IMPROVING MOBILITY FOR ELDERLY AND DISABLED DUTCH CITIZENS USING TAXIS

Trans>ision

CQM
Consultants in Quantitative Methods

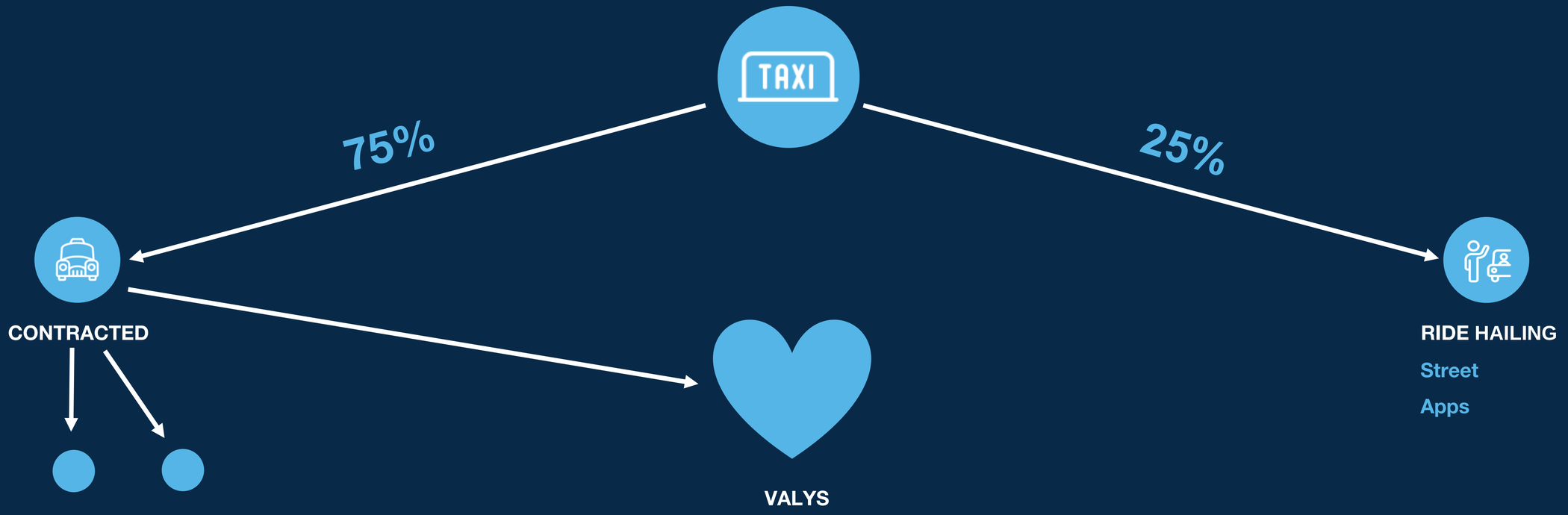
Geodan


de wedert
WIJ ZOEKEN JOU!
Voor op de weg of op kantoor
www.stoverd.nl/vacatures
SPRINTER TOURER
ZL-806-V
expertisecentrum
Sport+Revalidatie

VALYS TAXI

- Long-distance social and recreational trips
- Subsidised by the Dutch government
- Executed by 60 taxi subcontractors

TAXI MARKET



PER YEAR

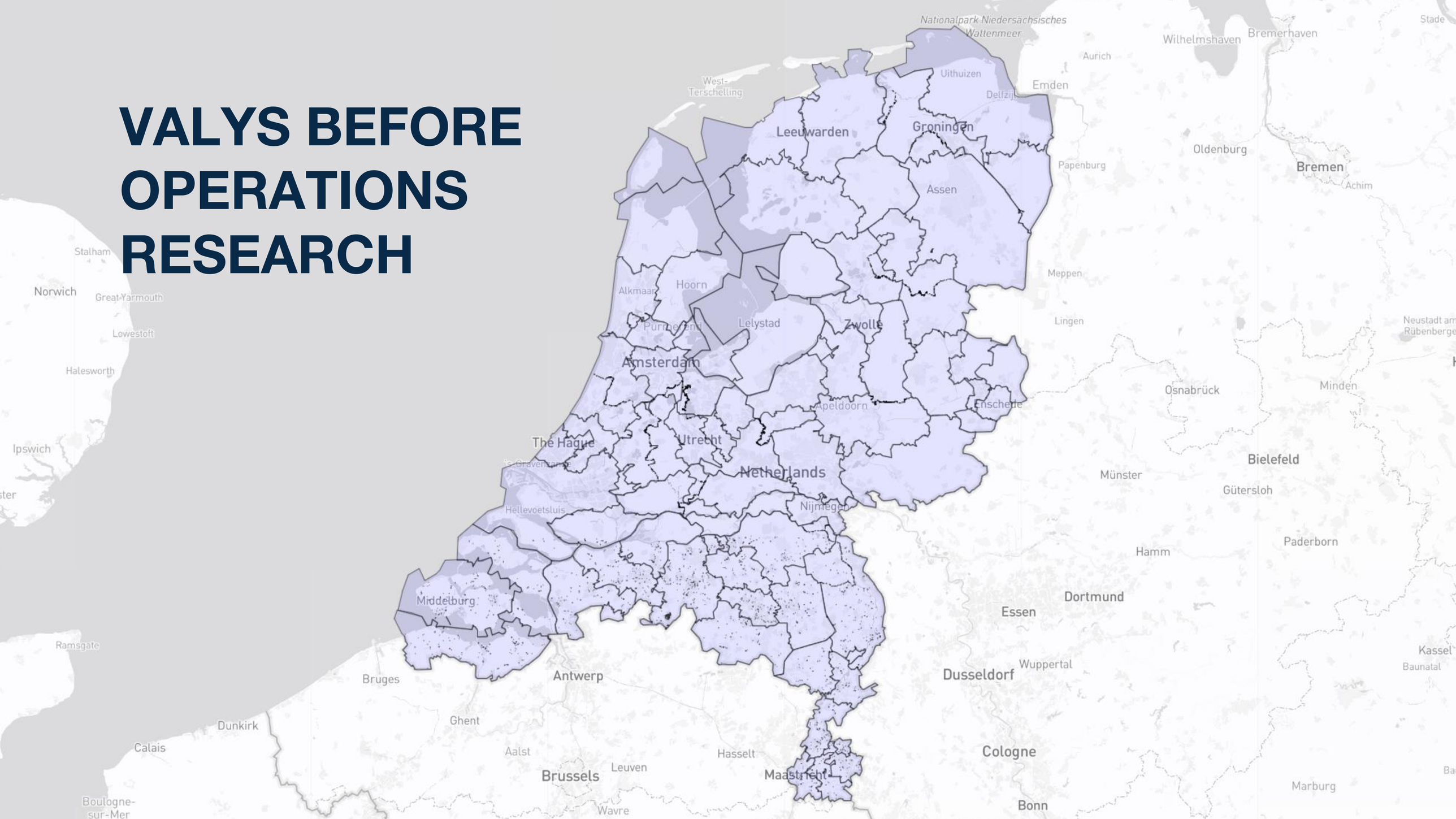
€ 75m euro budget

1 million trips

200.000 users

700 km per user

VALYS BEFORE OPERATIONS RESEARCH

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Emden
Moormerland
Leer
Wadden Sea
Leeuwarden
Franeker
Groningen
Hoogezand
Drachten
Veendam
Papenburg
Saterland
North Sea Coastal Zone
Den Burg
Bolsward
Sneek
Assen
Den Helder
Heerenveen
IJsselmeer
Emmen
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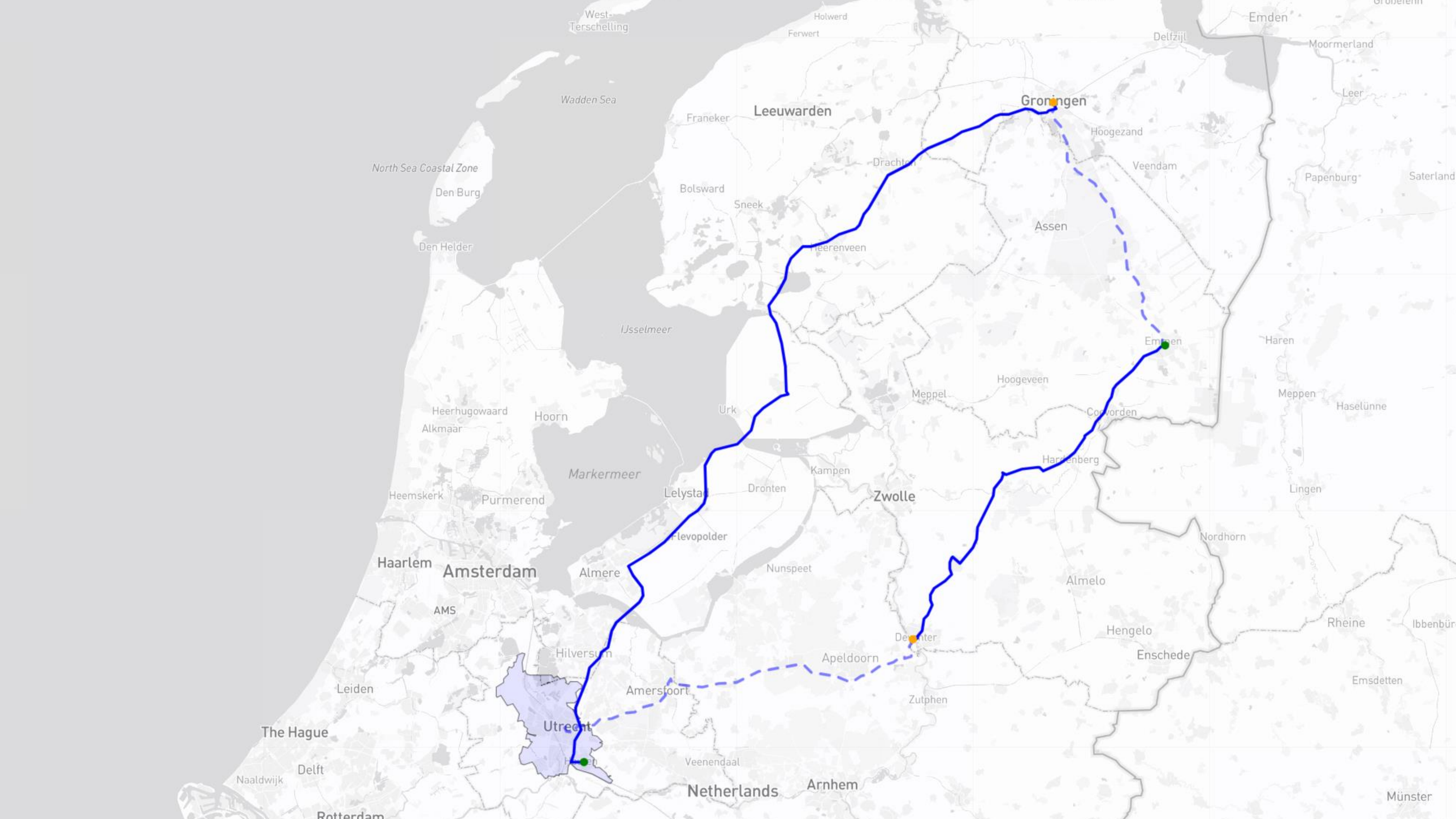
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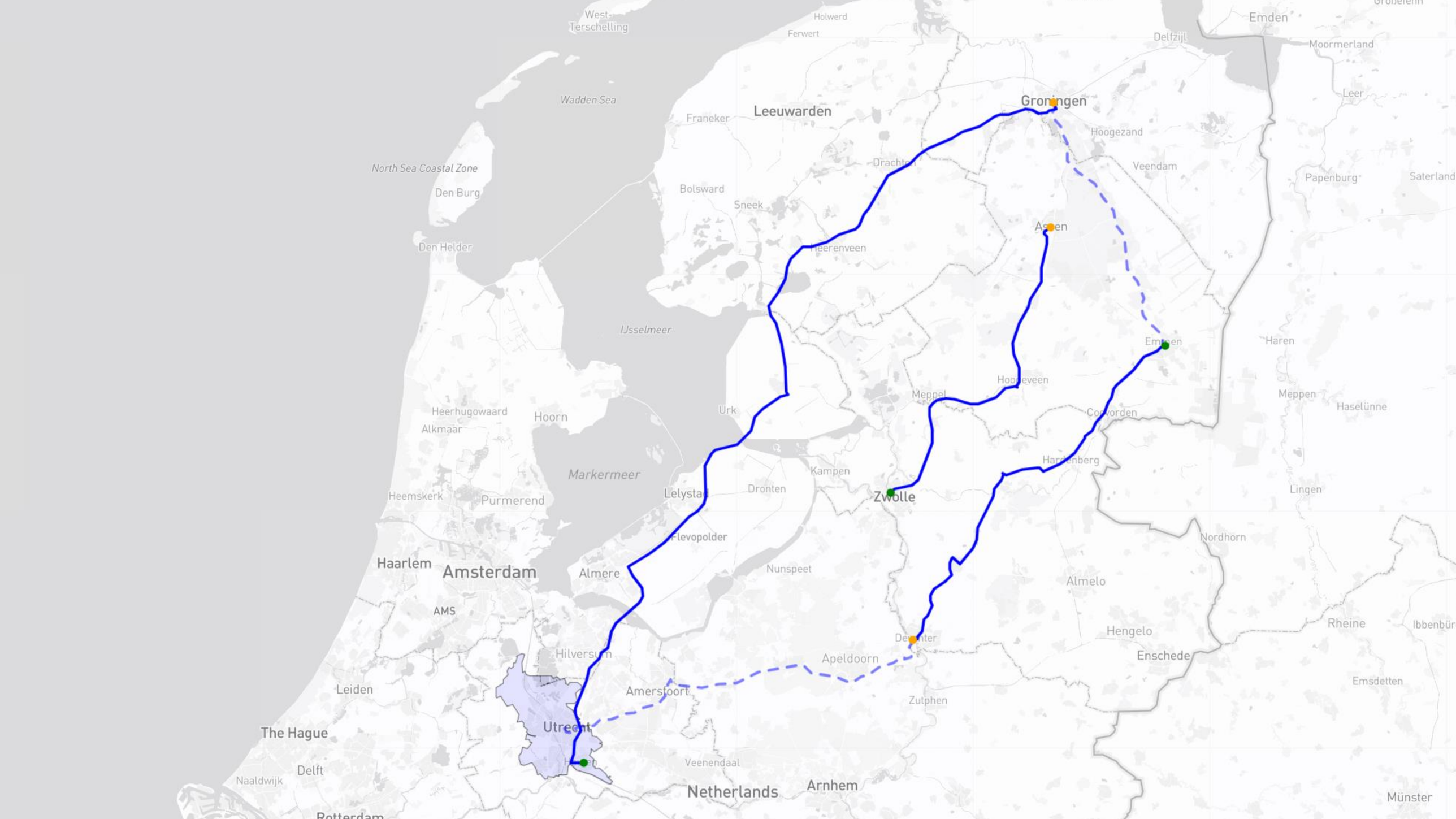
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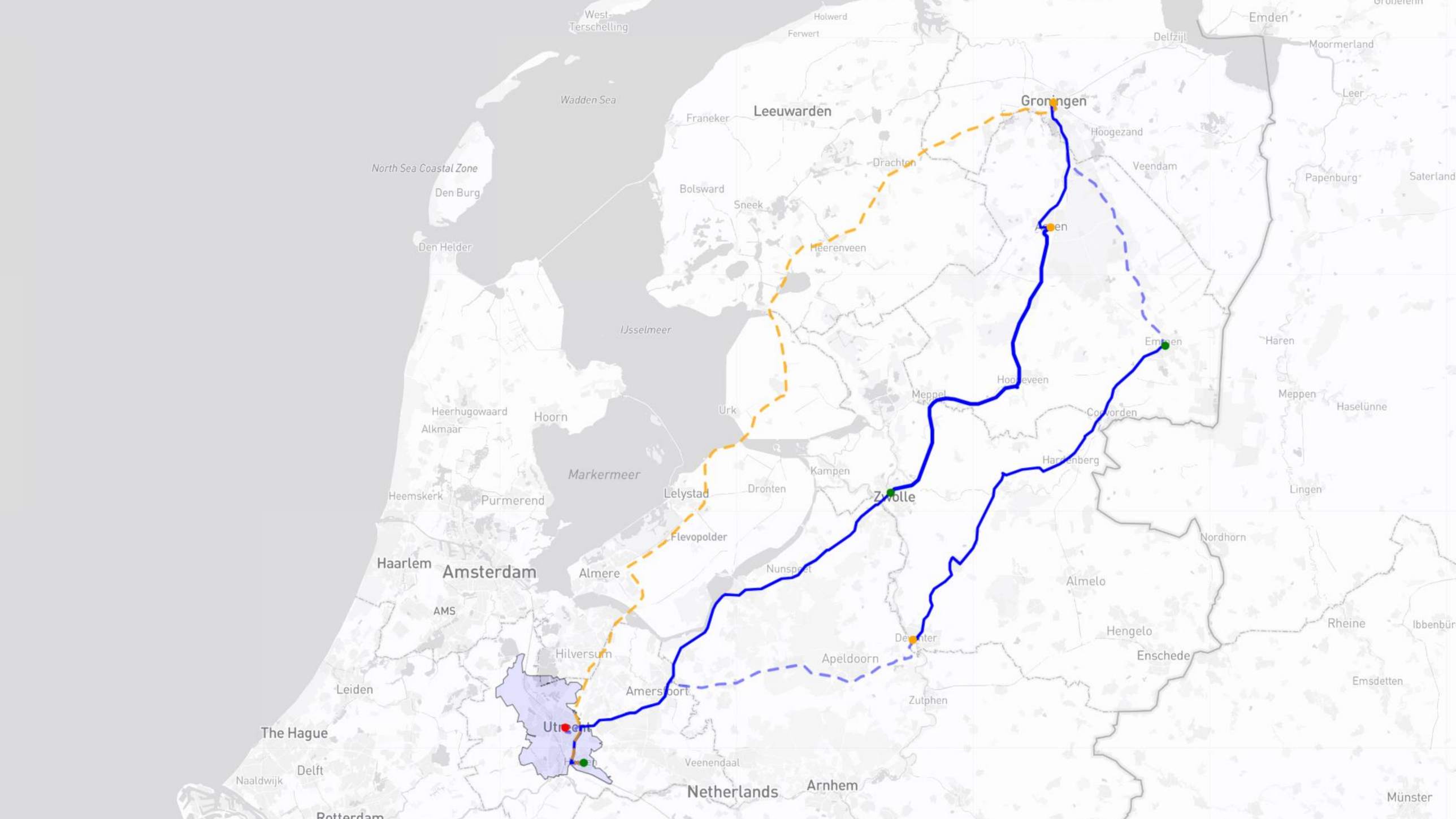
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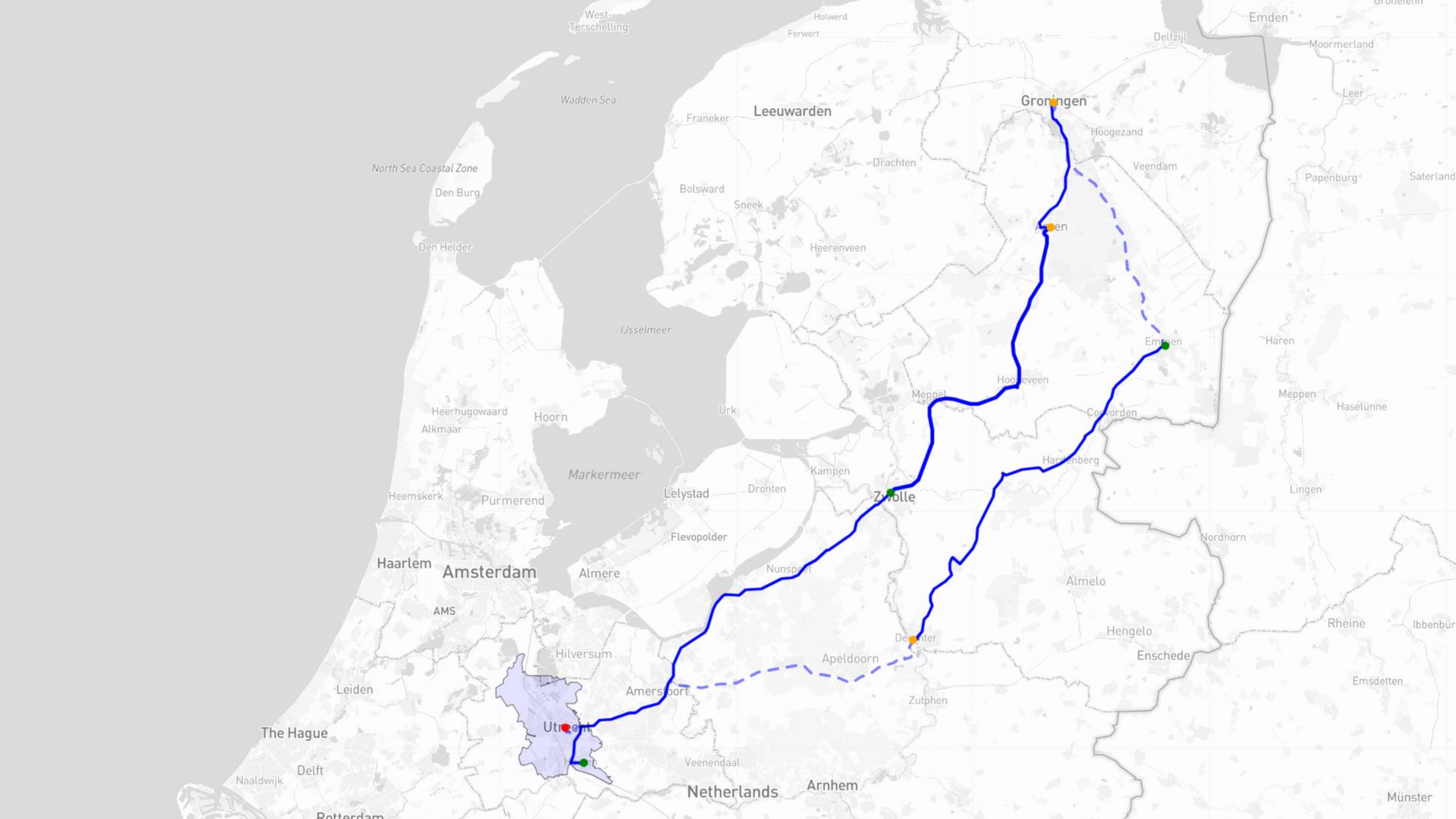
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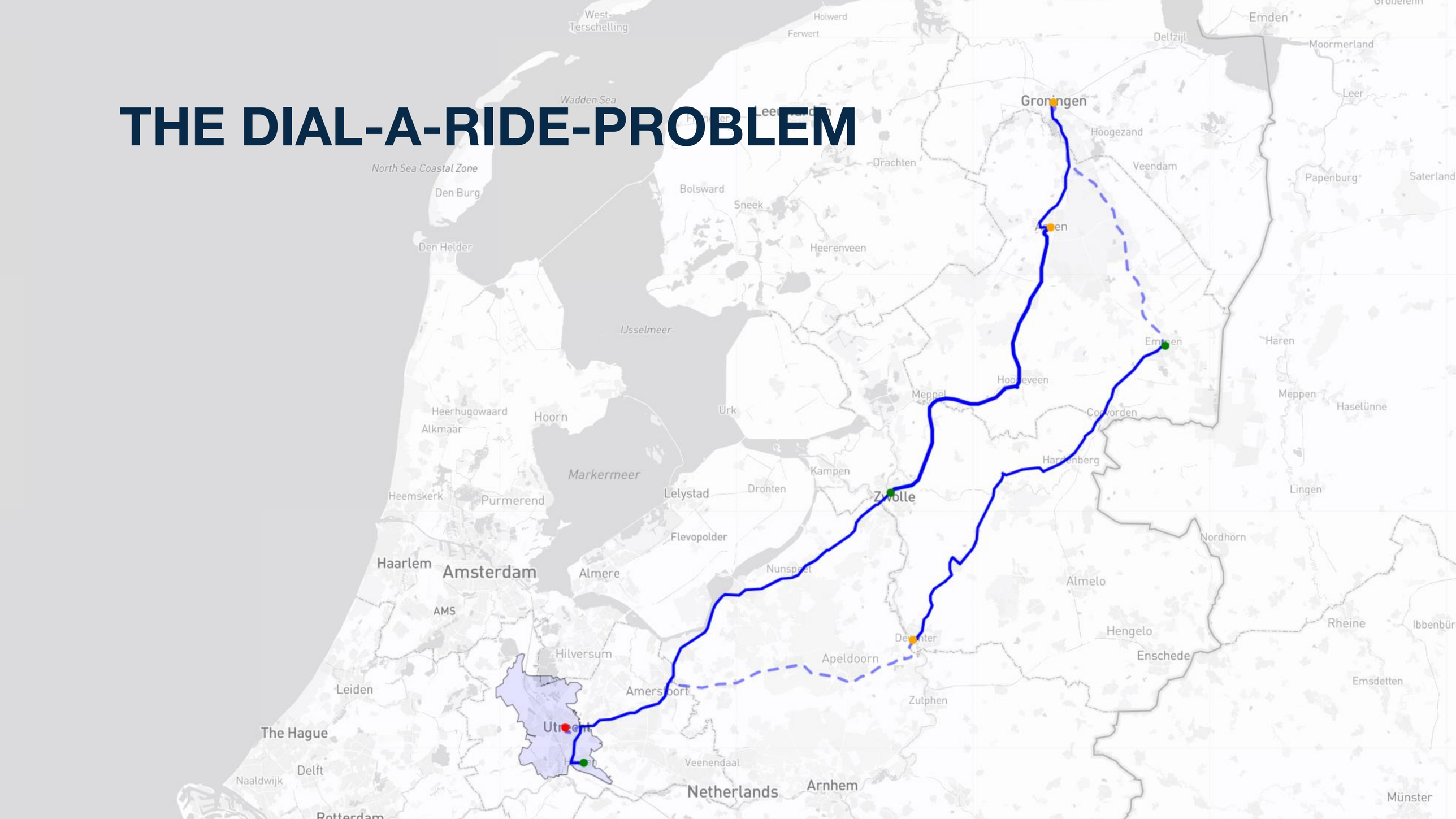
THE DIAL-A-RIDE-PROBLEM




Sabrina Schoenmaker
Passenger

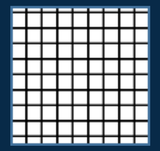

de weert
Sport+Revalidatie
ZL-806-V

PHASE I

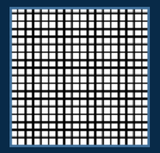
GIVEN ALL DISTANCES BETWEEN ALL POINTS, FIND A GOOD SOLUTION

PHASE II

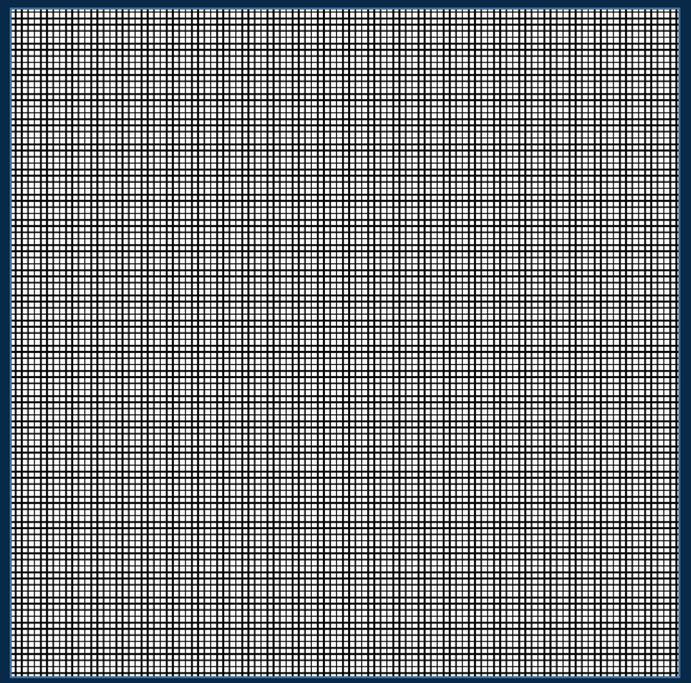
PROBLEM SIZE TODAY



10,000



100,000,000



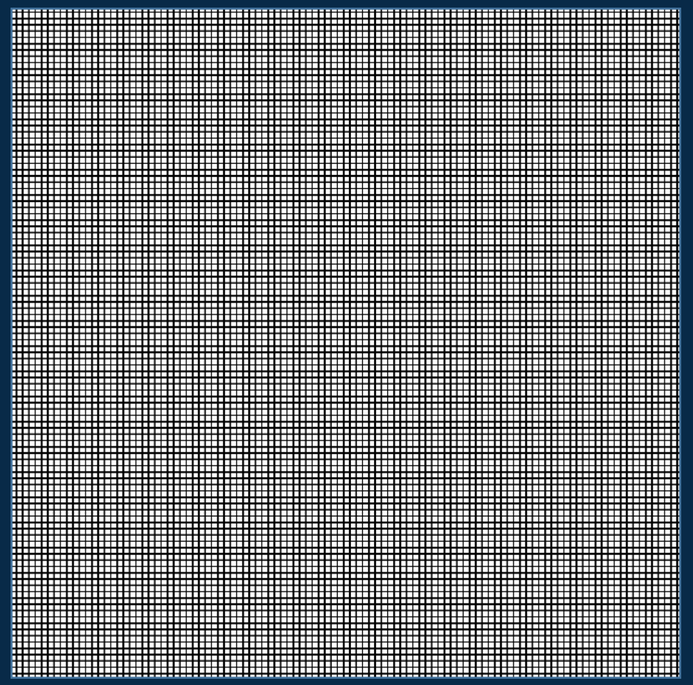
3,353,799,744

< 1 min

< 10 min

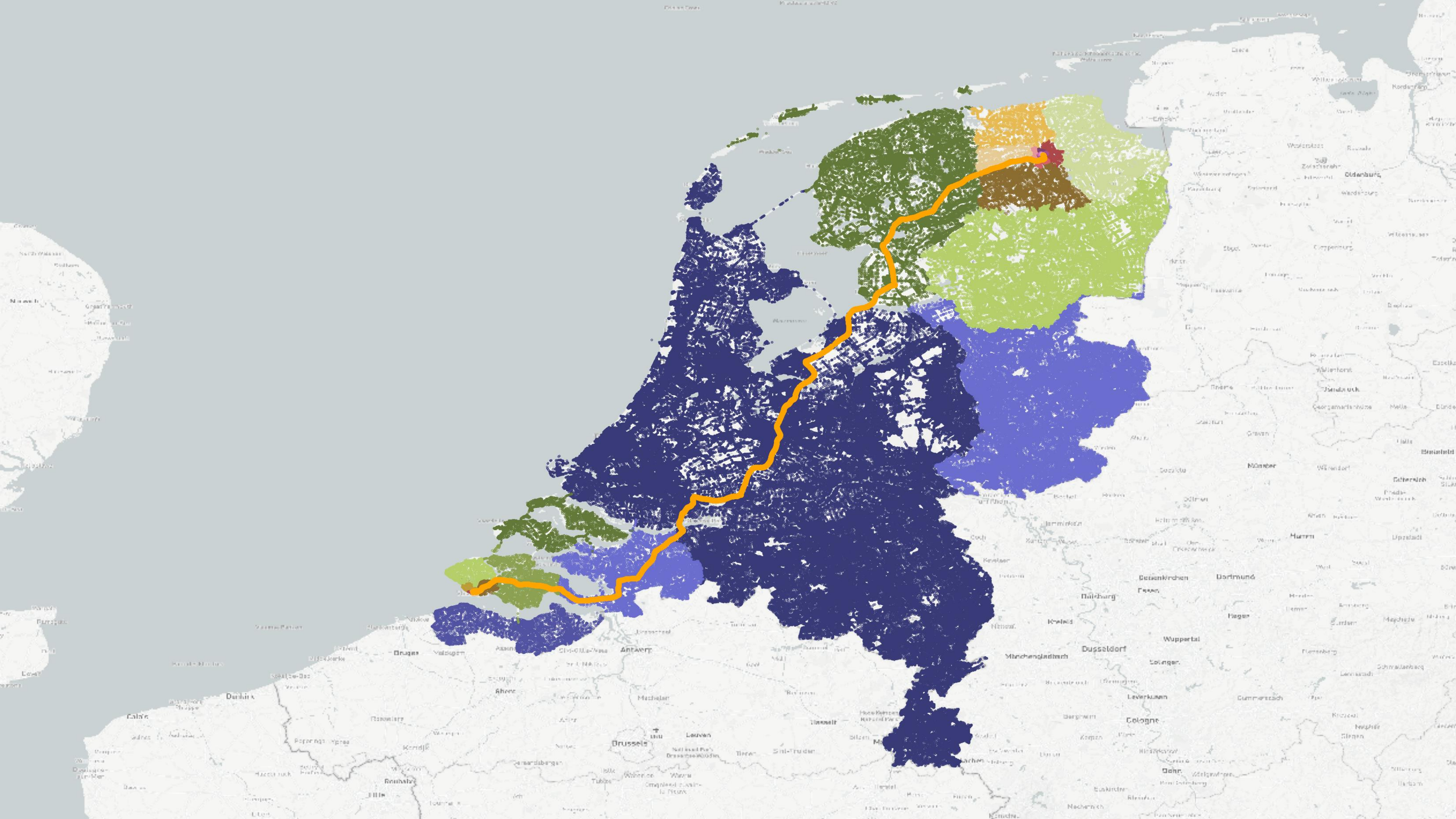
< 1 hours

MATRIX ENABLES RECORD



57,912 x 57,912

CQM, Bill Cook & Keld Helsgaun 2022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Leverkusen
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Aachen
Hasselt
Leuven
Brussels
Antwerp
Mechelen
Roeselare
Ypres
Calais
Dunkirk
Bruges
Zeebrugge
Ostend
Middelburg
Vlissingen

PHASE I

GIVEN THE DISTANCE MATRIX, FIND AN OPTIMAL TAXI PLAN

PHASE II

ITERATIVE (AGILE) ALGORITHM DEVELOPMENT

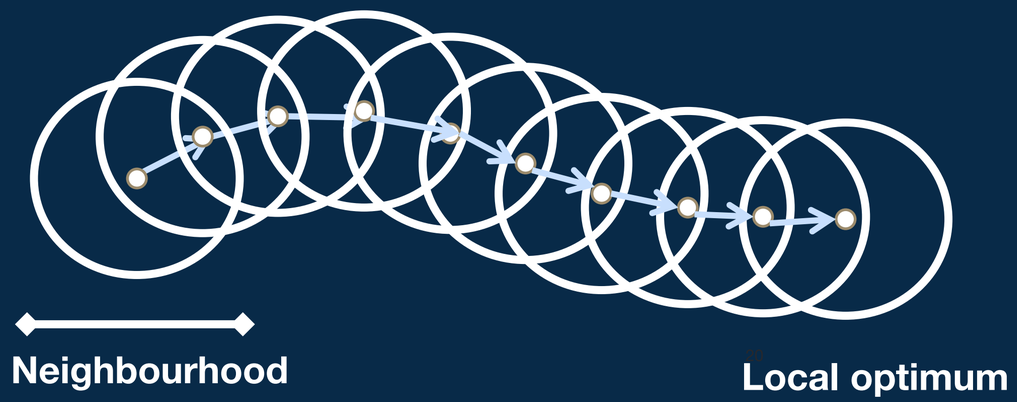
1. Do what always works: classic simulated annealing
2. Optimize for (orders of magnitude) more iterations per second
3. Modern Local Search
4. Mixed Integer Programming when applicable

1. CLASSIC SIMULATED ANNEALING

5,000 trips

01:00

4 hours

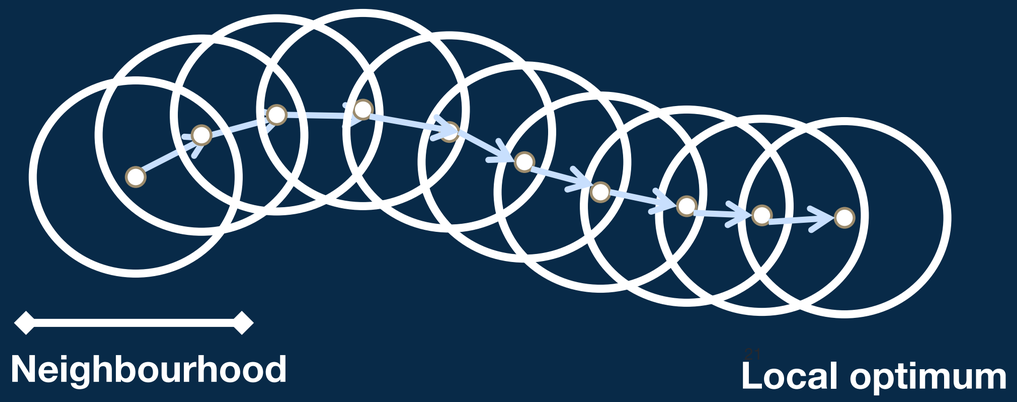


1. CLASSIC SIMULATED ANNEALING

5,000 trips

01:00

4 hours



Underlying model representation

	Pickup 1	Pickup 2	Drop off 2	Drop off 1		
	Pickup 3	Pickup 4	Drop off 3	Pickup 5	Drop off 4	Drop off 5
	Pickup 6	Drop off 6	Pickup 7	Pickup 8	Drop off 7	Drop off 8

This fully defines a (not necessarily feasible) solution

Neighbourhood

Random remove and insert trip

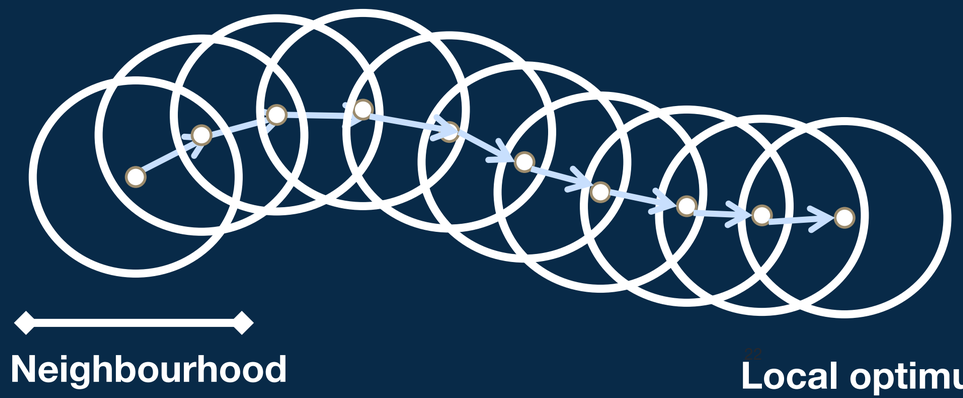
	Pickup 6	Drop off 6	Pickup 7	Pickup 8	Drop off 7	Drop off 8

1. CLASSIC SIMULATED ANNEALING

5,000 trips

01:00

4 hours



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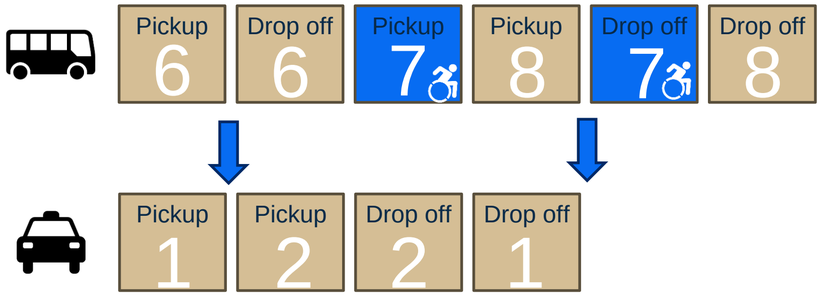
Neighbourhood

Random remove and insert trip



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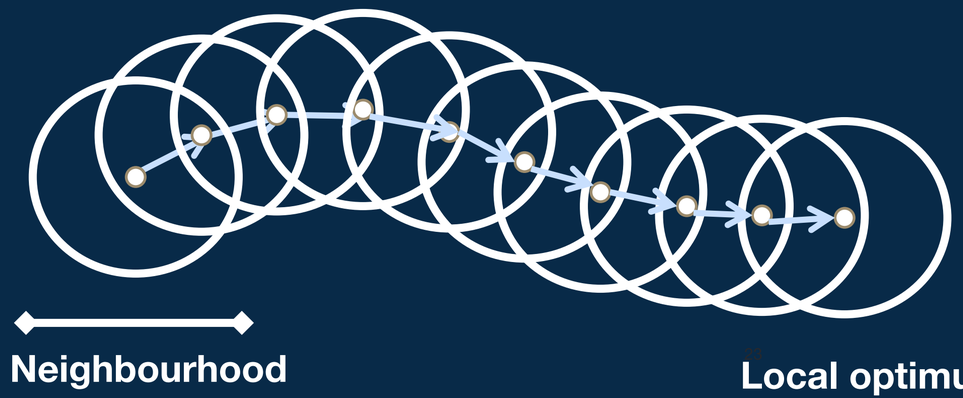

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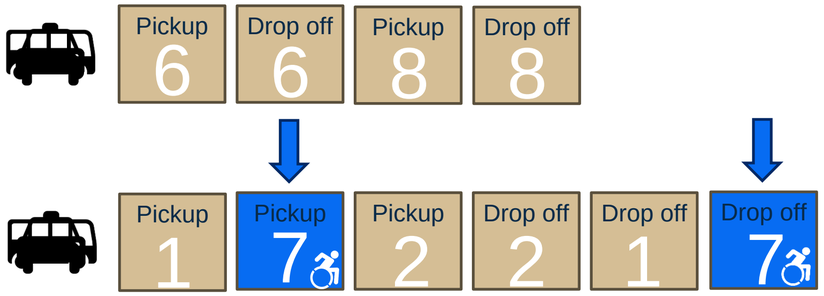


2. OPTIMIZING FOR MORE ITERATIONS/SECOND

Most computation time is in *checking feasibility* and *assigning times*:

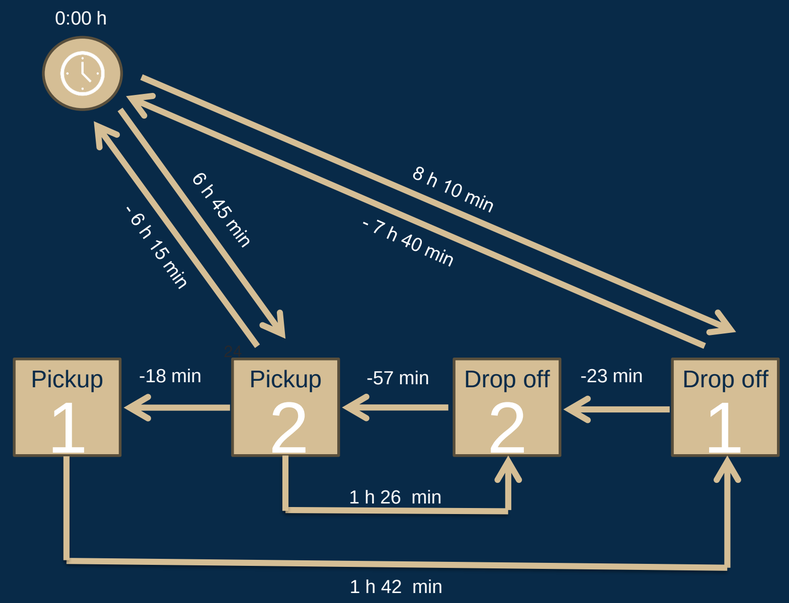
- Time windows feasible?
- Stay under 150% of shortest travel time for every passenger?
- Passenger limit for the car satisfied?
- Enough (wheelchair) vehicles in each region?

Checking the time windows: Simple Temporal Network

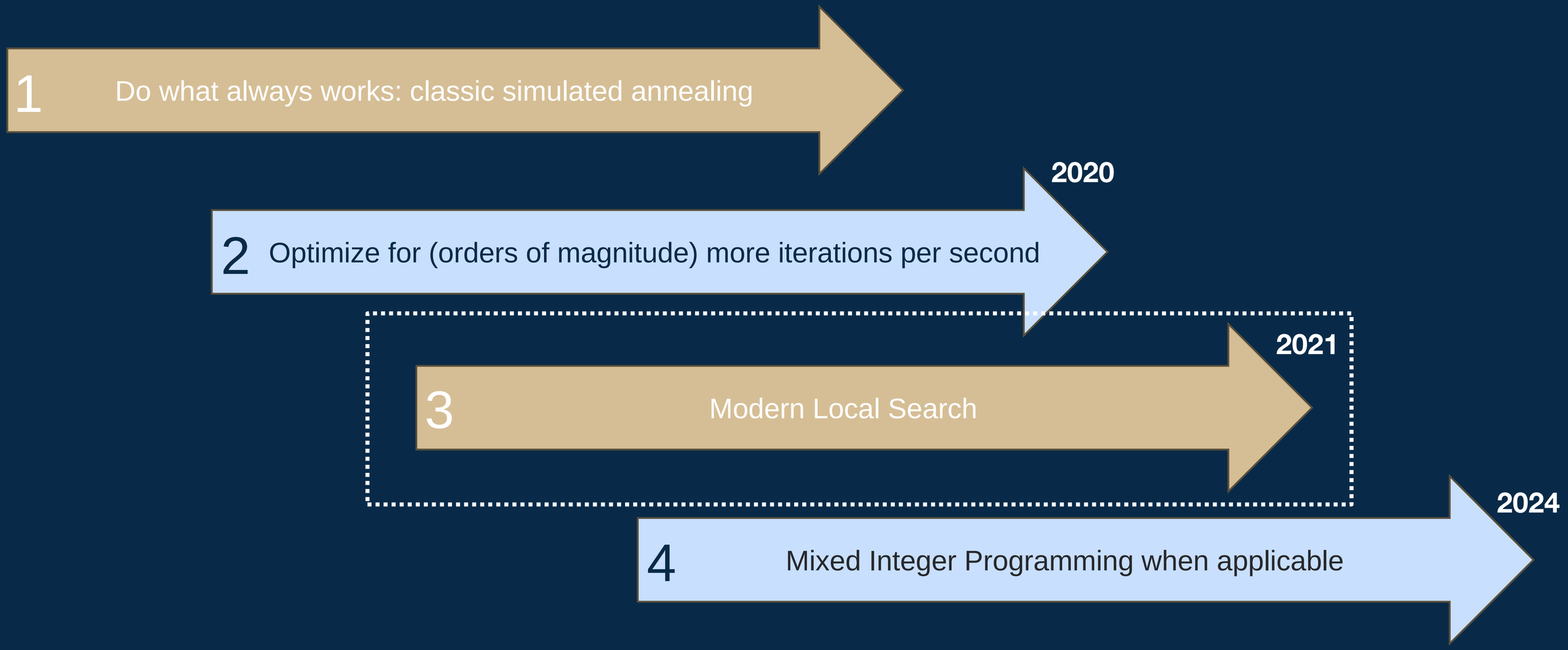
- A directed graph with nodes for each time point
  arcs represent ‘there should be at least/at most x time in between’
- Bellman-Ford algorithm checks time-wise feasibility and associated times

Many low-level optimization improved runtime by a factor >100x to tens of thousands of iterations per second on a single thread

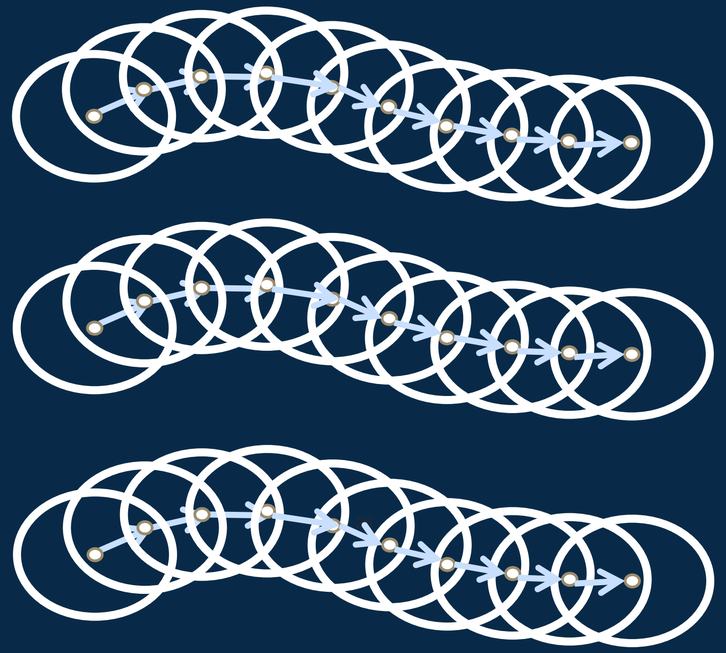
- Many quick checks to decide infeasibility before spending time on the Simple Temporal Network
- Variant of Yen’s improvement to Bellman-Ford to (mostly) require only a few Bellman-Ford iterations in expected O(m) time



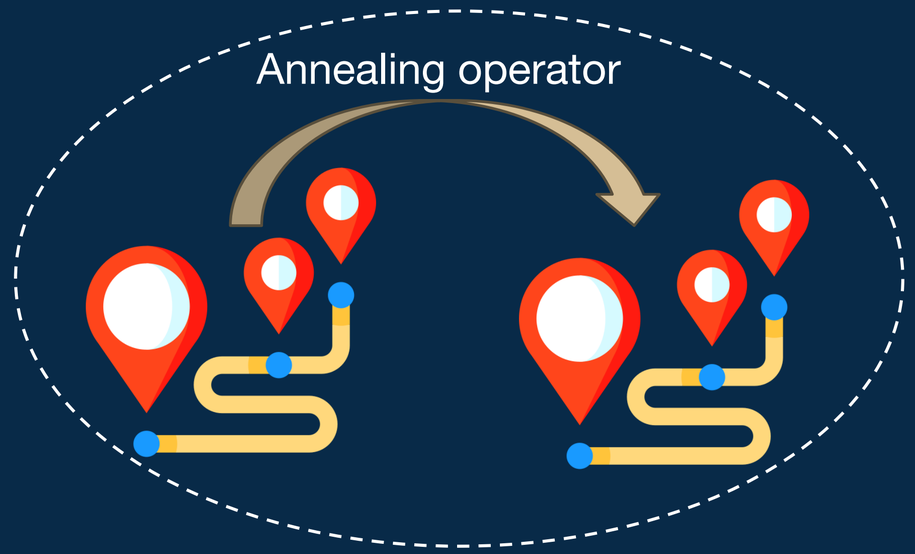
ITERATIVE (AGILE) ALGORITHM DEVELOPMENT

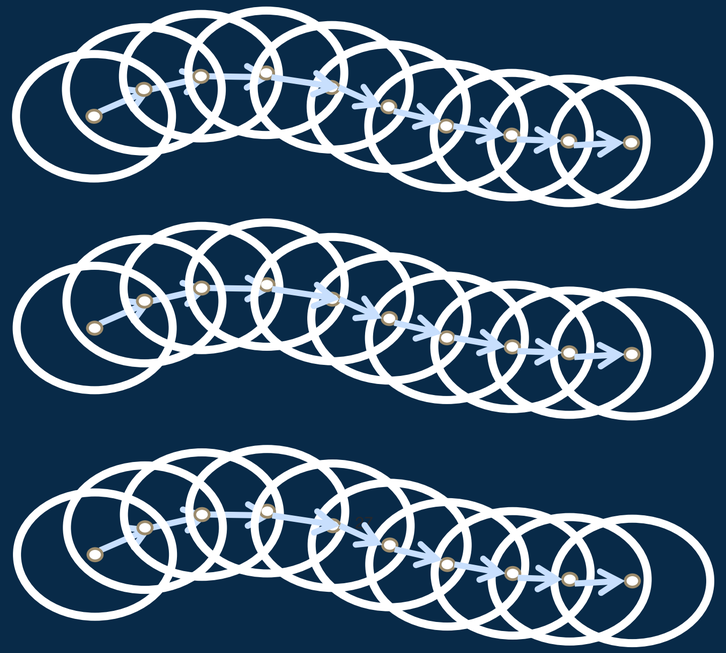


3. MODERN LOCAL SEARCH (2021)



3. MODERN LOCAL SEARCH: Parallelization





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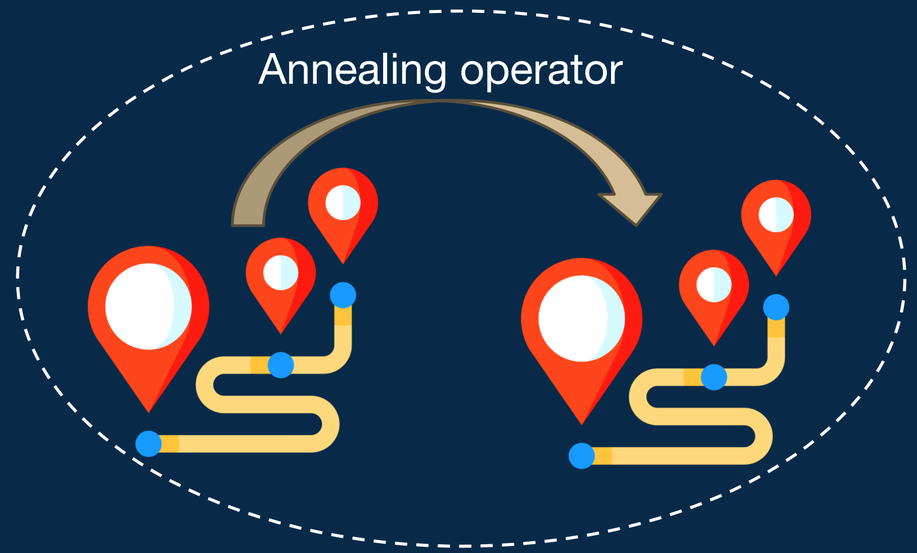
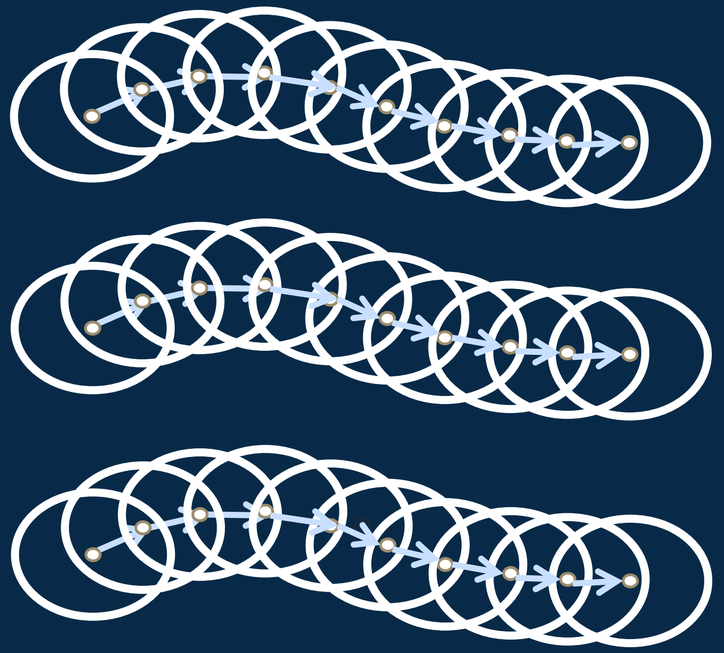
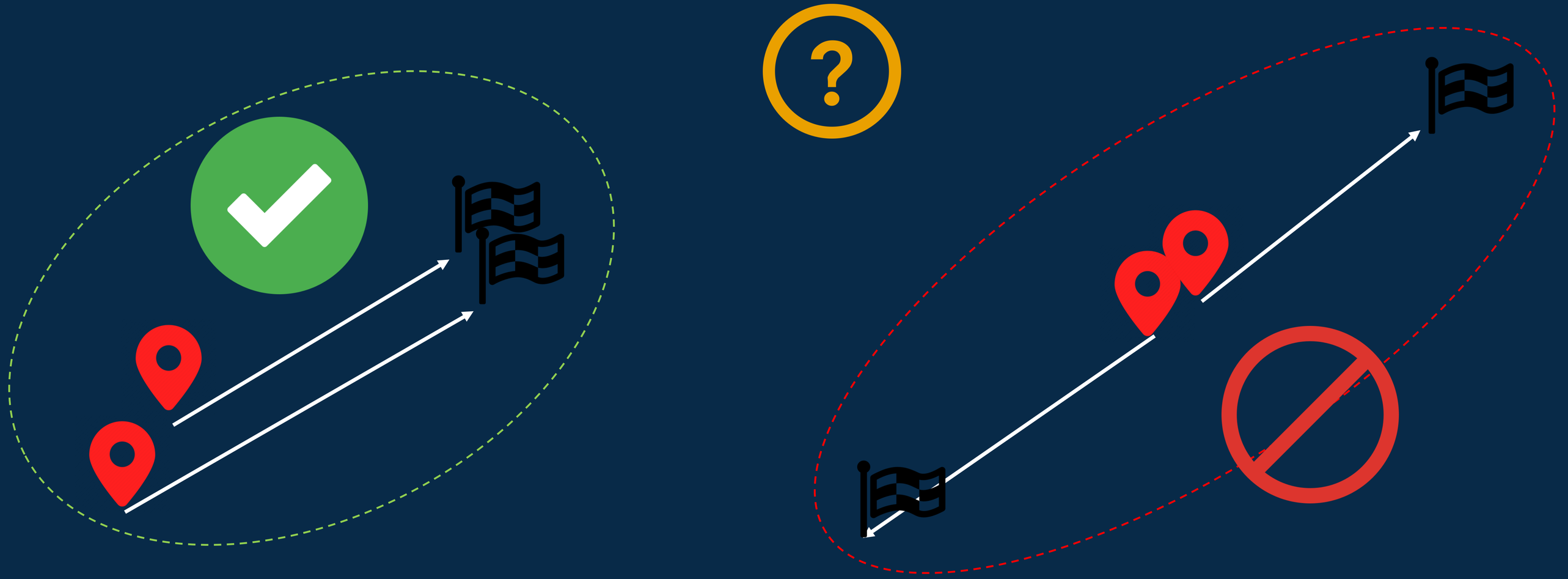


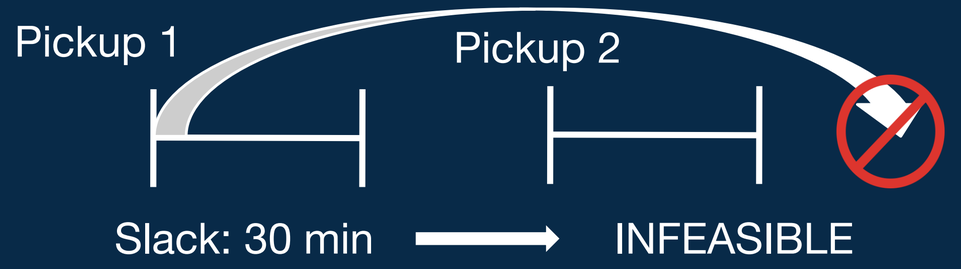


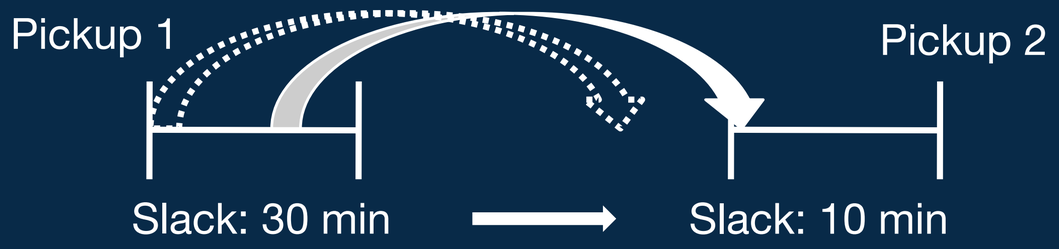
3. MODERN LOCAL SEARCH
Preprocessing pairwise compatibility

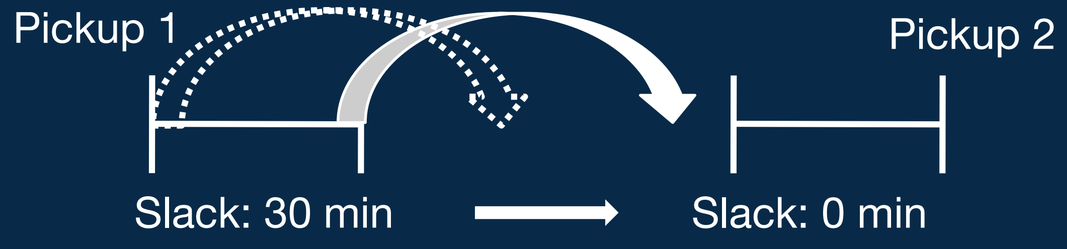


3. MODERN LOCAL SEARCH
Time setting using slack

1. Iterate through the stops in order.
2. Plan the stop as early as possible.
3. Track how much "slack" there is to move all planned stops later in time.
4. Move stops later in time to reduce waiting time.



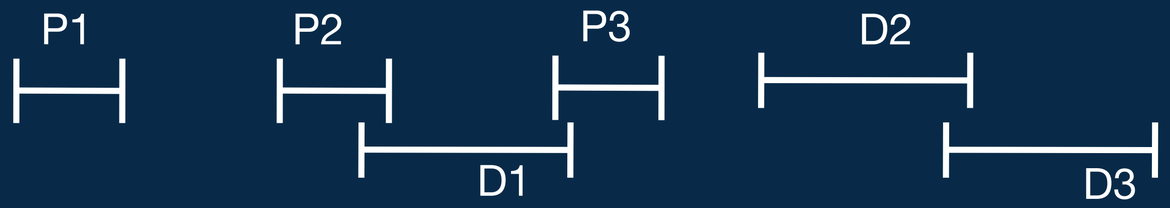




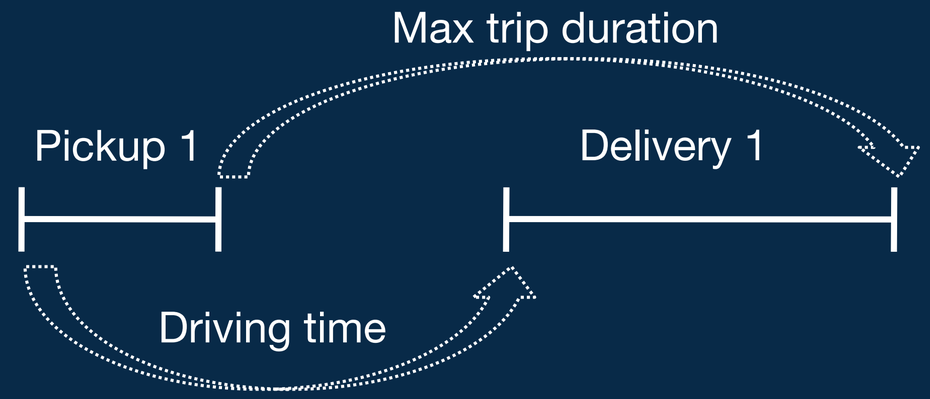
3. MODERN LOCAL SEARCH
Branch and prune: exploiting short time windows.

DETERMINE OPTIMAL ORDER OF STOPS

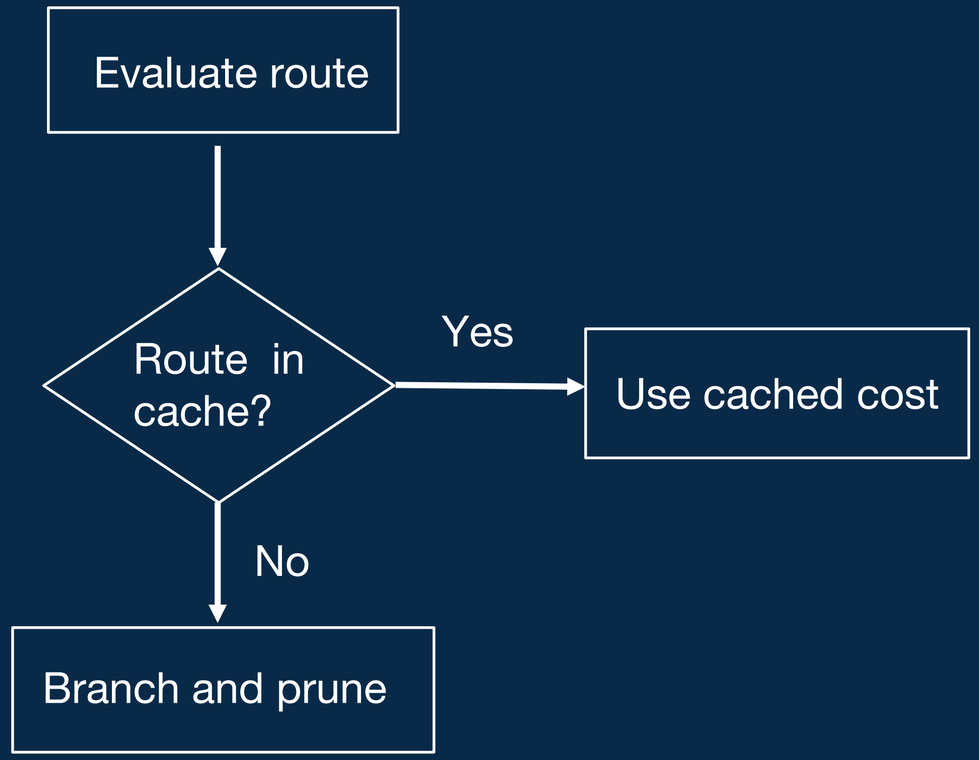
1. Sort stops by start of their time window.
2. Branch on overlapping time windows.
3. Prune branch if order is infeasible or of lower quality.



SOLUTION REPRESENTATION:
{ Trip 1, Trip 14, Trip 56 },
{ Trip 31, Trip 47, Trip 62 },
{ Trip 19, Trip 24, Trip 96 },
...

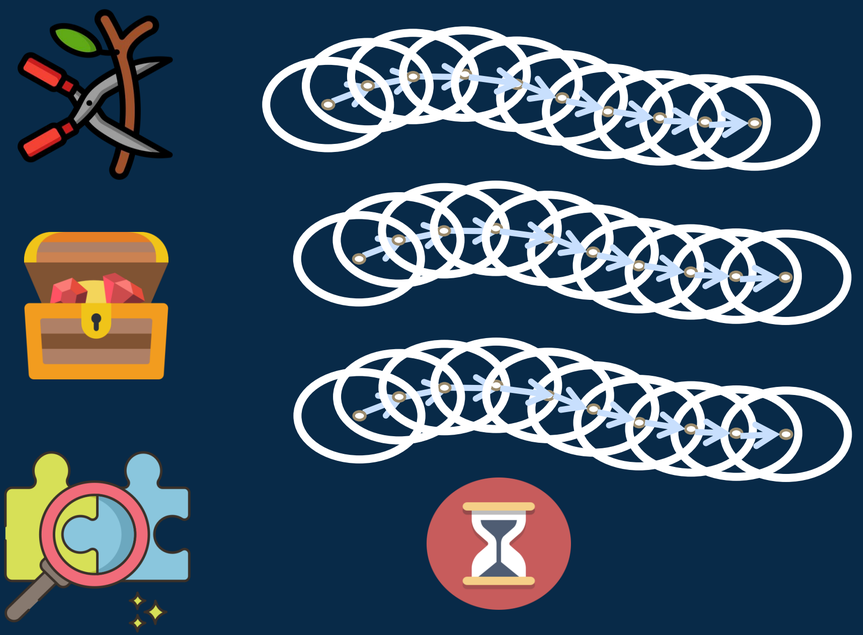


3. MODERN LOCAL SEARCH
Memory cache



Route	Cost
{ Trip 1, Trip 14, Trip 56 }	1260
{ Trip 31, Trip 47, Trip 62, Trip 88, Trip 114 }	2520
{ Trip 19, Trip 24 }	689
{ Trip 49, Trip 55, Trip 138, Trip 165, Trip 201 }	1908
...	...

3. MODERN LOCAL SEARCH (2021)



4 hours

20 sec

ITERATIVE (AGILE) ALGORITHM DEVELOPMENT

1 Do what always works: classic simulated annealing

2020

2 Optimize for (orders of magnitude) more iterations per second

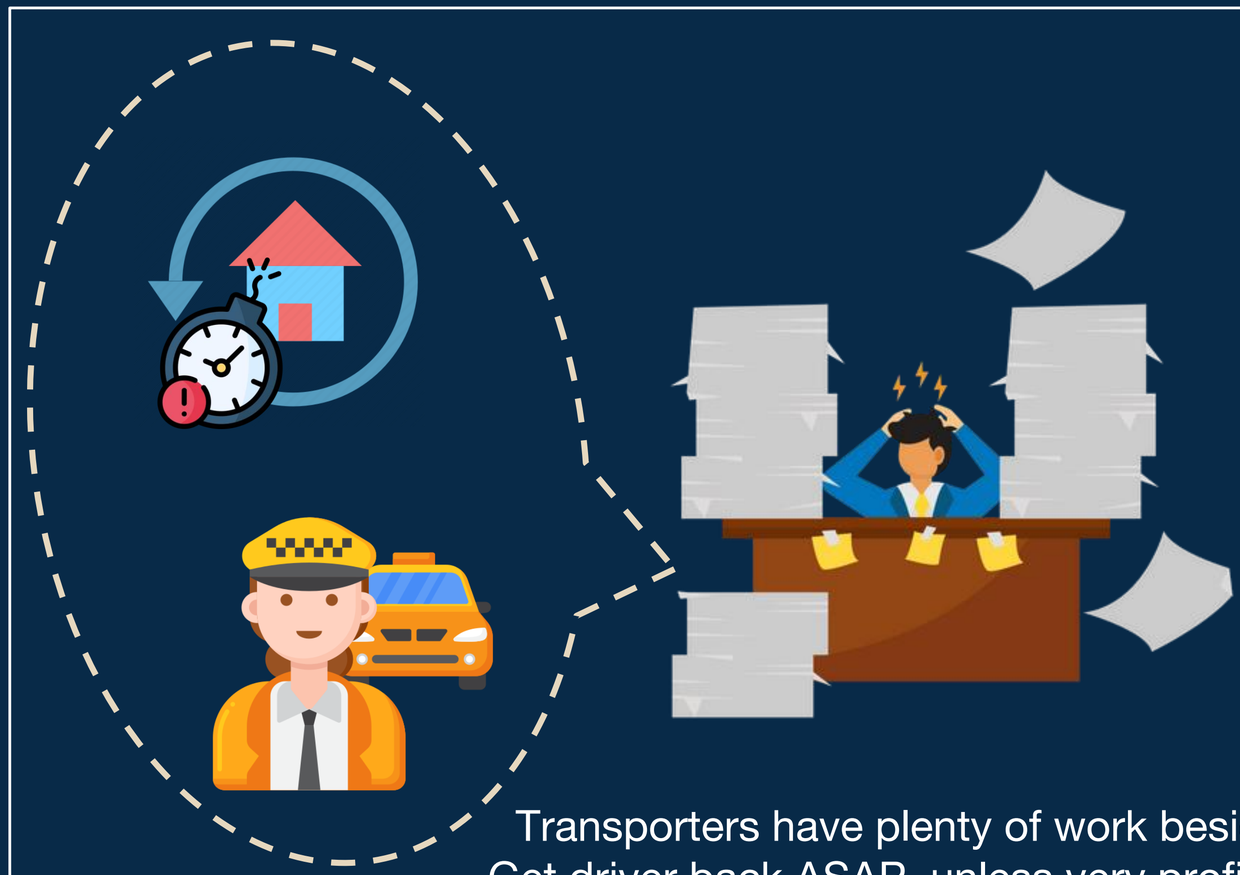
2021

3 Modern Local Search

2024

4 Mixed Integer Programming when applicable

4. INTEGER PROGRAMMING (2024)
Motivation: Shortage of drivers

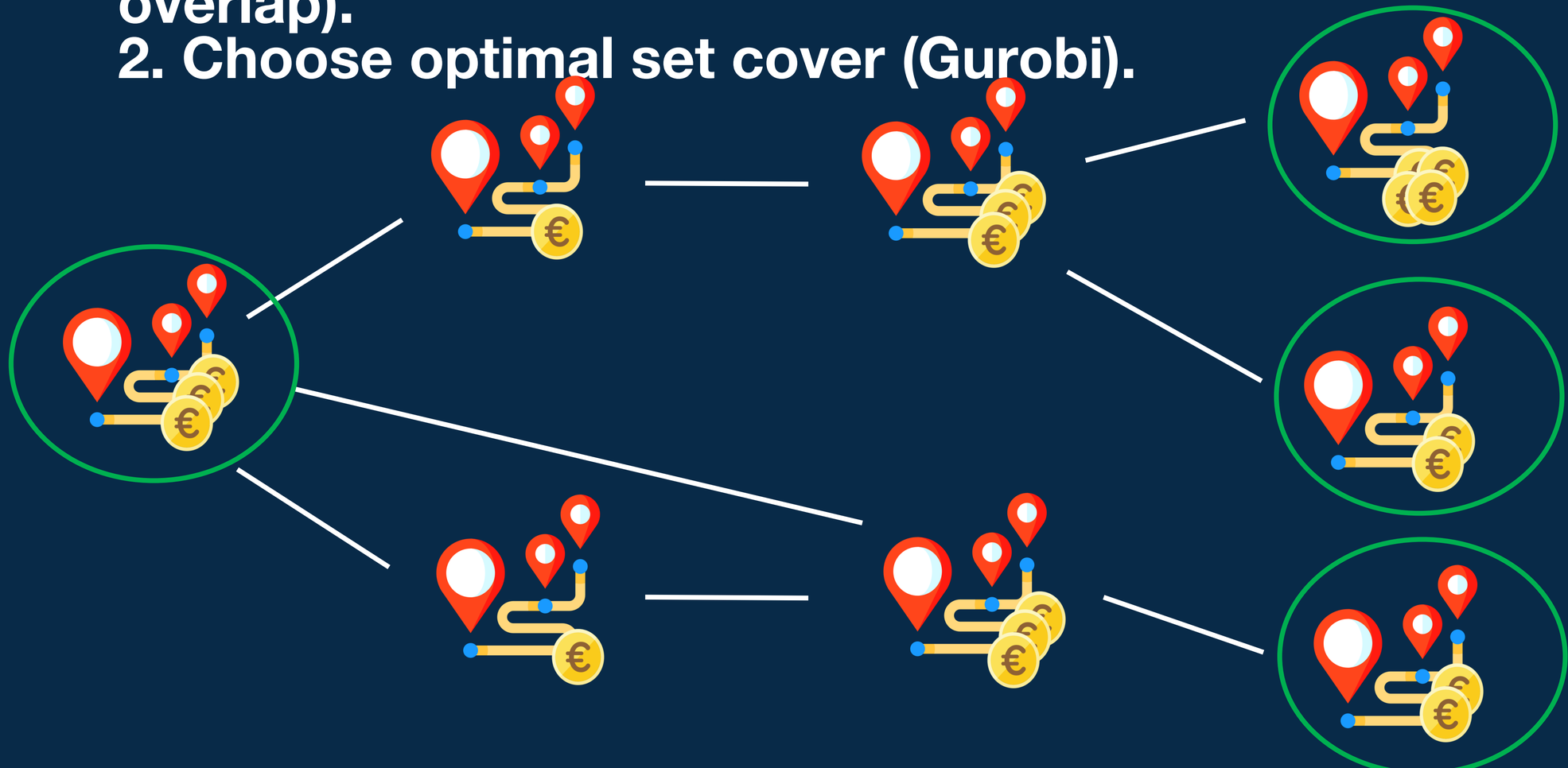


Valys

Transporters have plenty of work besides Valys:
Get driver back ASAP, unless very profitable route.

4. INTEGER PROGRAMMING (2024)

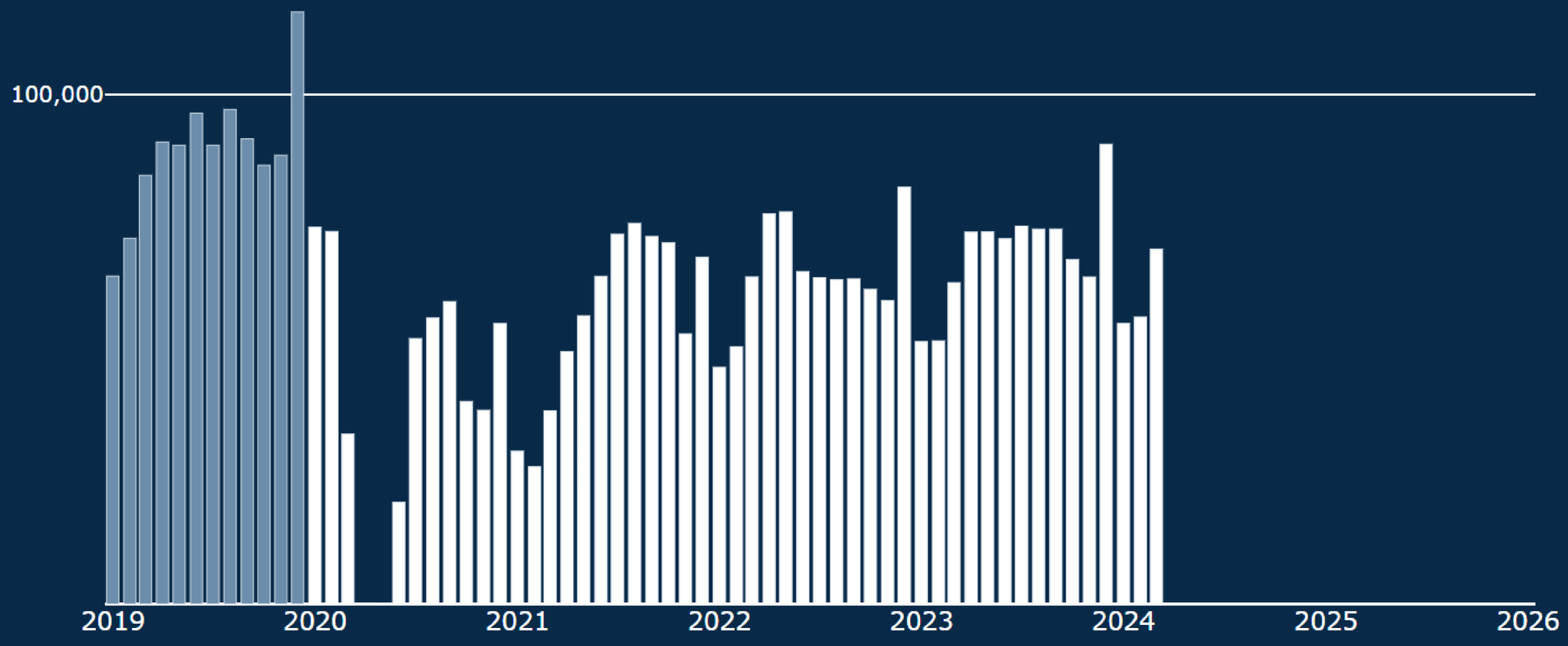
Solution:
1. Generate sufficiently profitable routes (they may overlap).
2. Choose optimal set cover (Gurobi).



Davor Bogicevic

Executive Director taxi operator RTC

PASSENGER TRIPS OVER TIME



KILOMETERS SAVED ON A TYPICAL DAY

BEFORE

2.320 trips

219.806 km

WITH OPERATIONS RESEARCH

2.320 trips

148.304 km

- 5-year average ~50k kilometers a day.
- 15 million kilometers saved per year

FINANCIAL BENEFITS

15m kilometers = 20% of operational driving costs saved

→ Resulting in better and lower tender bids for government projects

→ Better margin for taxi operators and Transvision

PASSENGERS


de wedert
WIJ ZOEKEN JOU!
Voor op de weg of op kantoor
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WHATS NEXT


Vertrek bussen
Valys