Aspects of routing problems in media product distribution

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Outline

- Newspaper and media product distribution
- RTD with Distribution Innovation AS and customers
- Cloud computing services for route construction and revision
- The routing problem
- Two solution approaches
- Results
- Conclusions

Technology for a better society

SINTEF

Our vision
Technology for a better society

Our role
We create value through research and innovation, and offer concrete solutions for sustainable development. We bridge the gap between academia and industry (“use-inspired” research).

Our distinctive character
The SINTEF Group is a multi-disciplinary institution with international top level expertise in several different areas of research.
We cooperate closely with universities, the authorities and industry, and combine research and business culture.

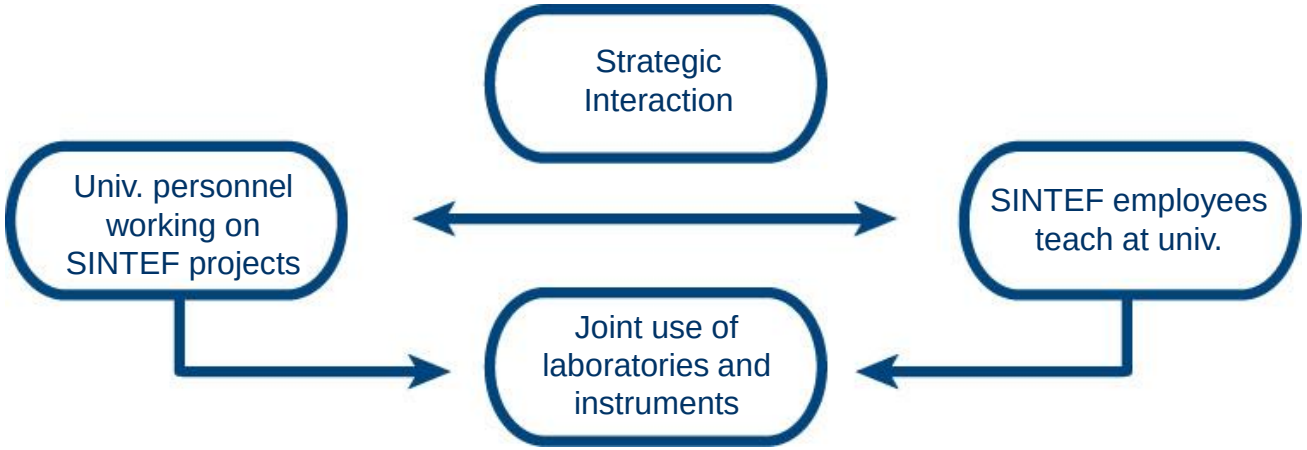
Our goal
SINTEF aims to become the most acknowledged
Research and Technology Organisation in Europe.

Our basic values
Honesty, Generosity, Courage and Loyalty

Our partners

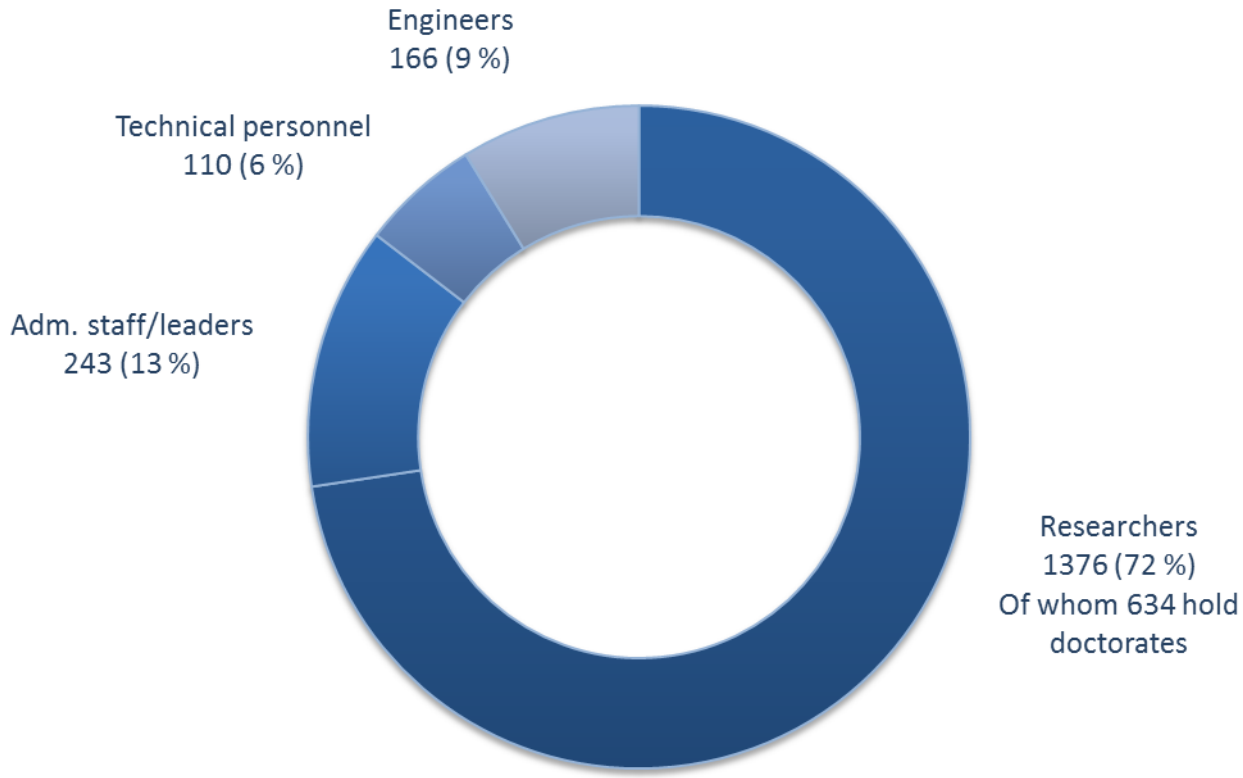
- The Norwegian University of Science and Technology, NTNU
  NTNU is a centre for technological education and research in Norway, with a solid foundation in the natural sciences.

- The University of Oslo, UiO
  The University of Oslo is Norway's largest and oldest institution of higher education.



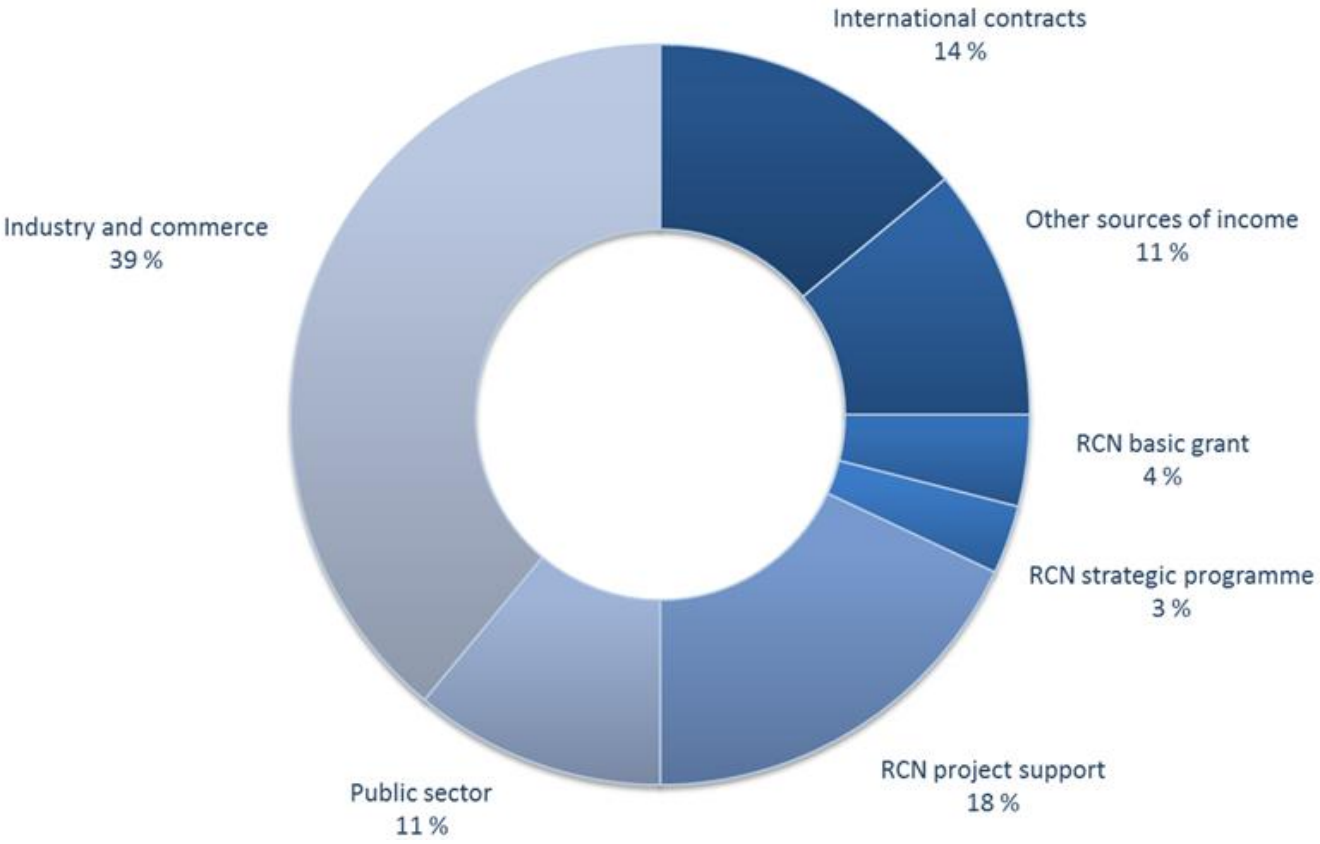
University / SINTEF Collaboration in RTD

Occupational groups in SINTEF



SINTEF has 2123 employees from 68 countries

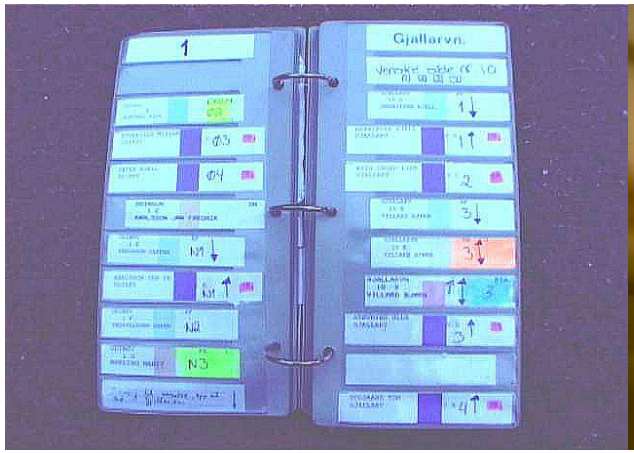
Gross operating revenue



The SINTEF Group turnover in 2009: NOK 2.8 billion (~ 350 million Euros

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

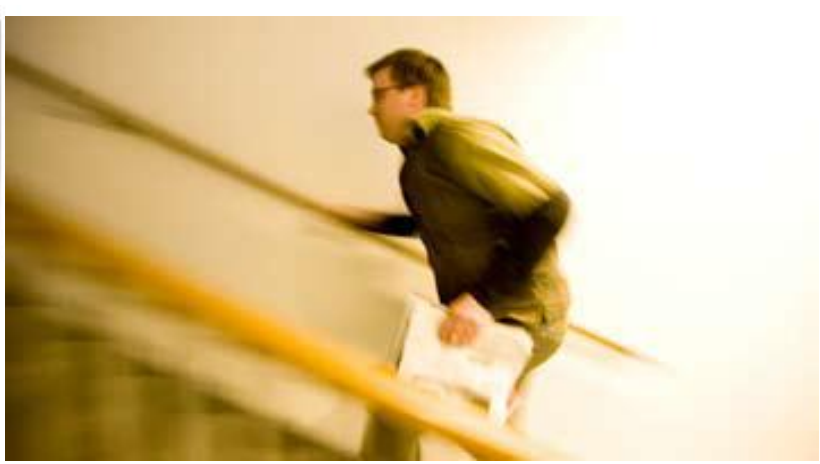


Reduce costs – Increase revenues

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

RTD Collaboration since 1999

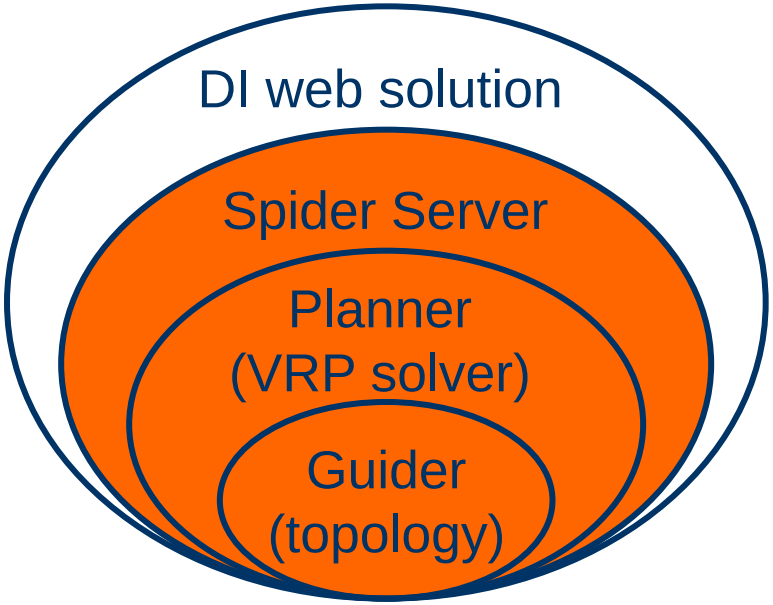
- Newspapers and their distribution companies
- PDA/Smartphone based delivery book
- Cloud computing based distribution management system
- Establishment of Distribution Innovation AS
  http://www.di.no



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, ...
- Finland, Sweden
- Integrated route construction and revision
- Spider VRP solver

System architecture

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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
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Sum l0nn, sos.kostn. og transp.godtgj. *MIN* = kr 8684,13
Kostnad pr. abonnement pr. mÅned = kr 32,77
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2. Avstand 3,3 km a 12,00 = 39,60 min
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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
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Dekn.%: 44,69
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Problem characteristics (1)

- Two-echelon distribution: from printing works to subscriber
- Focus on “last mile” carrier distribution:
  From drop point to subscriber doorsteps
- Vehicle Routing Problem with idiosyncrasies
- Possibly very large number (thousands) of points
- Aggregation, Node Edge Arc Routing Problem (NEARP)
- Mixture of pedestrian routes and car routes
- Car routes open, pedestrian routes closed
- Service time often large part of total time
- Requires detailed road topologies and
  accurate travel and service time models
- 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
  - topography, keys, ...

Relevant literature

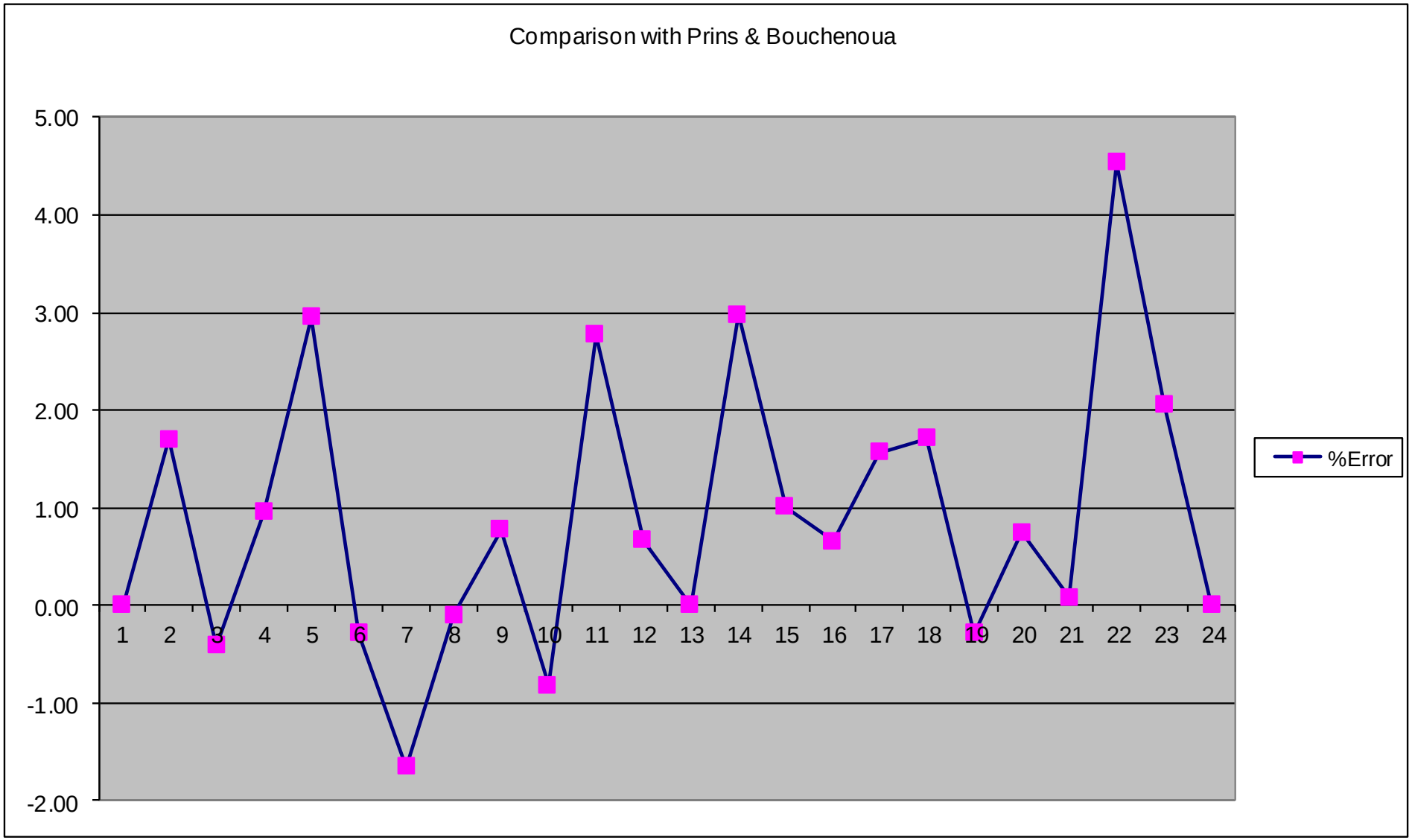
- Route balancing
  - Tsouros et al. (2006): Routing-Loading Balance Heuristic Algorithms for a Capacitated Vehicle Routing Problem
  - Jozefowiez et al. (2007): An evolutionary algorithm for the vehicle routing problem with route balancing
  - Pasia et al. (2007): Solving a Bi-objective Vehicle Routing 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
- 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” 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
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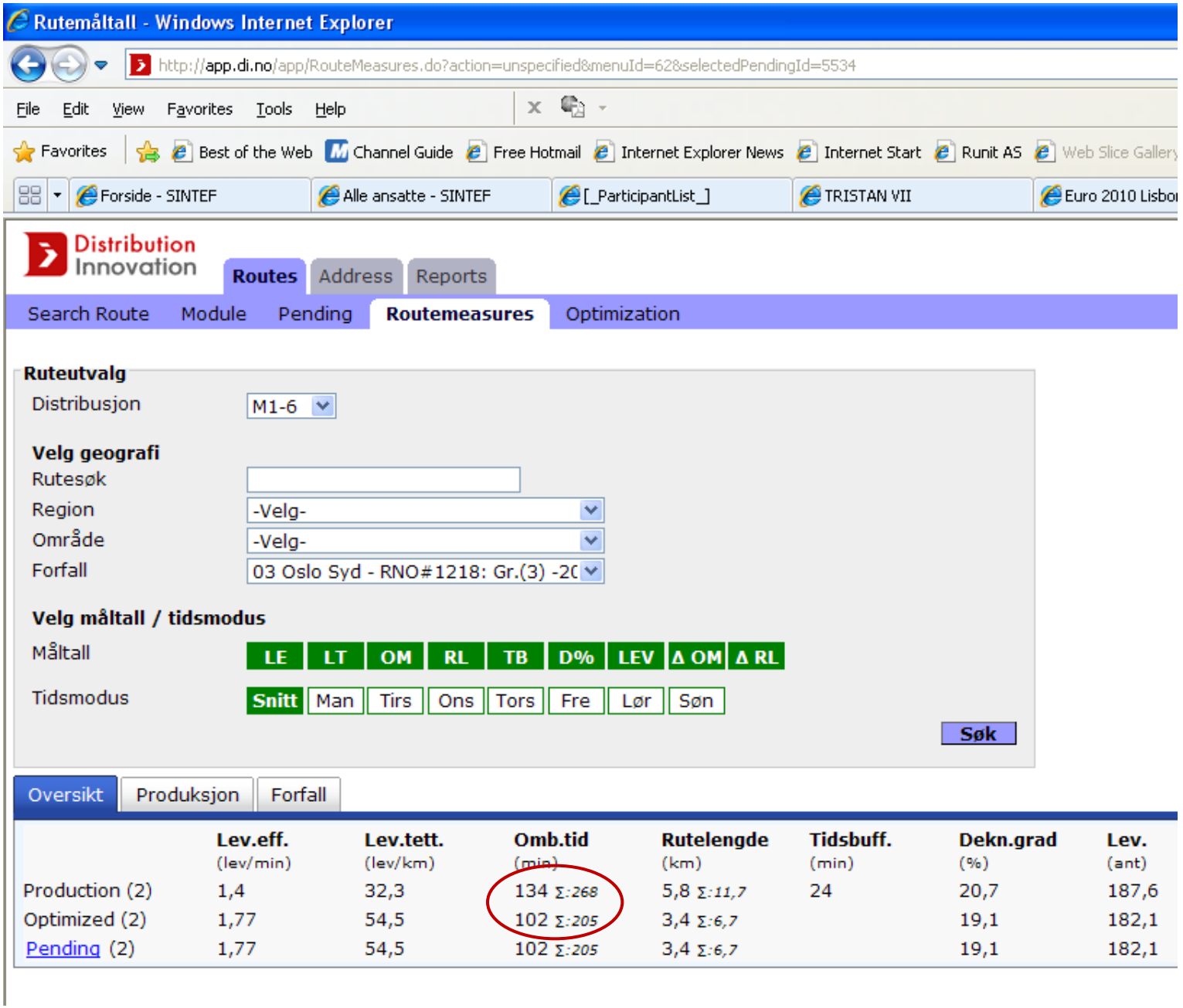
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Ruteutvalg
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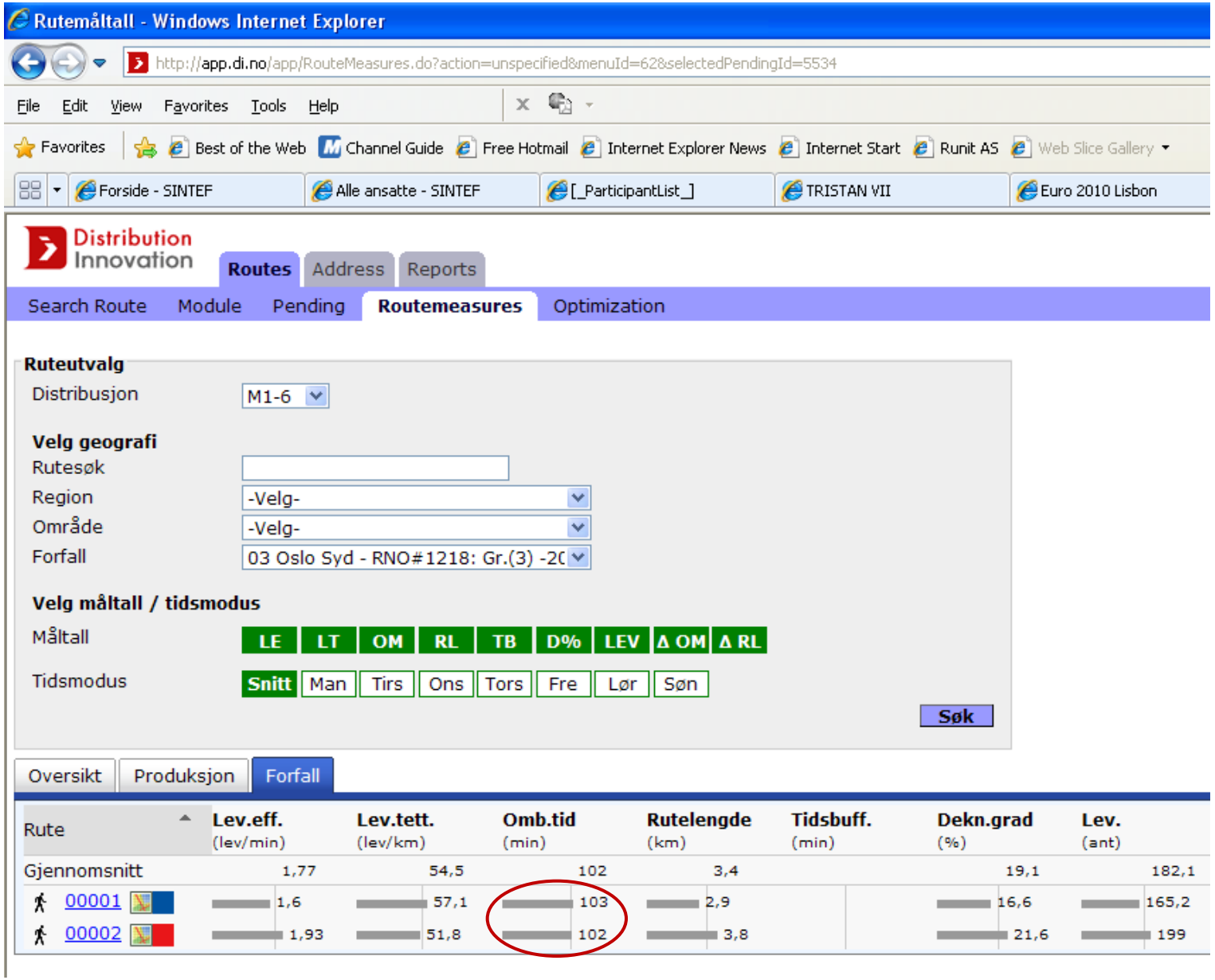
Optimized (2) 1,77 54,5 102 Σ:205 3,4 Σ:6,7 19,1 182,1
Pending (2) 1,77 54,5 102 Σ:205 3,4 Σ:6,7 19,1 182,1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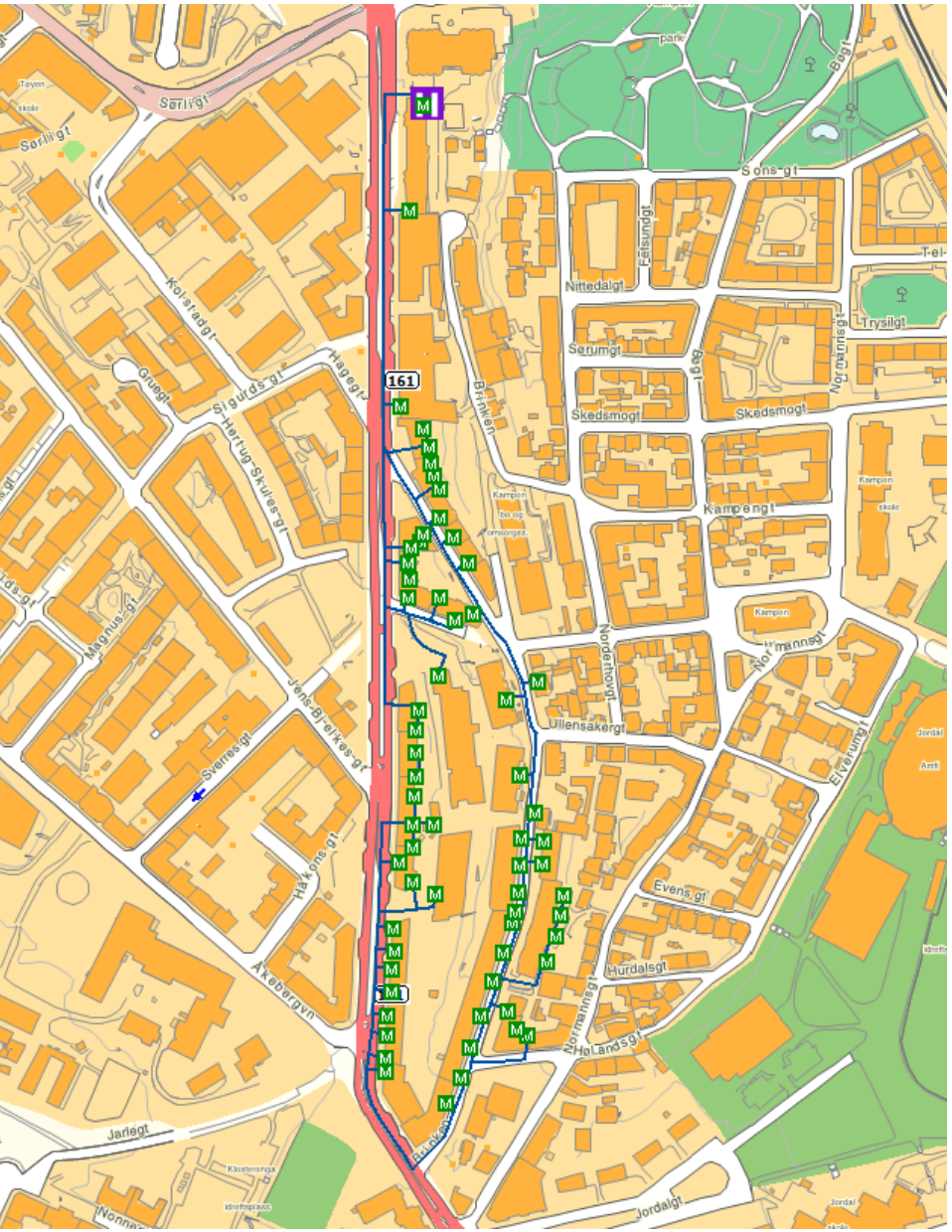
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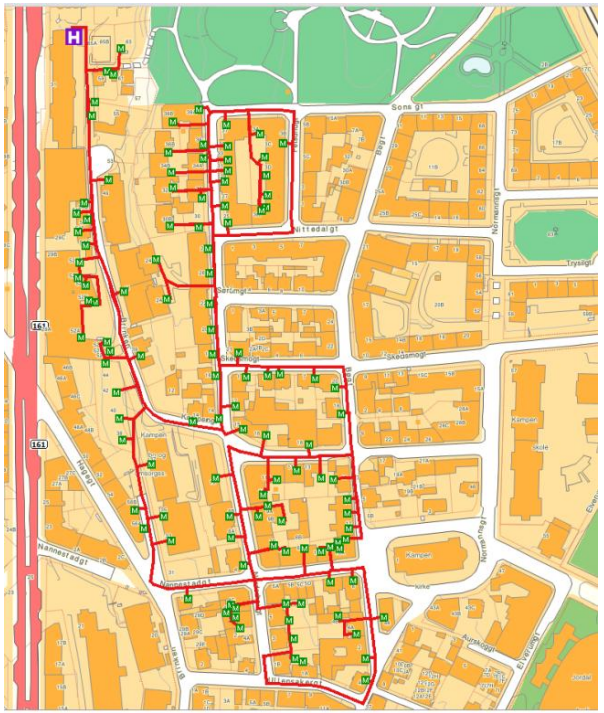
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Industrial instances

- Improvements in total duration of 2%-25%
- Duration balance and visual attractiveness typically ok
- In some cases
  - routes not well balanced
  - routes not visually appealing
- Observations
  - tuning of weights for soft constraints difficult
  - alternative penalty definitions did not solve the problem
  - some (inter tour) neighborhood operators tend to destroy secondary objectives / soft constraints

New approach (1)

- Main idea: create a solution with the desired structure
  - duration balance
  - visually appealing (compactness, non-overlapping)
- Simplicity
- Speed
- 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
- Further iterative improvement

Experimental results

- Only preliminary investigation on industrial, “bad” cases
- Results very promising
  - good balance
  - visually appealing
  - similar cost (total duration)
  - faster

Parallel / heterogeneous computing

- Need for parallel algorithms
  - speed vs. quality
  - instance robustness
  - larger size problems
- 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

Conclusions

- Newspapers have economical challenges
- New technology enables lower costs and higher revenues
- Construction / revision of home delivery routes very complex
  - large size
  - multiple criteria
  - idiosyncratic constraints
- Spider standard approach typically gives good results
- Bad results on some industrial instances (balance, “beauty”)
- New approach based on balanced clustering is promising
- More experimental studies and new benchmarks needed
  - comparison with literature on VRPRB
  - standard definition(s) of VRP with visual beauty, benchmarks
- Future directions:
  - Decomposition and aggregation methods
  - Parallel and cooperative search

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