EPG Ehrhardt Partner Group

GREENPLAN™

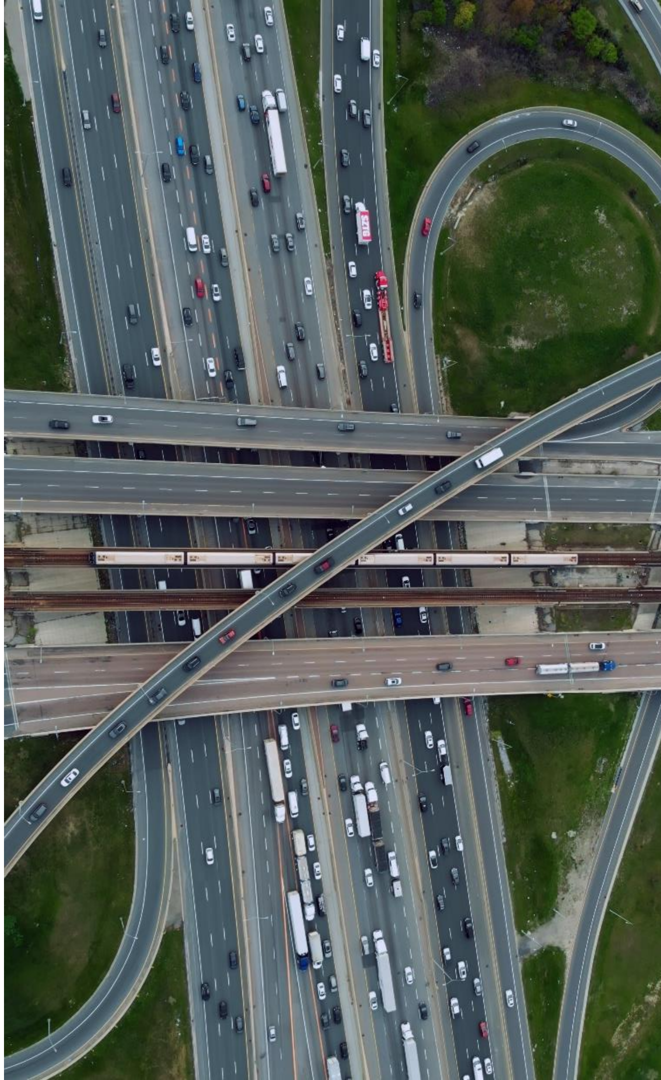
ROUTE PLANNING AND EXECUTION

Route planning and execution – the heart of transport management

Logistics Summit Düsseldorf 2024

AGENDA

- What customers expect from route planning
- Route planning complexity and evolution
- Deep dives to some important aspects: mapping, traffic and district handling
- Last innovations
- What you can expect from optimization



CUSTOMER AND MARKET DEMANDS AND NEEDS

Lower transport cost

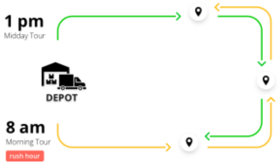
Less **vehicles** on the road, less **kilometers** driven, less **operational costs**, less **CO_2** emissions

HOW
Calculation with fully dynamic routes (without districts) as well as **overlapping districts.**

Higher punctuality

Precise ETAs and more on-time deliveries, leading to happier customers and happier drivers

HOW
Consideration of **predicted traffic flows** already in the **calculation of the routes**



Full adaptability

Tailormade route planning setup considering all special requirements

HOW
Sophisticated business rules engine and flexible modelling capabilities allow for a digital twin of your operations.

"Finally, I have all the freedom needed to improve my route planning."

TODAY'S ROUTING REQUIREMENTS DRIVEN BY COMPLEXITY WHICH NEEDS MATHEMATICAL MASTERING

Addresses

(typically, 100-150 per route, 50 routes per hub, per day)

Example with only 12 addresses: 12!

1 x 2 x 3 x 4 x 5 x 6 x 7 x 8 x 9 x 10 x 11 x 12

= 479.001.600 possibilities

×

Traffic

(speed variations, per street segment during the day, allowances, events, weather)

×

Specific requirements

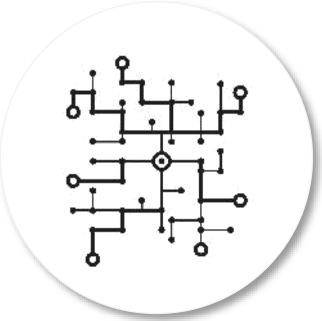
(business rules, time windows, vehicle capacities, skills, etc.)

=

Highly complex mathematical problems and super long calculation times

→ Mathematical mastering and short cuts required to produce optimal results in reasonable / given time (typically in 30-45 minutes)

EVOLUTION OF ROUTING PROVIDERS



From Excel-based

to

Mathematical modelling

From manual solution

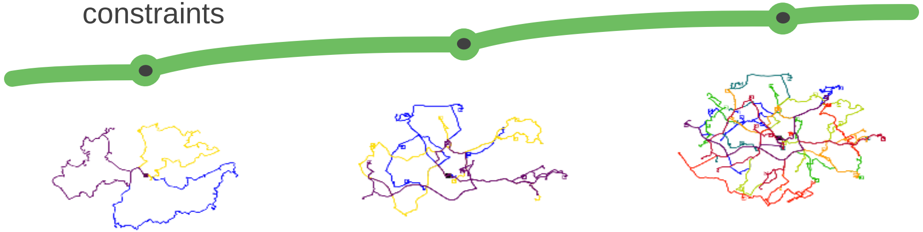
to

Automated optimization

Relatively **simple** planning problems with few or no constraints

Consideration of **further constraints** result in higher complexity

Increased volumes lead to larger instances to be optimized



Excel, manual

90s: OR and first algorithmics:

As of ~2010-15: Sophisticated Algorithms & AI:

ESSENTIAL FACTORS OF INNOVATIVE ROUTE PLANNING

Discrete mathematics

time-dependent travel times

traffic patterns

overlapping districts

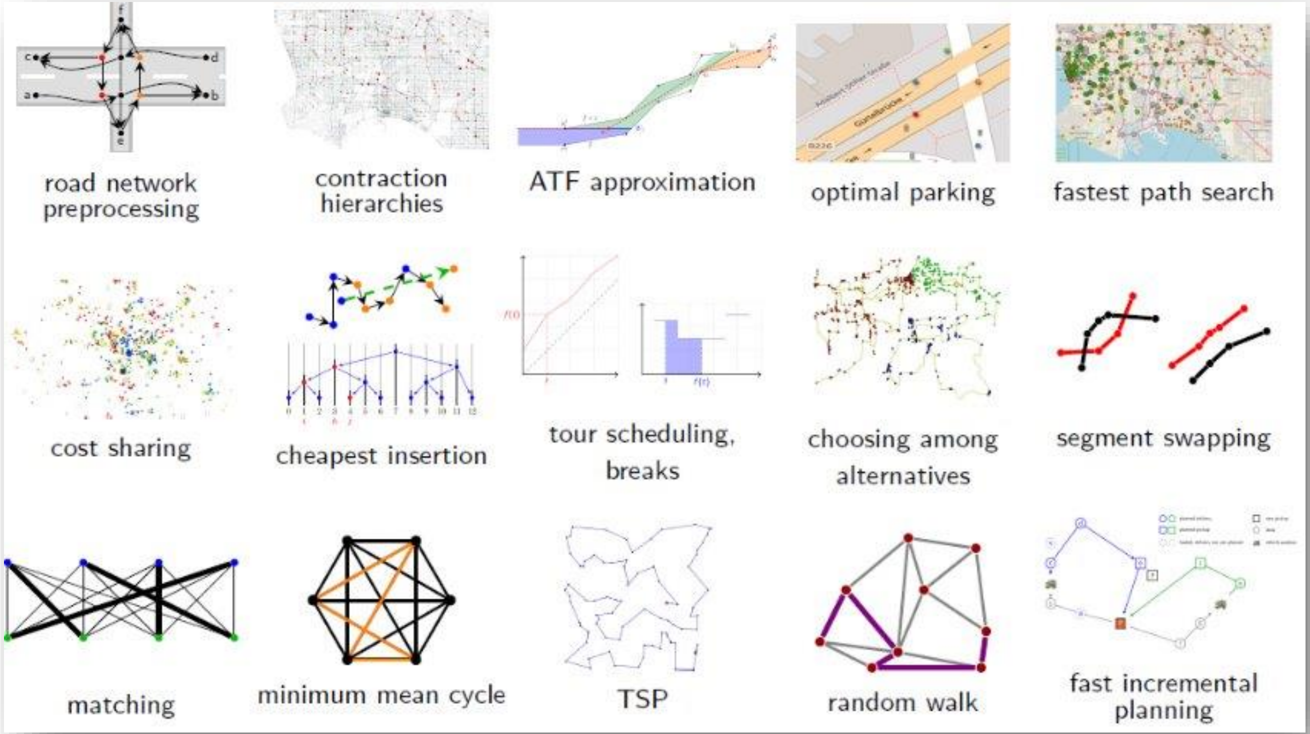
contraction hierarchies

street network

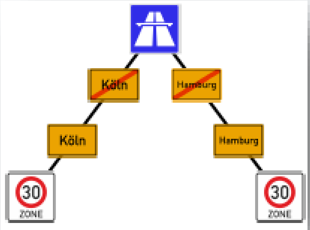
AI

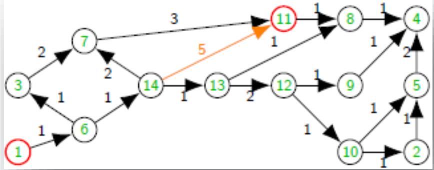
…and many more

KEY COMPONENTS OF INNER GREENPLAN CORE



DEEP DIVE 1: ROAD NETWORK PRE-PROCESSING: CONTRACTION HIERARCHIES





- Idea: exploit that fastest paths typically consist of one segment going up in road importance, and another going down
- Can we assign **levels** to the vertices of our road graph such that we can guarantee to find an optimum path consisting of one up and one down part, for all origin/destination pairs and all departure times
- Yes, if we add **shortcut edges**

A contraction hierarchy for Germany for one vehicle class can be stored in 4 GB and reconstructed within ~30 seconds from disk.

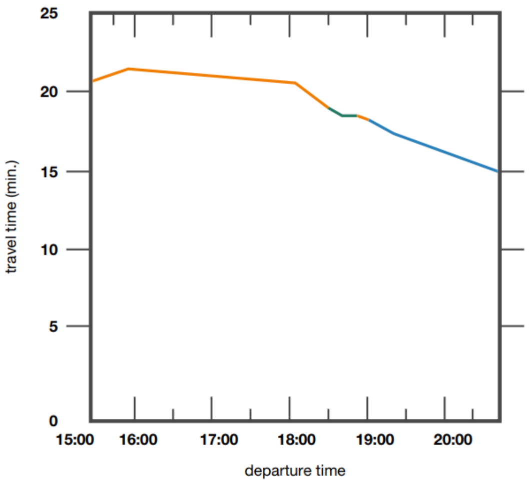
Then **one million** travel time functions can be computed in **less than a minute**

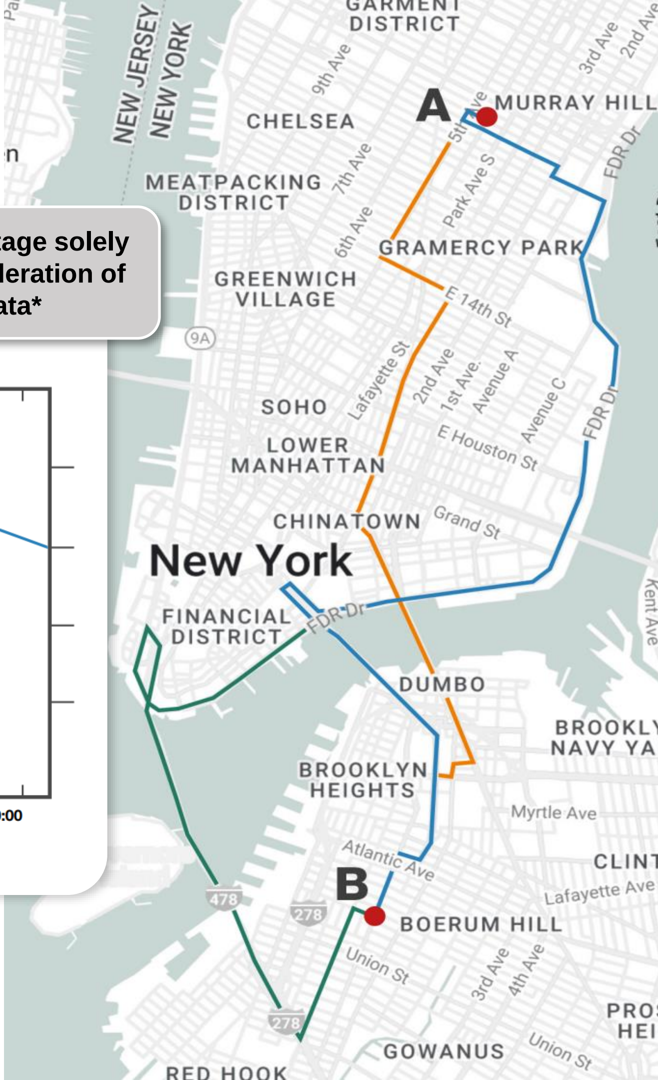
DEEP DIVE 2: TRAFFIC DATA

8% cost advantage solely through consideration of traffic data*

TOMTOM

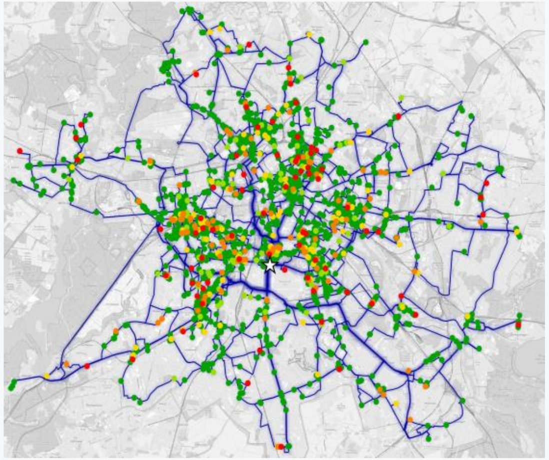
- Traffic data of every 200-meter street segment in 5-minute intervals
- Based on 600 million devices
- Depending on traffic, algorithm either chooses different roads or changes the order of the delivery/ pick-up stops
- Industry-unique approach from Greenplan, scientific paper proves superiority of this approach vs. competition
- Results of this approach: Cost efficient scheduling (= low idle time) + high quality delivery (= hitting delivery windows and SLA‘s)





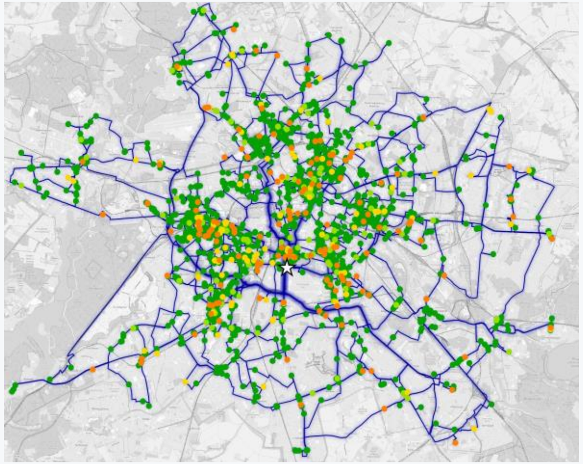
*) Vehicle Routing with Time-Dependent Travel Times: Theory, Practice, and Benchmarks”: https://arxiv.org/abs/2205.00889

DEEP DIVE 2: BETTER TOURS WITH TIME-DEPENDENT TRAVEL TIMES



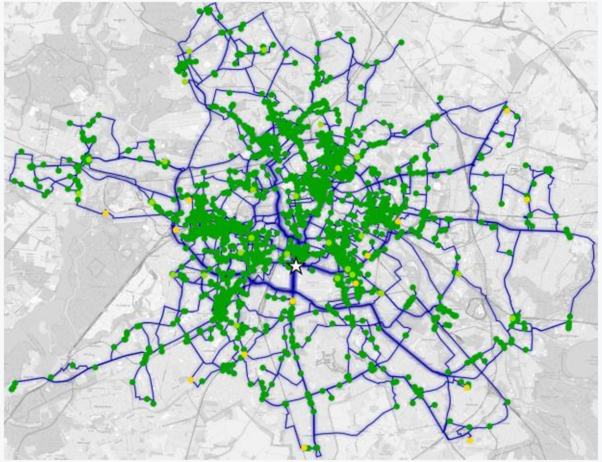
constant avg. travel times

28 tours, cost = 8859



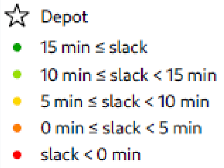
time-dependent travel times

28 tours, cost = 8850



time-dependent travel times & lateness penalties

29 tours, cost = 9149

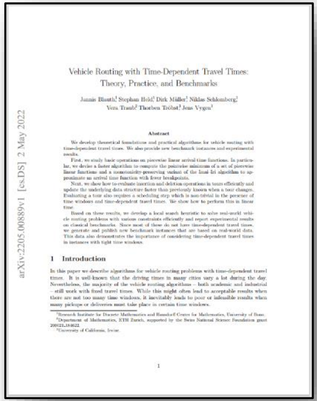


[J. Blauth, S. Held, D. Müller, N. Schlomberg, V. Traub, T. Tröbst, J. Vygen: Vehicle routing with time-dependent travel times: Theory, practice and benchmarks. arXiv:2205.0089]

DEEP DIVE 2: TRAFFIC DATA

Scientific study comparing Greenplan's USP (driving time-dependent calculation) with standard approaches

- Study basis: **10 major cities** (e.g. New York, Berlin, Nairobi), **map material from OpenStreetMap**, and **speed data/ driving times from Uber** for all Mondays from 06.01 - 09.03.2020
- Calculations performed with **time-of-day dependent driving times** (like Greenplan) **and with fixed driving times**

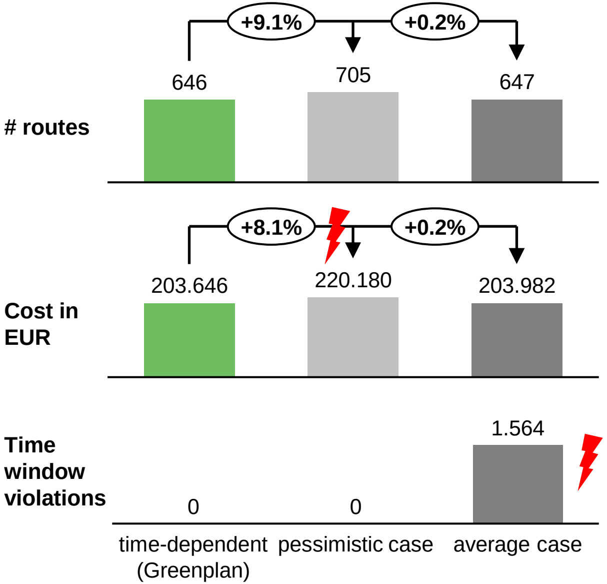

Vehicle Routing with Time-Dependent Travel Times: Theory, Practice, and Benchmarks

Jannis Blauth, Stephan Held, Dirk Müller, Niklas Schlomberg, Vera Traub, Thorben Tröbst, Jens Vygen

Abstract

1 Introduction

arXiv:2205.00889v1 [cs.DS] 2 May 2022



Calculating with time-of-day dependent driving times leads to the best routes; calculating with fixed driving times leads to either more costs (efficiency) or higher unpunctuality (quality).

*) Vehicle Routing with Time-Dependent Travel Times: Theory, Practice, and Benchmarks": https://arxiv.org/abs/2205.00889

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ONE OF BENELUX'S LARGEST SUPERMARKET CHAINS IMPROVES EFFICIENCY AND QUALITY

Home delivery

JUMBO

- [ ] Execution
- [ ] Planning
- [x] Engine + TMS Partner

The situation

590 vehicles in the Netherlands

- Up to 20,000 home deliveries per day
- 2 vehicle types (electrical and diesel) and 5 driver types
- 18 hubs throughout the country

All USPs

- Fully dynamic planning
- Consideration of time windows
- Business Rules

Results of scenario analyses based on relaxation of various restrictions:

- **Up to 15% fewer tours**
- **Up to 10% shorter delivery times**

= +10% increase in customer satisfaction

= 5-10% more orders per hour

DEEP DIVE 3: CAPACITY MANAGEMENT AND DISTRICT CUTTING – A ROUGH CALCULATION

1 parcel vehicle has **200 parcels (Addresses) capacity**

In one zip code area one typically can see **fluctuating volumes**
Day 1: 400
Day 2: 450

Question: **How many vehicles** do we need on **day 1 / day 2?**
Question: What is a **very bad situation?**

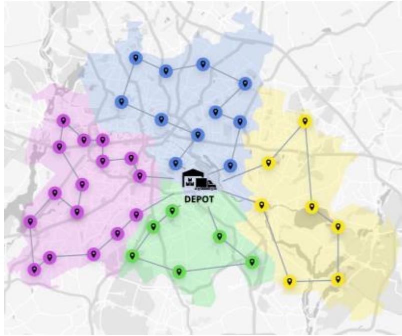
Question: **What is average capacity loss**? (Hint: law of great numbers)

Imagine Köln:
50 ZIP code areas
How many empty vehicles?

How to solve this?

DEEP DIVE 3: DYNAMIC AND OVERLAPPING DISTRICTS

Fixed districts
Optimal handling times



Similar routes, drivers know the area, **low handling times** (time spent finding address, parking space, entrance, etc.)

BUT – Longer driving times, more vehicles on the road. Consequently, higher cost for the company.

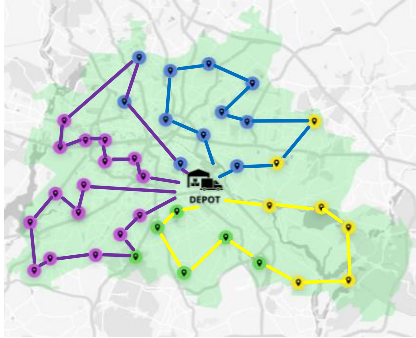
Overlapping districts
Optimal compromise

PostEurop Innovation Award

Optimal compromise between handling and driving time.

Drivers continue to work mainly in known areas while driving optimized routes and stop sequences. High acceptance among business and drivers.

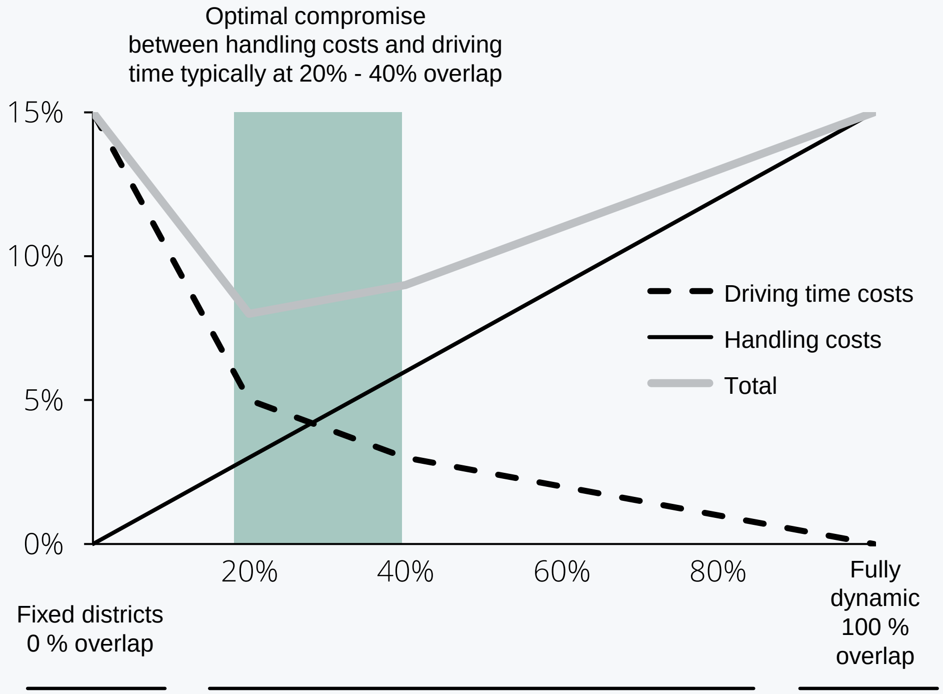
Dynamic planning
Optimal efficiency



Optimised routes and stop sequences, resulting in less kilometres/ fewer routes/ shorter driving time and lower costs.

BUT – Longer handling times as drivers may not know the area. Consequently, low acceptance among drivers.

DEEP DIVE 3: MANAGING THE TRADE-OFF BETWEEN HANDLING & DRIVING TIMES



- Fixed districts means low handling costs but high driving costs
- Fully dynamic means low driving time costs but often high handling costs
- Reason is the increased complexity for drivers to handle a new unknown address
- Overlapping districts as solution of this trade off
- Hard or soft district overlap depends on customer needs

GREENPLAN SIGNIFICANTLY REDUCES COSTS

Express

DANX Carousel

- [x] Execution
- [ ] Planning
- [ ] Engine

400 vehicles in NORDICS

100 vehicles in DK (roll-out)

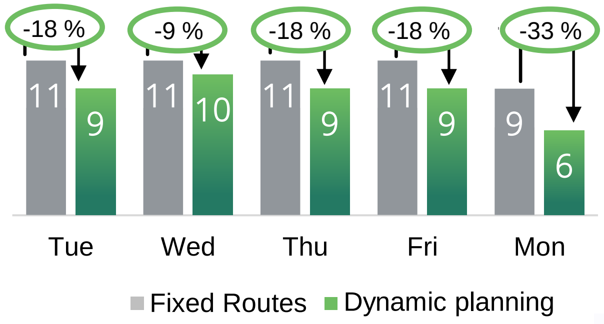
Company promise: Delivery of spare parts within 12 hours

The challenge

- Generating cost efficiencies
- Ensuring 99% on-time-performance
- Keeping driver operations as smooth as possible

- [x] Business Rules
- [x] USP overlapping districts

Number of routes, 1 week, 1 depot



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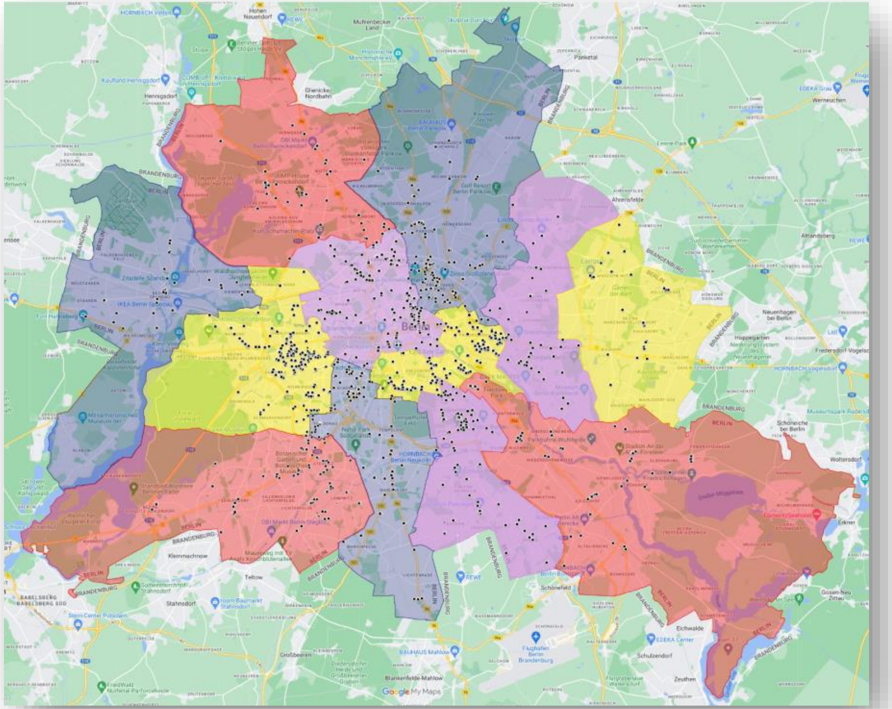
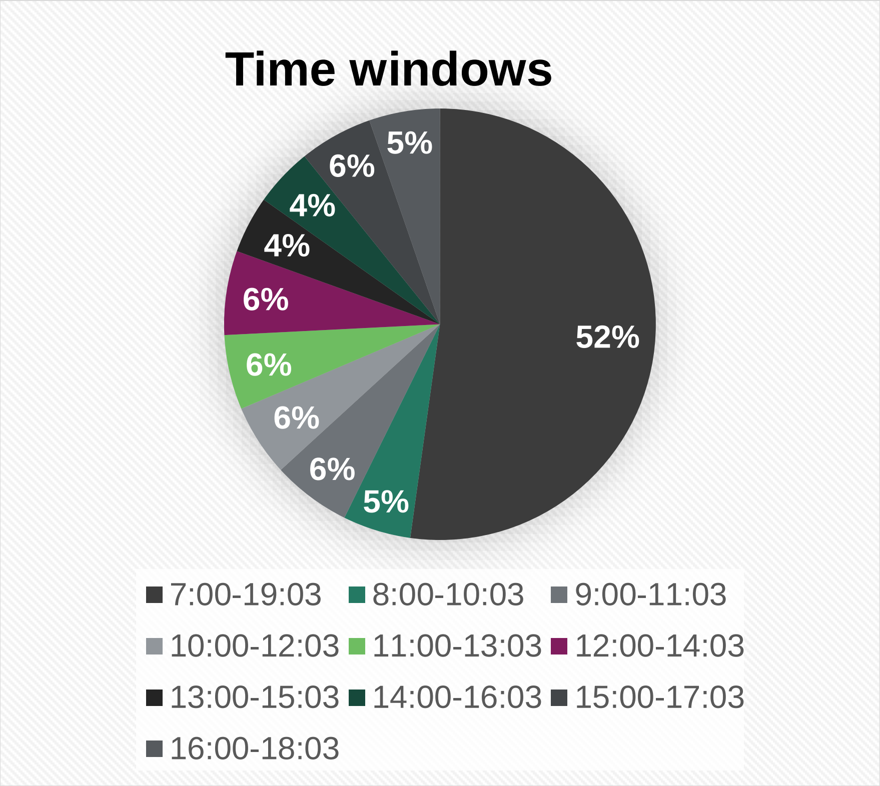
VALUE OF OVERLAPPING DISTRICTS: THE BERLIN CASE



- Sampled 1.000 shipments in Berlin
- One depot, 12 vehicles max cap 100, different time windows of 2 hours
- 12 city districts of Berlin serve as delivery districts:
  - Mitte, Pankow, Friedrichshain-Kreuzberg, Charlottenburg-Wilmersdorf, Neukölln, Lichtenberg, Marzahn-Hellersdorf, Reinickendorf, Spandau, Steglitz-Zehlendorf, Tempelhof-Schöneberg, Treptow-Kopenick

ASSUMPTIONS

- Only deliveries
- One depot
  - Open 06:00 – 18:00
  - Return by 20:00
- 12 vehicles
  - One vehicle type (Van)
- Visit time of 1 minute at each address
- Max. working time: 12h
  - No breaks
- Capacity: Maximum 100 shipments per tour

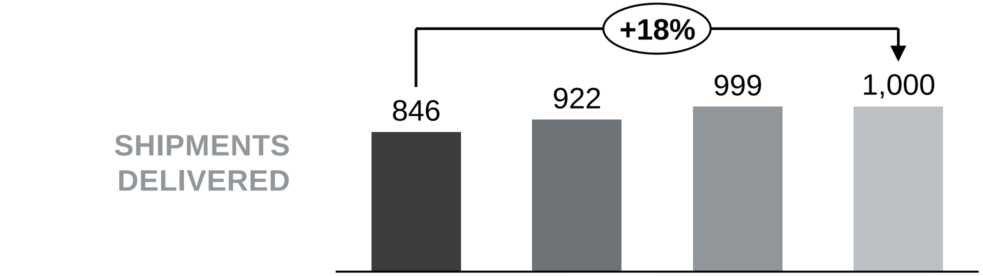


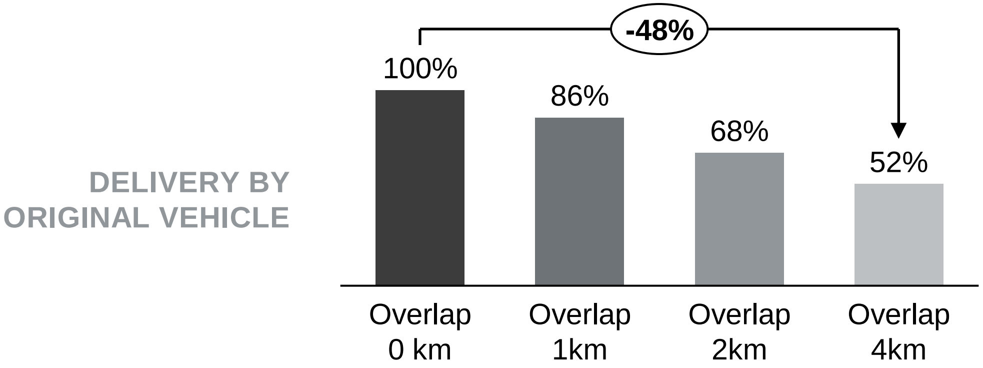
WHAT HAPPENS IF WE BLOW UP THE DISTRICTS

Without overlap, it is impossible to handle the unbalanced load

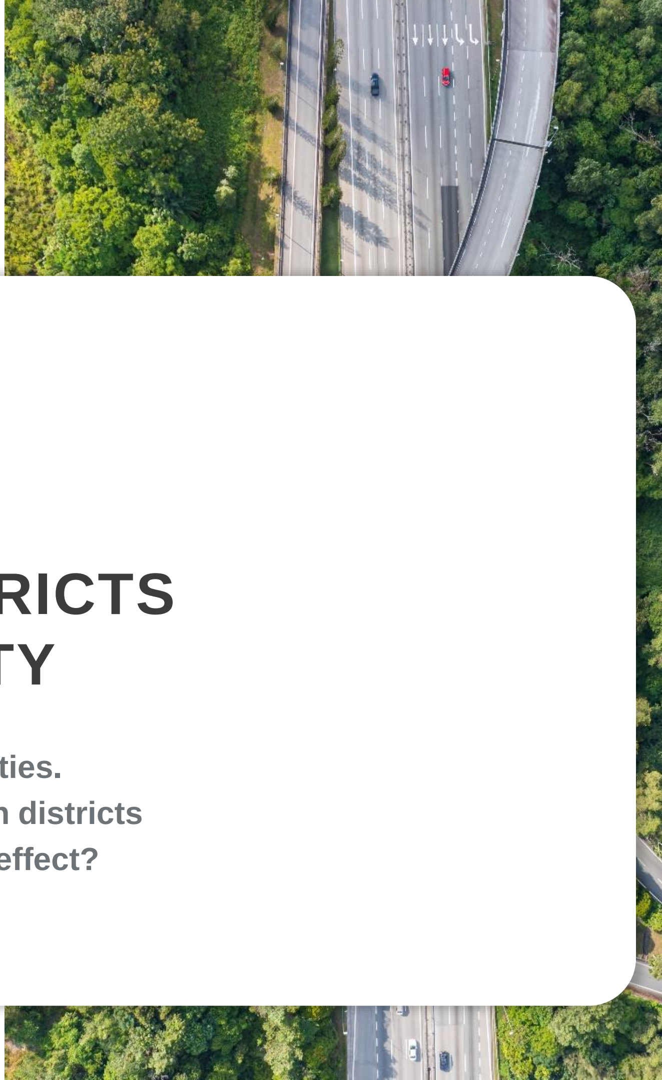
With just 2km of overlap, almost all shipments can be delivered

At the same time, volatility and hence handling time increase





SOFT OVERLAPS …



SOFT OVERLAPPING DISTRICTS TO INCREASE STABILITY

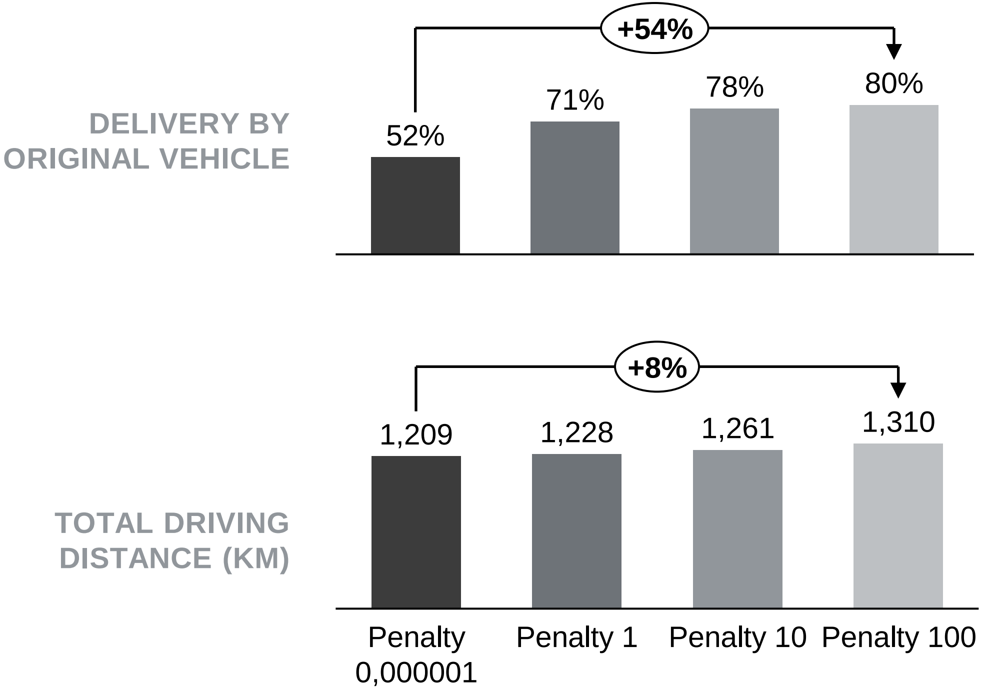
Volatility effects can be simulated via penalties.
What if we allow exchange of shipments between districts (shipment specific) but penalize the volatility effect?

WHAT HAPPENS AT 4KM OVERLAP WITH DIFFERENT PENALTIES?

Primary goal of delivering all shipments always achieved

Stability increases heavily with penalties

This efficiency plus comes (only) with minimized negative effects of increased working times and driving distance



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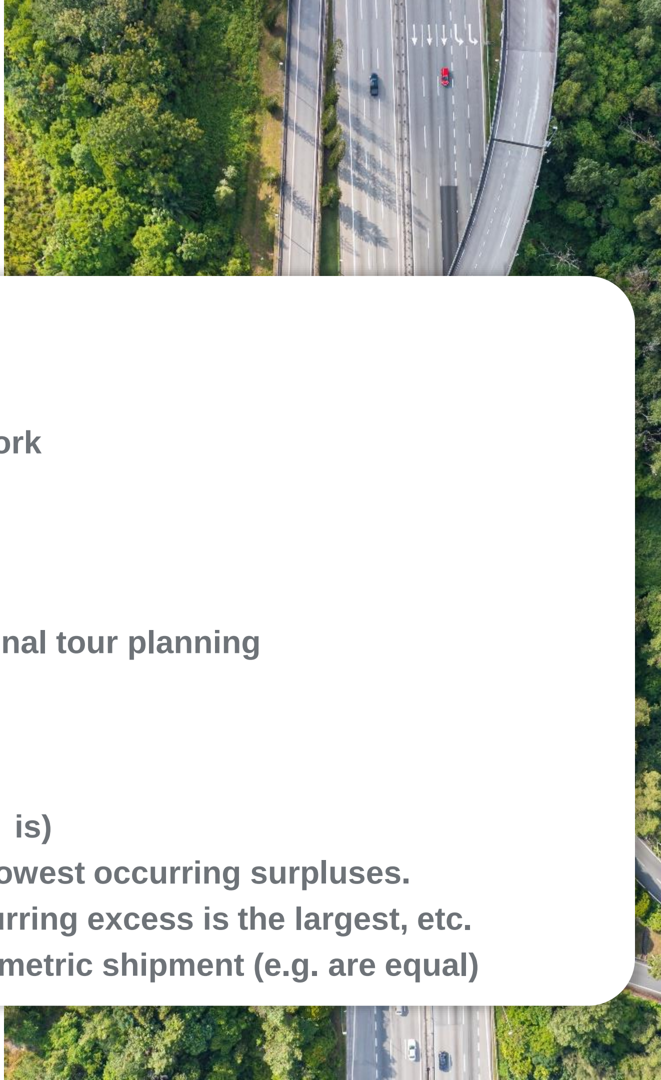


LATEST INNOVATION: FAIR COST + C02 ALLOCATION IN A NETWORK

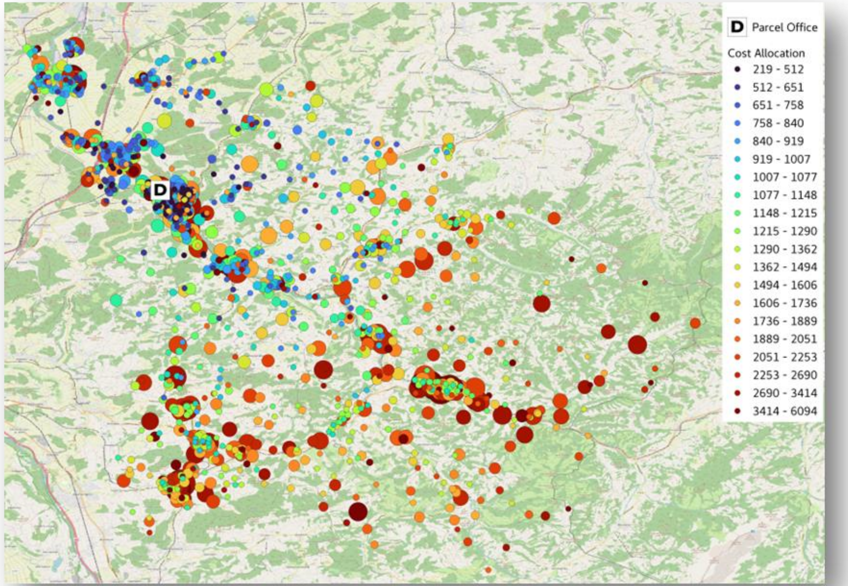
INTRODUCTION:

- Concept of cooperative game theory on fair cost allocation
- Estimates the delivery cost of each individual parcel in a given network

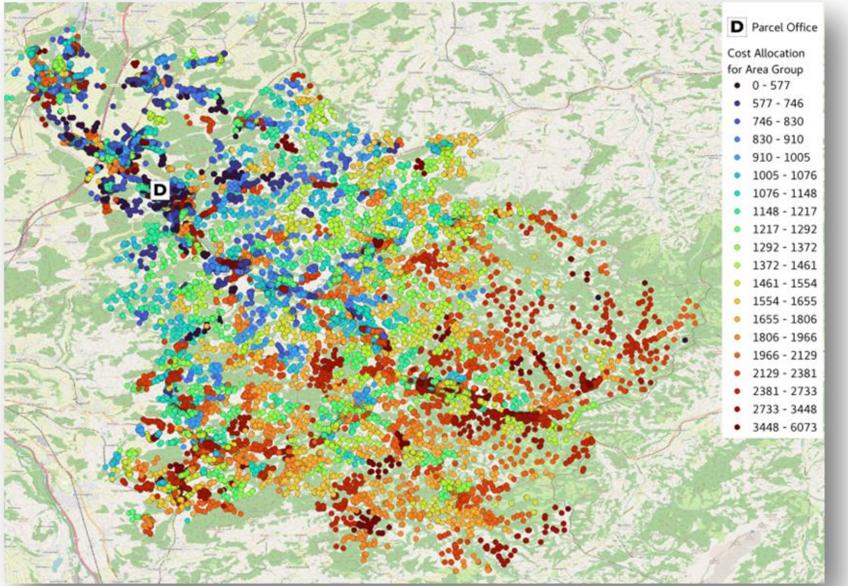
APPLICATION OF HAPPY NUCLEOLUS:

- Assign s costs to $y_s \geq 0$ to each consignment
- The total distributed costs correspond to the costs of optimal fractional tour planning
- For each set of Shipments :
  - $y(S) := \sum_{s \in S} y_s$ is the total allocated cost of S
  - $c(S)$ is the cost of optimal fractional tour planning only for S
  - $e(S, y) := c(S) - y(S)$ is the surplus of S (the larger, the happier S is)
- Among all possible distributions, first consider only those with the lowest occurring surpluses.
- Among these, consider only those for which the second-lowest occurring excess is the largest, etc.
- In the end, the happy nucleolus is thus clearly defined; costs of symmetric shipment (e.g. are equal)

FAIR COST SHARE IN A PARCEL NETWORK SHIPMENT COST ALLOCATION ILLUSTRATED



Shipment Cost Allocation



Area groups Cost Allocation European post

Size of bubbles = visit time

Red = busier area groups

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FUEL/ CHARGE STOP OPTIMIZATION

Greenplan plans refuelling/ recharging stops along a route and optimizes costs.

Criteria considered:

- Locations and brand of gas/ recharging stations
- Prices to refuel/ recharge per station
- Vehicle tank/ battery level before or after route
- Vehicle consumption

Relevant for:

- **Gasoline-driven vehicles**: In long haul, especially when crossing state or country borders where fuel prices differ heavily
- **Electric vehicles**: In short haul with limited reach and potentially long recharging times

GREENPLAN DELIVERS VALUE ACROSS INDUSTRIES – WITH 8-20% EFFICIENCY GAINS

POSTAL, PARCEL, ECOMMERCE, EXPRESS	ROAD FREIGHT, GENERAL CARGO, LOGISTICS	RETAIL, GROCERY, HOME DELIVERY, PHARMACY	FIELD SERVICES
European Express Company: **Reduction of km driven of 9-33%** (dependent on the day)	Global Road Freight Company: **8% better than next competitor** (Global tender of largest TMS and routing companies)	European Retailer with **7.5% cost reduction** (8 countries)	German Facility Mgmt Company: **Average jobs increased from 3 to 7.4 per day/ technician**

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THANK YOU!

epg.com
greenplan.de

PROVEN AND AWARDED

Greenplan has won several industry-leading awards

Deutsche Post DHL | UNI BONN

developed with world-class knowledge

Logistics knowledge and worldclass mathematical brilliance combined

amazon **1st**

Amazon Last Mile Challenge 2021

42% better than second place (MIT)
220 participants from 22 countries

GARTNER

1 of the selected route planning providers in Gartner's Market Guide 2023

for vehicle routing and scheduling (VRS)

United Nations

Best digital "Solution with impact" Germany 2023

awarded at the German World Summit Awards of the United Nations.
Nominated for global 1st prize

BESTES PRODUKT 2023 LogiMAT

1.

Best Product 2023 LogiMAT

in the category
Software, Communication, IT

PostEurop Innovation Award

1st

PostEurop Innovation Award 2020

for overlapping districts

ECONNECTIONS **1**

selected as 1 of 7 scale-ups in 2022 to make 500m online purchases more sustainable

postnl Google Cloud IKEA
Deloitte. bol.com mollie