“Efficient Route Optimisation, the Future of Parcel Delivery”

Dr Fabrice Durier

Outline

I. **Data Science @ Royal Mail**
   - Typical Projects
   - Optimisation Problems

II. **Business Case**
   - Parcels: Growth and Challenges
   - Enhancing Customer satisfaction
   - Route Optimisation Benefits

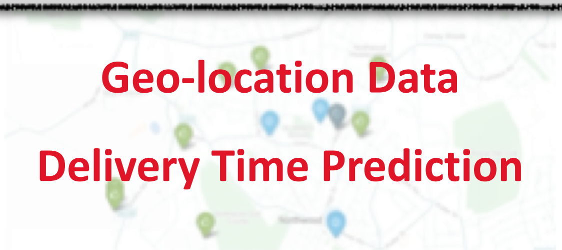
III. **Science & Technology**
   - A known Problem
   - An Agile approach

IV. **Live Demo**

Data Science Projects

Range of Business Cases

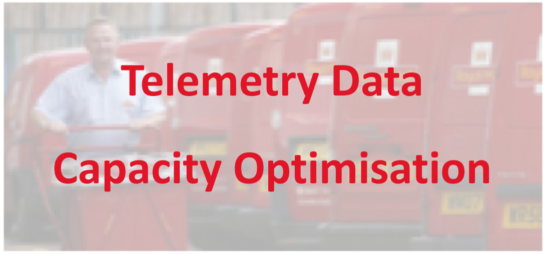
Estimated Delivery Window



Geo-location Data

Delivery Time Prediction

Fleet Management

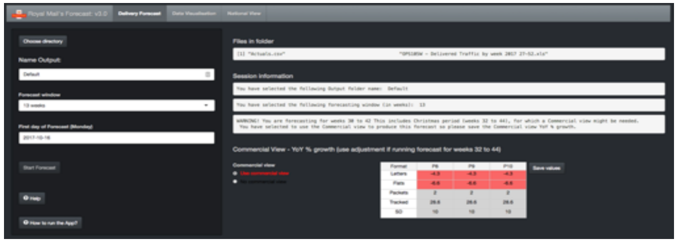


Telemetry Data

Capacity Optimisation

Mail Forecast

Time-Series Analysis



Fraud Detection

NLP

Anomaly Detection

Business Case

Parcel Delivery:
a Growing Market

- ✓ UK-wide parcel traffic of **1.9 billion items**, up by 9%
- ✓ Royal Mail handled **1 billion parcels** in 2017-18, at **<u>52% of Market Share</u>**
- ✓ Delivering to over **29 million addresses** across the country, **6 days a week**.
- ✓ **Growing expectations** for quality: shorter time-window, competitive cost…

Route Optimisation Tools

Enhancing Customer Satisfaction

Royal Mail SameDay

- ✓ Account for local **variation of demand**
- ✓ Provide **shorter time window** predictions

Increasing Operation Efficiencies

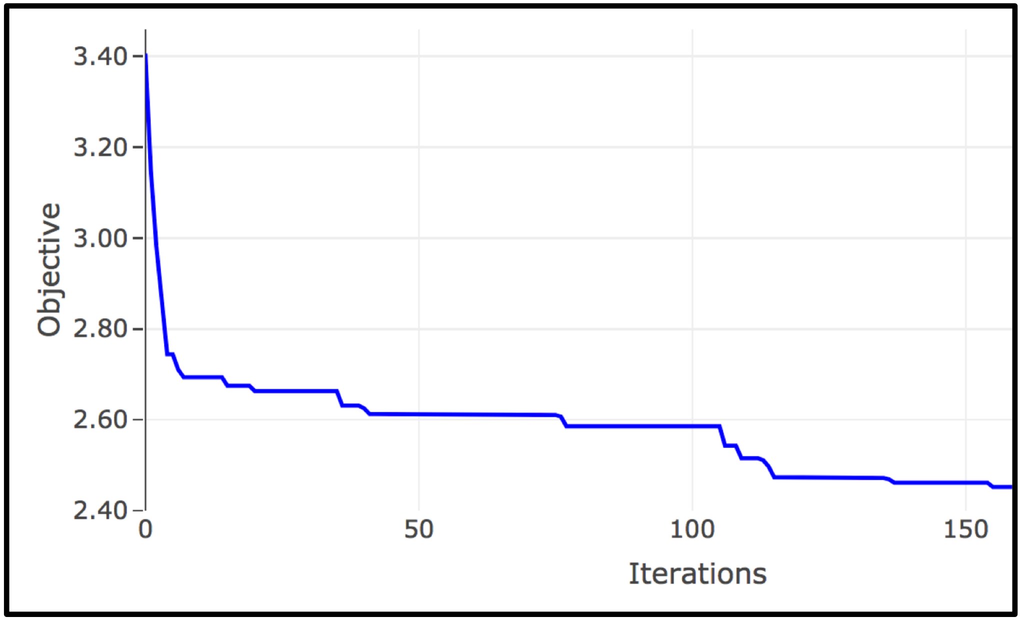
- ✓ Provide detailed **parcel-sorting** and **delivery-ordering** manifests
- ✓ Potential **saving up to 20-30%** on both on time for delivery and fuel costs

Route Optimisation Objective

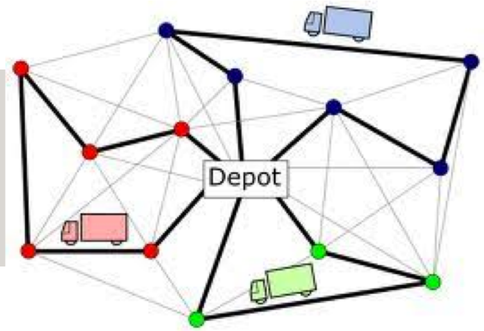
$$\text{Objective} = \frac{\omega_T \times \text{Time} + \omega_D \times \text{Distance}}{\#\ \text{Parcels}}$$

Cost Model

- ✓ **Hourly Rate:** ω_T = £0.25/min
- ✓ **Kilometric Rate:** ω_D = £0.19/km
  - ➢ **Fuel Price:** £1.3/l
  - ➢ **Fuel Consumption:** 7km/l



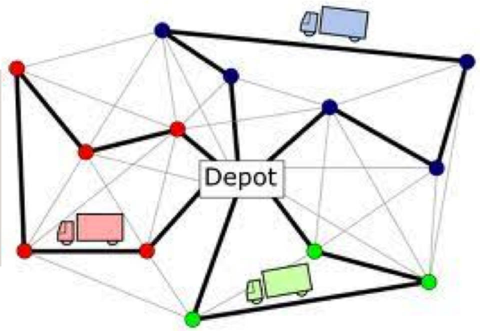
Vehicle Routing Problems



A long History of Academic Research

- ✓ Generalisation of the **Traveling Salesman Problem**
- ✓ **NP-hard** Combinatorial Problem
- ✓ Many approaches to **reach Near-Optimum** solutions
- ✓ **Modern variants** accounting for diversity of constraints

Vehicle Routing Problems



THE TRUCK DISPATCHING PROBLEM*

G. B. DANTZIG[1] AND J. H. RAMSER[2]

1959

SCHEDULING OF VEHICLES FROM A CENTRAL DEPOT TO A NUMBER OF DELIVERY POINTS

G. Clarke*

Cooperative Wholesale Society, Manchester, England

and

J. W. Wright

College of Science and Technology, University of Manchester, England

1962

EXACT ALGORITHMS FOR THE VEHICLE ROUTING PROBLEM, BASED ON SPANNING TREE AND SHORTEST PATH RELAXATIONS

N. CHRISTOFIDES

Imperial College, London SW7 2BX, England

A. MINGOZZI

SOGESTA, Urbino, Italy

P. TOTH

University of Bologna, Bologna, Italy

1980

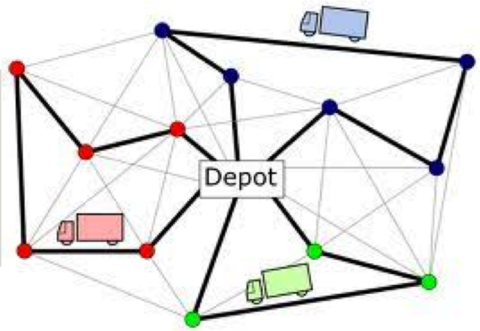
Algorithms

eta-Heuristics

d Algorithms

Learning

Vehicle Routing Problems



THE TRUCK DISPATCHING PROBLEM*

1959

LOCAL SEARCH IN CONSTRAINT PROGRAMMING: EXPERIMENTS WITH TABU SEARCH ON THE VEHICLE ROUTING PROBLEM

Bruno De Backer and Vincent Furnon

1999

gorithms

A general heuristic for vehicle routing problems

David Pisinger *
Stefan Ropke *

25th February 2005

2005

stics

Algorithms

An Effective Implementation of *K*-opt Moves for the Lin-Kernighan TSP Heuristic

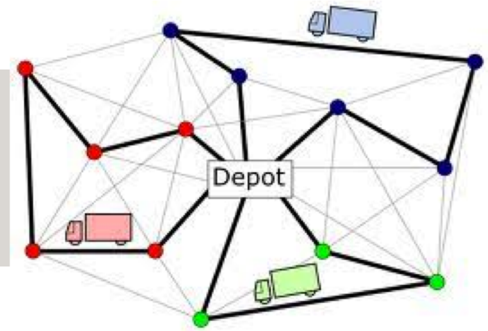
Keld Helsgaun

2007

ng

University of Bologna, Bologna, Italy

Vehicle Routing Problems



Solving Vehicle Routing Problem Using Ant Colony and Genetic Algorithm

Wen Peng and Chang-Yu Zhou

School of Computer Science and Technology, North China Electric Power University, Beijing 102206

2008

A Genetic Algorithm for Solving the Generalized Vehicle Routing Problem

P.C. Pop[1], O. Matei[1], C. Pop Sitar[1], and C. Chira[2]

2010

s

Solving the Vehicle Routing Problem using Genetic Algorithm

Abdul Kadar Muhammad Masum[1]
Dept. of Business Administration
International Islamic University Chittagong

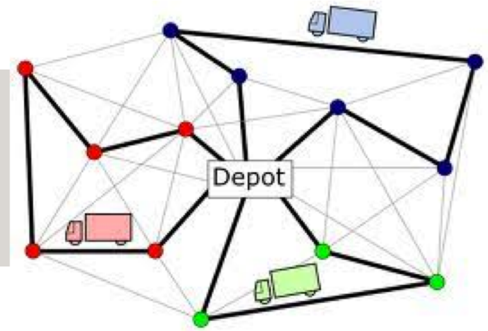
Mohammad Shahjalal[2]
Dept. of Electrical & Electronic Engineering
International Islamic University Chittagong

Md. Faisal Faruque[3]
Dept. of Computer Science & Engineering
University of Information Technology & Sciences

Md. Iqbal Hasan Sarker[4]
Dept. of Computer Science & Engineering
Chittagong University of Engineering & Technology

2011

Vehicle Routing Problems



Solving Vehicle Routing Problem Using Ant Colony

NEURAL COMBINATORIAL OPTIMIZATION WITH REINFORCEMENT LEARNING

Irwan Bello*, Hieu Pham*, Quoc V. Le, Mohammad Norouzi, Samy Bengio
Google Brain

2017

Learning Combinatorial Optimization Algorithms over Graphs

Hanjun Dai*, Elias B. Khalil*, Yuyu Zhang, Bistra Dilkina, Le Song
College of Computing, Georgia Institute of Technology

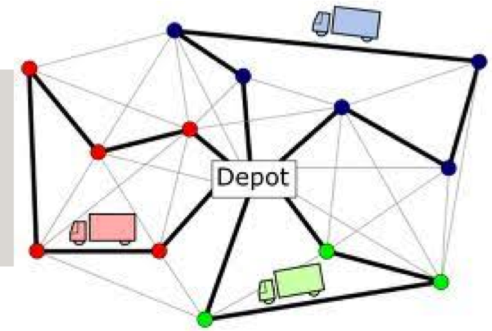
2017

Deep Reinforcement Learning for Solving the Vehicle Routing Problem

Mohammadreza Nazari,[1] Afshin Oroojlooy,[1] Lawrence V. Snyder,[1] Martin Takáč[1]

2018

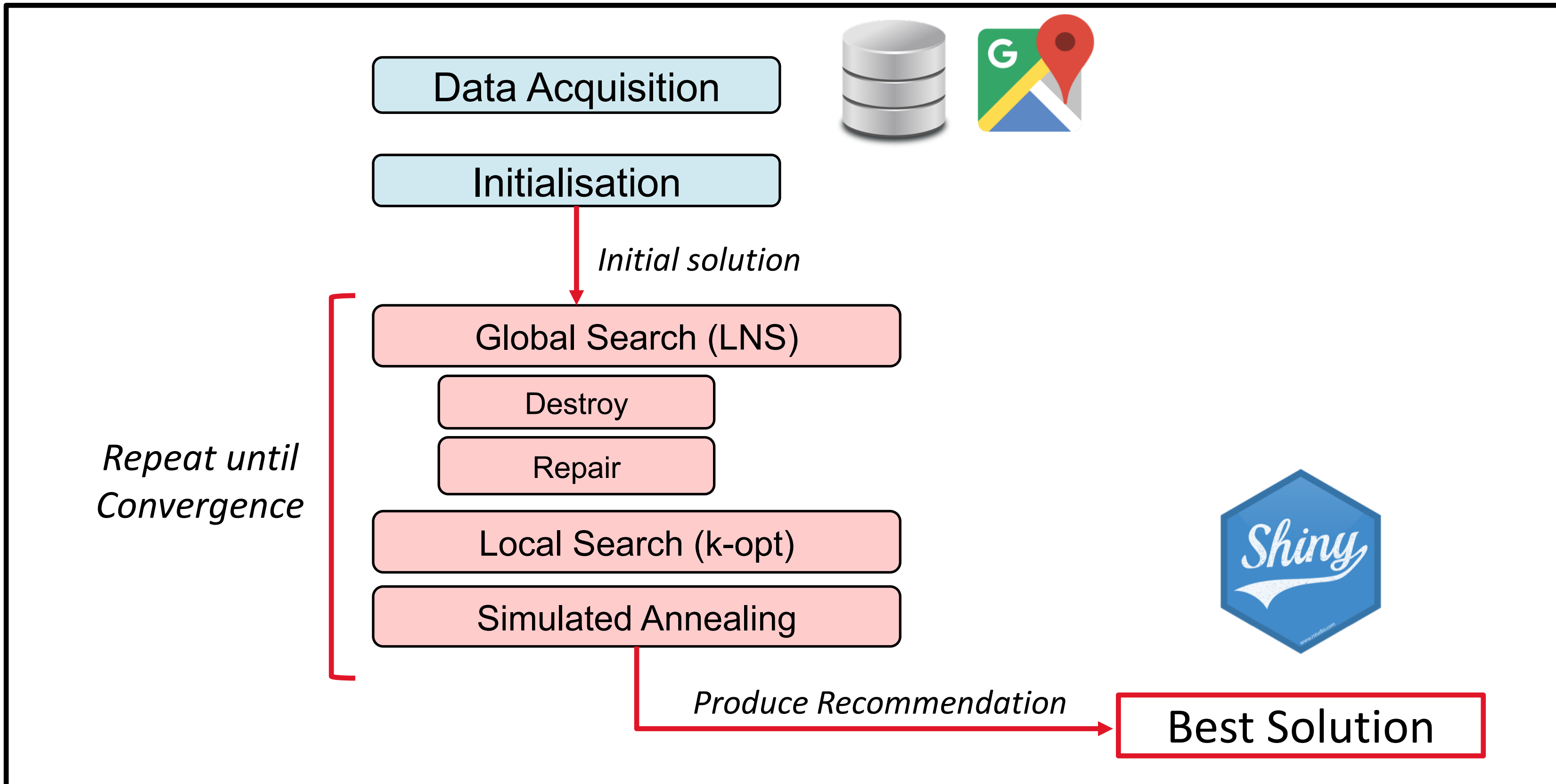
Vehicle Routing Problems



A long History of Academic Research

- ✓ 1960 – 1980: Looking for **Exact Algorithms**
- ✓ 1990 – 2010: Development of **Meta-Heuristics**
- ✓ 2010 – 2015: Introduction of **Bio-inspired Algorithms**
- ✓ 2016+: First attempts at **Reinforcement Learning**

Software Architecture



Data Acquisition

Royal Mail

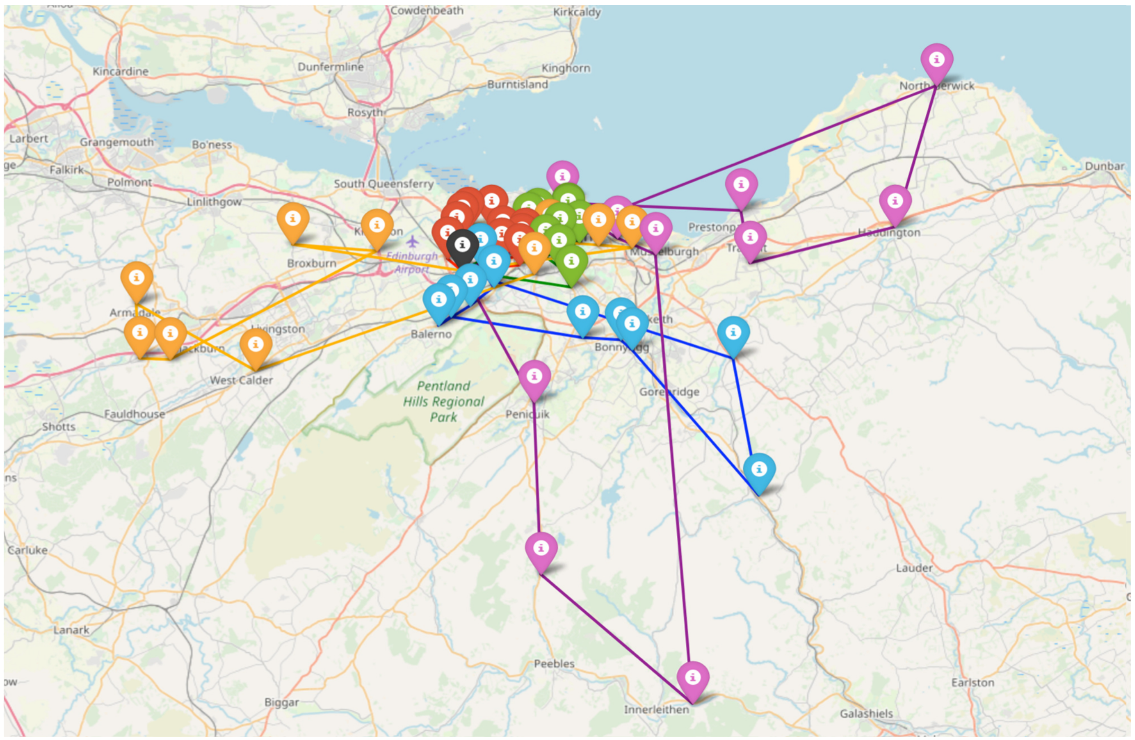
Delivery Service

	barcode	postcode	latitude	longitude
0	MB276583140GB	EH21 6NX	55.939856	-3.0655134
1	PJ867032419GB	EH14 5SW	55.890223	-3.3303288
2	HP492870531GB	EH11 3BD	55.936345	-3.2533391
3	LV978251603GB	EH7 5NW	55.960307	-3.1723718
4	EG047658129GB	EH15 2NW	55.944777	-3.0945816
5	NW850641927GB	EH12 9AW	55.932246	-3.2797301
6	PG537108942GB	EH14 5QE	55.896023	-3.3148871
7	EY839407561GB	EH9 2LP	55.931263	-3.1838993
8	QT318256470GB	EH33 2QT	55.933932	-2.9493796
9	KL236579840GB	EH52 6NG	55.946943	-3.509429

Travel Matrix

	EH12 9PB	EH21 6NX	EH14 5SW	EH11 3BD	EH7 5NW
EH12 9PB	0	[illegible]	14	9	29
EH21 6NX	27	0	28	29	22
EH14 5SW	15	25	0	16	33
EH11 3BD	10	25	16	0	20
EH7 5NW	31	23	36	22	0
EH15 2NW	28	7	30	30	14
EH12 9AW	7	25	15	9	28
EH14 5QE	14	25	3	15	33
EH9 2LP	25	25	26	18	16
EH33 2QT	33	16	35	36	28
EH52 6NG	21	37	27	28	41

Initialisation



Setup

- ✓ **Delivery:** 50 parcels
- ✓ **Max. Vans:** 5
- ✓ **Time Window:** 4h

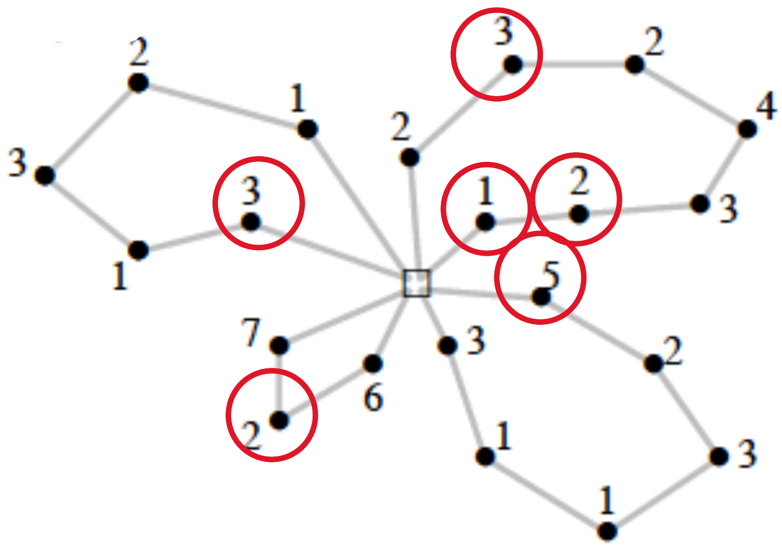
Close-First

- ✓ **Total Time:** 895 min
- ✓ **Total Distance:** 530 km
- ✓ **Cost:** £6.48/pc

Large Neighbourhood Search (LNS)

Destroy and Repair Operators

Repair

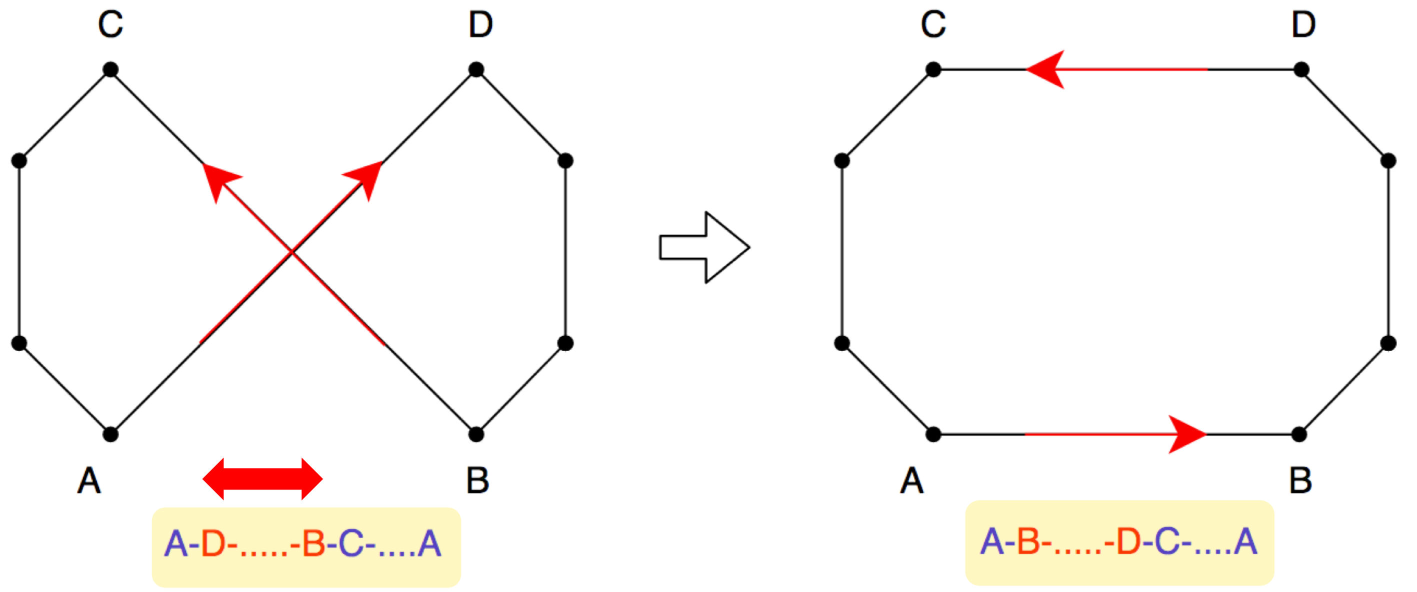


1. **Start from Input Solution**
2. **Destroy a fraction of the Route:** Partial route + Stash of DPs
3. **Repair the full Route:** insert DPs from the stash using a Greedy heuristic

Local Searches (k-Opt)

Swap Operators on a Tour

Mirror Segment

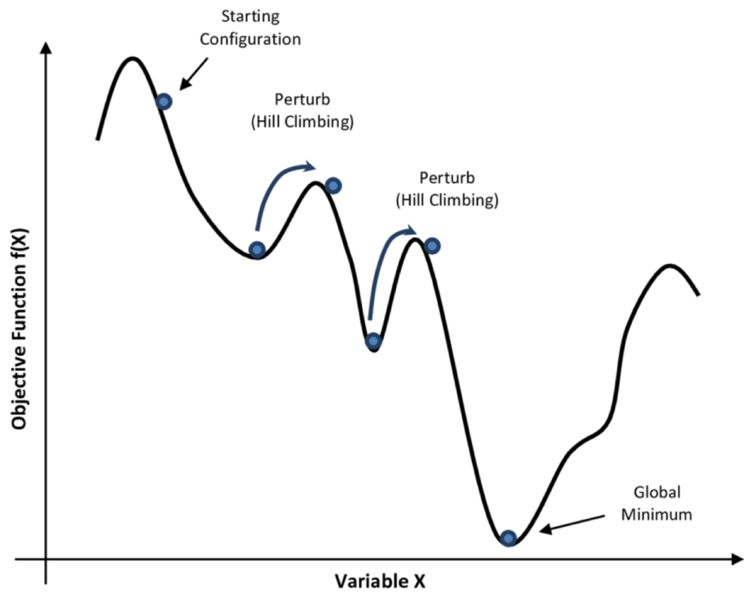


Simulated Annealing (SA)

Avoiding Local Optima

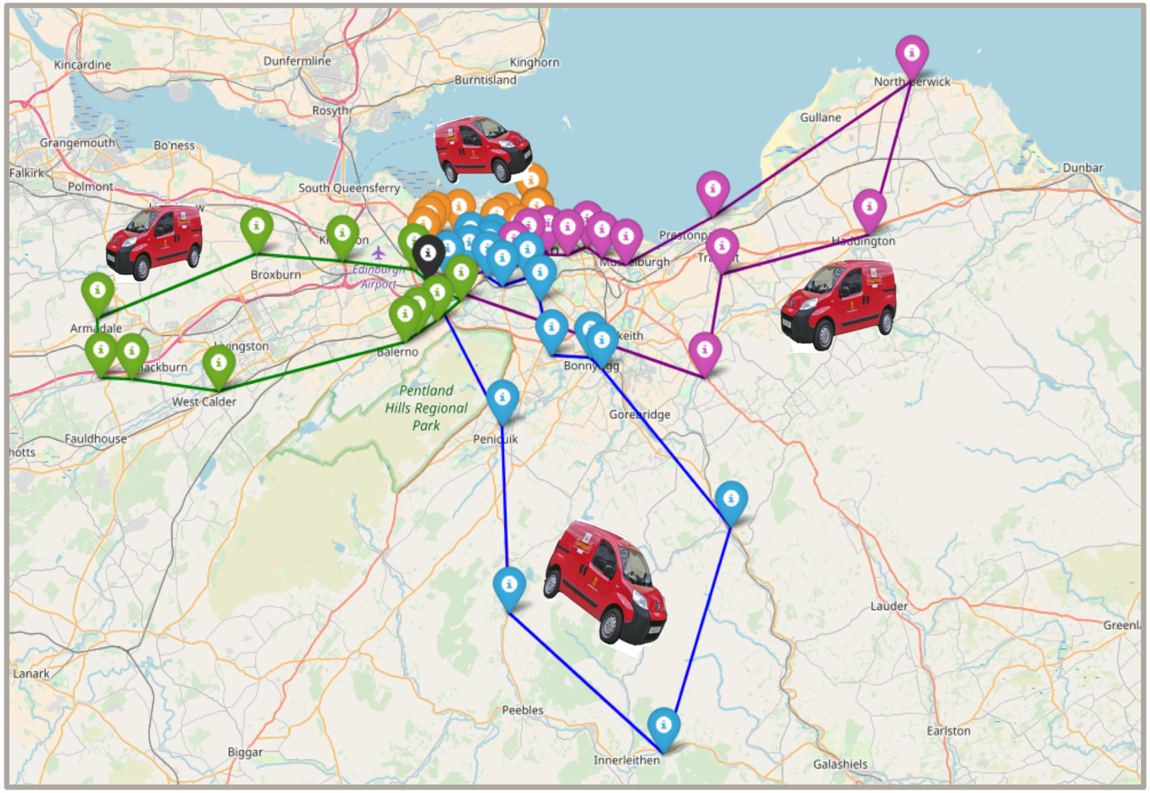
```
apply_simulated_annealing(best, input, output):
    update_temperature()
    if cost(output) < cost(best):
        best = output
        input = output
    elif P(input, output, T) > random(0,1):
        input = output

    return best, input
```

$$\boxed{P(\text{Output}) = e^{\frac{-[C(out)-C(in)]}{T}}}$$



Deliverable

Recommendation



Results

- ✓ **Total Time:** 756 min
- ✓ **Total Distance:** 383 km
- ✓ Cost: £5.24/pc
- ✓ Savings: 20%

Demo