Vehicle Routing in Media Product Distribution

Geir Hasle, Oddvar Kloster, Morten Smedsrud
Department of Applied Mathematics, SINTEF ICT, Oslo, Norway

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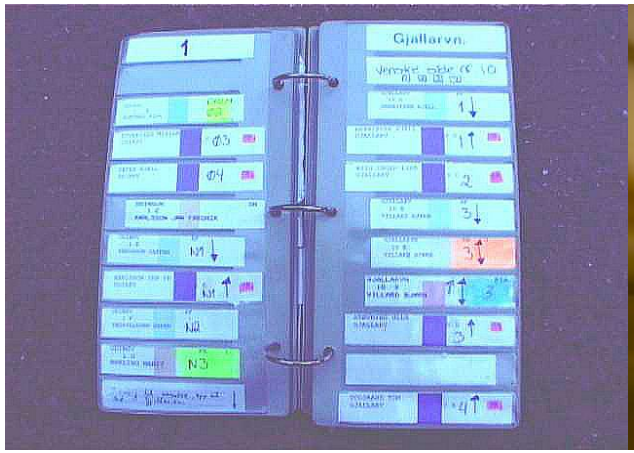
Outline

- Context
- The routing problem
- Results
- Conclusions

Technology for a better society

Newspaper distribution

- Subscription newspapers, home delivery
- Decreasing revenues
- Distribution costs > 40% of total costs
- Route revision very costly and time-consuming
- Reduce costs – Increase revenues



Reduce costs – Increase revenues

- More efficient carrier routes
- More efficient route revision
- Better utilization of distribution system
- Additional products
- Necessitates better communication, flexibility, dynamics

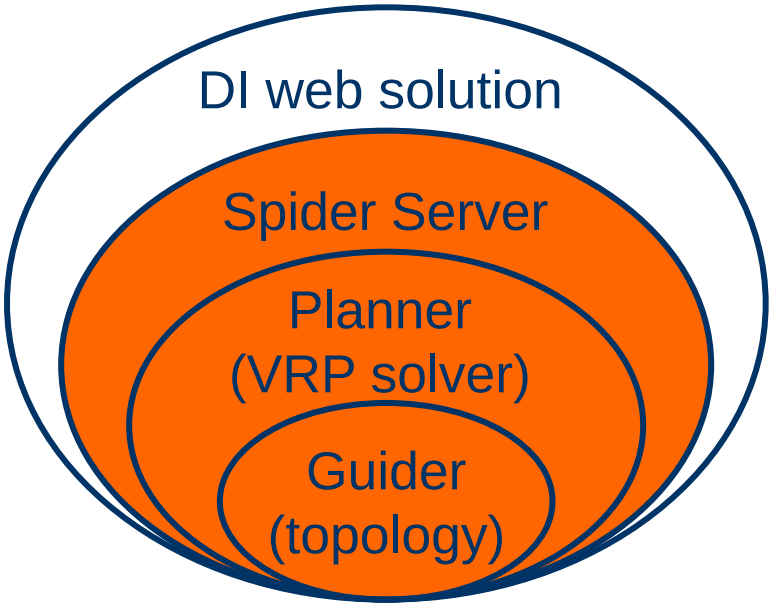
RTD Collaboration since 1999

- Newspapers and their distribution companies
- PDA/Smartphone based delivery book
- Cloud computing based distribution management system
- Establishment of Distribution Innovation AS
  http://www.di.no
- The DI solution

DI solution

- > 80% of newspaper home deliveries in Norway
- > 5.000 carriers download their route every night
- > 1 million deliveries per day
- magazines, books, CDs, flowers, Danish pastry ...
- Finland, Sweden
- Integrated route construction and revision
- Spider VRP solver

System architecture




A: PASSPORT - Session1
File Edit Transfer Options Session Macro Help
=>PF2=TILBAKE,PF5=ENDRE,PF6=SLETT,PF10=BLANKER,PF11=RUTEKONS,PF12=TILLEGGSOPP
A F T E N P O S T E N DISTRIBUSJONSSYSTEM KOSTNADS- OG TIDSBEREGNING
Rute: 21509 Utg.: M Ukedag: 0 Pr. dato: 221105 Betjenes med: G
Ant.l0nn: 265 -Ant. abo og andre, 0 -Ant. pressede Sone: 3 O/U: U
265 + 0 = 265 a kr. 23,76 + 0 Spes.abo a kr. 0,00 = kr 6296,40
Avstandsl0nn: 3,3 km a kr. 52,80 = kr 174,24
Vintertillegg: 5 mnd. a kr. 291,00 :12 = kr 121,25
Sum l0nn *MIN* = kr 6892,17
26,00 % tillegg for feriepenger og arb.avgift = kr 1791,96
Sykkelgodtgj. = kr 0,00
Transp.godtgj. 3,3 km x 26,00 dager x kr.: 0,00 = kr 0,00
Transp.strekn. 0,0 km x 26,00 dager x kr.: 0,00 = kr 0,00
Sum l0nn, sos.kostn. og transp.godtgj. *MIN* = kr 8684,13
Kostnad pr. abonnement pr. mÅned = kr 32,77
1. Klargj0ring f0r start = 15 min
2. Avstand 3,3 km a 12,00 = 39,60 min
3. 0 oppg. uten n0kkel a 0,35 = 0,00 min
4. 53 oppg. med n0kkel a 0,50 = 26,50 min
5. 206 etasjer a 0,35 = 72,10 min
6. 0 lev. i enebolig a 0,15 = 0,00 min
7. 63 lev. i rekkehus a 0,20 = 12,60 min
8. 4 lev. i FK (ute) a 0,15 = 0,60 min
9. 0 fellesleveringer a 0,00 = 0,00 min
Totalt = 166,40 min
Dekn.%: 44,69
Beregnet tid 128,13 min.
Reell tid 128,13 min.
Beregn. dagl0nn 248,87 kr
Reell dagl0nn 260,42 kr
Beregn. timel0nn 116,54 kr
Reell timel0nn 121,95 kr
Timetillegg o/18 ..... kr
Antall husstander 593
TB
A2--Session1 R 4 C 1 3:22p 22/11/05

Problem characteristics (1)

- Two-echelon distribution: from printing works to subscriber
- Focus on “last mile” carrier distribution:
  From drop point to subscriber doorsteps
- Node-based VRP with idiosyncrasies
- Possibly very large number (many thousands) of points
- Aggregation -> CARP on a mixed graph
  (Node Edge Arc Routing Problem (NEARP))
- Mixture of pedestrian routes and car routes
- Car routes open, pedestrian routes closed (in Sweden: the opposite ...)
- Service time often large part of total time
- Retardation and acceleration
- Alternative pickup points
- Requires detailed road topologies and
  accurate travel and service time models
- Meandering (“zigzagging”) not allowed for cars (in Norway, they do not care ...)
- Topography, keys, ...

Problem characteristics (2)

- Main objectives
  - cost, closely related to # routes, duration of routes
  - route balancing (duration)
  - “visual beauty”
    - non-overlapping routes
    - compact routes
- Constraints
  - route duration
  - # routes
  - meandering, topography, keys, ...

Relevant literature

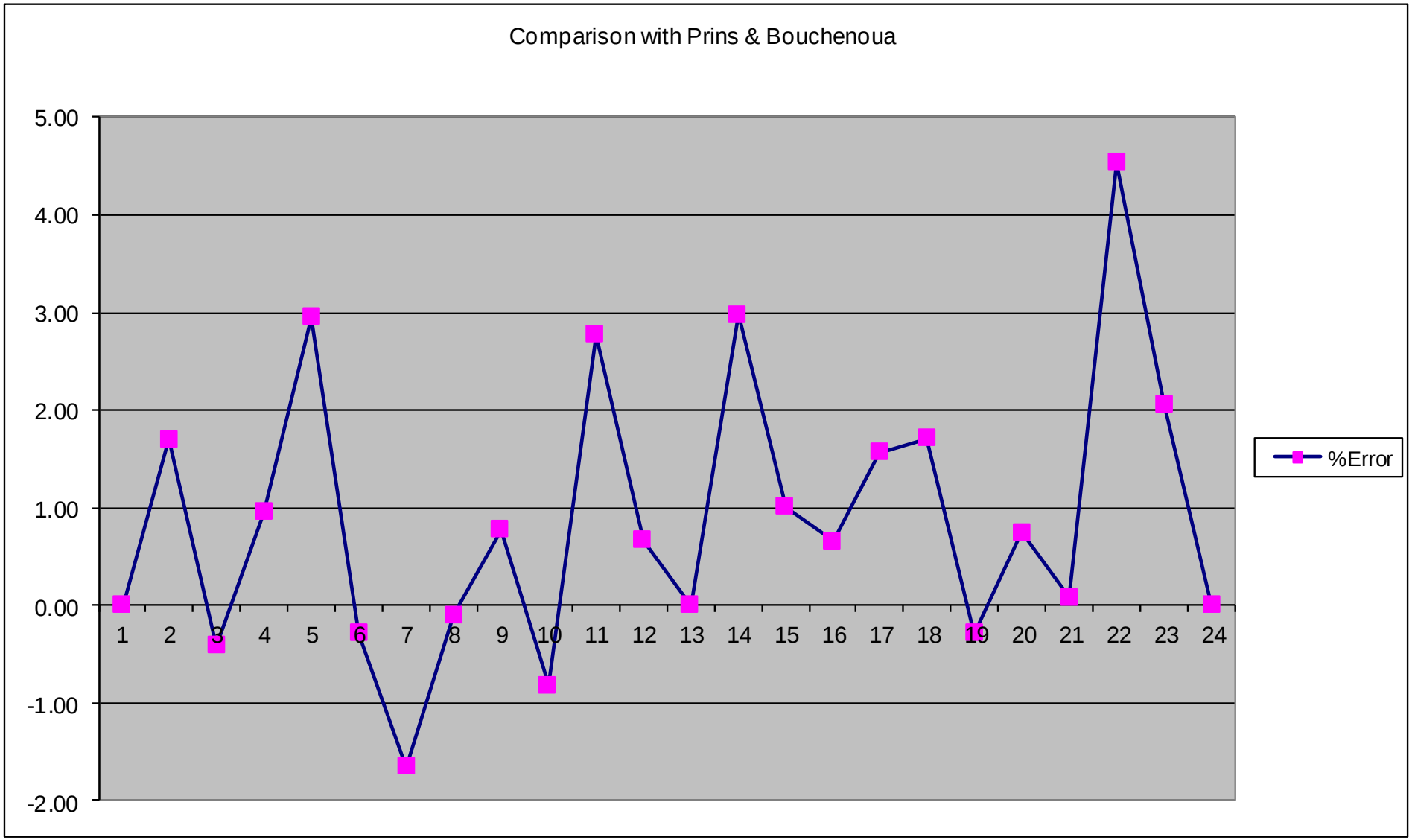
- Multi-objective VRP
  - Jozefowiez et al (2008) Multi-objective VRP. Survey, some 70 references
- Route balancing
  - Tsouros et al. (2006): Routing-Loading Balance Heuristic Algorithms for a Capacitated Vehicle Routing Problem
  - Jozefowiez et al. (2007): An evolutionary algorithm for the vehicle routing problem with route balancing
  - Pasia et al. (2007): Solving a Bi-objective Vehicle Routing Problem by Pareto-Ant Colony Optimization
  - Borgulya (2008): An algorithm for the capacitated vehicle routing problem with route balancing
- Visual beauty
  - Lu & Dessouky (2005): A new insertion-based construction heuristic for solving the pickup and delivery problem with time windows
  - Hao & Miller-Hooks (2006): Interactive Heuristic for Practical Vehicle Routing Problem with Solution Shape Constraints
  - Matis (2008) DSS for the street routing problem
- Route balancing and visual beauty
  - Kim et al. (2005): Waste collection vehicle routing problem with time windows
  - He et al. (2009): Balanced K-means Algorithm for Partitioning Areas in Large-Scale Vehicle Routing Problem

“Standard” Spider approach

- Aggregation of demand based on road topology
  - Nodes, edges, arcs
- Duration-constrained (open) NEARP
- Route balance and visual beauty soft constraints
- Weighted sum of duration objective and penalties
- Spider standard algorithmic approach
  - Extended Savings construction
  - Iterated local search
    - VNS with repertoire of 15 operators
    - Ruin and recreate for diversification
  - Route reduction phases with special objective (if relevant)
  - Good results on C/DVRP, VRPTW, PDPTW, CARP, industry cases

NEARP benchmark

- NEARP Prins & Bouchenoua CBMix (23 instances)
- No lower bounds, no proven optima, only one competitor
- UB error 0.94%
- 8 best known solutions (6 new)


Comparison with Prins & Bouchenoua
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
%Error

Industrial instances

- Improvements in total duration of 2%-25%
- Duration balance and visual beauty typically ok
- In some cases
  - routes not well balanced
  - routes not visually appealing
- Observations
  - tuning of weights for soft constraints in a scalarized objective difficult (no surprise ...)
  - alternative penalty definitions did not solve the problem
  - some (inter tour) LS neighborhood operators tend to destroy secondary objectives / soft constraints

Alternative approaches

- Real multi-criterion formulation
  - user interaction
  - response time
- Targeted heuristics

Addressing route balance

- Minimize difference in route length
  - Jozefowiez et al. 2007: Multi-objective evolutionary algorithm
  - Pasia et al. 2007: Pareto ant colony optimization
  - Borgulya 2008: Multi-objective evolutionary algorithm
- Minimize difference in workload
  - **Kim et al. 2005: Capacitated clustering, SA**
  - Tsouros et al. 2006: Greedy heuristics

Addressing “visual beauty”

- Two major aspects
  - Route compactness
  - Overlap/crossings between routes
- Different approaches
  - **Kim et al. 2005: Capacitated clustering, SA**
  - Lu & Dessouky 2005: Crossing length percentage, insertion heuristics
  - Hao & Miller-Hooks 2006: Two measures, heuristics, user interaction
    - clustering distance
    - # “unhappy” customers (not assigned to route with closest centroid)

New approach (1)

- Main idea: create a solution with the desired structure
  - duration balance
  - visually appealing (compactness, non-overlapping)
- Simple
- Fast
- New construction heuristic: “Clusterer”

- Continuation with “standard” machinery

New approach (2)

- Estimate # routes needed (minimum could be given by user)
- Solve balanced capacitated (duration) clustering problem
  - Modified *k*-means algorithm, adaptive cluster weights
  - Fast TSP solver to find duration of each cluster (2-opt, relocate)
- restart with 1 route less if # routes to be minimized
- After-burner: Intra-tour optimization (3-opt)

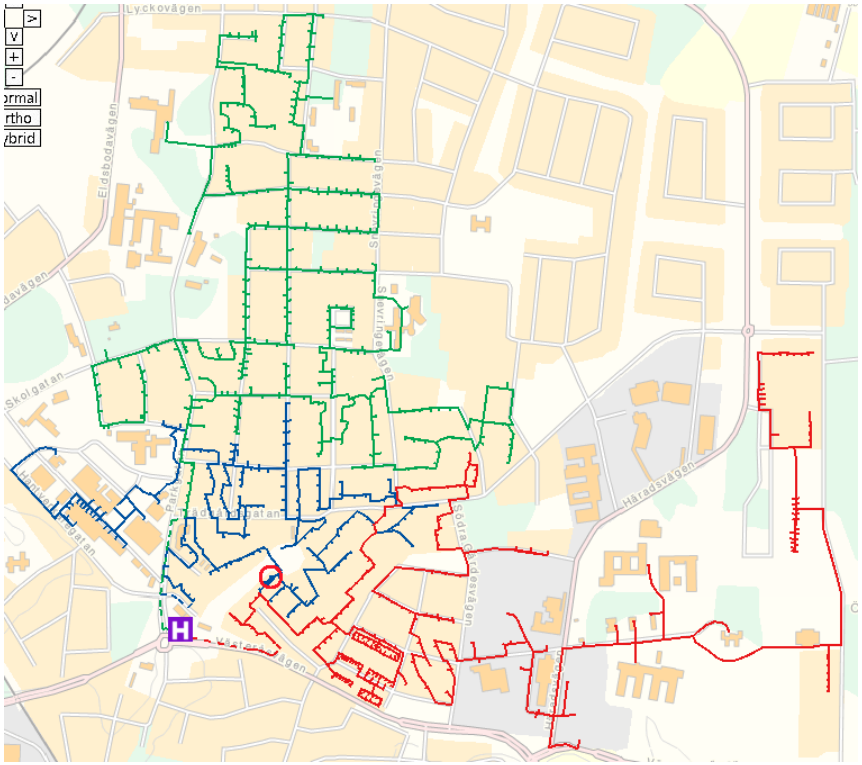
- Possibly: Further iterative improvement
  - constraints on deterioration of balance and visual beauty

Experimental results

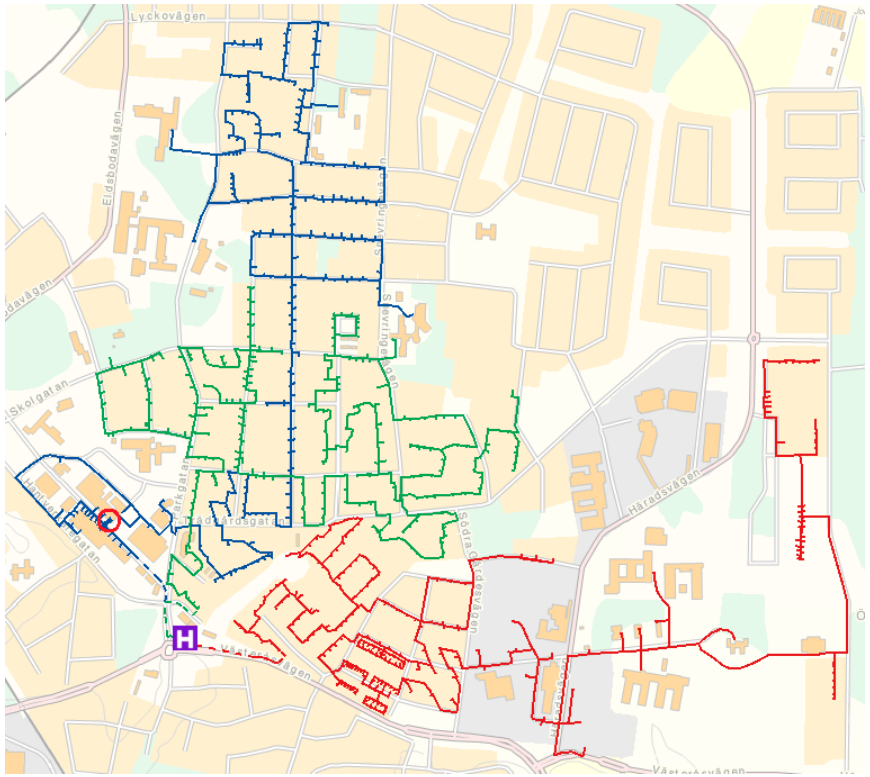
- Preliminary investigation on industrial, “bad” cases
- Results much better with new approach
  - only construction and (intra-tour) 3-opt
  - good balance
  - visually appealing
  - similar cost (total duration)
  - faster
- Still a few bad cases

Even more beautiful with our new clustering method

After



Before



Further work

- Stabilize Clusterer, test industrial cases
- Effects of further iterative improvement

- Benchmarks from the literature
- Generalize clustering distance, time
- Cost of soft constraints

Conclusions

- Construction / revision of home delivery routes very complex
  - large size
  - multiple criteria
  - idiosyncratic constraints
- Route balance and “visual beauty” very important
- Spider standard approach typically gives good results
- Bad results on some industrial instances (balance, “beauty”)
- New approach based on balanced capacitated clustering constructor is promising
- More experimental studies and new benchmarks needed
  - comparison with literature on VRPRB
  - standard definition(s) of VRP with visual beauty, benchmarks

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Parallel and heterogeneous computing

- Need for parallel algorithms
  - speed vs. quality
  - instance robustness
  - larger size problems
  - multi-criterion optimization
- Different levels of granularity
  - solution
  - iteration
  - algorithm
  - cooperating solvers
- Modern commodity computers
  - clock frequency reduced due to technological limits
  - Moore's law still valid: multiple cores
  - Graphics Processing Units: massive data parallelism

Cloud computing

- Central services, accessibility through web
- Less investment in hardware and software
- Central updates
- Possible security issues

- Automated routing services
  - demand unknown
  - need for elastic computational resources
  - parallel computation