KTH ROYAL INSTITUTE OF TECHNOLOGY

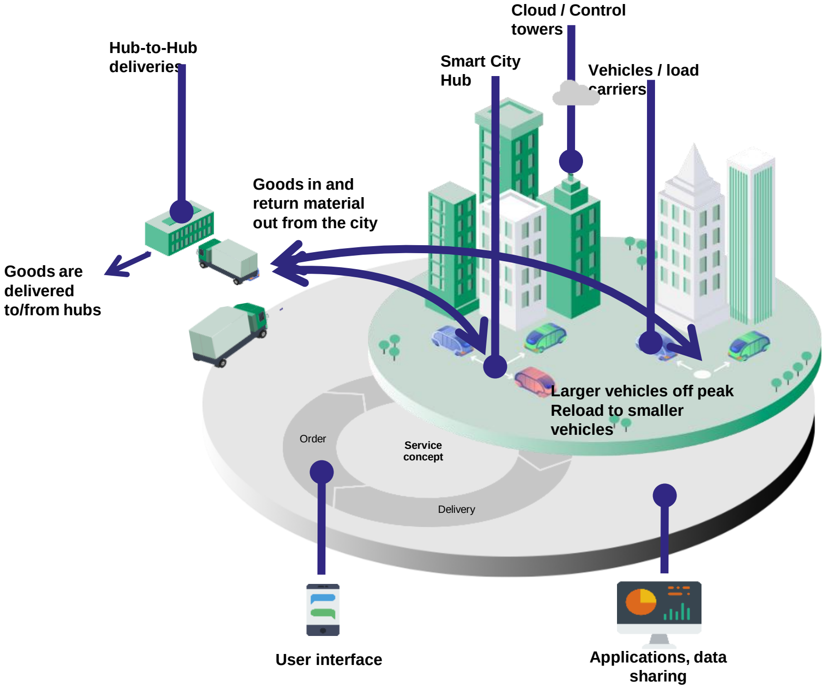
Urban Transport Modelling and Optimization

Sequential consolidation of passenger and freight transport in urban environments

From the project vision…

Vision

To understand and create conditions for a sustainable transport system in the city.



By addressing…

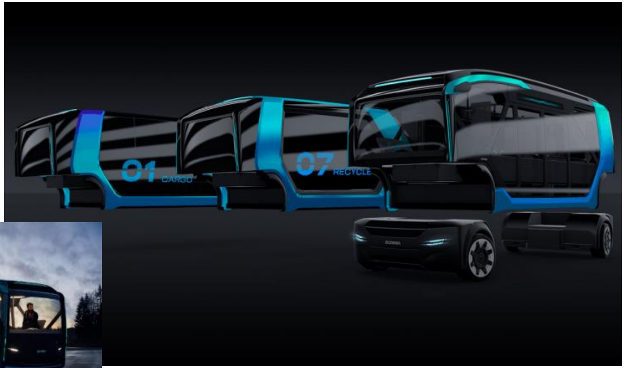
We have a chance to also affect…

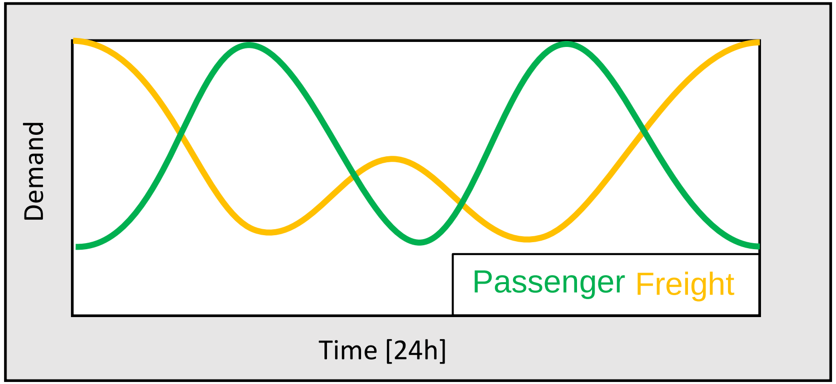
…to the research question

1. What are the **impacts** of sequentially consolidating demand flows for different stakeholder?

2. Can the urban logistic system be made more **sustainable**?

3. Is the **level of service** for customer affected?

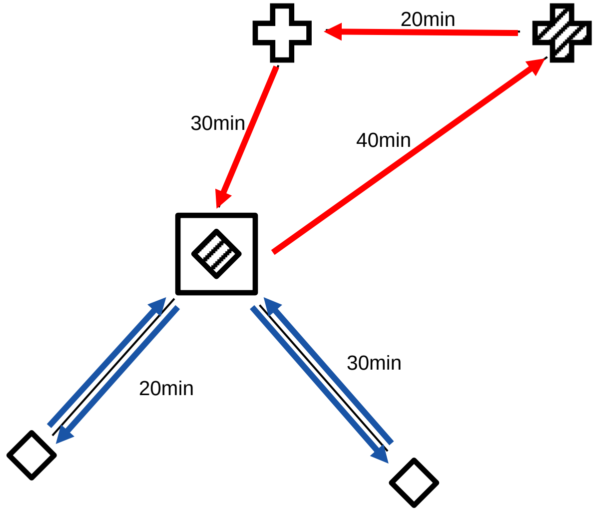




Illustrative Example - Conventional Vehicles

Freight → Passenger → Freight (Chaining of requests)

Customer	Pick-Up Time	Drop-Off Time
1 (Freight)	9:00am	9:30am
2 (Freight)	11:00am	11:20am
3 (Passenger)	10:00am	10:20am



Vehicle 1: Blue
Vehicle 2: Red

Total Vehicles: 2
Module Changes: 0
Empty Time: (30+20+40+30)min

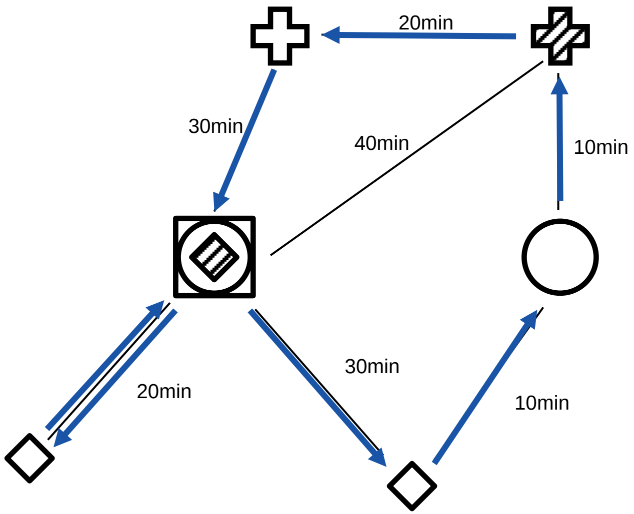
Illustrative Example - Multi-Purpose Vehicles

Freight → Passenger → Freight (Chaining of requests)

Customer	Pick-Up Time	Drop-Off Time
1 (Freight)	9:00am	9:30am
2 (Freight)	11:00am	11:20am
3 (Passenger)	10:00am	10:20am

Switching Module Time Penalty: 10min

Vehicle 1: Blue



Total Vehicles: 2 → 1
Module Changes: 0 → 2
Empty Time: 120min → (10+10+30+20) min

Theoretical Advantages:
- Reduction of fleet size
- Reduction of empty time

Multi-Purpose Vehicle Routing Problem

Objectives:

User cost – passenger travel time, waiting time passenger/freight
Operator cost – fleet size, vehicle kilometer, module exchange
+ unserved demand

Decision Variables:

Arrival time
$s_{i,k}$ continuous
node, platform

Vehicle routing
$x_{i,j,k,t}$ binary
Node start, Node end, platform, type

Constraints:

Range, Capacity, Time-windows, Module Type, Vehicle and passenger flow, Route termination, Decision variable domains

NP-hard combinatorial optimization problem

Adaptive Large Neighbourhood Search

1. Create a feasible solution

D	1+	2+	2-	1-	S	3+	3-	D

Adaptive Large Neighbourhood Search

1. Create a feasible solution

2. Destroy the solution

D	1+	2+	2-	1-	S	3+	3-	D

D	1+	1-	S	3+	3-	D

Adaptive Large Neighbourhood Search

1. Create a feasible solution
2. Destroy the solution
3. Repair the solution

D	1+	1-	S	3+	3-	D

Adaptive Large Neighbourhood Search

1. Create a feasible solution
2. Destroy the solution
3. Repair the solution

D	1+	1-	S	3+	3-	D

D	1+	2+	1-	2-	S	3+	3-	D

Adaptive Large Neighbourhood Search

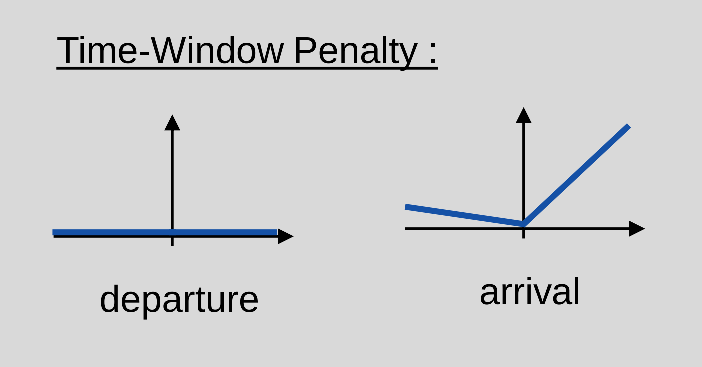
1. Create a feasible solution
2. Destroy the solution
3. Repair the solution
4. Evaluate the solution
5. Analyse best solution

D	1+	2+	2-	1-	S	3+	3-	D
D	1+	2+	1-	2-	S	3+	3-	D

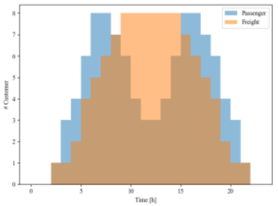
D	1+	2+	1-	2-	S	3+	3-	D

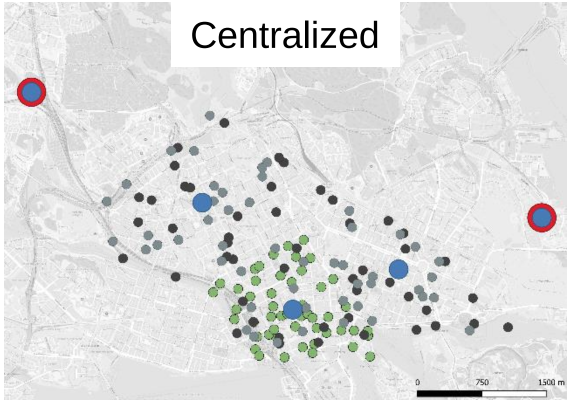
Model assumptions

1. Soft Time window penalties
2. Constant vehicle travel speed
3. Operation of multi-purpose vehicles is possible on the road network
4. The exchange of a module is done with the help of two workers at dedicated areas
5. The vehicle size (capacity), vehicle range and vehicle costs are the same for conventional and multi-purpose vehicles
6. Same operational costs for multi-purpose and conventional vehicles only difference is the additional cost for exchanging the module

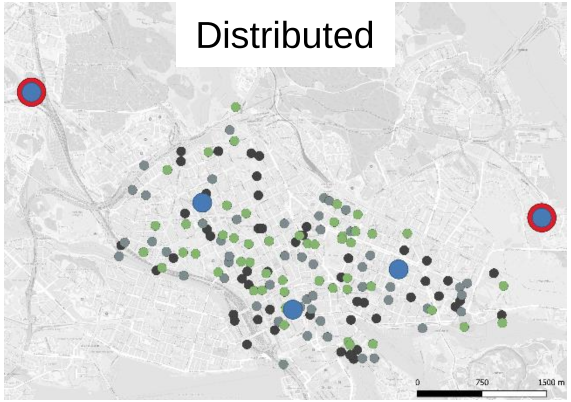


Case Studies

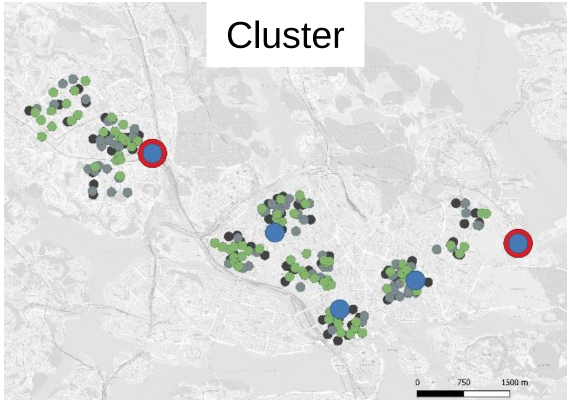




Delivery of central stores restaurants, grocery stores



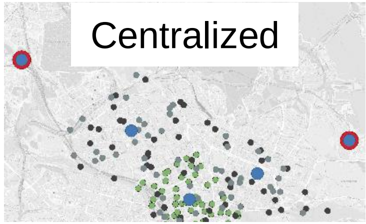
Random distribution of customer

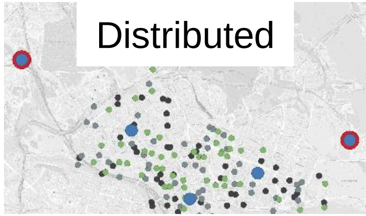


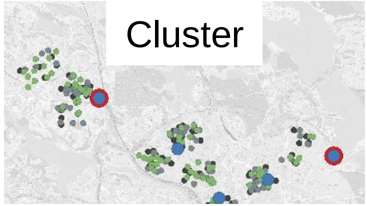
Strategic customer selection

- Depots outside the city as practiced today
- Service depots at strategic positions in the served area → short distance between customers and depots

Results







		Peaks	Peaks	Peaks
conventional	Fleet Size:	6V	6V	10V
Multi-purpose	Fleet Size:	6V + 2MC	5V + 2MC	8V + 3MC
	Pas.WT:	lower	lower	higher
	Pas. IVT:	lower	higher	higher
	Total Veh-km:	higher	higher	higher

Conclusions & Outlook

1

What are the **impacts** of sequentially consolidating demand flows for different stakeholder?
- Similar overall costs

2

Can the urban logistic system be made more sustainable?
- Longer routes
- Smaller fleet size

3

Is the level of service for customer affected?
- Lower waiting times for passenger

- Explore different mode of operations (2-echelon operations, multi-operator consolidations, etc.)
- Explore impact of depot positions and depot size

Thank you for your attention!

Jonas Hatzenbühler, M.Sc.

PhD Candidate – Future Urban Transport Systems
jonas.hatzenbuhler@abe.kth.se
Transport Planning, Economics and Engineering (TEE)
KTH Stockholm

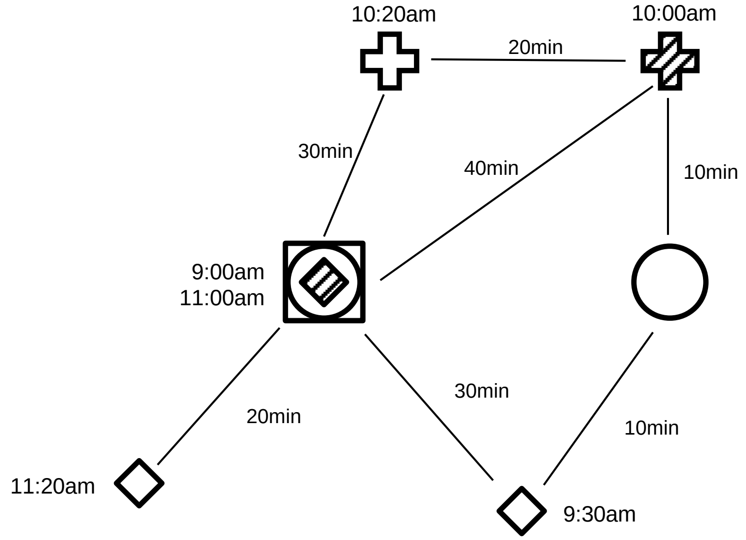
Back-up

Illustrative Example

Freight → Passenger → Freight (Chaining of requests)

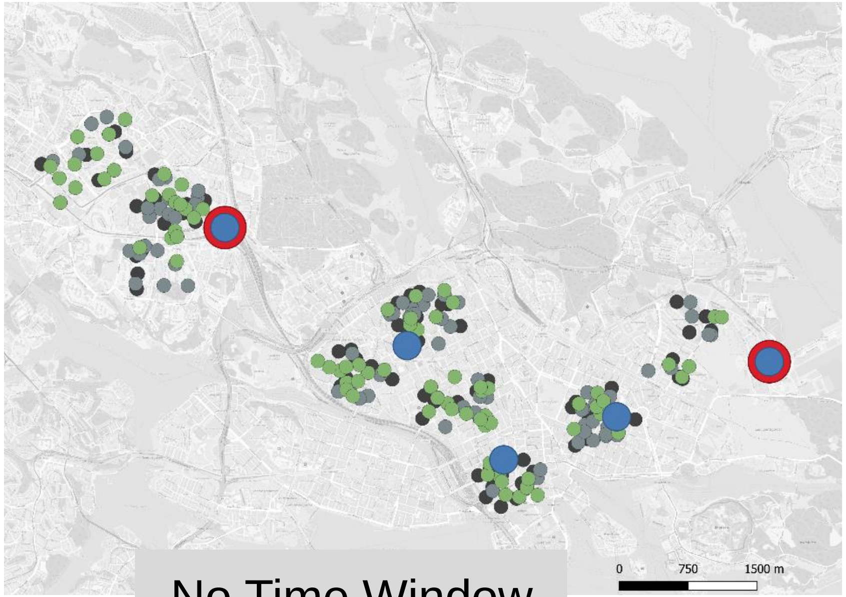
Customer	Pick-Up Time	Drop-Off Time
1 (Freight)	9:00am	9:30am
2 (Freight)	11:00am	11:20am
3 (Passenger)	10:00am	10:20am

Switching Module Time Penalty: 10min

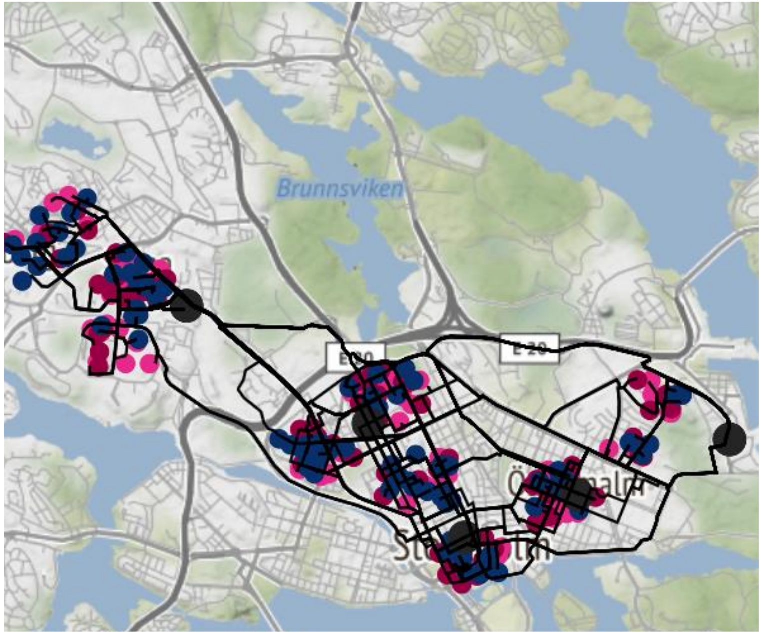


Example Analysis

- http://127.0.0.1:8050/

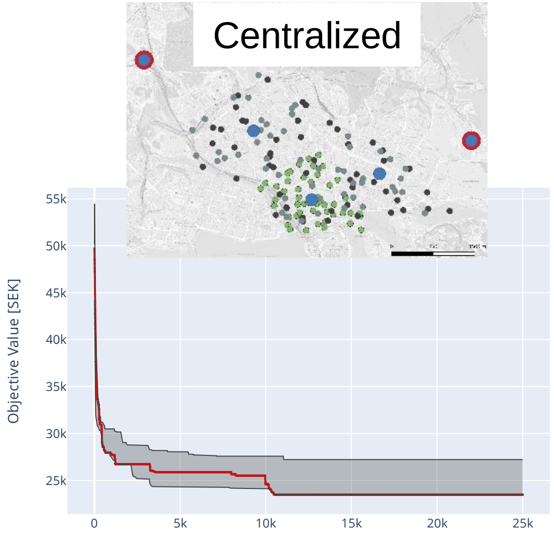


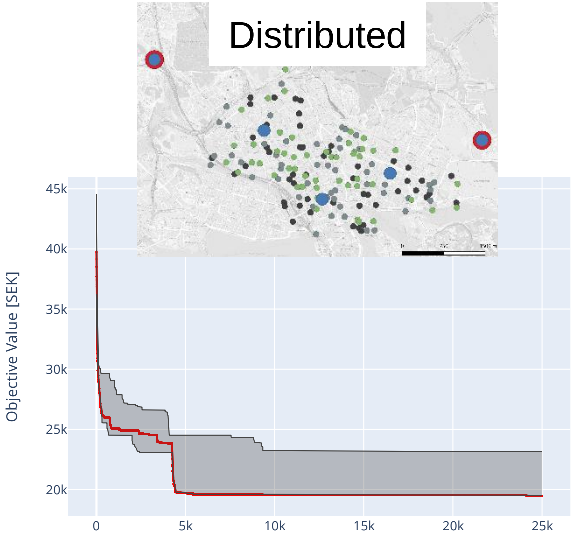
No Time Window

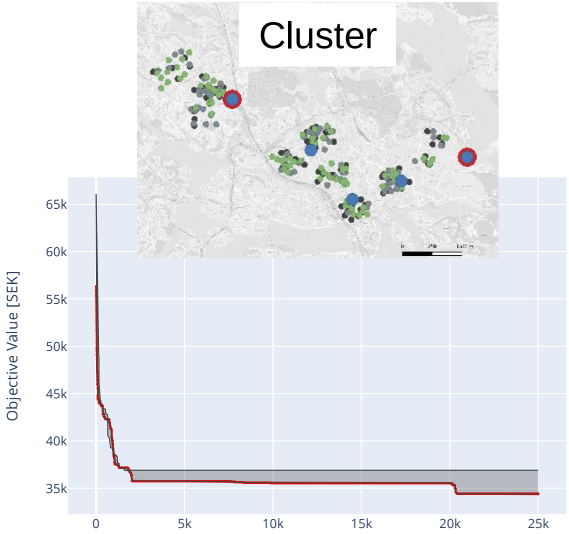


Results

ALNS performance







Total Computation Time: ~40min
Time until best Solution: ~6min

Adaptive Large Neighbourhood Search

Destroy operators:

- **Worst Removal**

D	1+	2+	2-	1-	S	3+	3-	D

D	1+	1-	S	3+	3-	D

Adaptive Large Neighbourhood Search

Destroy operators:

- Worst Removal
- **Random Removal**

D	1+	2+	2-	1-	S	3+	3-	D

D	2+	2-	S	3+	3-	D

Adaptive Large Neighbourhood Search

Destroy operators:

- Worst Removal
- Random Removal
- **Path-Removal**

D	1+	2+	2-	1-	S	3+	3-	D

D	3+	3-	D

Adaptive Large Neighbourhood Search

Destroy operators:

- Worst Removal
- Random Removal
- Path-Removal
- **Random Vehicle Removal**

D	4+	5+	5-	4-	S	6+	6-	D
D	1+	2+	2-	1-	S	3+	3-	D

D	4+	5+	5-	4-	S	6+	6-	D

Adaptive Large Neighbourhood Search

Destroy operators:

- Worst Removal
- Random Removal
- Path-Removal
- Random Vehicle Removal

2+	2-

D	1+	1-	S	3+	3-	D

D	2+	1+	2-	1-	S	3+	3-	D

Repair operators:

- **Greedy Insertion**

1. If a request cannot be inserted a new vehicle is created!
2. If all vehicles are in use request is considered unserved!

Adaptive Large Neighbourhood Search

Destroy operators:

- Worst Removal
- Random Removal
- Path-Removal
- Random Vehicle Removal

Repair operators:

- Greedy Insertion
- **Best Vehicle Insertion**

2+	2-

D	1+	1-	S	3+	3-	D

D	1+	1-	2+	2-	S	3+	3-	D

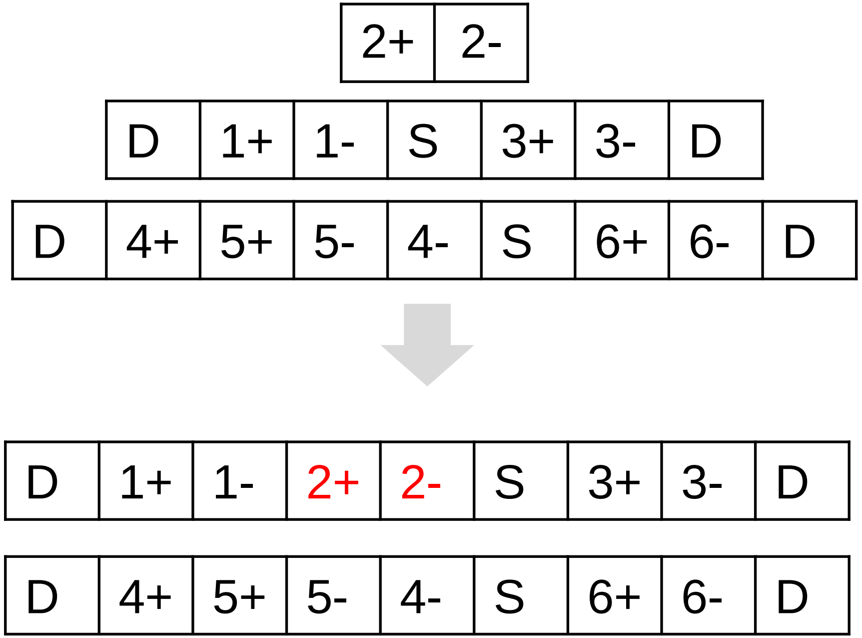
Adaptive Large Neighbourhood Search

Destroy operators:

- Worst Removal
- Random Removal
- Path-Removal
- Random Vehicle Removal

Repair operators:

- Greedy Insertion
- Best Vehicle Insertion
- **Best Inter-Vehicle Insertion**



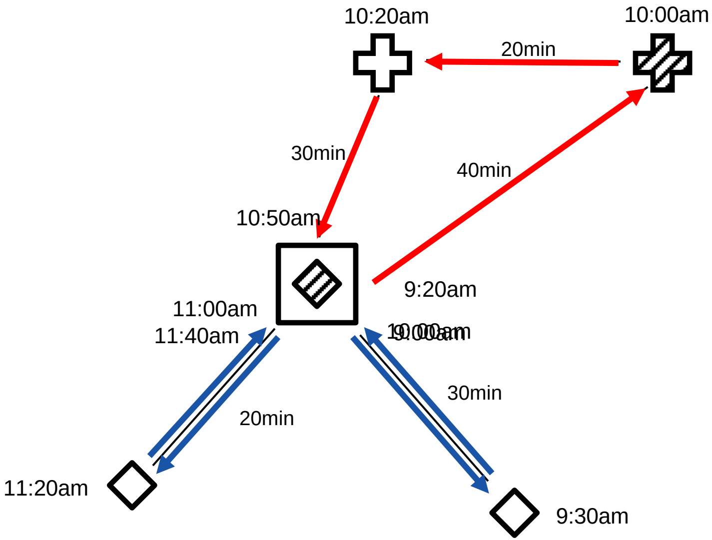
Illustrative Example - Conventional Vehicles

Freight → Passenger → Freight (Chaining of requests)

Customer	Pick-Up Time	Drop-Off Time
1 (Freight)	9:00am	9:30am
2 (Freight)	11:00am	11:20am
3 (Passenger)	10:00am	10:20am

Switching Module Time Penalty: 10min

Vehicle 1: Blue
Vehicle 2: Red



Total Vehicles: 2
Module Changes: 0
Empty Time: (30+20+40+30)min

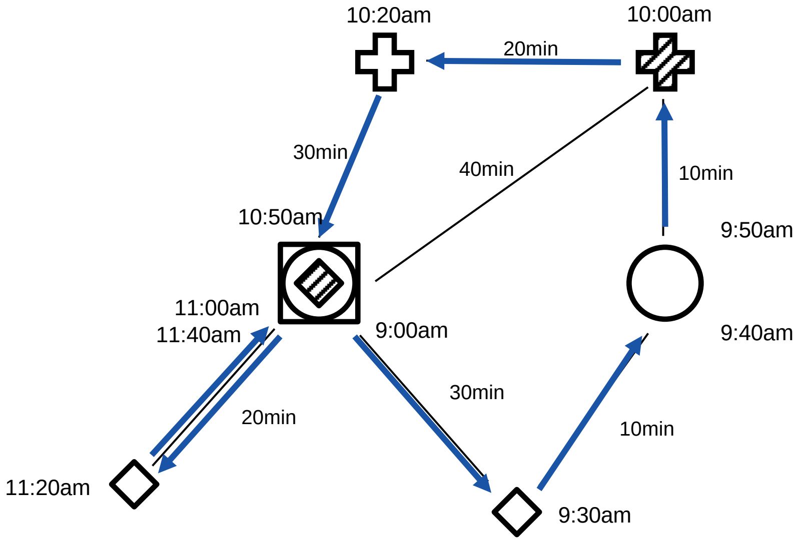
Illustrative Example - Multi-Purpose Vehicles

Freight → Passenger → Freight (Chaining of requests)

Customer	Pick-Up Time	Drop-Off Time
1 (Freight)	9:00am	9:30am
2 (Freight)	11:00am	11:20am
3 (Passenger)	10:00am	10:20am

Switching Module Time Penalty: 10min

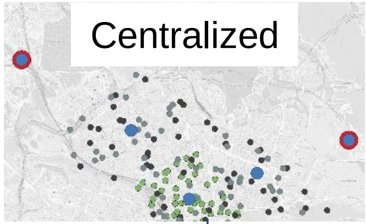
Vehicle 1: Blue

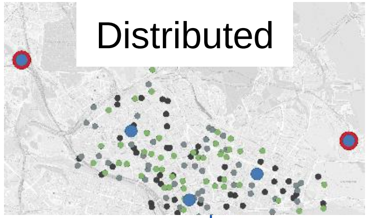


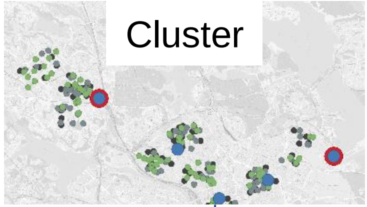
Total Vehicles: 2 → 1
Module Changes: 0 → 2
Empty Time: 120min → (10+10+30+20) min

<u>Theoretical Advantages:</u>
- Reduction of fleet size
- Reduction of empty time

Results – Oper Perspective

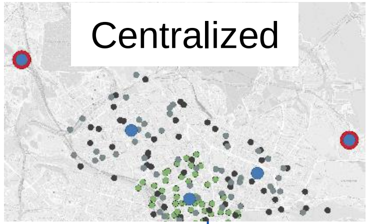


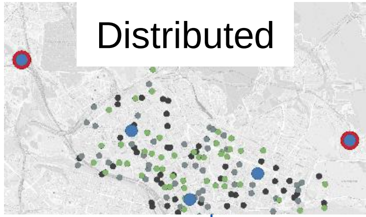


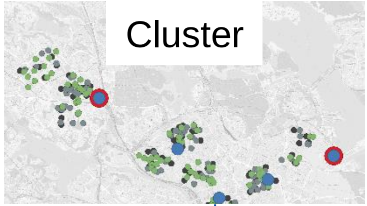


		Centralized		Distributed		Cluster	
		no Time Window	Peaks	no Time Window	Peaks	no Time Window	Peaks
conventional	Fleet Size:	6V	3V	5V	5V	10V	10V
Multi-purpose	Fleet Size:	2V + 2MC	3V + 2MC	2V + 2MC	4V + 1MC	10V + 5MC	10V + 1MC
	Pas.WT:	-	higher	lower	-	lower	lower
	Pas. IVT:	lower	-	-	lower	higher	higher
	Total Veh-km:	lower	lower	-	higher	lower	higher

Results – User Perspective







		Centralized		Distributed		Cluster	
		no Time Window	Peaks	no Time Window	Peaks	no Time Window	Peaks
conventional	Fleet Size:	6V	6V	6V	6V	10V	10V
Multi-purpose	Fleet Size:	6V + 2MC	6V + 0MC	6V + 4MC	6V + 1MC	10V + 4MC	8V + 3MC
	Pas.WT:	-	lower	lower	-	lower	higher
	Pas. IVT:	-	-	-	-	-	lower
	Total Veh-km:	lower	higher	lower	lower	higher	higher

Conclusions

Due to Technology	Stakeholder perspective	Scenario

• Similar overall costs
• Longer routes
• Lower waiting times for passenger
• Higher waiting times for freight
• Smaller fleet size
	• Operator:
	  • Shorter routes
	  • Smaller fleet sizes
	• User:
	  • Lower waiting times
	  • Lower in-vehicle times
	• Balanced:
	  • Similar results as user perspective
		• In general, similar effects on user and operator cost
		• Spatial
		  • Cluster do not lead to a fleet size reduction
		• Temporal
		  • Time window constraints minimize the use of modules