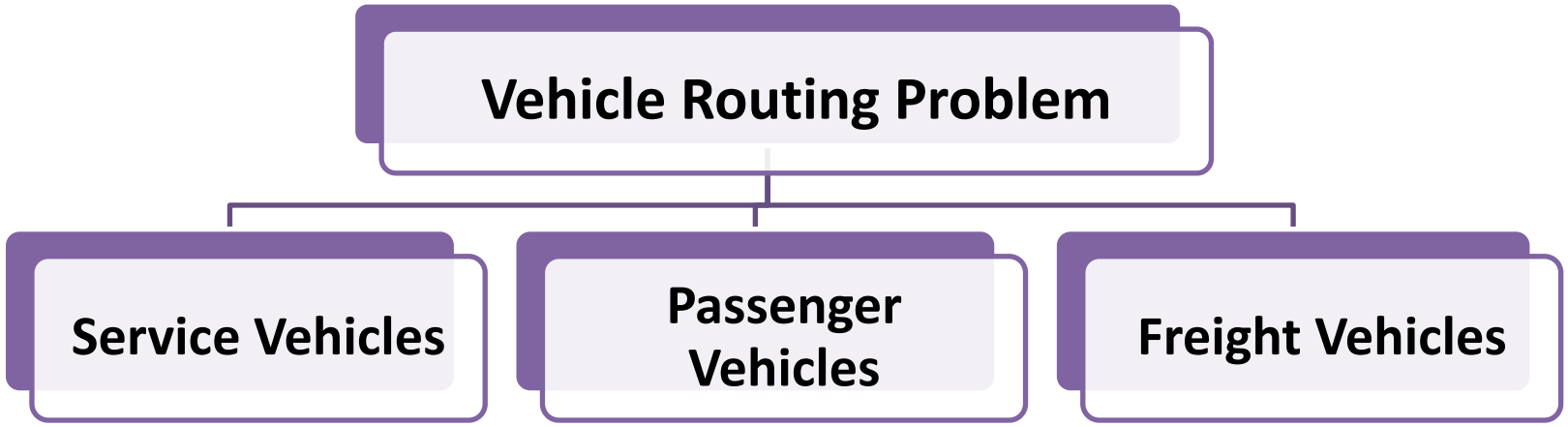
Vehicle Routing Problem (VRP)

- 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



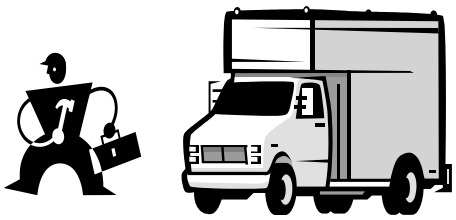
- The objective is to deliver shipments to all stops at minimum cost in a set of cycles without violating vehicle capacity

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

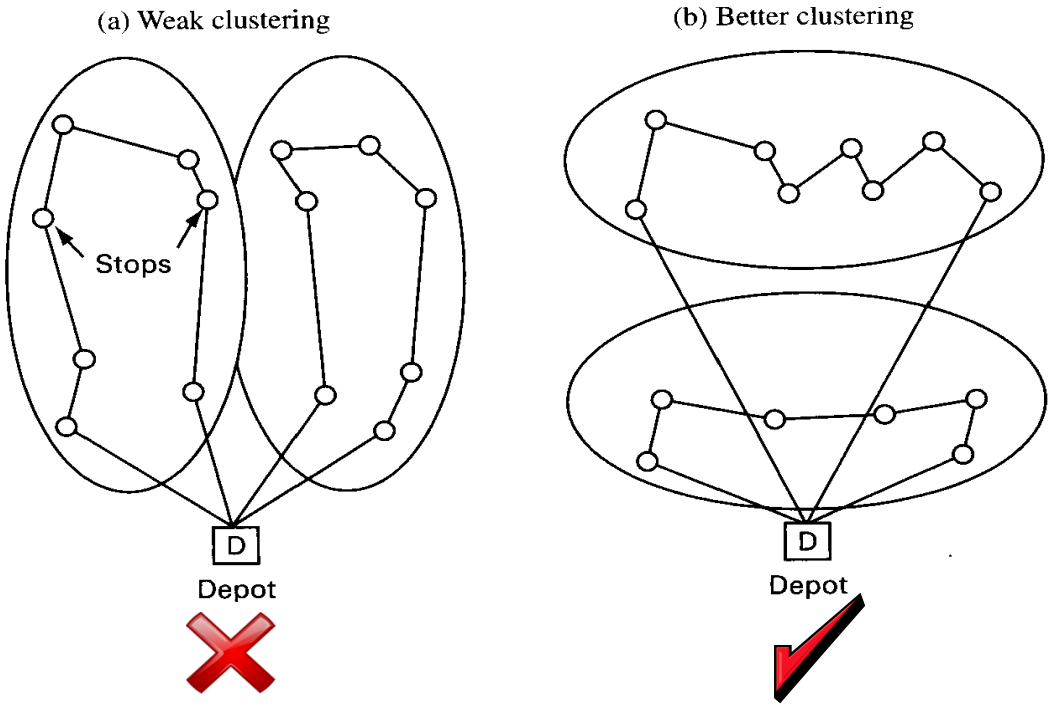
- Carriers: ships, trucks, rail or air
- Are capacity limited
- Commercial software is clearly targeted at the trucking segment

Principles of Good Routing

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

Load trucks with stop points closest to each other

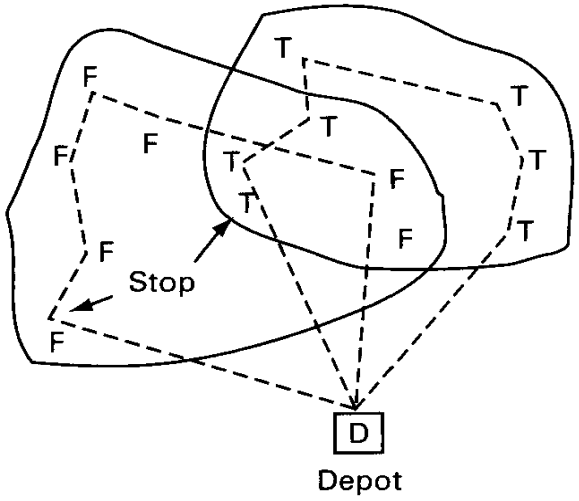
- Minimize the inter-stop travel between stops → Minimize the total travel time on the route



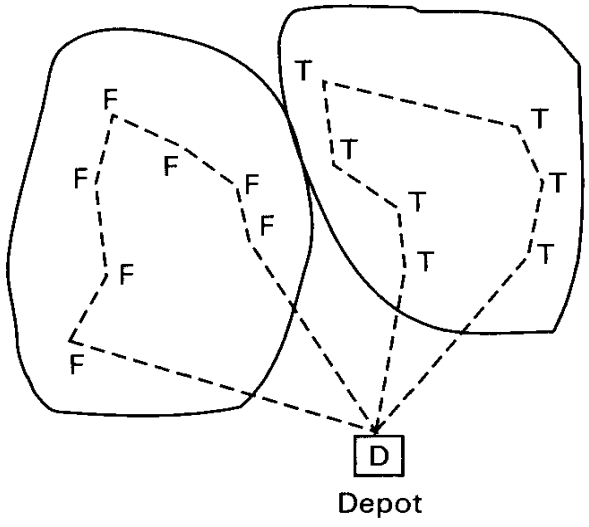
Principles of Good Routing

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

(a) Weak clustering—routes cross



(b) Better clustering

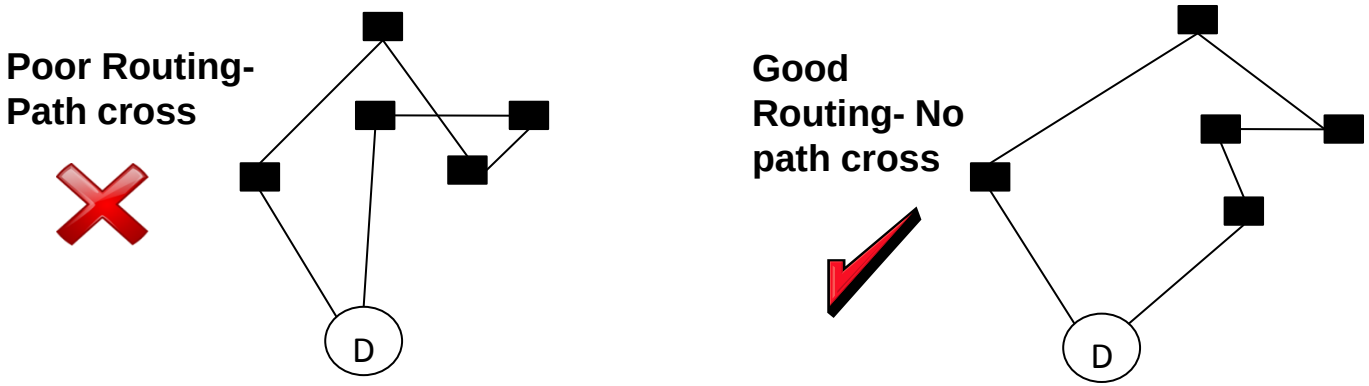


Principles of Good Routing

Build routes beginning with the farthest stop from depot

- Efficient routes can be developed through building stop clusters around the farthest stop from the depot and then work towards the depot

Stops should be sequenced so that no path cross each other



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

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

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

- 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

- 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

Global Positioning Systems (GPS) Receivers

- The state of the vehicle can be correlated with its exact location throughout the day
- GPS equipped system can determine how long, where the driver was on break

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

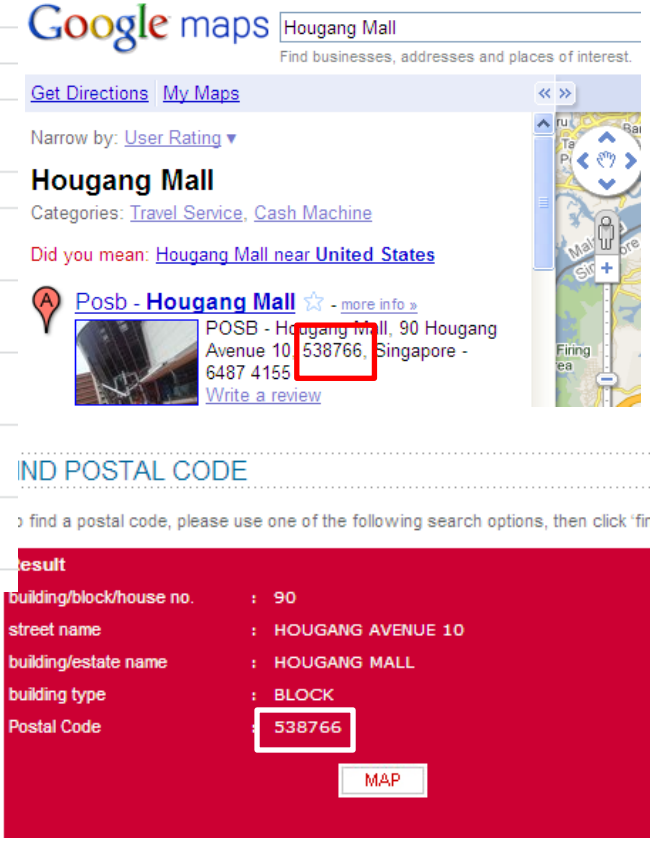
Today's Problem

Step 1: 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	738964
2	Hougang Mall	538766
3	Tampines Mall	529510
4	East Point	528833
5	Causeway Point	738099
6	United Square	307591
7	Takashimaya	238873
8	Ang Mo Kio Hub	569933
9	Jurong Point	648888
10	Changi International Airport	819642

No.	Locations	Postal Codes
11	Vivo City	098585
12	East Coast Seafood Centre	449883
13	Thomson Plaza	574408
14	White Sand Shopping Centre	518457
15	Tanjong Katong Complex	400845
16	National University of Singapore	119260
17	Tai Keng Shopping Centre	534933
18	North Point Shopping Centre	769098



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	East Point	Causeway Point	United Square	Takashimaya	Ang Mo Kio Hub	Jurong Point	Changi International Airport	Vivo City	East Coast Seafood Centre	Thomson Plaza	White Sands Shopping Centre	Tanjong Katong Complex	National University of Singapore	Tai Keng Shopping Centre	North Point Shopping Centre
9 Woodlands Ave 9		18.7km	25.4km	27.8km	1.3km	19.5km	21.0km	12.7km	19.1km	30.6km	29.9km	31.7km	18.3km	24.0km	24.7km	20.3km	17.9km	7.5km
Hougang Mall	18.7km		11.5km	13.9km	19.2km	13.7km	14.6km	6.8km	29.7km	17.2km	19.7km	13.7km	12.4km	10.1km	9.7km	25.5km	5.4km	15.7km
Tampines Mall	25.4km	11.5km		3.9km	24.4km	16.1km	17.0km	17.7km	31.5km	9.4km	20.8km	7.1km	16.3km	3.8km	8.9km	27.9km	9.7km	19.6km
East Point	27.8km	13.9km	3.9km		28.0km	17.2km	18.0km	18.5km	32.8km	8.1km	21.5km	7.3km	17.3km	6.5km	9.3km	28.9km	12.3km	23.2km
Causeway Point	1.3km	19.2km	24.4km	28.0km		19.0km	20.4km	12.1km	19.2km	30.6km	29.4km	31.1km	17.7km	23.4km	24.1km	19.7km	17.3km	7.7km
United Square	19.5km	13.7km	16.1km	17.2km	19.0km		2.8km	6.6km	18.8km	21.5km	10.5km	13.4km	3.0km	21.4km	9.6km	14.0km	7.8km	14.1km
Takashimaya	21.0km	14.6km	17.0km	18.0km	20.4km	2.8km		8.9km	20.1km	22.5km	5.8km	13.6km	4.3km	22.4km	8.2km	10.5km	9.8km	19.7km
Ang Mo Kio Hub	12.7km	6.8km	17.7km	18.5km	12.1km	6.6km	8.9km		26.6km	23.0km	16.7km	18.5km	8.1km	14.8km	11.4km	22.5km	7.0km	8.1km
Jurong Point	19.1km	29.7km	31.5km	32.8km	19.2km	18.8km	20.1km	26.6km		37.3km	20.7km	32.4km	19.0km	37.1km	25.4km	11.7km	24.7km	25.4km
Changi International Airport	30.6km	17.2km	9.4km	8.1km	30.6km	21.5km	22.5km	23.0km	37.3km		23.4km	9.3km	22.1km	9.6km	14.4km	31.0km	17.9km	26.6km
Vivo City	29.9km	19.7km	20.8km	21.5km	29.4km	10.5km	5.8km	16.7km	20.7km	23.4km		16.5km	11.3km	26.7km	15.6km	8.1km	15.1km	27.0km
East Coast Seafood Centre	31.7km	13.7km	7.1km	7.3km	31.1km	13.4km	13.6km	18.5km	32.4km	9.3km	16.5km		15.3km	14.1km	5.8km	24.2km	11.2km	26.1km
Thomson Plaza	18.3km	12.4km	16.3km	17.3km	17.7km	3.0km	4.3km	8.1km	19.0km	22.1km	11.3km	15.3km		18.9km	11.4km	15.5km	8.5km	10.3km
White Sands Shopping Centre	24.0km	10.1km	3.8km	6.5km	23.4km	21.4km	22.4km	14.8km	37.1km	9.6km	26.7km	14.1km	18.9km		13.1km	32.7km	12.2km	20.1km
Tanjong Katong Complex	24.7km	9.7km	8.9km	9.3km	24.1km	9.6km	8.2km	11.4km	25.4km	14.4km	15.6km	5.8km	11.4km	13.1km		20.1km	5.0km	20.1km
National University of Singapore	20.3km	25.5km	27.9km	28.9km	19.7km	14.0km	10.5km	22.5km	11.7km	31.0km	8.1km	24.2km	15.5km	32.7km	20.1km		19.4km	27.4km
Tai Keng Shopping Centre	17.9km	5.4km	9.7km	12.3km	17.3km	7.8km	9.8km	7.0km	24.7km	17.9km	15.1km	11.2km	8.5km	12.2km	5.0km	19.4km		14.0km
North Point Shopping Centre	7.5km	15.7km	19.6km	23.2km	7.7km	14.1km	19.7km	8.1km	25.4km	26.6km	27.0km	26.1km	10.3km	20.1km	20.1km	27.4km	14.0km	

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 and time constraint .

Routings (Destinations)	Postal Codes	Routing (in sequence of A,B,C ...)
9 Woodlands Ave 9	738964	
Causeway Point	738099	A
North Point Shopping Centre	769098	B
Ang Mo Kio Hub	569933	C
Hougang Mall	538766	D
Tai Keng Shopping Centre	534933	E
Tanjong Katong Complex	400845	F
East Coast Seafood Centre	449883	G
Tampines Mall	529510	H
East Point	528833	I
White Sand Shopping Centre	518457	J
Changi International Airport	819642	K
United Square	307591	L
Takashimaya	238873	M
Thomson Plaza	574408	N
Vivo City	098585	O
National University of Singapore	119260	P
Jurong Point	648888	Q
9 Woodlands Ave 9	738964	R

Today's Problem

- RFD Pte Ltd uses container trucks (capacity=33.3m^3) for transportation. (Capacity constraint introduced)
- Demand (volume) of each location is given

Routings (Destinations)	Postal Codes	Volume Demand (cbm)
Causeway Point	738099	4.5
North Point Shopping Centre	769098	4.5
Ang Mo Kio Hub	569933	3
Hougang Mall	538766	2
Tai Keng Shopping Centre	534933	2
Tanjong Katong Complex	400845	3
East Coast Seafood Centre	449883	3
Tampines Mall	529510	2
East Point	528833	2
White Sand Shopping Centre	518457	2
Changi International Airport	819642	4.5
United Square	307591	4.5
Takashimaya	238873	3
Thomson Plaza	574408	4.5
Vivo City	098585	3
National University of Singapore	119260	2
Jurong Point	648888	3
	Total	**52.5**

Total volume of goods to transport = **52.5m^3**; RFD Pte Ltd needs more than 1 trip OR more than 1 container, to transport all the goods

Suggested Routings

Location	Postal Code	Routing	Capacity Demand (cbm)
Causeway Point	738099	B1	4.5
Thomson Plaza	574408	B2	4.5
United Square	307591	B3	4.5
Takashimaya	238873	B4	3
Vivo City	098585	B5	3
National University of Singapore	119260	B6	2
Jurong Point	648888	B7	3
		Total	**24.5**

Truck 1/Route 1 (Total Volume= 24.5m^3<33.3 m^3)

- Deliver to locations with largest volume first
- Ensure no path cross each other
- Apply nearest neighbor principle if possible

Suggested Routings

Location	Postal Code	Routing	Capacity Demand (cbm)
North Point Shopping Centre	769098	A1	4.5
Ang Mo Kio Hub	569933	A2	3
Hougang Mall	538766	A3	2
Tai Keng Shopping Centre	534933	A4	2
Tanjong Katong Complex	400845	A5	3
East Coast Seafood Centre	449883	A6	3
Changi International Airport	819642	A7	4.5
White Sand Shopping Centre	518457	A8	2
Tampines Mall	529510	A9	2
East Point	528833	A10	2
		Total	**28**

Truck 2/Route 2 (Total Volume= 28 m^3<33.3 m^3)

- Deliver to locations with largest volume first
- Ensure no path cross each other
- Apply nearest neighbor principle if possible

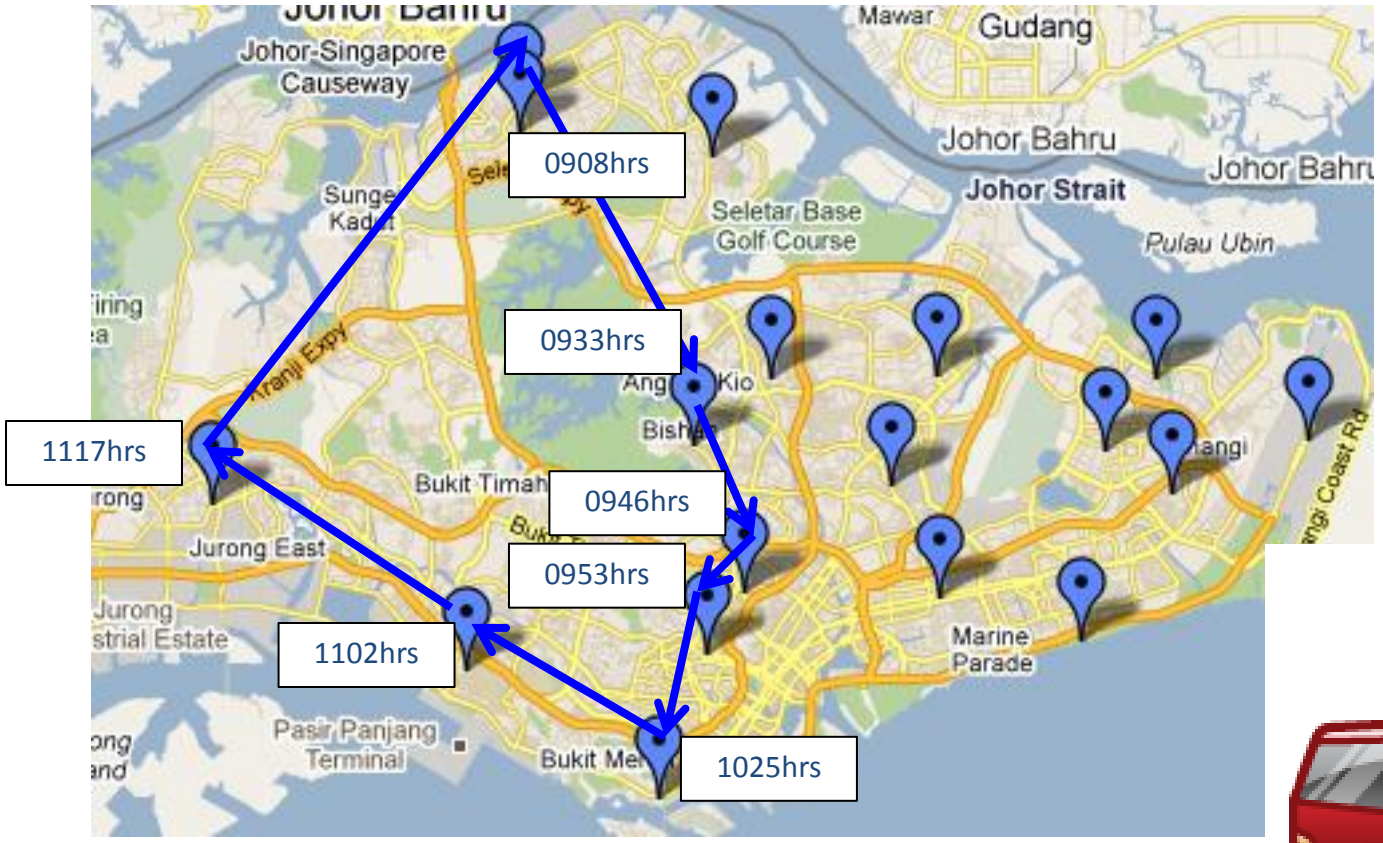
Suggested Routings

With capacity constraints, RFD Pte Ltd needs to use <u>x2</u> container trucks (capacity=33.3cbm each) for transportation

Today's Problem

- Some customers (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 $2m^3$, $3m^3$ & $4.5m^3$ are taken to be 2 min, 3 min & 5 min respectively
- Adjust routing accordingly, taking into consideration the time constraints

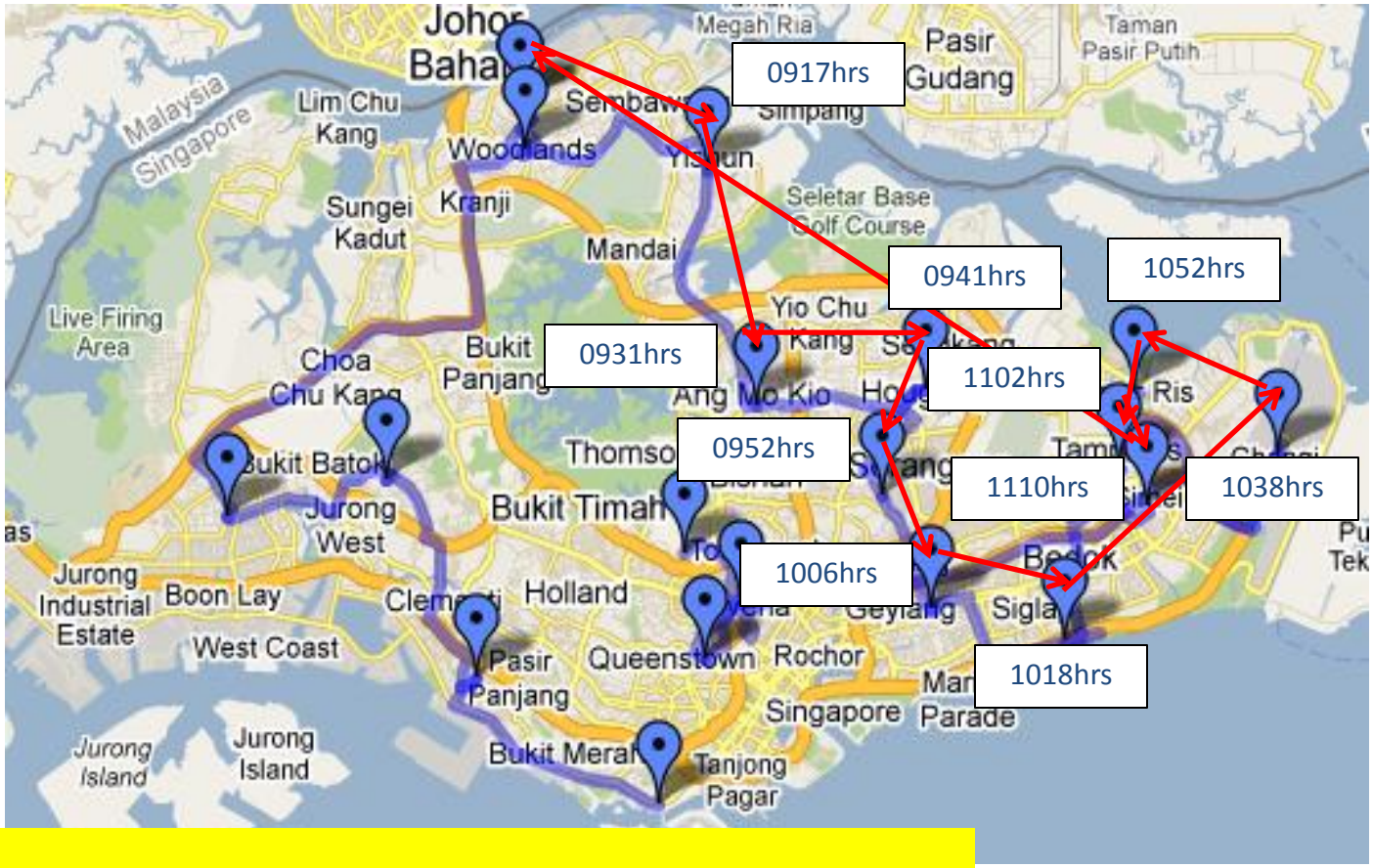
Today's Problem



[Truck 1/Route 1]

- Same routing (as earlier) still applicable after checking against the time windows

Today's Problem



Truck 2/Route 2

- Same routing (as earlier) still applicable after checking against the time windows

Conclusion

- Assumptions made include: there is no traffic jam, trucks do not skip roads with ERP
- Objective is to minimize total transportation cost
  - Cost may be computed if more information is provided (E.g. petrol price, driver's wage)
- With proper planning, RFD Pte Ltd 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, RFD Pte Ltd is able to
  - Update the driver real time if there are any emergencies
  - Determine the locations of the trucks via maps and tools
    - TMS software

Learning Outcome

- Vehicle Routing Problem (VRP)
- Principles of Good Routing
- Technologies to enhance Vehicle Routing
- Real-Life Application of Vehicle Routing