The Node Edge Arc Routing Problem - applications and heuristics

Geir Hasle, Truls Flatberg, Oddvar Kloster, Eivind J. Nilssen, Morten Smedsrud
Department of Applied Mathematics, SINTEF ICT, Oslo, Norway

EURO XXIII

23rd European Conference on Operational Research

Bonn, Germany, July 5-8, 2009

Outline

- Challenges for Routing Technology
- Heuristic Strategies for Large-Scale VRPs
- Newspaper and media product distribution
- The Node Edge Arc Routing Problem (NEARP)
- Conclusions

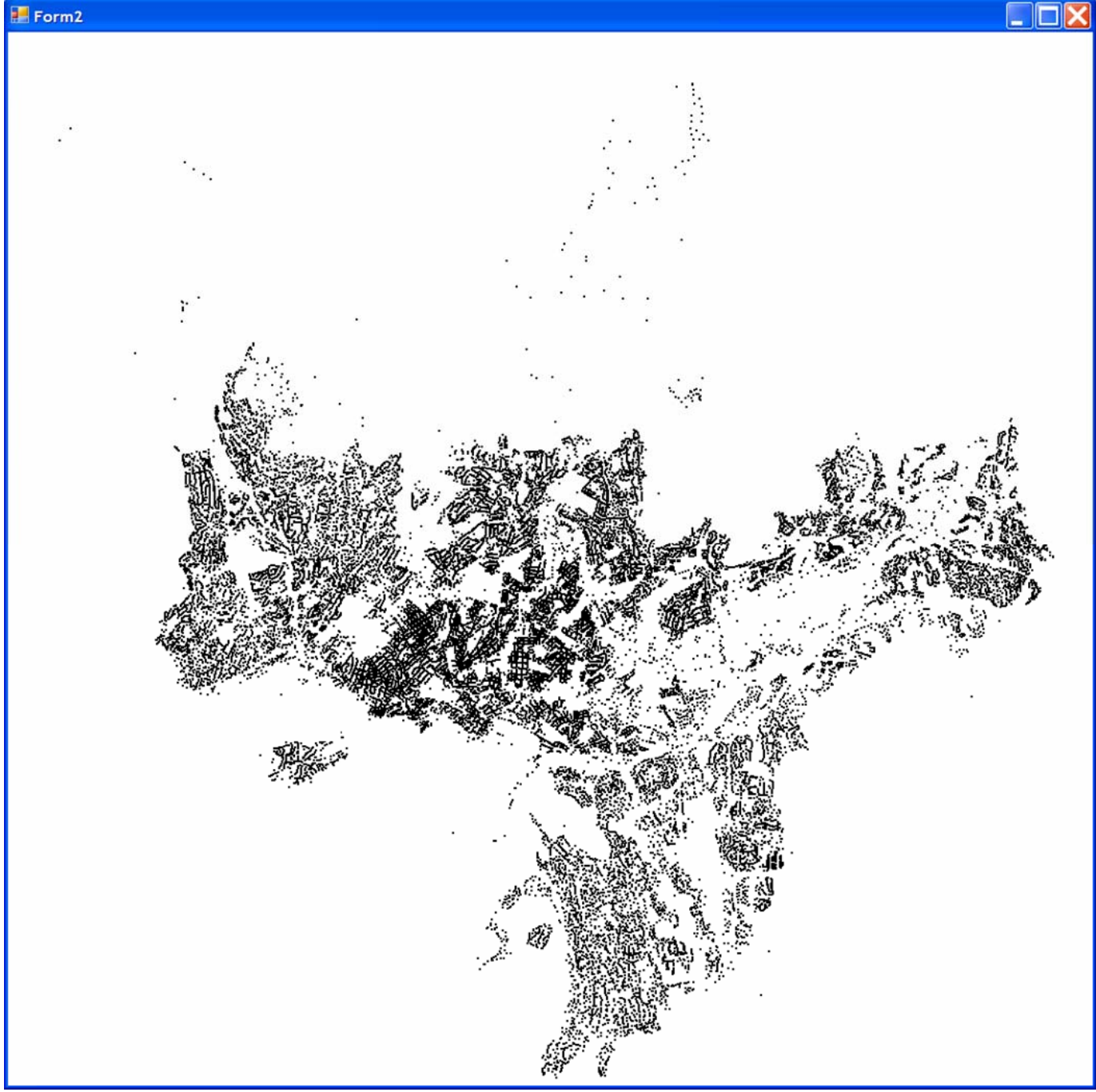
Messages

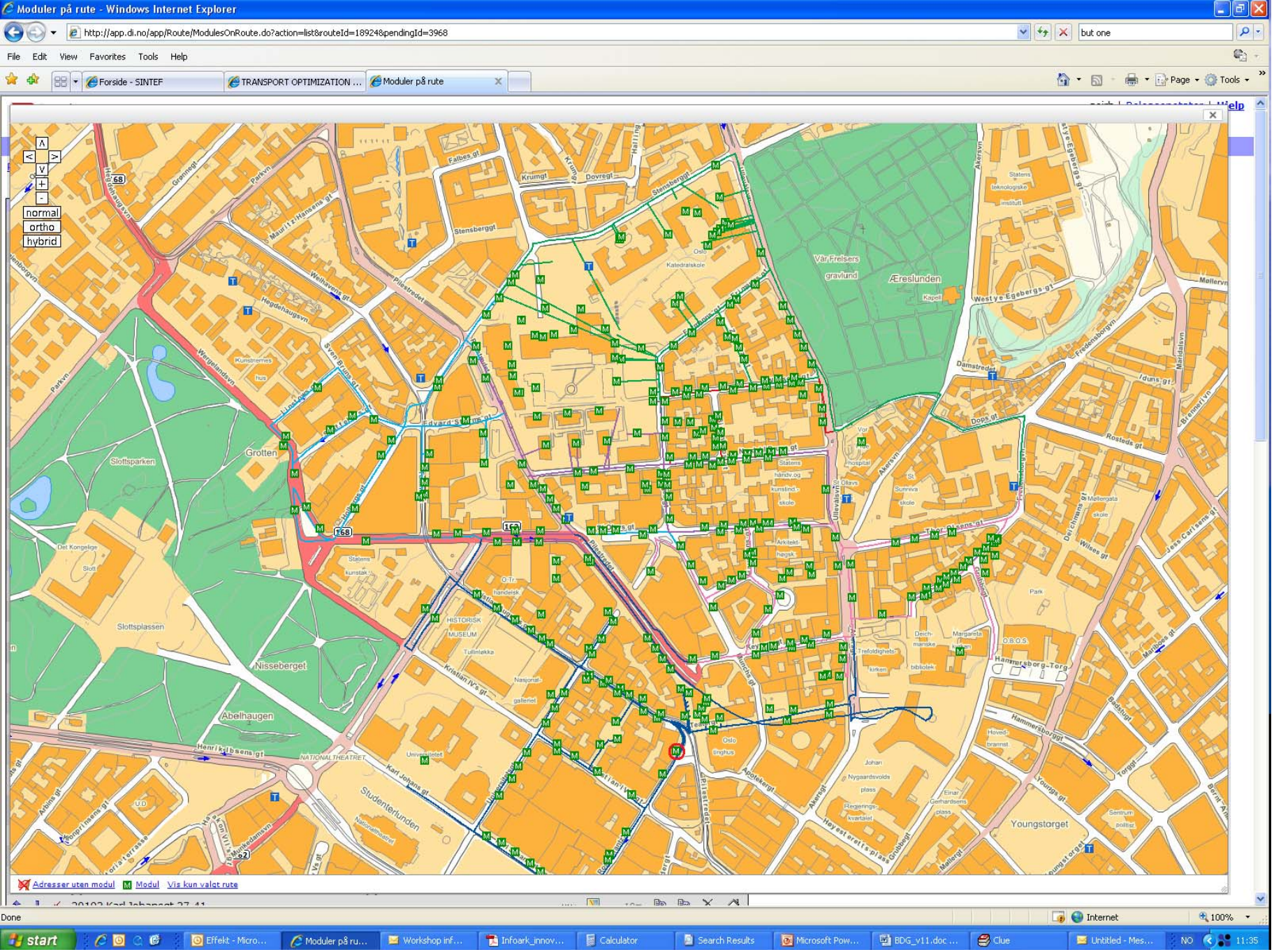
- Many challenges for routing technology
- Computational complexity is one of them
- Several strategies for containing complexity
- The Node Edge Arc Routing Problem (NEARP, or the Multi-vehicle Capacitated General Routing Problem on a Mixed Graph) is scientifically interesting and highly relevant to industry

Challenges for Routing Technology

- Industrial awareness
- Information accessibility
- User interfaces
- Model adequacy and flexibility
- Software engineering
- Robustness
- Solution quality for large-size and complex problems
- Computational complexity

- Newspaper distribution
- City of Oslo
- 500k inhabitants
- 200k households
- 35k modules

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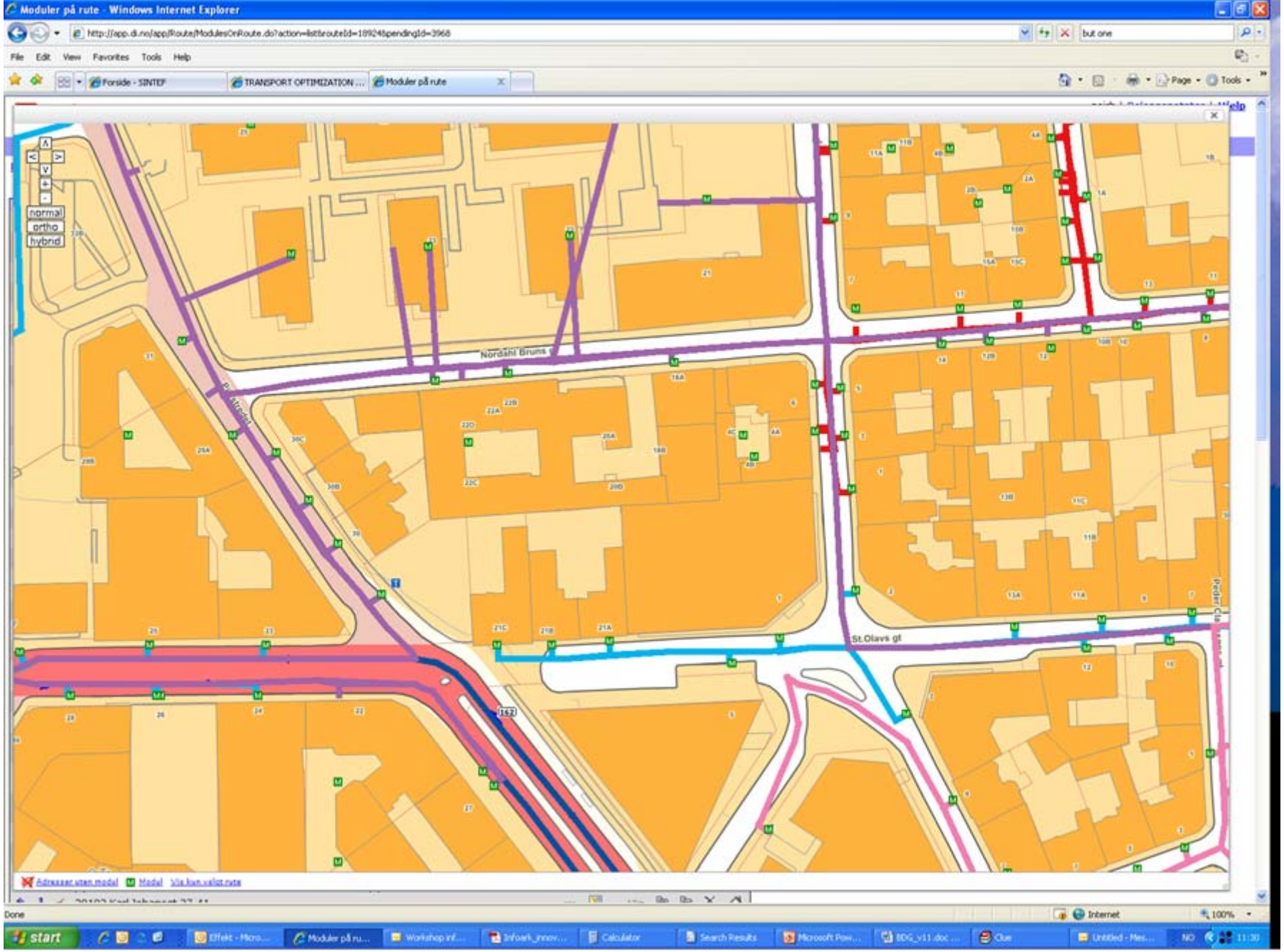
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How to contain complexity?

- Good algorithms
- Decomposition
- Abstraction, problem reduction
- Parallel computing
- Search reduction

Abstraction

- Ignoring detail, bottom-up
- Always done, modelling
  - Euclidean distances
  - Cost is distance
  - Constant speeds
  - Identical vehicles
  - Triangle inequality
  - Linearization
  - ....
  - May reduce industrial relevance ...
- Aggregation

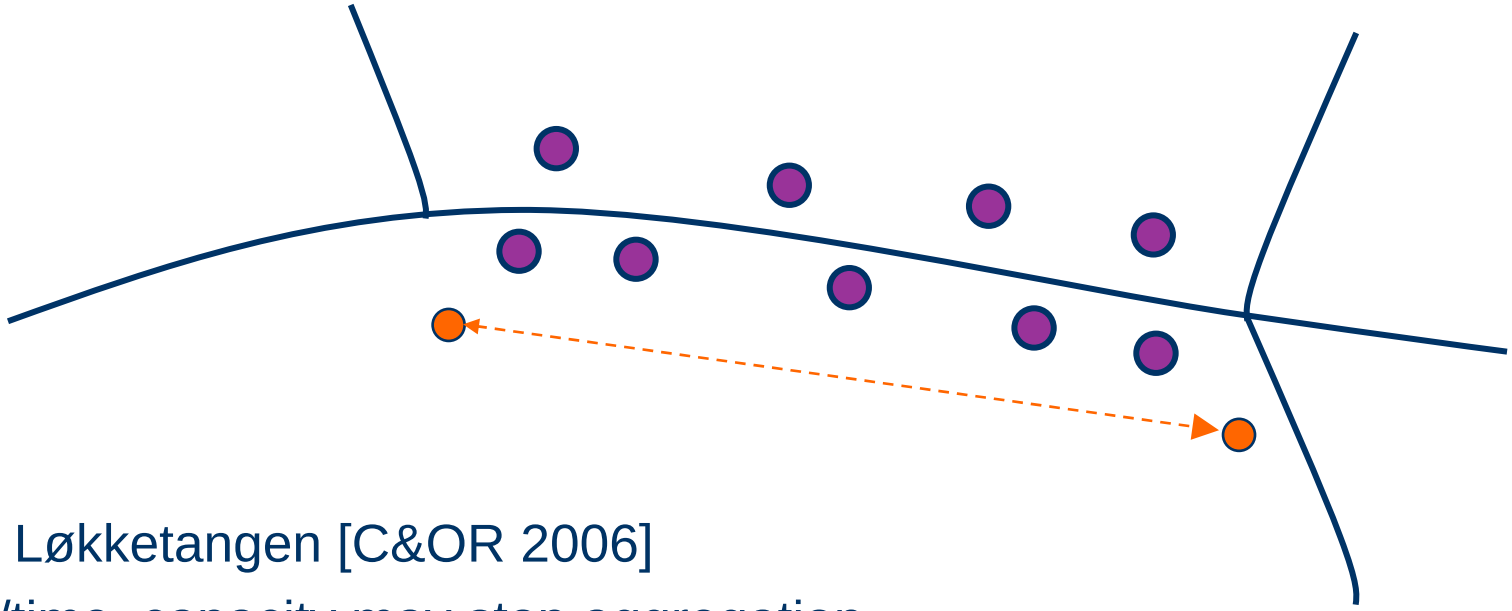
Aggregation of demand

- Collection of transportation demand
- Use of road topology
- Capacity threshold
- Other constraints

- De-aggregation and further improvement
- Multi-level aggregation / refinement

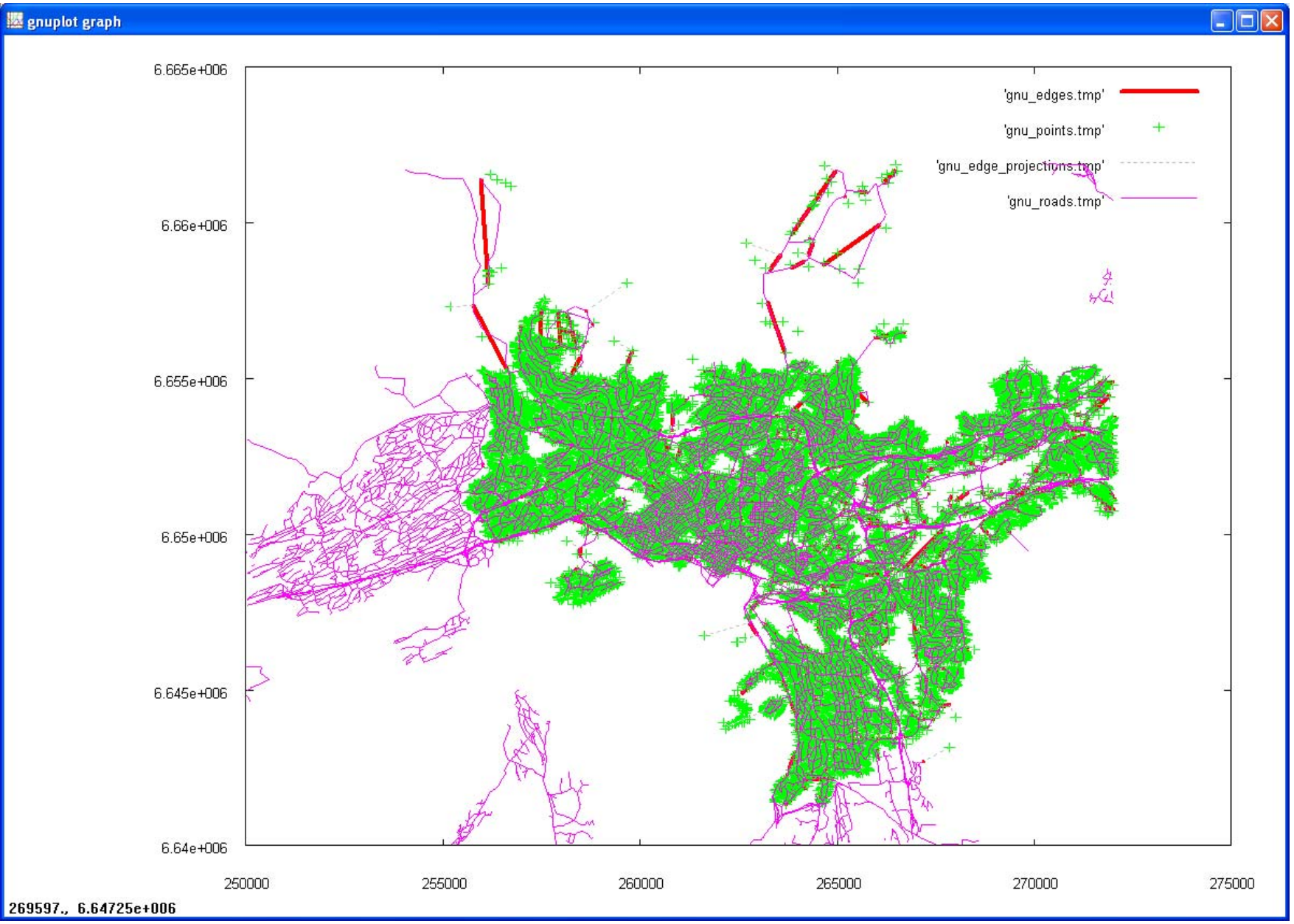
- < 10 papers in the literature

Demand aggregation based on road topology, proximity



- Oppen & Løkketangen [C&OR 2006]
- Distance/time, capacity may stop aggregation
- Issues on traversal possibilities, constraints
- Typical reduction factor of 5-20
- Needs extention to arc model (Node Edge Arc Routing Problem, NEARP)

Aftenposten 33.200 orders -> 5.600 aggregates

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A: PASSPORT - Session1
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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
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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
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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
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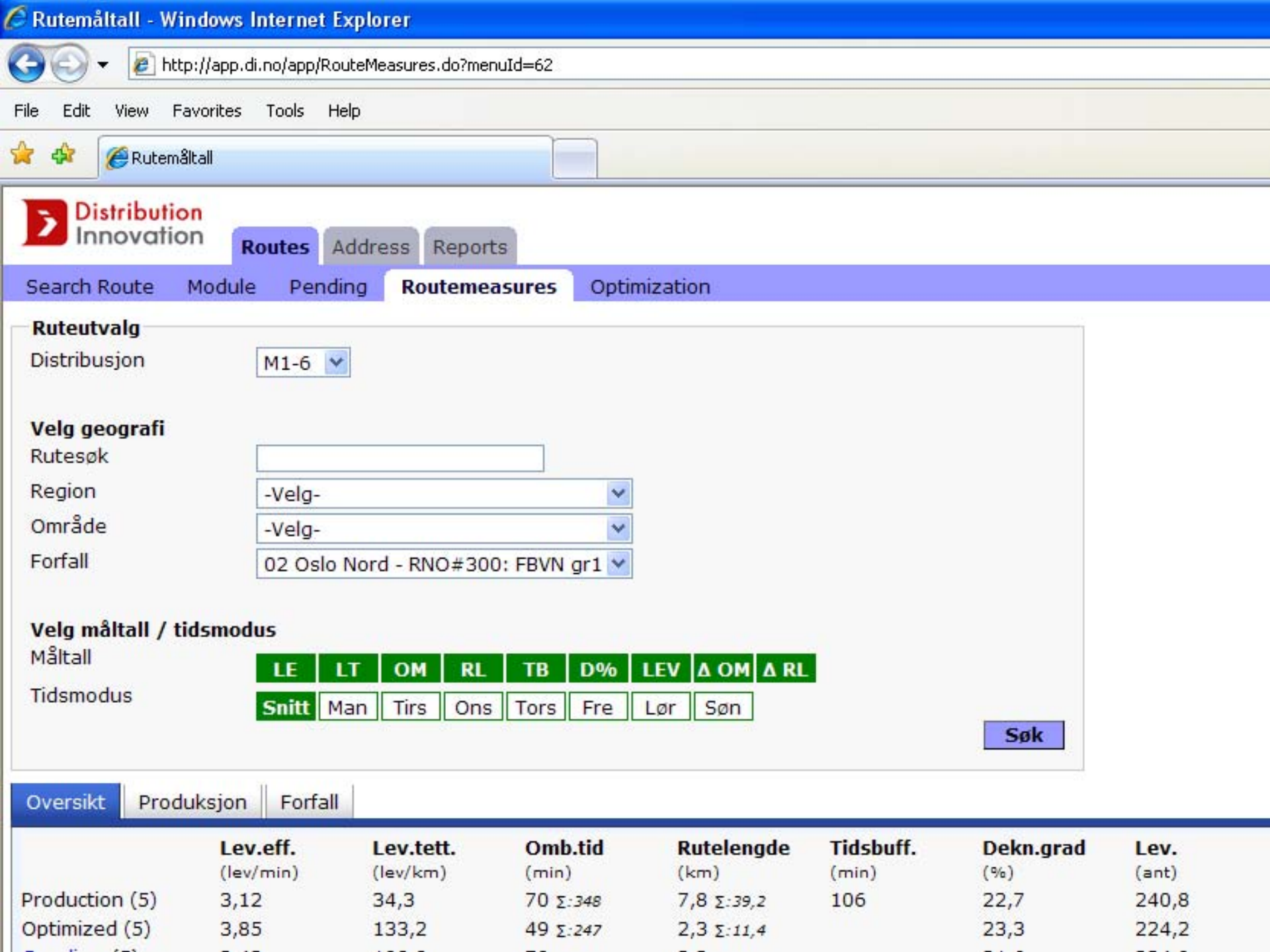
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Rutemåltall
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Distribusjon
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Velg geografi
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Region
-Velg-
Område
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Forfall
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Velg måltall / tidsmodus
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Oversikt
Produksjon
Forfall
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Omb.tid (min)
Rutelengde (km)
Tidsbuff. (min)
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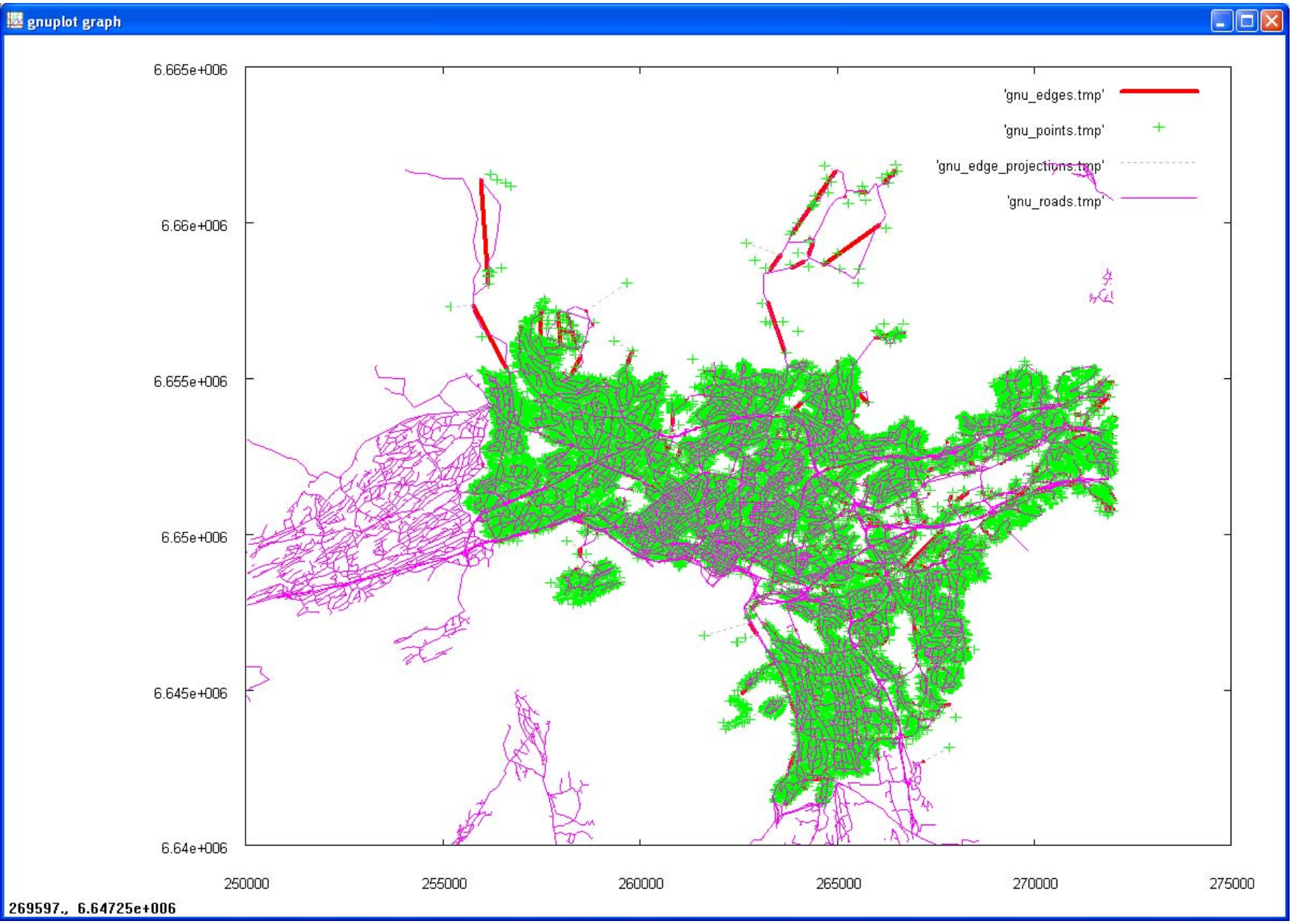
Production (5) 3,12 34,3 70 Σ:348 7,8 Σ:39,2 106 22,7 240,8
Optimized (5) 3,85 133,2 49 Σ:247 2,3 Σ:11,4 23,3 224,2

Node and Arc Routing

- For ”Household routing problems” demand is really located in a node
  - mail delivery
  - newspaper and other media products
  - waste collection
  - typically modelled as CARP in the literature
- ”Real” arc routing problems
  - snow removal, road cleaning, road maintenance
  - gritting, salting, ...
- Abstraction, aggregation of demand
  - mix of nodes, arcs, edges
  - travel cost (deadheading), service cost
- Node Edge Arc Routing Problem (NEARP)
  - Christian Prins and Samir Bouchenoua 2004
  - Generalization of the CVRP, CARP, General Routing Problem
  - Multi-vehicle Capacitated General Routing Problem on a Mixed Graph
  - Definition, test problems, memetic algorithm

Aftenposten 33.200 orders -> 5600 aggregates



VRP solver - Spider

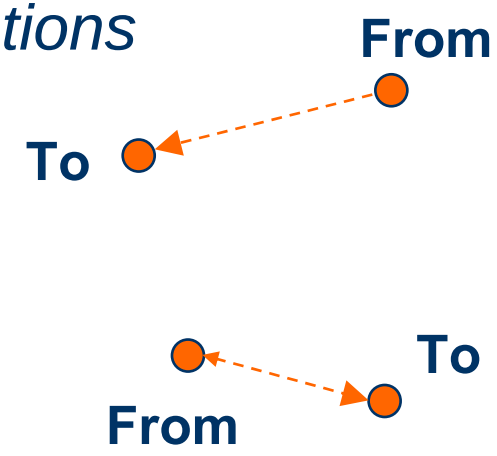
- Rich model
- A single algorithmic machinery
  - construction phase
  - tour depletion phase(s)
  - iterative improvement
    - VND
    - destroy and rebuild
  - different phases, each with its own objective
- Good results on a variety of benchmarks from the literature
- More computing time than focused academic solvers
- Has been commercialized through several channels

Previous situation

- Every task (pickup, delivery, tour start/end...) has a *location*
- Topology Module (Guider) provides distance, cost and time services:
  - $d(l_1, l_2)$, $c(l_1, l_2)$, $t(l_1, l_2)$
  - Possibly time dependent
  - Not necessarily symmetric
  - Triangle inequality holds
- Special location *Anywhere*
- Tasks may have alternative locations
- One is selected in plan

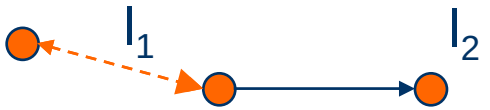
Extending locations

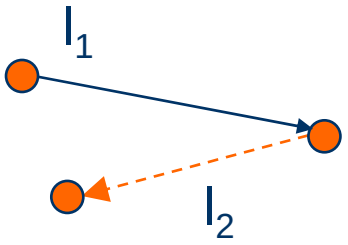
- Previously: Only *Node Locations*
- New type of locations: *Edge Locations*
- **From**: Node location
- **To**: Node location
- **Reversible**: bool

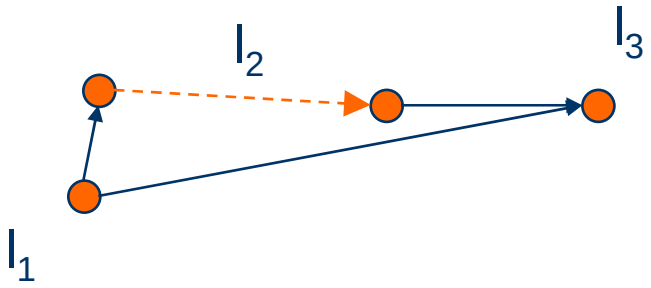


Impact on topology

- $d(l_1, l_2)$, $c(l_1, l_2)$, $t(l_1, l_2)$
- When l_1 is edge, use l_1:To
- When l_2 is edge, use l_2:From
- Triangle inequality may not hold

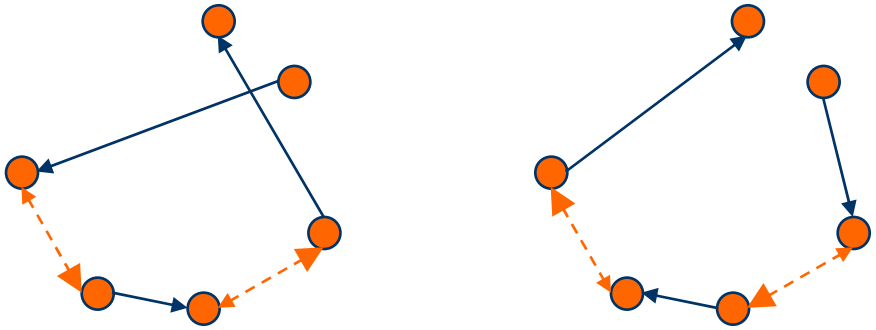






Impact on operators

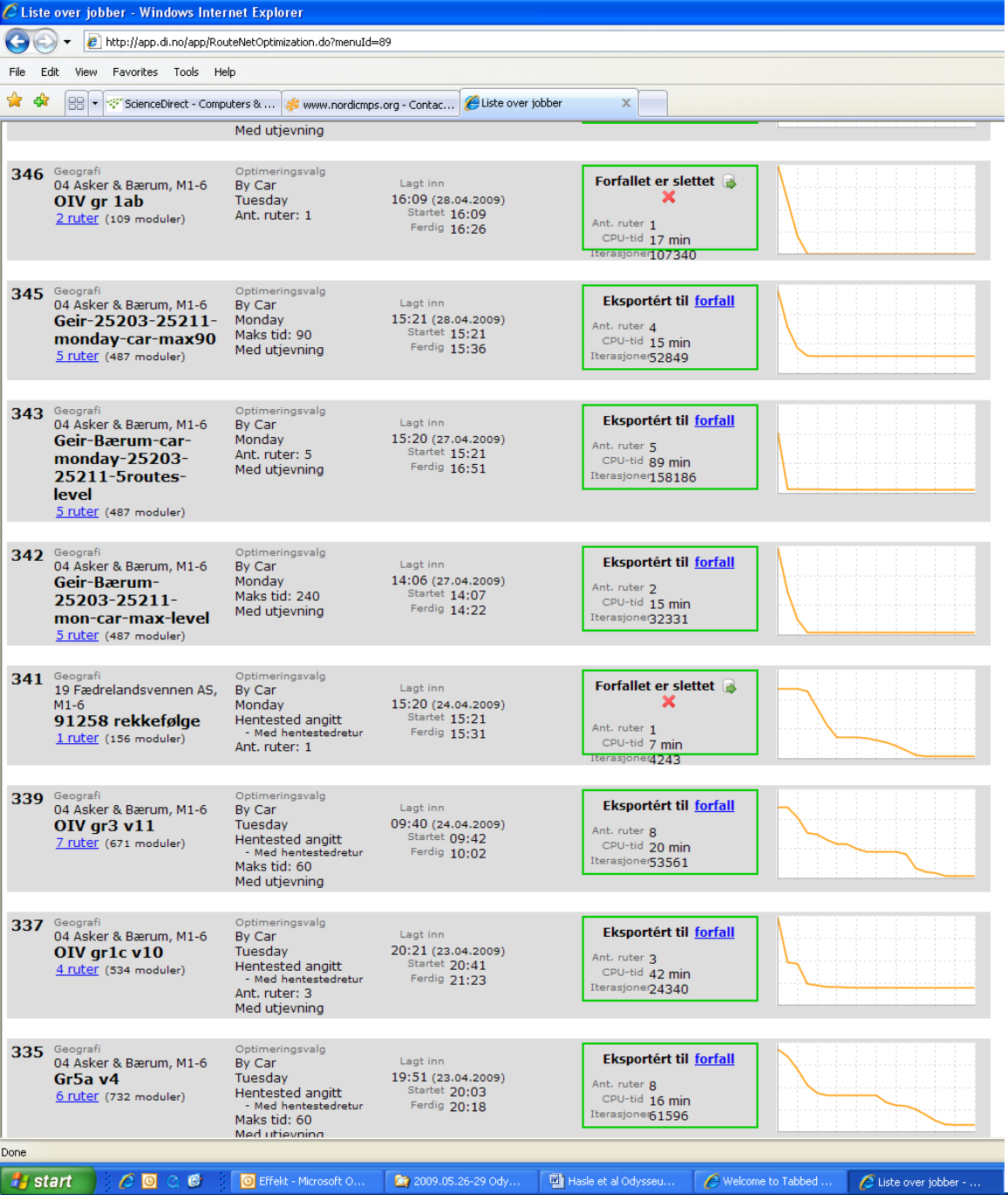
- When reversing subtours (2-opt, 3-opt), we reverse all reversible edge locations



- That's it

Edge locations

- Aggregation along road segments
- Modelling Arc Routing Problems, mixed problems
- All model extensions may be used
  - Non-homogenous fleet
  - Linked tours with precedences
  - Mixture of order types: Deliveries, Pickups, Direct, Single Visits
  - Multiple time windows, soft time windows
  - Capacity in multiple dimensions, soft capacity
  - Alternative locations on tours and orders
  - Periodic orders, alternative time periods
  - Non-Euclidean, asymmetric, dynamic travel times
  - A variety of constraint types and cost components ...
- Same algorithmic machinery, no ARP operators
- Performance?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Liste over jobber
Med utjevning
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Optimeringsvalg By Car Tuesday Ant. ruter: 1
Lagt inn 16:09 (28.04.2009) Startet 16:09 Ferdig 16:26
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Ant. ruter 1 CPU-tid 17 min Iterasjoner 107340
345 Geografi 04 Asker & Bærum, M1-6 Geir-25203-25211-monday-car-max90 5 ruter (487 moduler)
Optimeringsvalg By Car Monday Maks tid: 90 Med utjevning
Lagt inn 15:21 (28.04.2009) Startet 15:21 Ferdig 15:36
Eksportert til forfall
Ant. ruter 4 CPU-tid 15 min Iterasjoner 52849
343 Geografi 04 Asker & Bærum, M1-6 Geir-Bærum-car-monday-25203-25211-5routes-level 5 ruter (487 moduler)
Optimeringsvalg By Car Monday Ant. ruter: 5 Med utjevning
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342 Geografi 04 Asker & Bærum, M1-6 Geir-Bærum-25203-25211-mon-car-max-level 5 ruter (487 moduler)
Optimeringsvalg By Car Monday Maks tid: 240 Med utjevning
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341 Geografi 19 Fædrelandsvennen AS, M1-6 91258 rekkefølge 1 ruter (156 moduler)
Optimeringsvalg By Car Monday Hentested angitt - Med hentestedretur Ant. ruter: 1
Lagt inn 15:20 (24.04.2009) Startet 15:21 Ferdig 15:31
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Ant. ruter 1 CPU-tid 7 min Iterasjoner 4243
339 Geografi 04 Asker & Bærum, M1-6 OIV gr3 v11 7 ruter (671 moduler)
Optimeringsvalg By Car Tuesday Hentested angitt - Med hentestedretur Maks tid: 60 Med utjevning
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Optimeringsvalg By Car Tuesday Hentested angitt - Med hentestedretur Ant. ruter: 3 Med utjevning
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335 Geografi 04 Asker & Bærum, M1-6 Gr5a v4 6 ruter (732 moduler)
Optimeringsvalg By Car Tuesday Hentested angitt - Med hentestedretur Maks tid: 60 Med utjevning
Lagt inn 19:51 (23.04.2009) Startet 20:03 Ferdig 20:18
Eksportert til forfall
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Effekt - Microsoft O...
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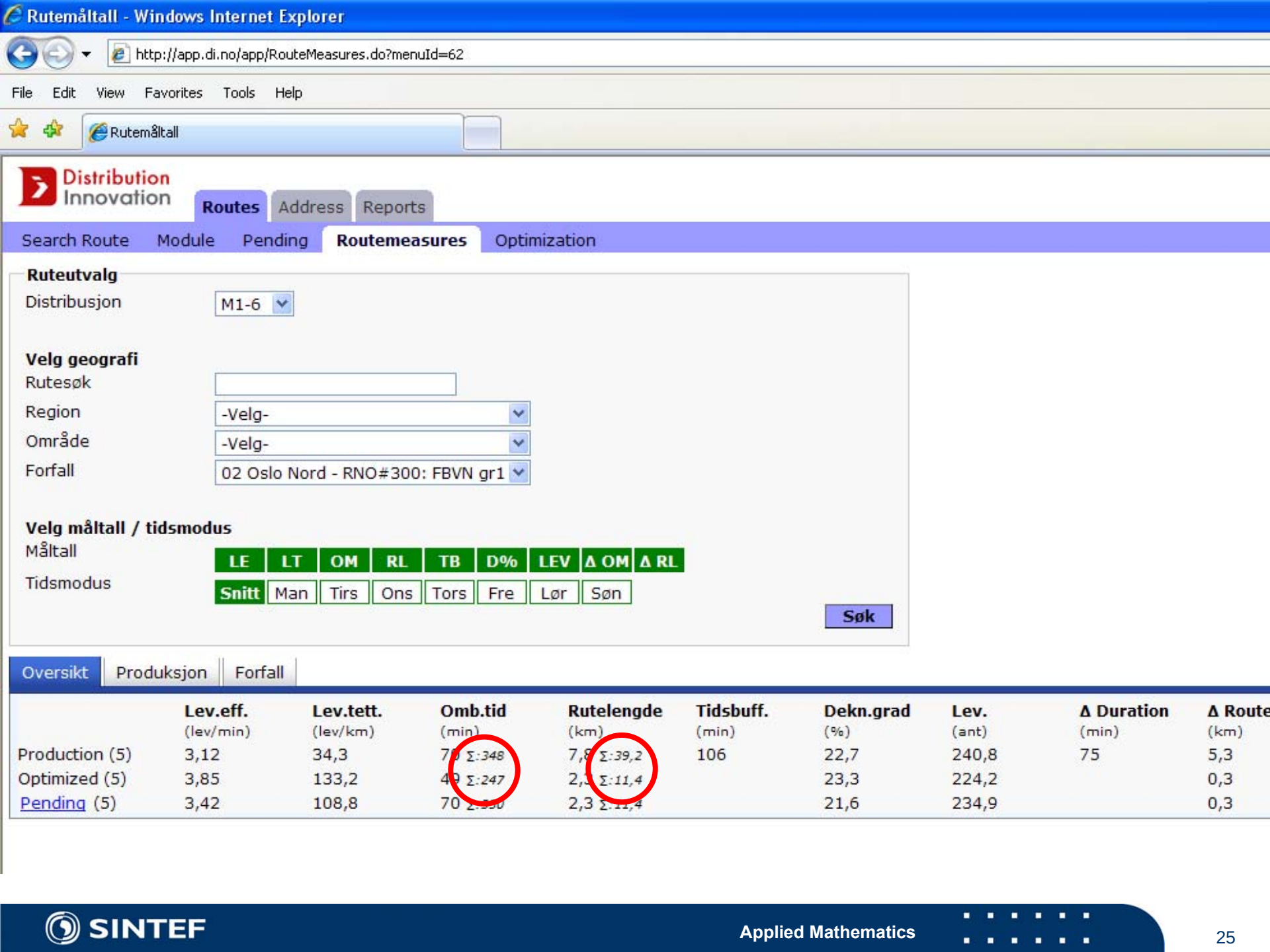
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Rutemåltall
Distribution Innovation
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Ruteutvalg
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Område -Velg-
Forfall 02 Oslo Nord - RNO#300: FBVN gr1
Velg måltall / tidsmodus
Måltall LE LT OM RL TB D% LEV Δ OM Δ RL
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Oversikt Produksjon Forfall
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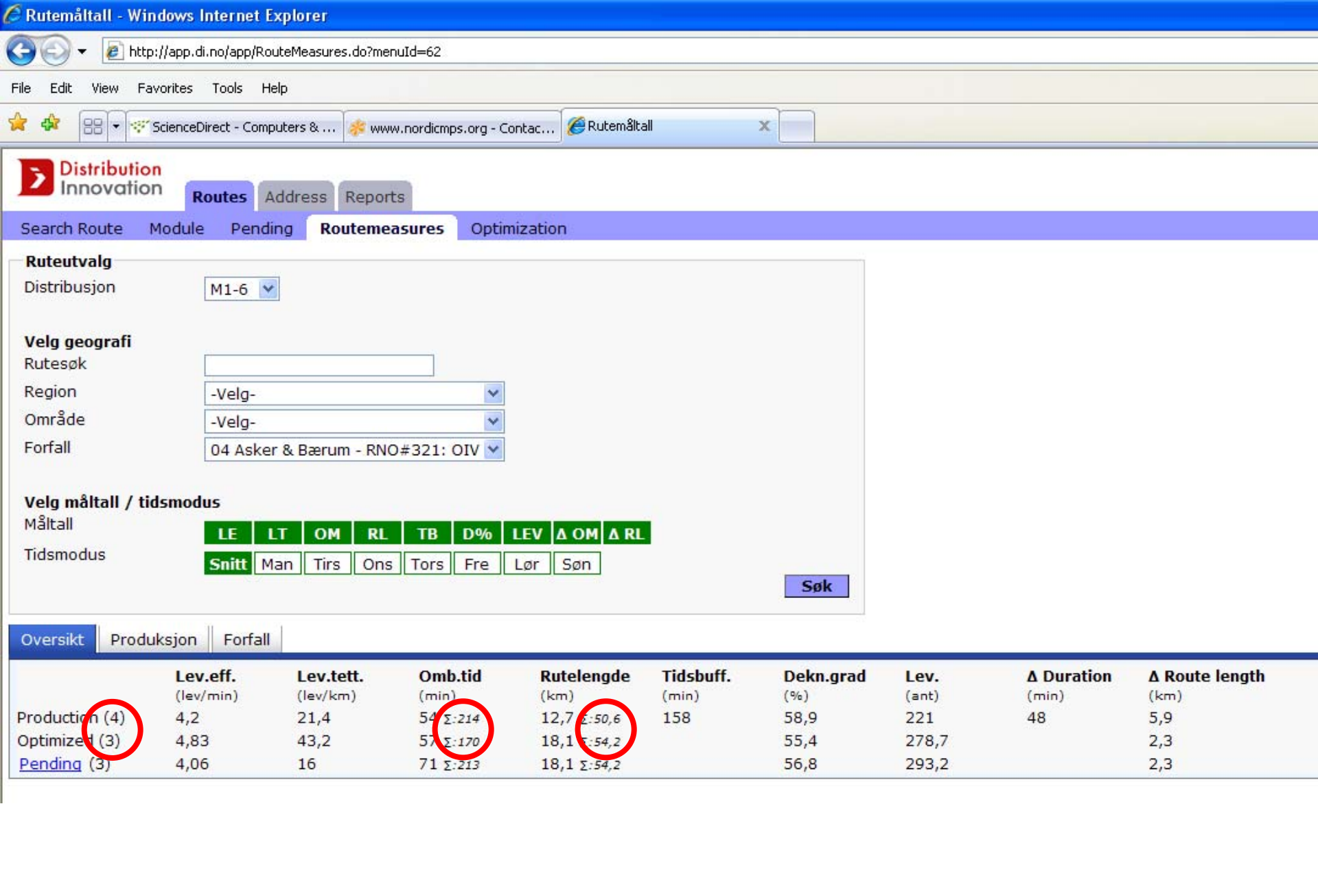
Production (5) 3,12 34,3 Σ:348 Σ:39,2 106 22,7 240,8 75 5,3
Optimized (5) 3,85 133,2 Σ:247 Σ:11,4 23,3 224,2 0,3
Pending (5) 3,42 108,8 70 2,3 21,6 234,9 0,3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Rutemåltall
Distribution Innovation
Routes
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Reports
Search Route
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Optimization
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M1-6
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04 Asker & Bærum - RNO#321: OIV
Velg måltall / tidsmodus
Måltall
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Søk
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Production (4) 4,2 21,4 54 Σ:214 12,7 Σ:50,6 158 58,9 221 48 5,9
Optimized (3) 4,83 43,2 57 Σ:170 18,1 Σ:54,2 55,4 278,7 2,3
Pending (3) 4,06 16 71 Σ:213 18,1 Σ:54,2 56,8 293,2 2,3

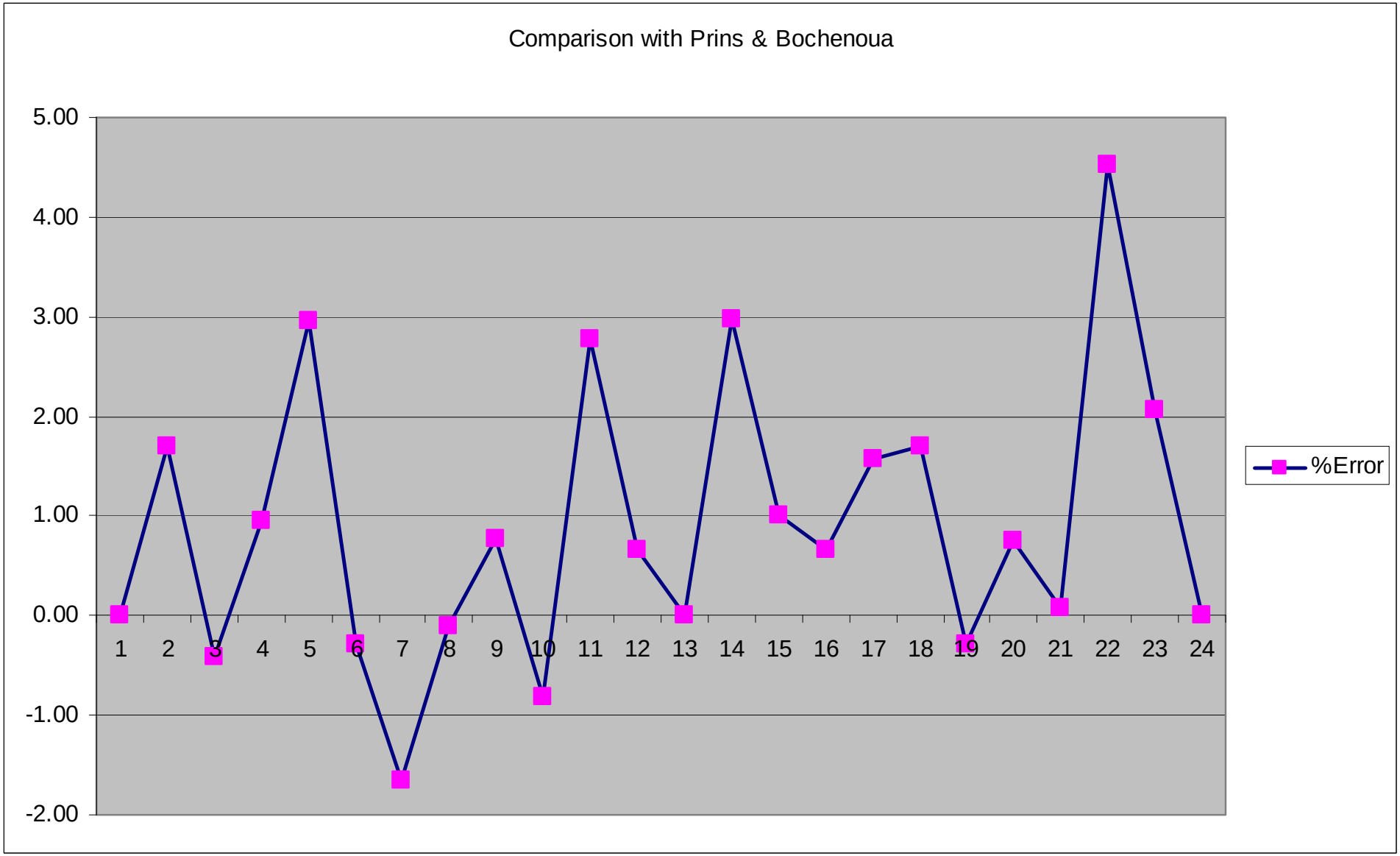
NEARP experiments

- Intel Core2 Duo T7800 2.6 GHz, 3.5 Gb memory, MS Windows XP Professional version 2002 SP 2
- Neighborhood operators
  - Insert
  - Relocate
  - 2-opt
  - 3-opt
  - Cross (2-opt*)
  - Cross-exchange (2 variants)
- Diversification: destroy and repair
- 900/1800 seconds timeout

Computational tests - NEARP

- Prins & Bouchenoua CBMix (23 instances)
- No lower bounds yet, no proven optima, only one competitor
- UB error 0.94%
- 8 best known solutions (6 new), 0 incomplete ...
- 519 seconds

- Improvements needed, exploit ARP-structure


Comparison with Prins & Bochenoua
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-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

Conclusions

- Many challenges for routing technology
- Computational complexity and detailed information are two
- Aggregation heuristics provide an important remedy
  - problem reduction
  - abstraction
- The NEARP is an interesting model, more work needed
- Robust algorithms for rich node-routing problems is a good starting point
- Needs algorithmic extensions that handle ARP structure
- Work has been started to provide good lower bounds for the NEARP

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- Seventh Triennial Symposium on Transportation Analysis
- Tromsø, Norway, June 20.-25., 2010
- http://www.tristan7.org/
- Deadline for abstract submission: October 31, 2009

The Collab project

- High-performance transportation optimization through parallel and collaborative methods
- Rich VRP, Dynamic SPP
- 2009-2011
- Partners
  - Group of optimization, SINTEF ICT
  - Group of Heterogeneous Computing, SINTEF ICT
  - The Agora Innoroad Laboratory, University of Jyväskylä, Finland
  - ITMMA, University of Antwerp, Belgium
  - CIRRELT, Quebec, Canada
- Temporary researcher position at SINTEF
- Funded by the Research Council of Norway / SMARTRANS
- Extensions