Heuristic Strategies for Solving Large-Scale Vehicle Routing Problems

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TRANSPORT OPTIMIZATION CHALLENGES IN CONTEMPORARY PRACTISE
Jyväskylä, Finland, May 12-14, 2009

Outline

Transport Optimization Challenges in Contemporary Practice

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

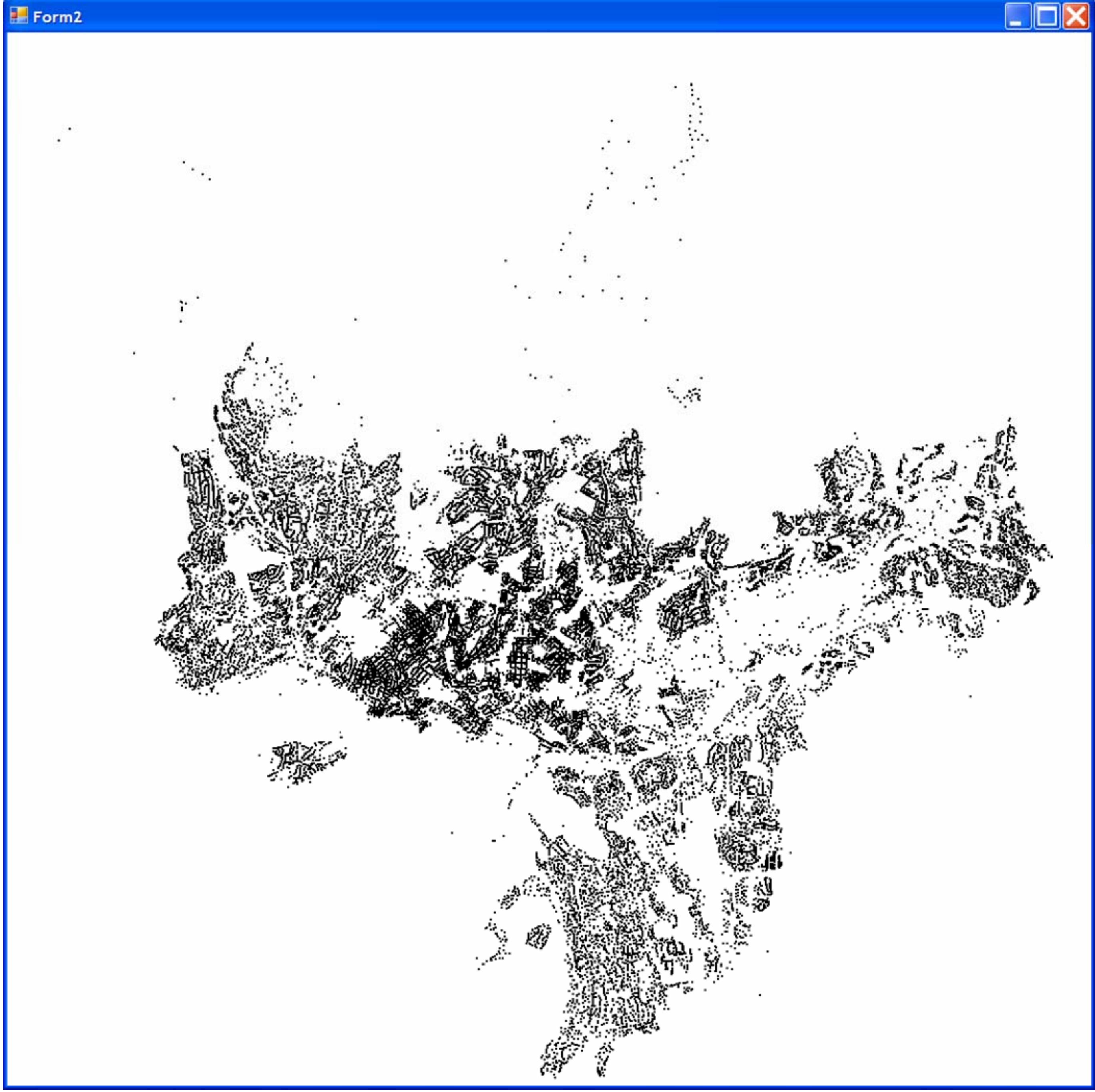
Messages

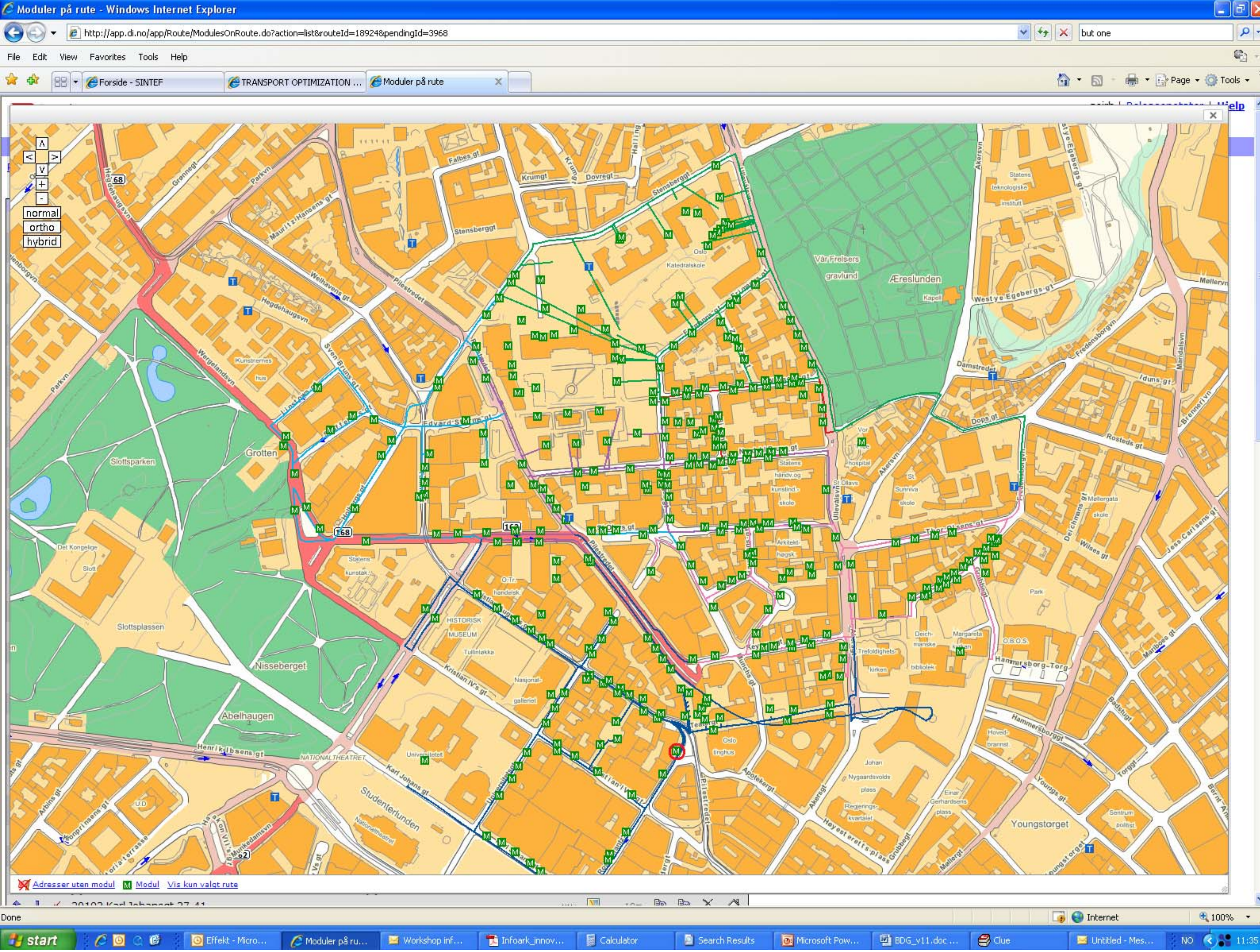
- Many challenges for routing technology
- Computational complexity is one of them
- Several strategies for containing complexity
- The VRP research community should be careful
  - Solving the right problem
  - Speedup tricks are useful for world records and maximizing #publications
  - They may break down for real life problems

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
- 34.554 modules

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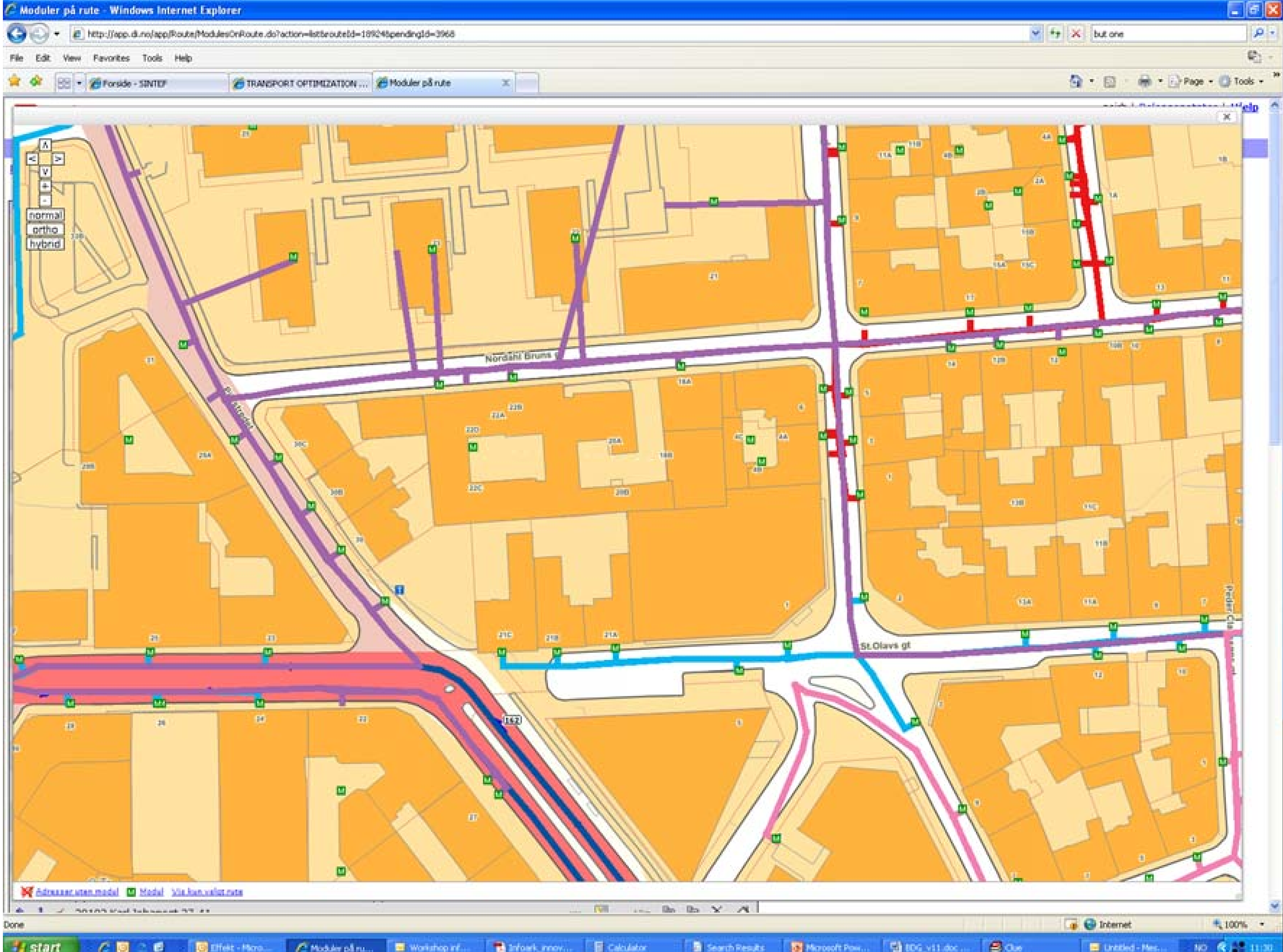
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- Challenges for Routing Technology
- Heuristic Strategies for Large-Scale VRPs
  - Olli Bräysy, Wout Dullaert, Pasi Porkka, Geir Hasle
- Newspaper and Media Product Distribution
- The Node Edge Arc Routing Problem
- Conclusions

How to contain complexity?

- High performance algorithms
- Decomposition
- Abstraction
- Parallel computing
- Search Reduction

Decomposition

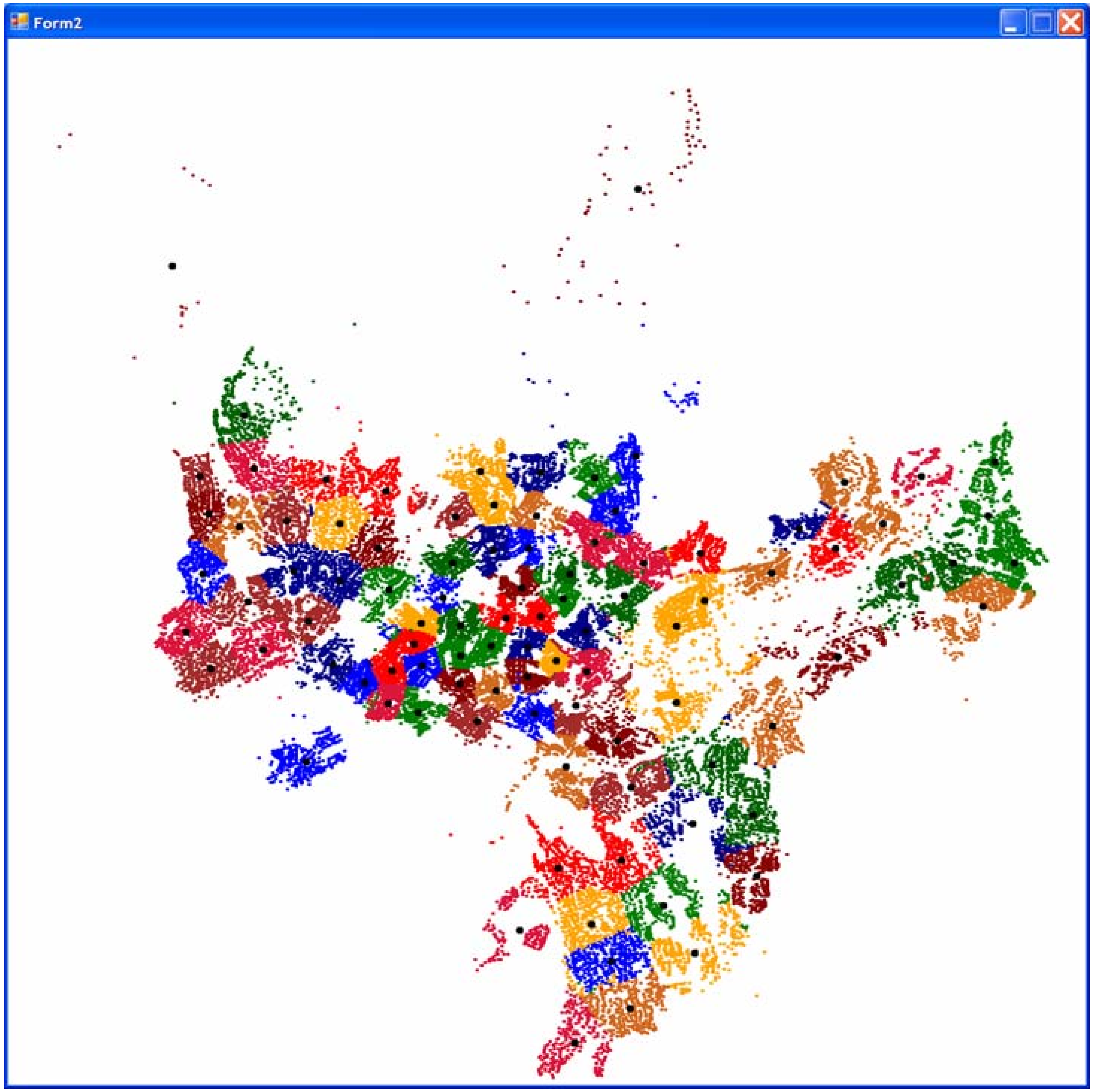
- Top-down strategy
- Split the problem into manageable pieces
- Solve the subproblems
- Patch the solutions together
- You will typically lose optimality
- Basis for further improvement

VRP Decomposition

- Geographical
- Organizational
- Temporal
- Product
- Vehicle
- Assignment / Sequencing
- Location / Routing, Period / Routing
- Column Generation
- Cluster-first-route-second and vice versa
- Clustering methods useful for splitting

- Some 40 papers in the literature

Geographical decomposition
35.000 orders – 100 sub-areas



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

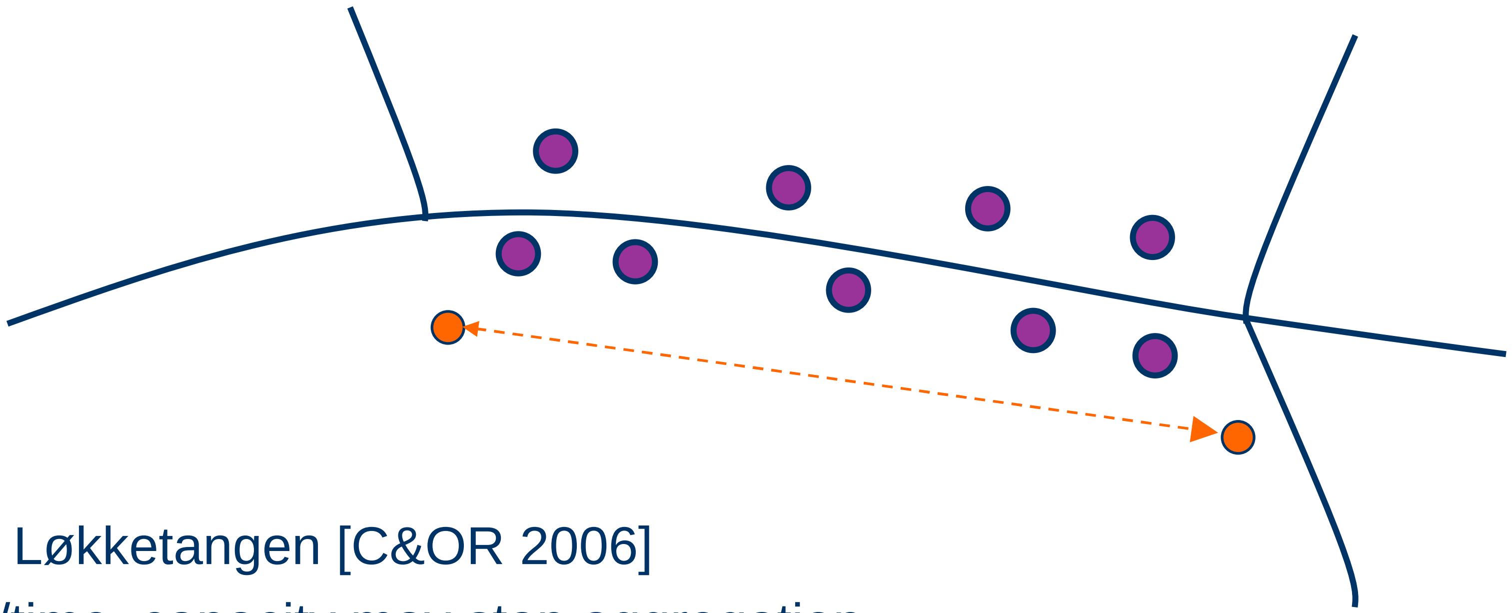
Aggregation of demand

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

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

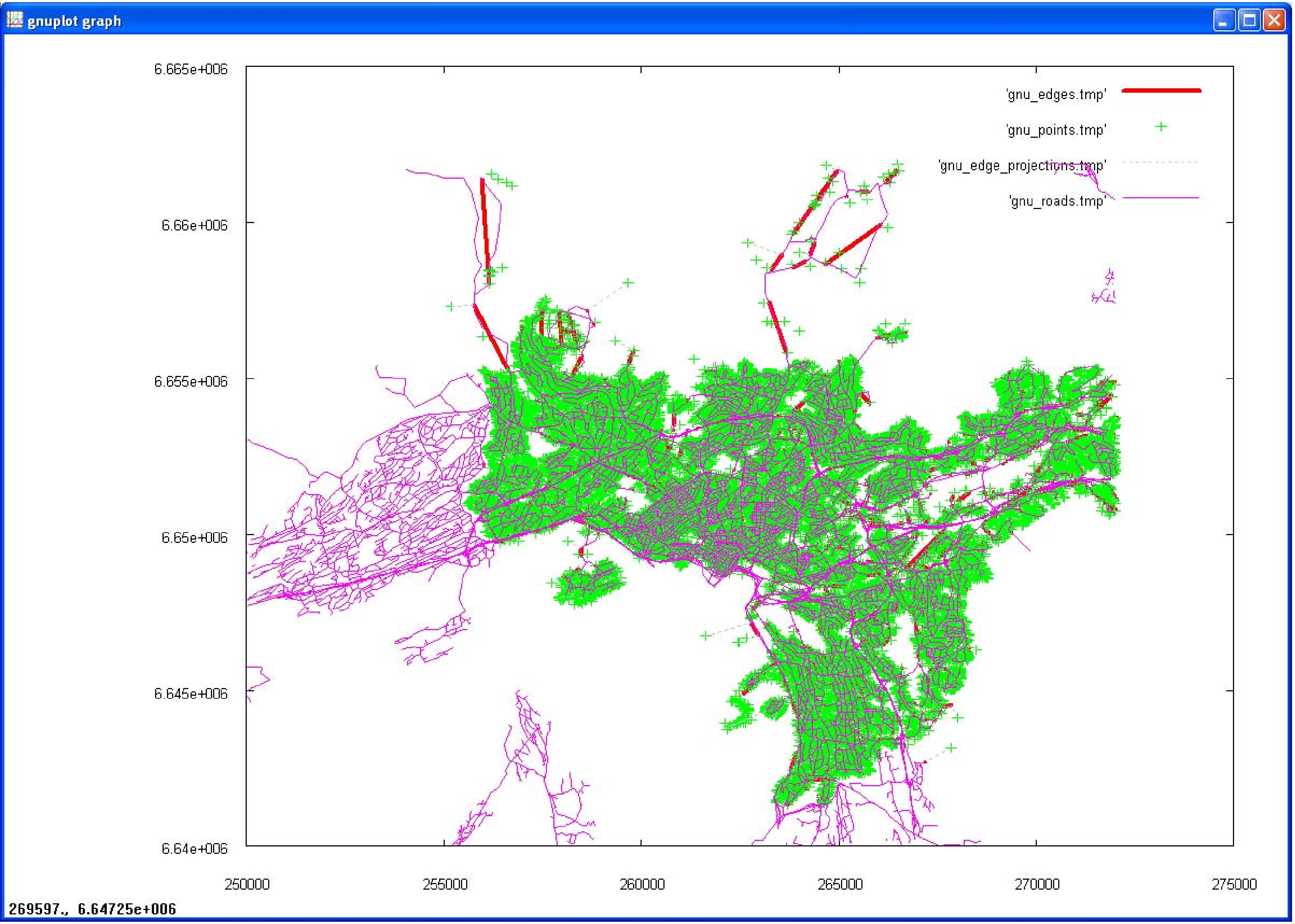
- < 10 papers in the literature

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)
- More comprehensive aggregation (Joni Brigatti's talk)

Aftenposten 33.200 orders -> 5600 aggregates

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Parallel computing

- Idea very old, Charles Babbage
- ”The Beach Law” (Gottbrath et al. 1999) does not hold these days
- Moore’s law still does
  - reduced clock speed
  - increasing # multiple cores
- Sequential programs run slower on multi-core computers
- Graphics Processing Unit
  - data parallelism, stream computing
  - rapid performance increase
  - general purpose programmability
- Hybrid computing

Parallel computing

- Some tasks in EA and LS are embarassingly parallel
- ”Simple” parallelization through multi-threading
  - fine-grained to medium level granularity
  - very interesting for routing technology
  - not so interesting for VRP research, no literature
- More interesting parallelization
  - Coarse-grained, asynchronous
  - Multi-search
  - Collaborative search
  - Parallel multi-level
- Recent review by Crainic, 80 references
- Additional 30 papers
- Hybrid computing not really investigated

Search speedup

- Local search: Delta evaluation
- Interesting LS neighborhoods do not scale well
- Restricted neighborhoods
  - Candidate list strategies (Glover)
  - Granular tabu search (Toth & Vigo)
  - Fast Local Search in Guided Local Search (Voudouris et al.)
- Restructuring of neighborhood exploration
  - First accept
  - Sequential search, decomposition of moves with pruning
    (old idea, Christofides & Eilon, Lin & Kernighan, revived by Irnich et al.)

- Some 15 VRP papers

Search speedup

- Fast propagation of constraints, important
- May be very effective, but use with care ...
- Real-life aspects, time-varying speeds?

- More aggressiveness / opportunism in Local Search?
- Better understanding of what is going on
  - search landscapes
  - design of operators

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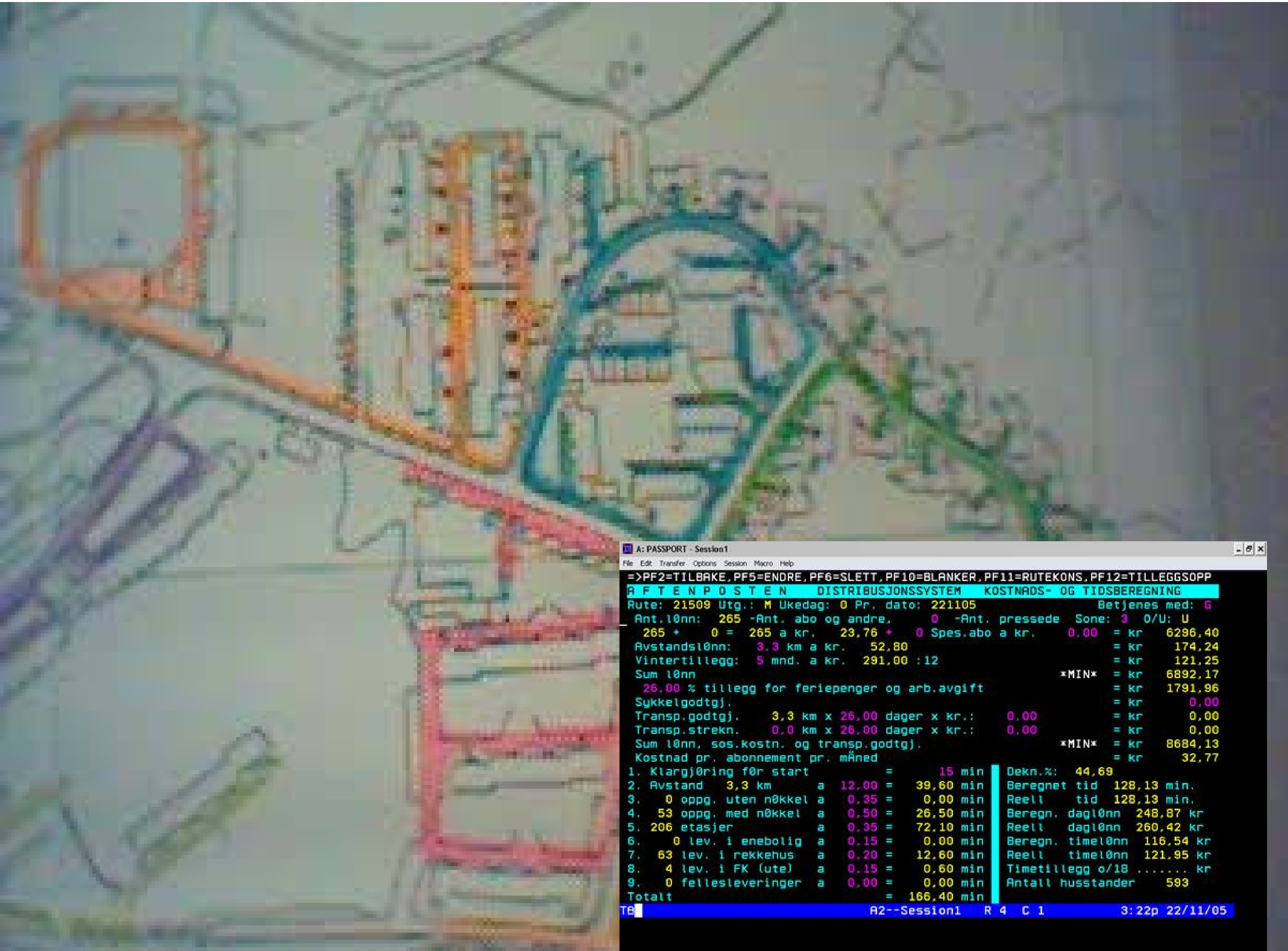
  - Truls Flatberg, Oddvar Kloster, Eivind J. Nilssen, Morten Smedsrud, Geir Hasle
- Conclusions



A: PASSPORT - Session1

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4.  53 oppg. med n0kkel   a   0,50 =    26,50 min | Beregn. dagl0nn  248,87 kr
5. 206 etasjer            a   0,35 =    72,10 min | Reell   dagl0nn  260,42 kr
6.    0 lev. i enebolig   a   0,15 =     0,00 min | Beregn. timel0nn  116,54 kr
7.  63 lev. i rekkehus    a   0,20 =    12,60 min | Reell   timel0nn  121,95 kr
8.   4 lev. i FK (ute)    a   0,15 =     0,60 min | Timetillegg o/18 ....... kr
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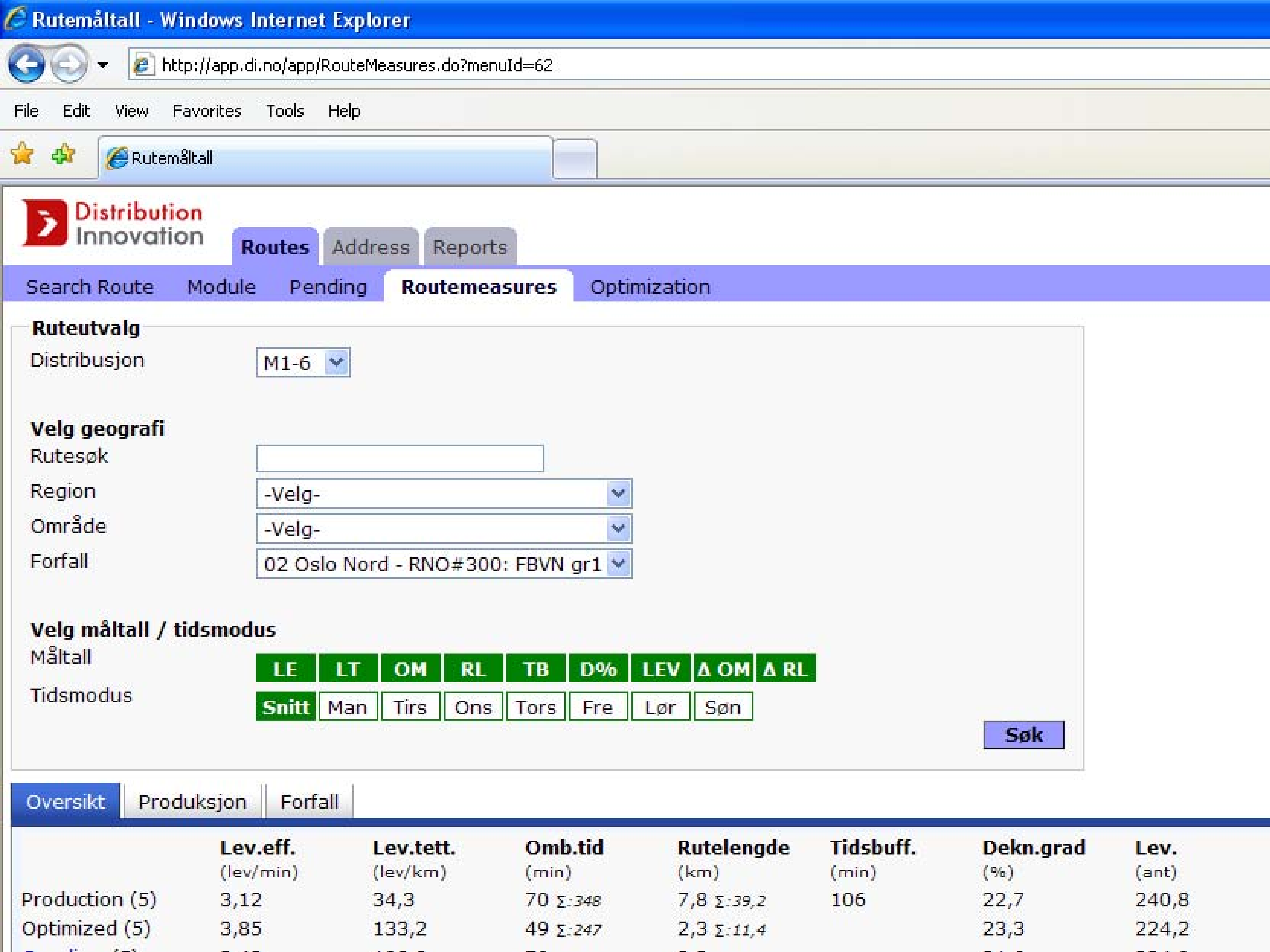
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Velg måltall / tidsmodus
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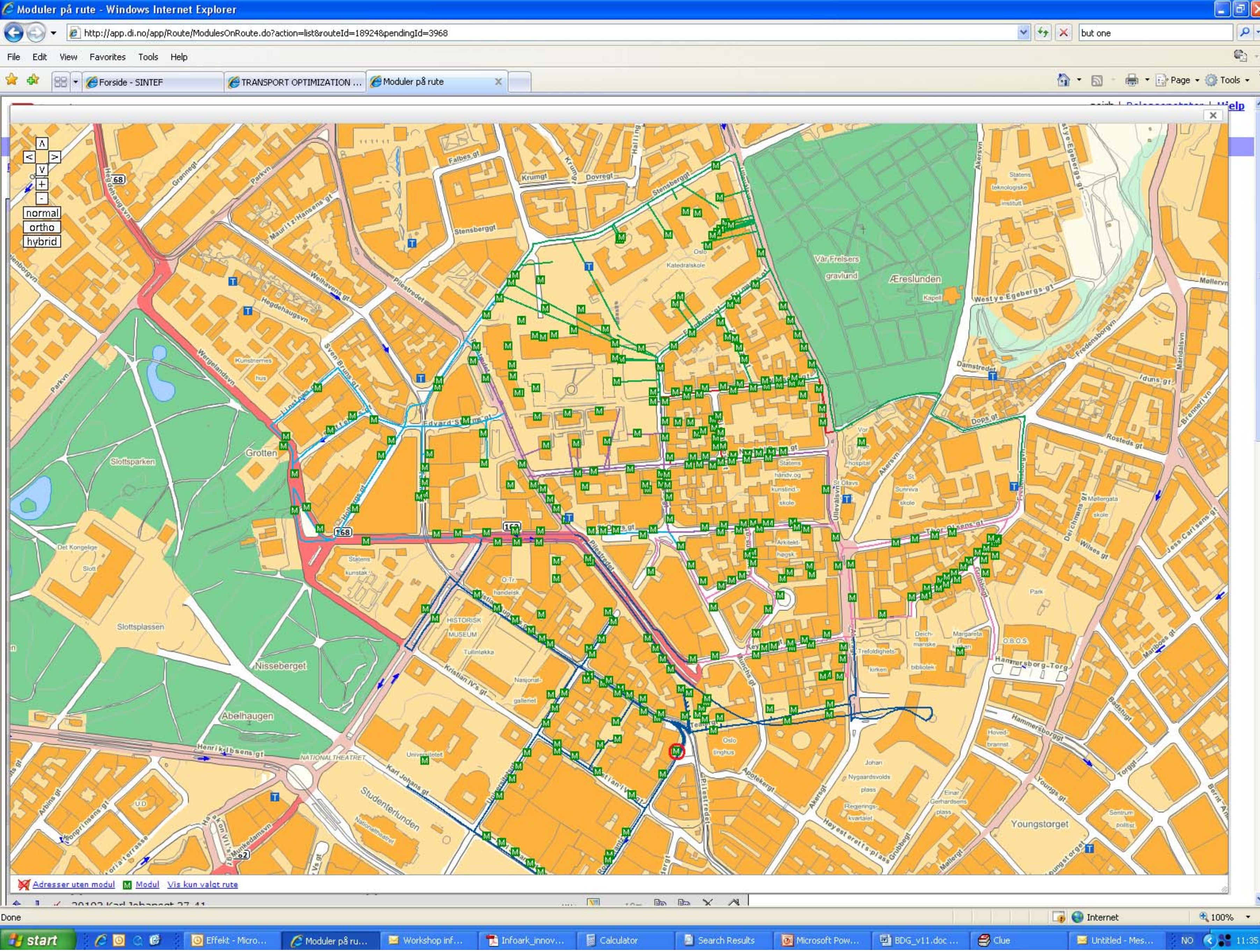
Optimized (5) 3,85 133,2 49 Σ:247 2,3 Σ:11,4 23,3 224,2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TRANSPORT OPTIMIZATION ...
Moduler på rute
normal
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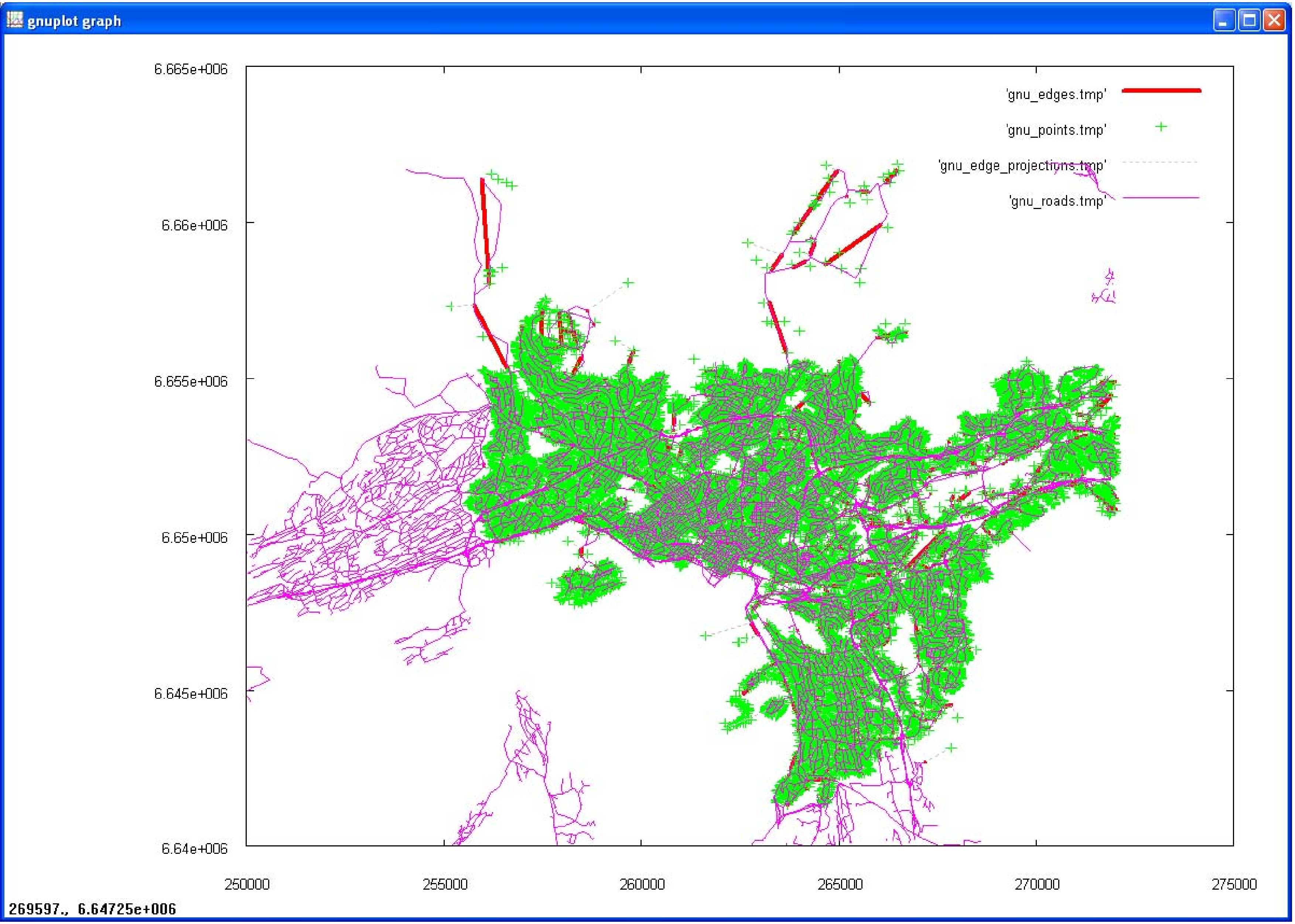
Slottsparken
Grotten
Slottsplassen
Nisseberget
Abelhaugen
Vår Frelsers gravlund
Æreslunden
Youngstorget
Studenterlunden
Adresser uten modul
Modul
Vis kun valgt rute
Done
Internet
100%

Node and Arc Routing

- For ”Household routing problems” demand is located in a node
  - mail delivery
  - newspaper and other media products
  - waste collection
  - typically modelled as CARP in the literature
- Arc routing
  - snow removal, cleaning
  - 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
  - Definition, test problems, memetic algorithm

Aftenposten 33.200 orders -> 5600 aggregates



VRP solver - Spider

- Rich model
- Basically a single algorithmic machinery
  - construction phase
  - tour depletion phase(s)
  - iterative improvement
    - VND
    - destroy and rebuild

- Good results on benchmarks from the literature
- More computing time

Previous situation

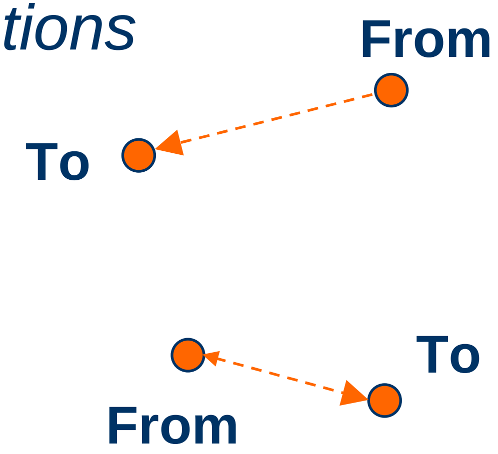
- Every task (pickup, delivery, tour start/end...) has a *location*
- Topology Module (Guider) provides distance, cost and time services:

  - $d(l_1, l_2)$, $c(l_1, l_2)$, $t(l_1, l_2)$
  - Possibly time dependent
  - Not necessarily symmetric
  - Triangle inequality holds

- Special location *Anywhere*
- Tasks may have alternative locations
- One is selected in plan

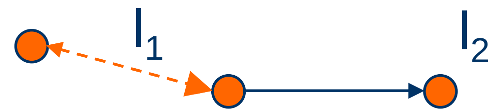
Extending locations

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

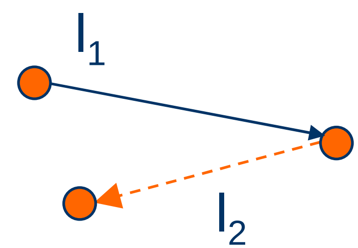


Impact on topology

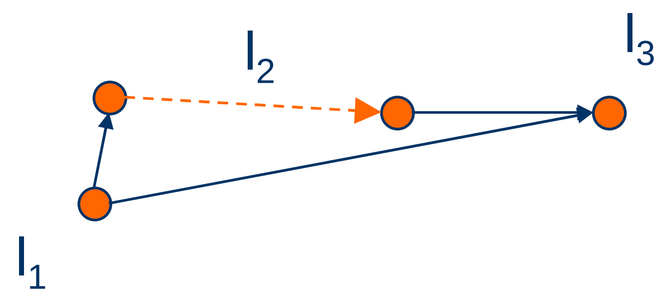
- $d(l_1, l_2)$, $c(l_1, l_2)$, $t(l_1, l_2)$
- When l_1 is edge, use l_1:To



- When l_2 is edge, use l_2:From

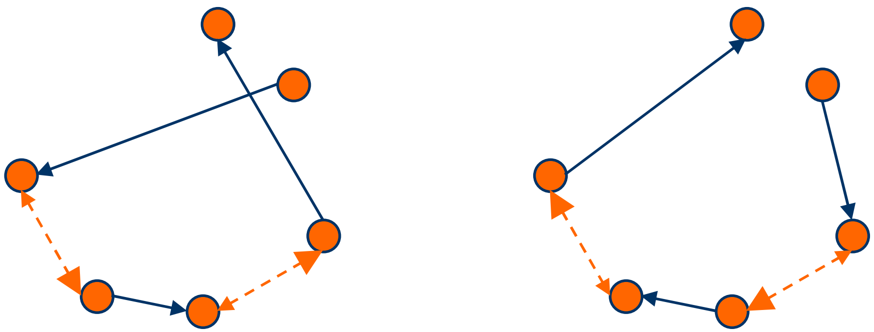


- Triangle inequality may not hold



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?

CARP / NEARP experiments

- Intel Core2 Duo T7800 2.6 GHz, 3.5 Gb memory, MS XP Professional version 2002 Service Pack 2
- Insert, Relocate, 2-opt, Cross, Cross-exchange (2 variants), 3-opt, ruin and recreate
- 900 seconds timeout

Computational tests - CARP

- Benavent et al. (34 instances)
  - LB error 1.02%
  - UB error 0.60%
  - 16 best known solutions (13 optimal)
  - 176 seconds
- Golden et al. (23 instances)
  - LB error 0.83%
  - UB error 0.70%
  - 14 best known solutions (14 optimal)
  - 1 incomplete ...
  - 58 seconds
- Eglese et al. (24 instances)
  - LB error 3.63%
  - UB error 1.25%
  - 3 best known solutions (1 new)
  - 3 incomplete ...
  - 421 seconds

Computational tests - 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), 0 incomplete ...
- 519 seconds

- Improvements needed, ARP-structure

Conclusions

Transport Optimization Challenges in Contemporary Practice

- More attention to rich, large-size problems
- More work on how to deal with computational complexity
- Combination of strategies
- More aggressive search
- More research on search

- The NEARP is an interesting model
- More attention should be devoted to it
- Algorithms for node-routing may work well

- We will not be out of work in a while

Messages

- Many challenges for routing technology
- Computational complexity is one of them
- Several strategies for containing complexity
- The VRP research community
  - should investigate them more
  - should be industrially relevant
- Clever speedup tricks are useful for breaking world records (minimizing travel cost and maximizing #publications)
- They may hinge on assumptions that make them break down for real life problems

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The conference where the sun never se
Hope to see you at
TRISTAN 7
Tromsø, Norway - 20.-25. June 2010
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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
- Email to tristan@sintef.no with the following text in the Subject field: 'TRISTAN: your surname, your given name'

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