Media Product Distribution

Decomposition and aggregation heuristics for solving large-scale multi-criteria DVRPs

Rich VRP

Geir Hasle

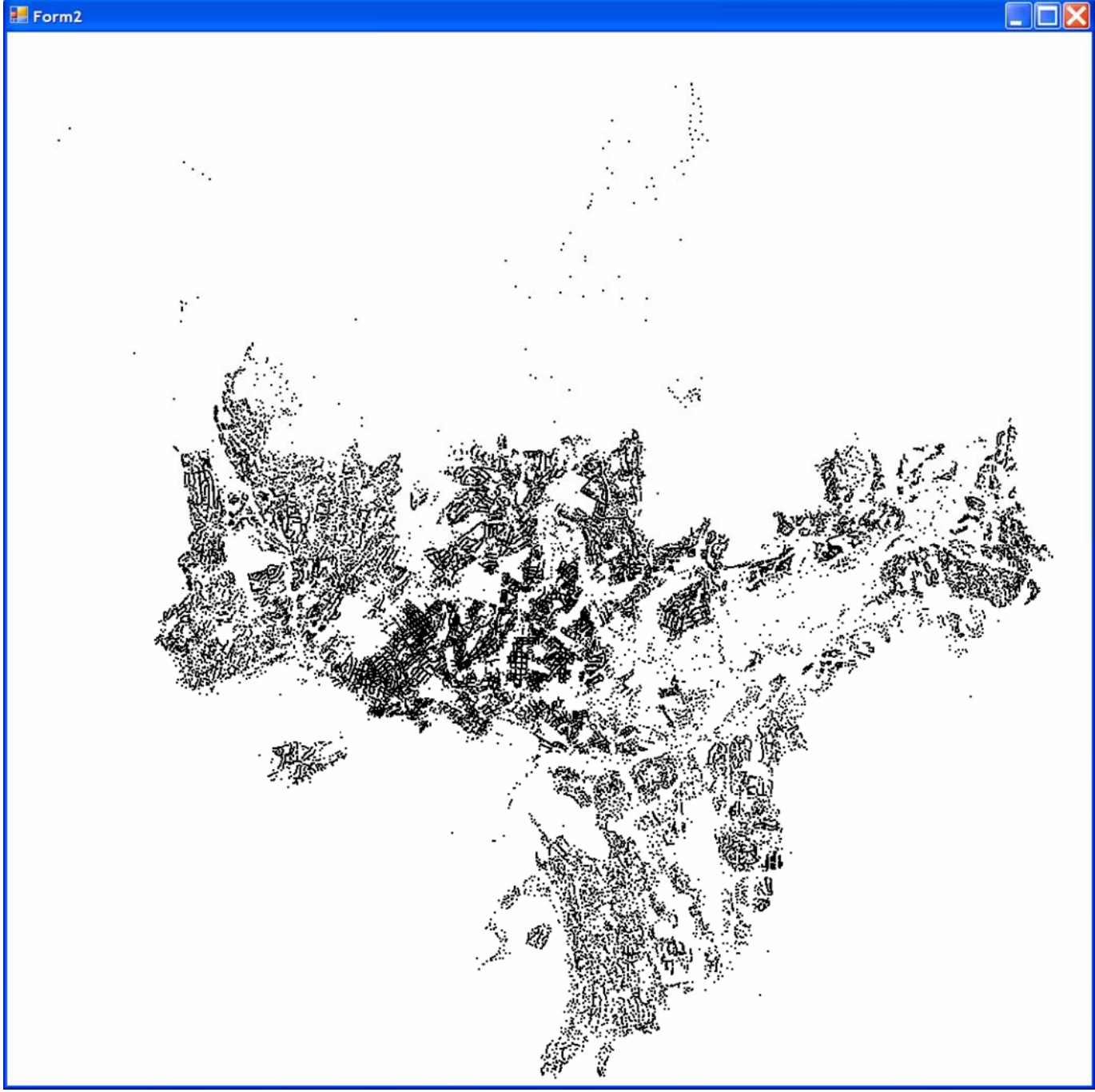
1st Collab workshop

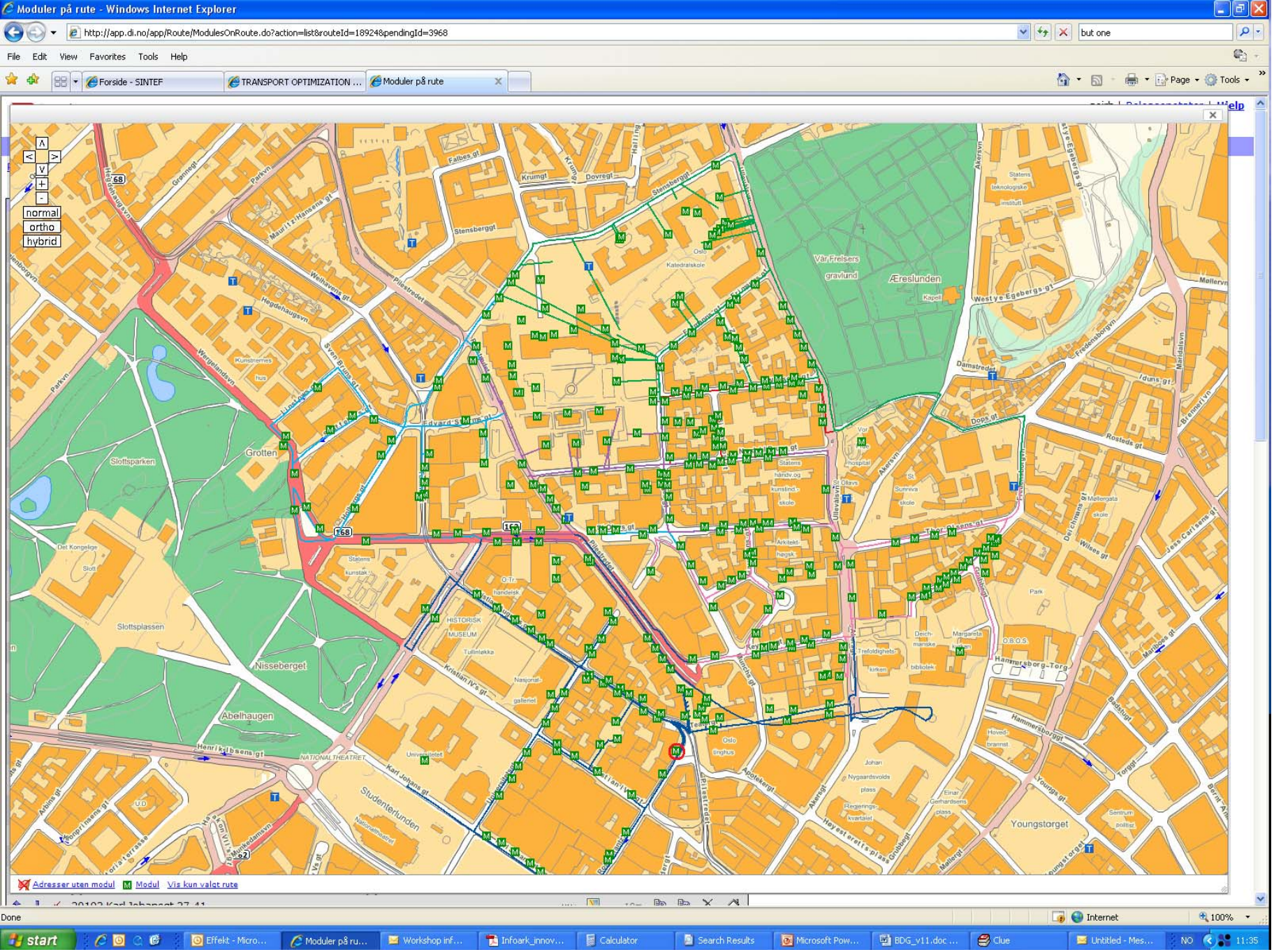
Holmen fjordhotel, Asker, April 11-13, 2010

Outline

- Newspaper and media product distribution
- Strategies for Large-Scale VRPs

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

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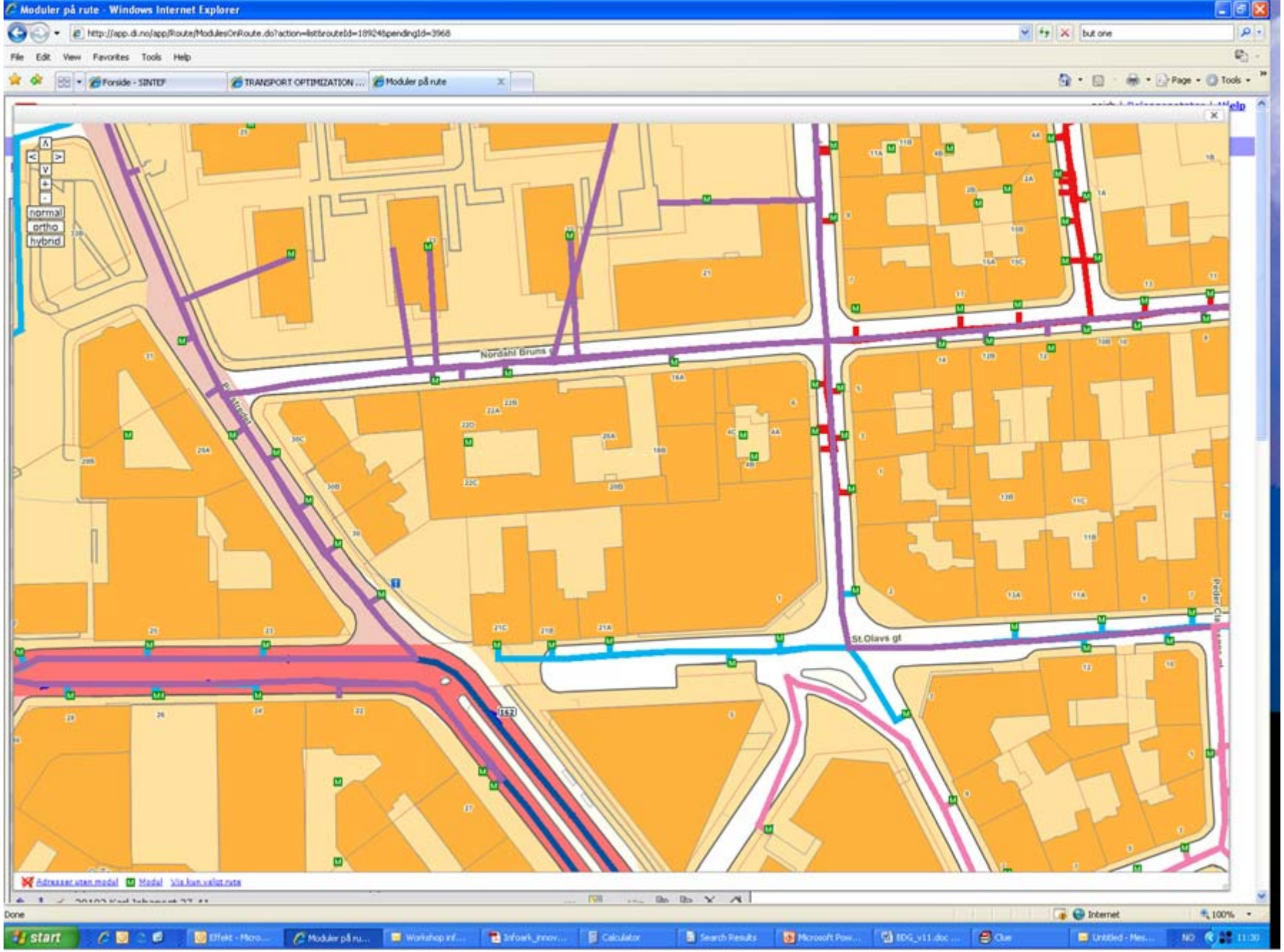
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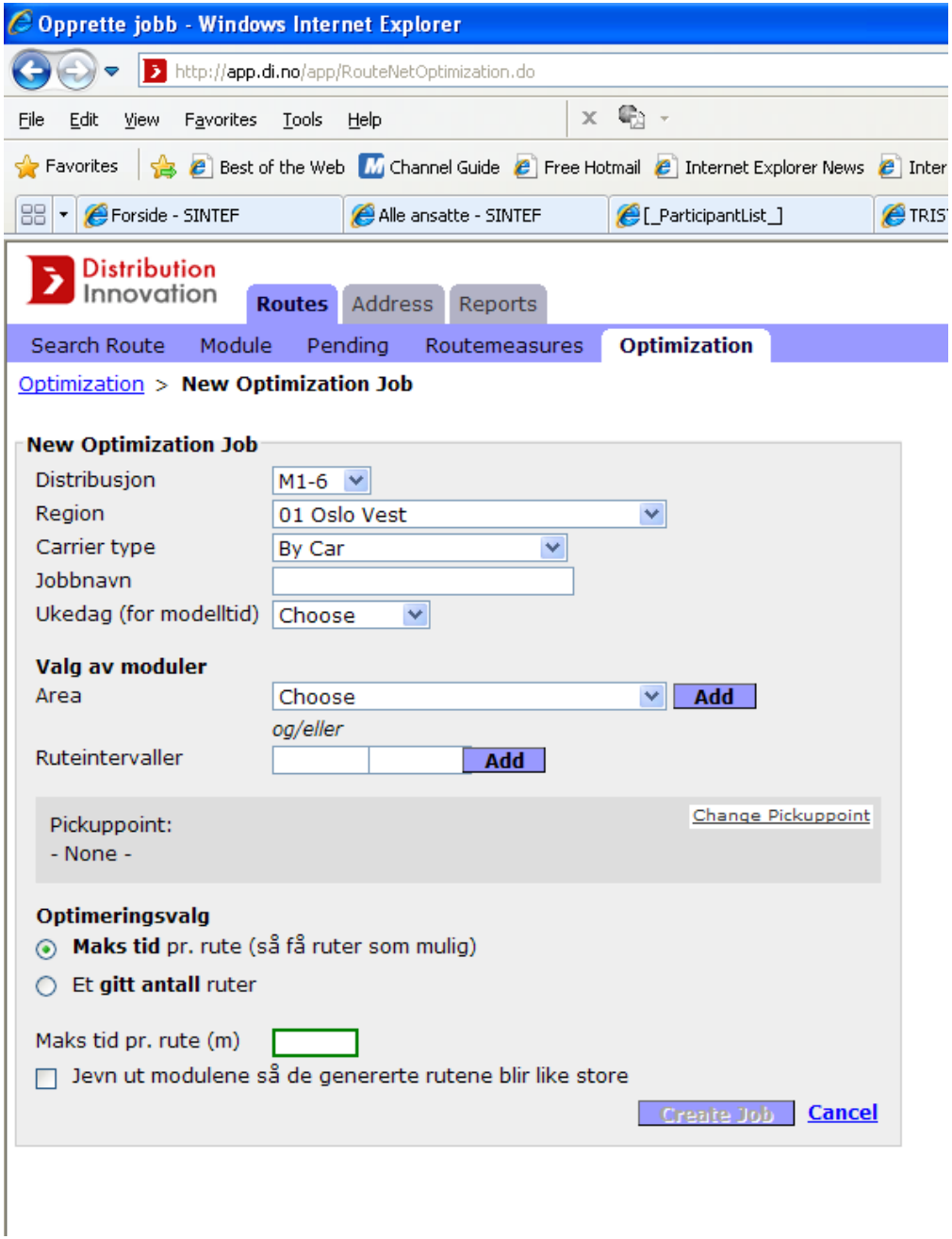
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Change Pickuppoint
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Maks tid pr. rute (så få ruter som mulig)
Et gitt antall ruter
Maks tid pr. rute (m)
Jevn ut modulene så de genererte rutene blir like store
Create Job
Cancel

1220	Geografi 02 Oslo Nord, M1-6 **Gr.4D2 -20747-751** **H/3R/K/J v.3.2** 3 ruter (168 moduler)	Optimeringsvalg By Car Friday Hentested angitt - Lukket rute - Med hentestedretur Ant. ruter: 3 Med utjevning	Lagt inn 17:40 (12.03.2010) Startet 19:00 Ferdig 19:27	**Eksportert til forfall** Ant. ruter 3 CPU-tid 27 min Iterasjoner 674051	
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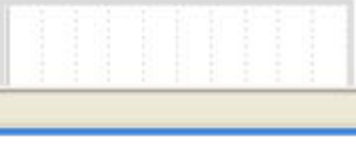
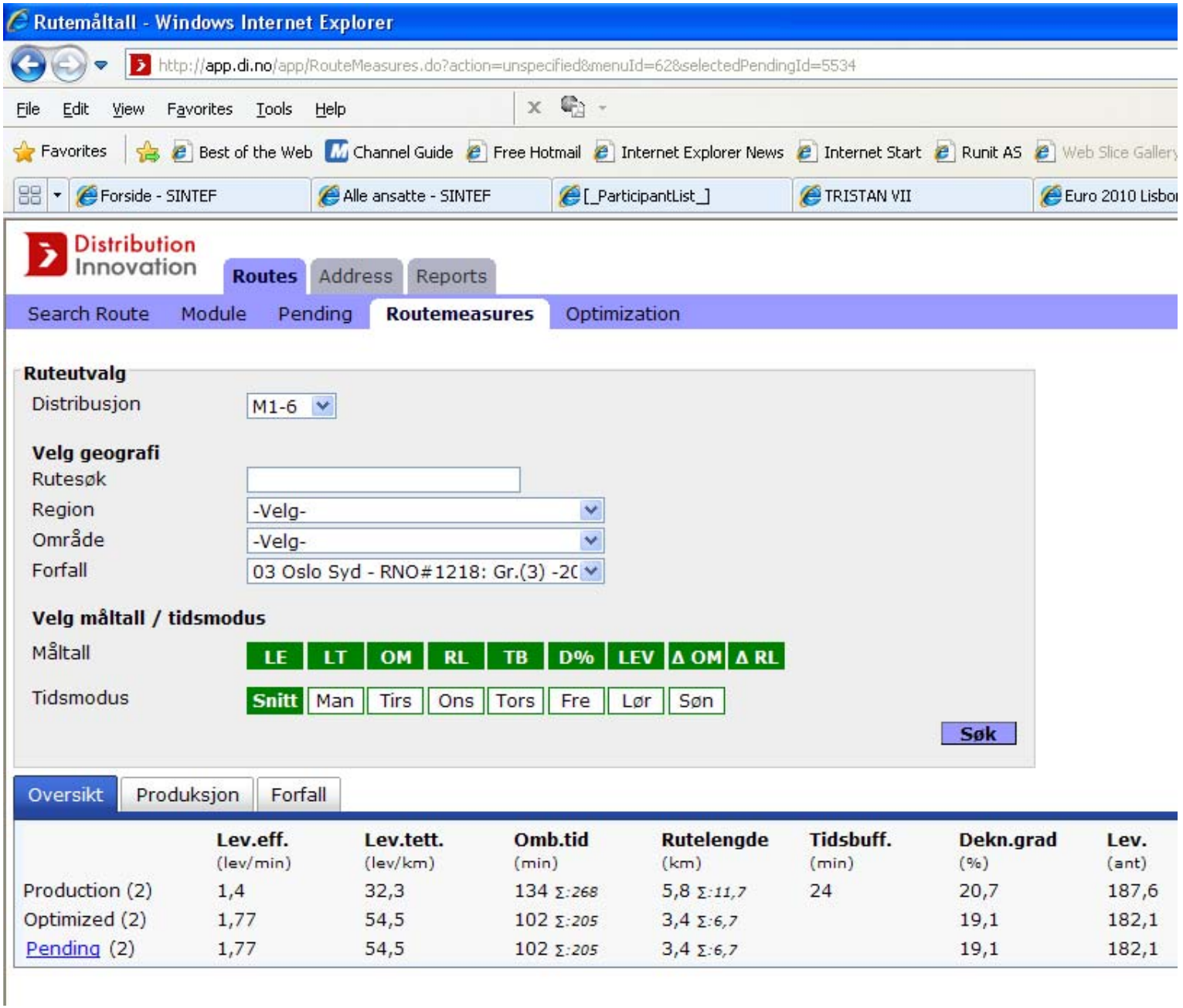
1218	Geografi 03 Oslo Syd, M1-6 **Gr.(3) -20947+949** **H/2R/G/J v.3.4** 2 ruter (182 moduler)	Optimeringsvalg By Feet Friday Hentested angitt - Lukket rute - Med hentestedretur Ant. ruter: 2 Med utjevning	Lagt inn 17:35 (12.03.2010) Startet 18:23 Ferdig 18:38	**Eksportert til forfall** Ant. ruter 2 CPU-tid 15 min Iterasjoner 270674	
1217	Geografi 03 Oslo Syd, M1-6 **Gr.(3) -20947+949**	Optimeringsvalg By Feet Friday	Lagt inn 17:34 (12.03.2010)	**Eksportert til forfall** Ant. ruter 2	



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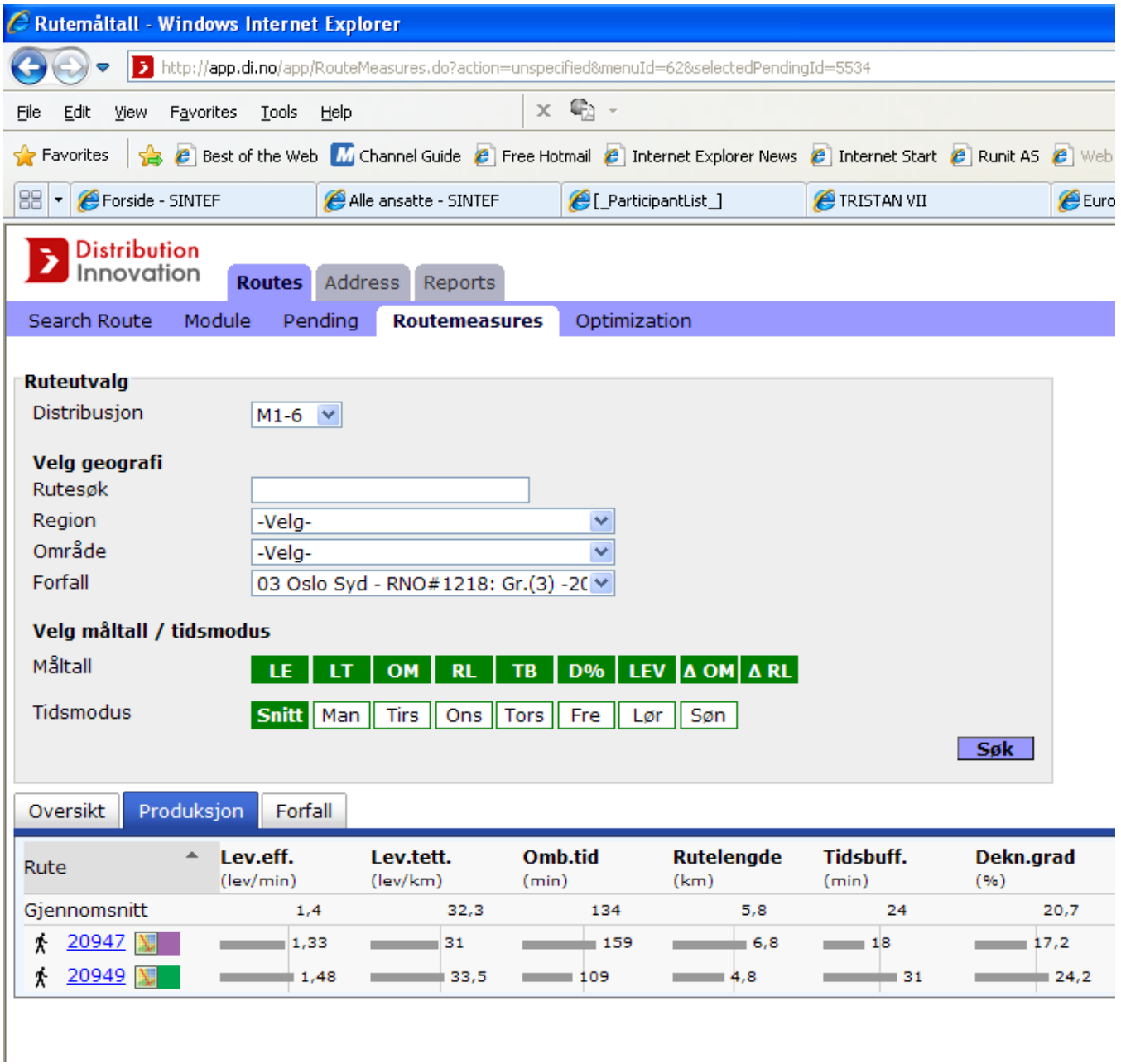
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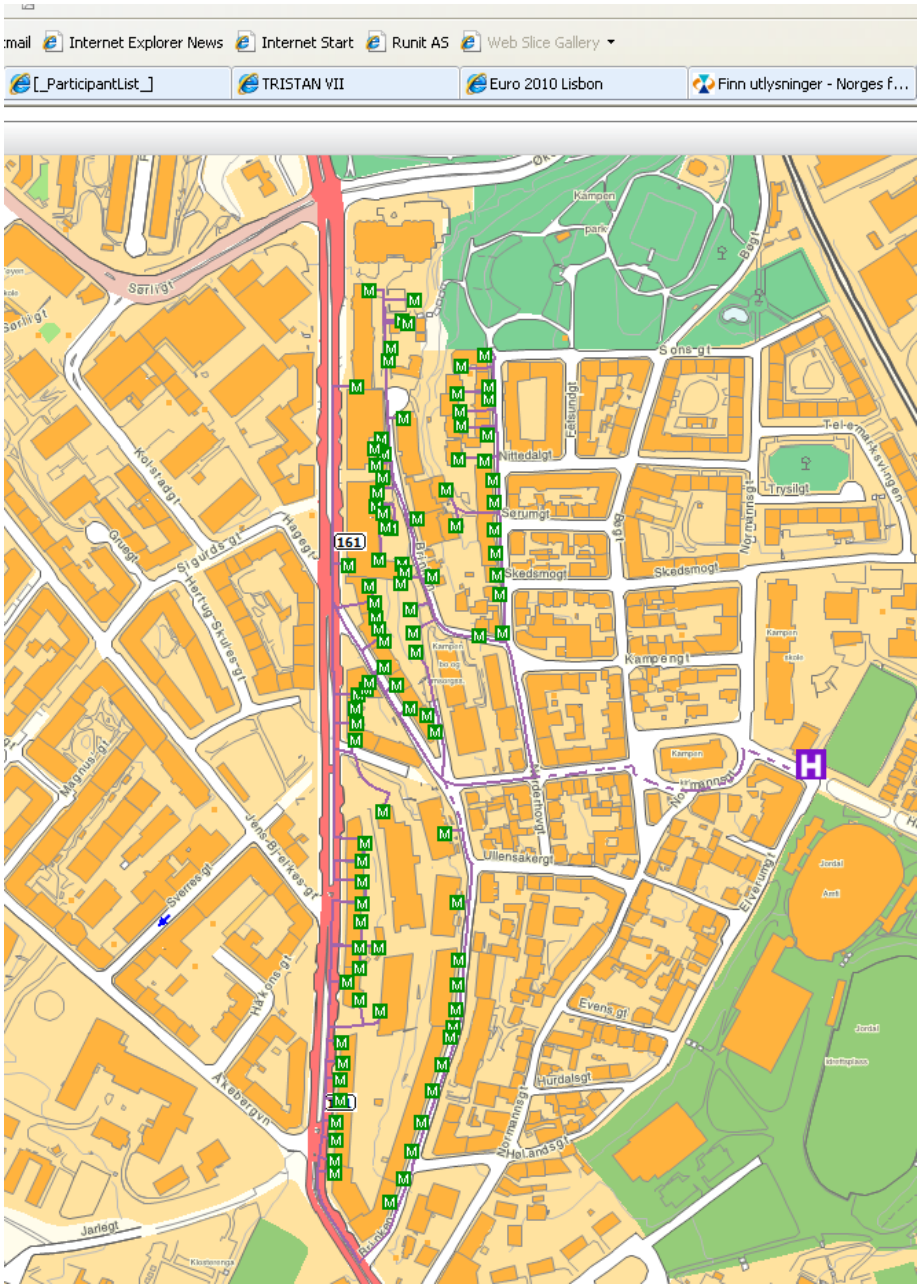
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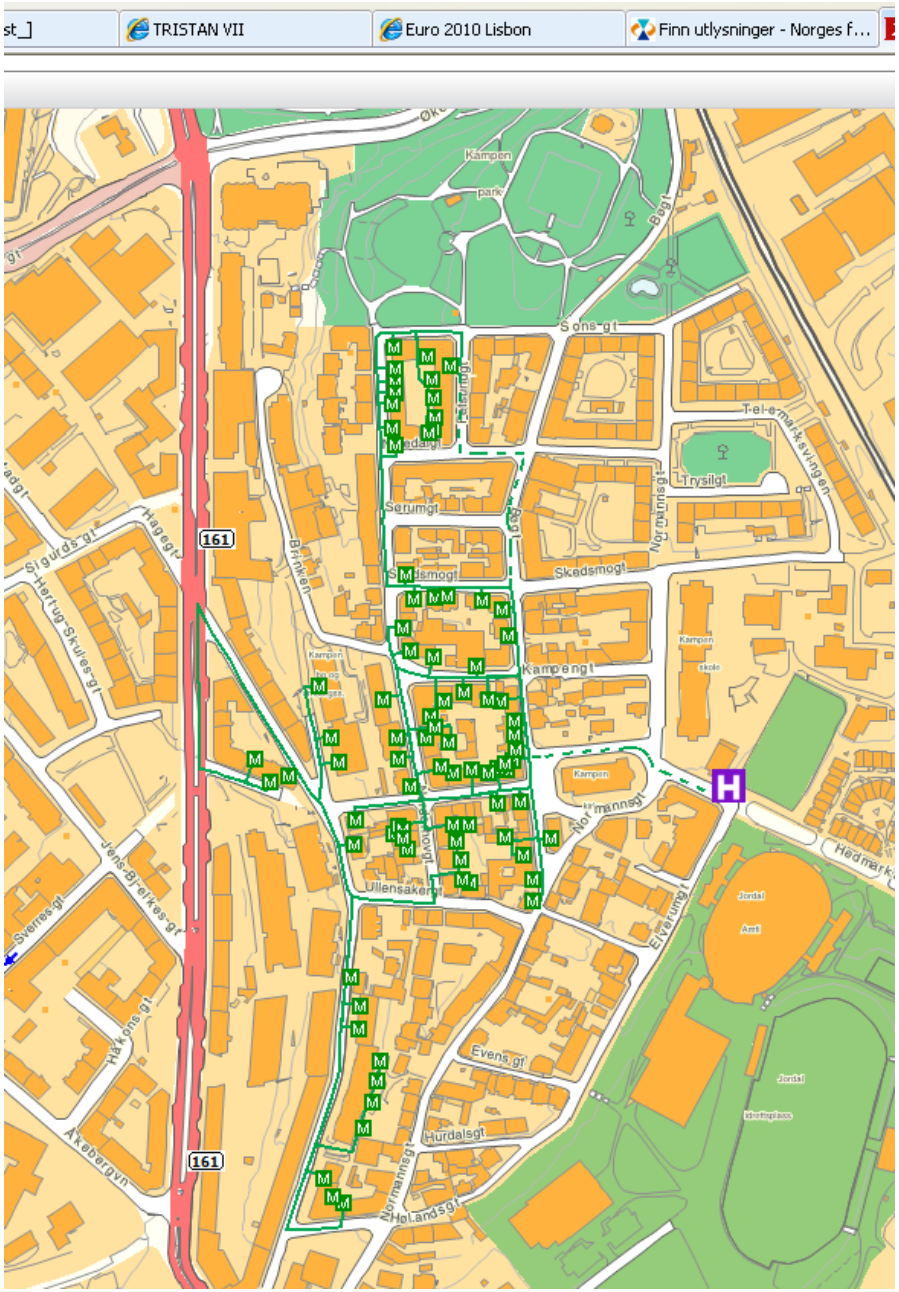
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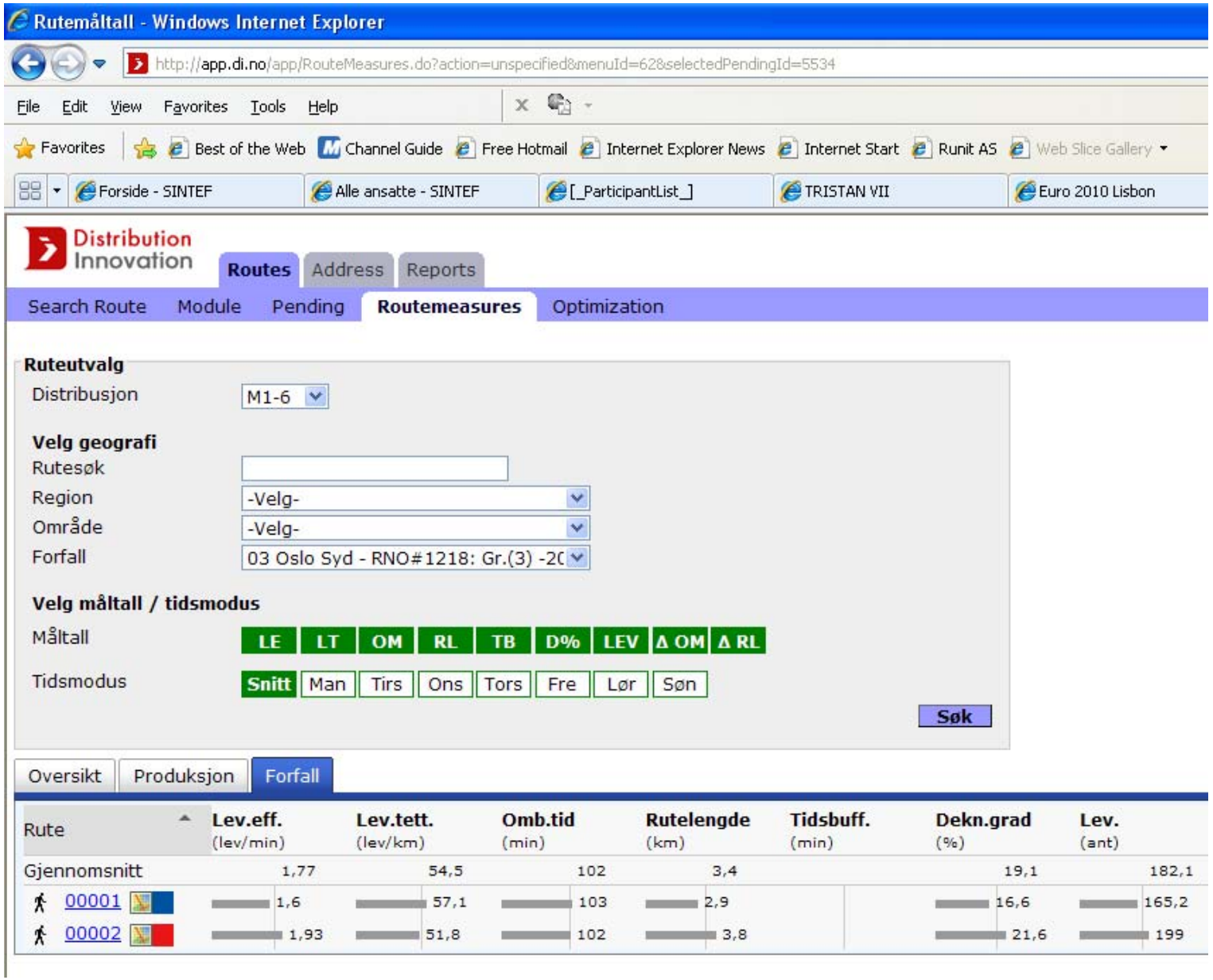
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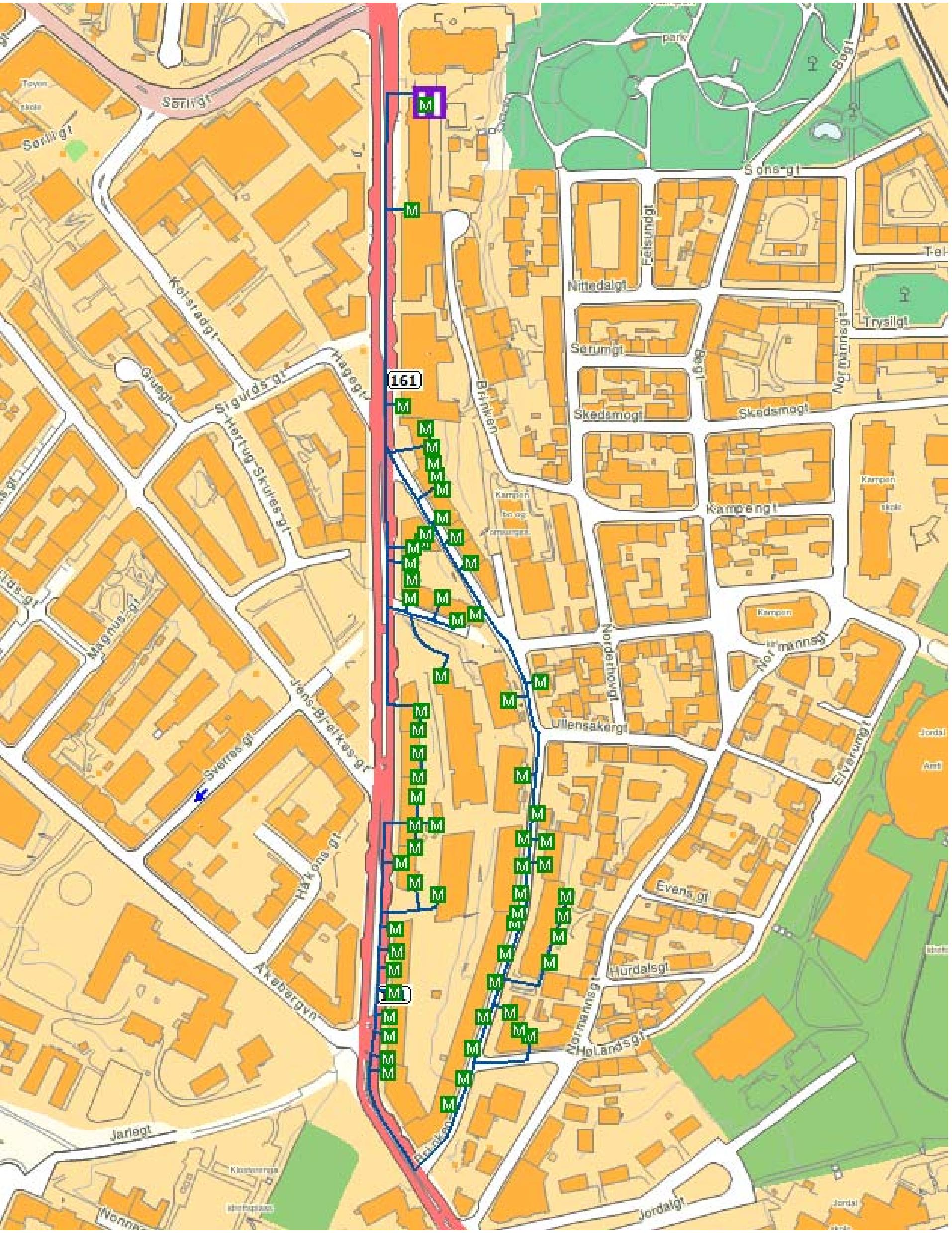
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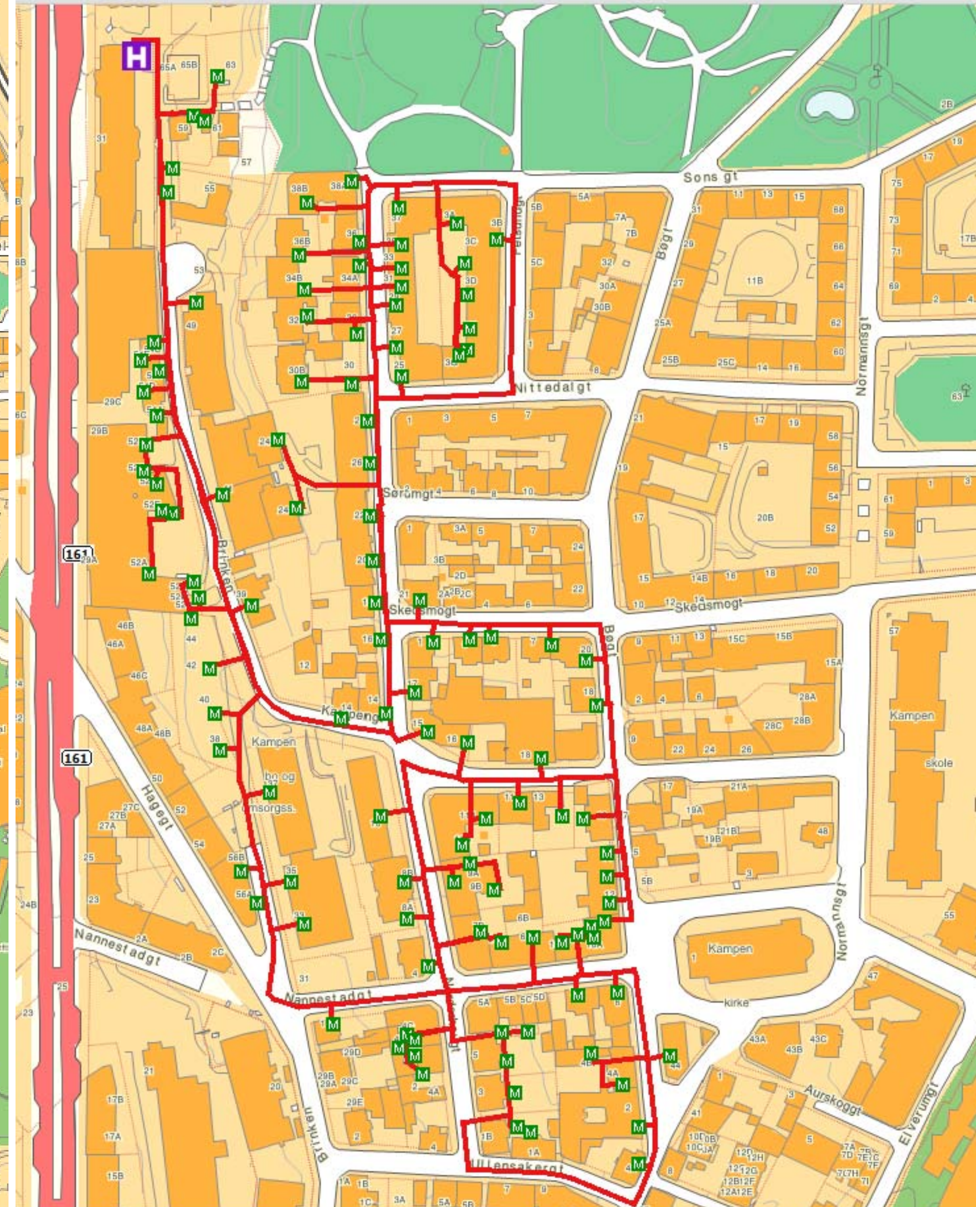
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Problem description

- Last mile part of two-tiered distribution
- (Open) DVRP with extensions
- Objectives
  - total duration
  - route balancing
  - clustering, route separation
- Constraints
  - route duration

- Determination of pickup points
- Distribution from print shop

Additional niceties

- Determination of vehicle type (pedestrian, car)
- Combined routes

Approach – until recently

- Use our rich VRP solver
  - extended with edge locations
  - abstraction/aggregation
- Problems with multiple criteria
  - clustering

SPIDER - Generalisations of CVRP

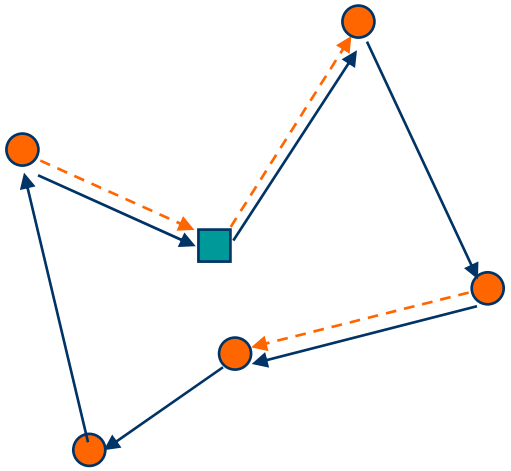
- Heterogeneous fleet
  - Capacities
  - Equipment
  - Arbitrary tour start/end locations
  - Time windows
  - Cost structure
- Linked tours with precedences
- Mixture of order types
- Multiple time windows, soft time windows
- Capacity in multiple dimensions, soft capacity
- Alternative locations, tours and orders
- Arc locations, for arc routing and aggregation of node orders
- Alternative time periods
- Non-Euclidean, asymmetric, dynamic travel times
- Compatibility constraints
- A variety of constraint types and cost components
  - driving time restrictions
  - visual beauty of routing plan, non-overlapping

Overall problem solving strategy (Spider)

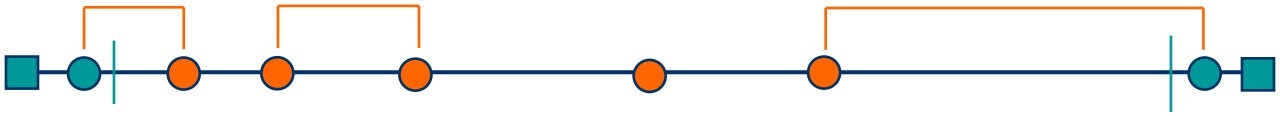
- Construction
- ILS
  - VND
  - Ruin and Recreate

Order

- Different types:
  - Delivery
  - Pickup
  - Direct (P&D)
  - Service

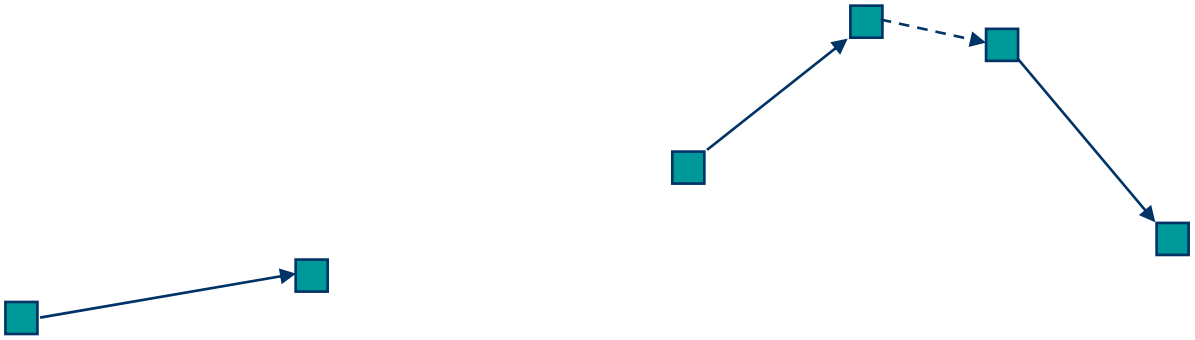


- Plan structure
  - task
  - task sequence
  - tour
  - plan



Tour

- Time windows and locations given by start/stop tasks
- Selected vehicle and driver (alternative equipages)
- Linked tours
  - (may have different vehicles)



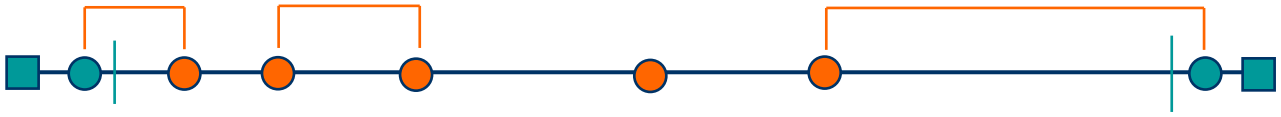
Vehicle and Driver

- Capacity
- Travelling attributes
  - Speed profile
  - Height, weight, length
  - Obey one-way restrictions?
- Driving time regulations

Cost elements

- Travel cost (distance, time, tolls)
- Tour usage cost
  - Cost for starting a tour
  - Cost per order on tour
- Cost for unserviced order
- Waiting time cost
- Cost for alternative locations
- Cost for same/different location
- Cost for breaking work regulations
- Cost for “ugly”, overlapping routes

Constraints



- Consistency
  - Complete order
  - Pickup/delivery (Direct orders) same tour and precedence
- Time
  - Travel time, Duration
  - Time windows, multiple, hard and soft
- Vehicle capacities, multiple dimensions, hard and soft
- Total capacities over a set of tours

Constraints

- Compatibility vehicle/order vehicle/location product/compartment
- Orders on same tour
- Corresponding locations (when alternatives)
  - Order: Choose corresponding locations for pickup and delivery task
  - Tour: Choose corresponding locations for start/stop tasks
- Corresponding time periods for sets of orders
  - E.g. Delivery day 1,3,5 or day 2,4,6

Locks

- Prevent optimiser changing part of plan
- Task: Time lock
- Tour: Lock whole or initial part of tour
- Order: Lock (un)assignment

Uniform Algorithmic Approach

- Goals
  - Reach a good local optimum fast
  - Explore interesting parts of search space efficiently
- 3 phases
  - Construction
  - Tour Reduction
  - Iterative Improvement: Iterated Variable Neighborhood Descent
- based on
  - Variable Neighborhood Descent (Hansen & Mladenovic)
  - Diversification when VND reaches local optimum
  - Iterated Local Search (Martin, Lourenço et al)

Construction of Initial Solution

- Various Sequential Construction Heuristics
- Extended to cover Richer Model
  - Several types of order
  - Non-standard constraints
  - Non-homogeneous fleet
  - Multiple Depots
  - Multiple Tours per Vehicle
- New Constructor
  - Inhomogeneous problems
  - Multiple depots
  - Multiple tours per vehicle
  - More search

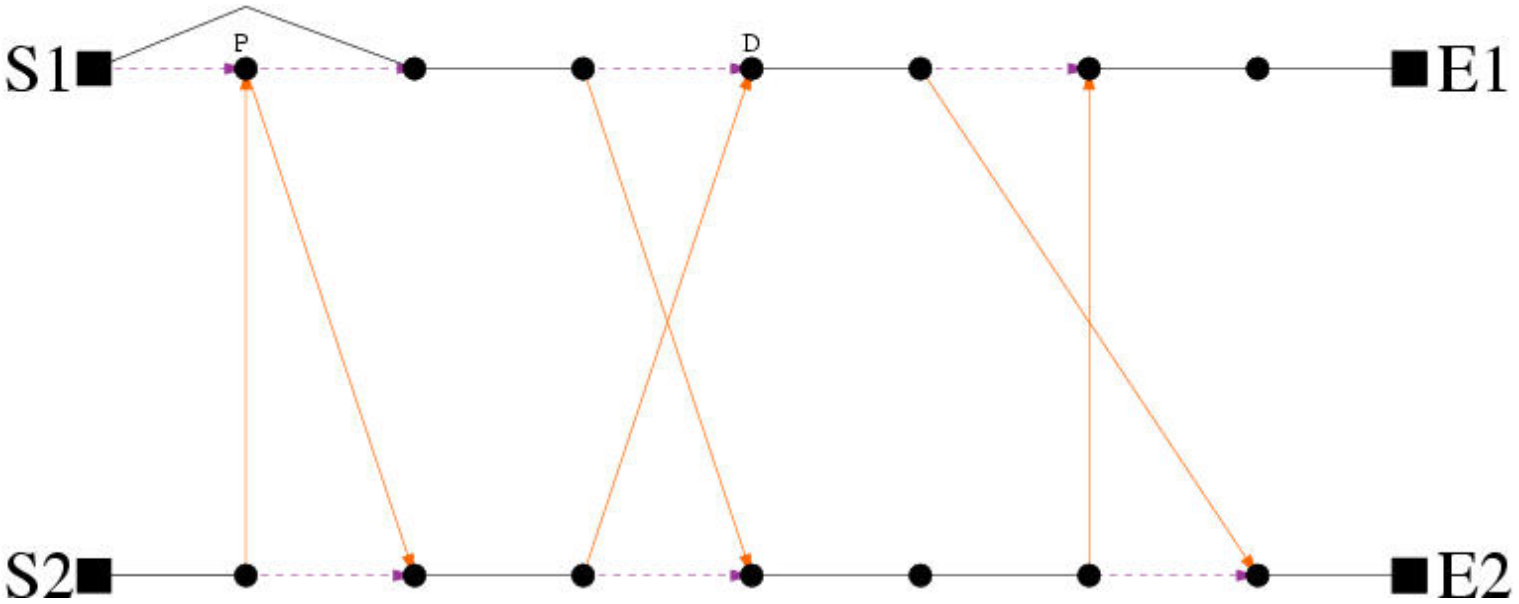
Variable Neighborhood Descent

- Repertoire of 12 operators

- Insert
- Remove
- 2-opt
- Or-opt
- 3-opt
- Relocate
- Cross (2-opt*)
- Exchange (Cross-Exchange)
- Tour Depletion
- Change alternative location
- Change alternative time period
- Change vehicle
- Variety, efficiency, sequence?

Illustration: Exchange

- Inter-tour operator
- Full neighborhood is typically large
- Remedy: Limit on maximum segment length
- Alternative: Focus on promising cut points



Iterated Local Search (Martin, Lourenço et al)

- Goal: Efficient search in new basins of attraction
- When VND reaches local optimum: diversify
- Random restart
- Alternative initial solution
- Path relinking
- Noising
- LNS, VLNS
- Change of objective

Large Neighborhood Search (Shaw)

- Take away a substantial number of commitments
  - randomly
  - “similar” commitments
- Reconstruct with fast insertion method
  - Cheapest insertion
  - Regret-based insertion
- Accept new solution if
  - better, diverse
  - Threshold Acceptance
  - Simulated Annealing
- Iterate
- Alternative modifications
  - Limited Local Search
  - Full VND Machinery
  - Distance Metrics

New approach (under development)

- Create balanced clusters from start
- Solve capacitated clustering problem
- Intra-route optimization

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

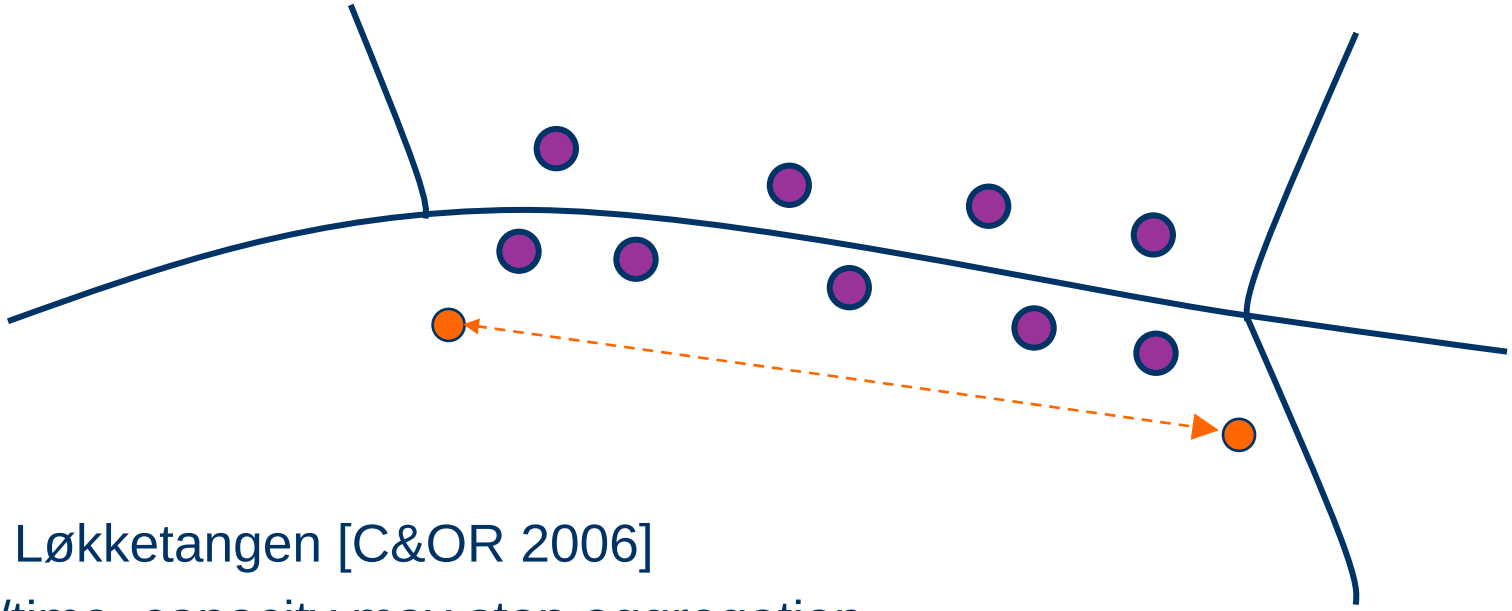
Aggregation of demand

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

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

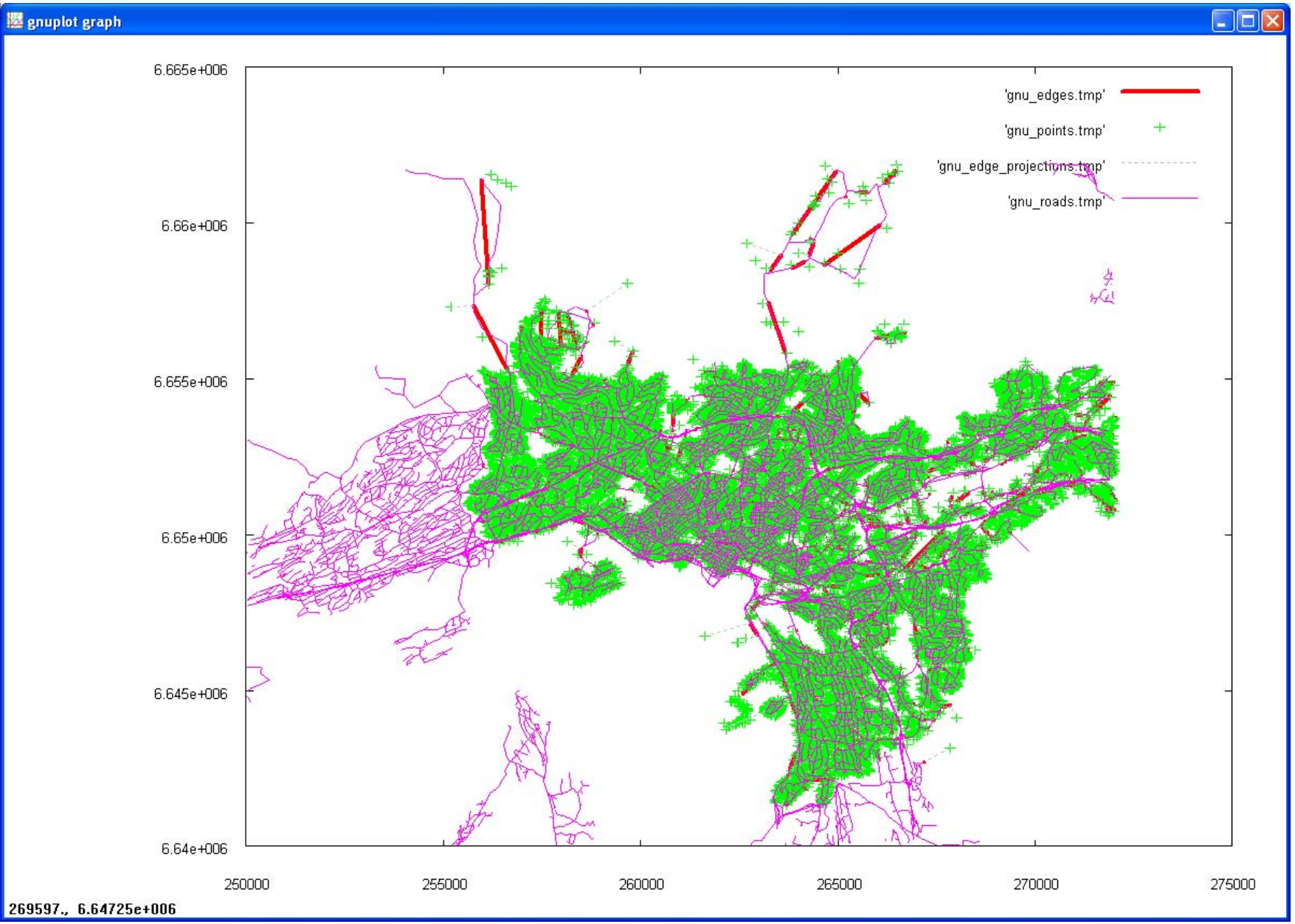
- < 10 papers in the literature

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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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
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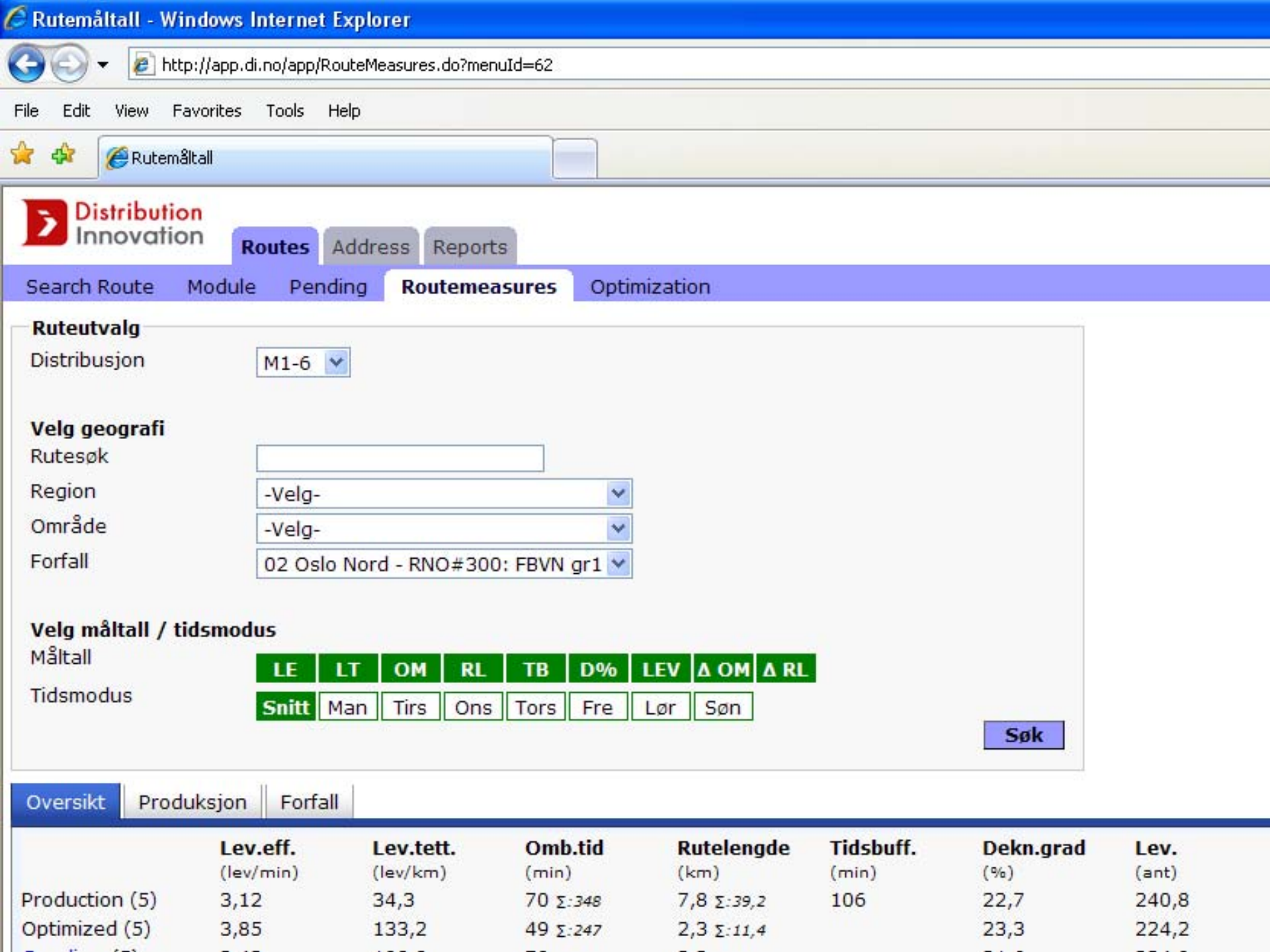
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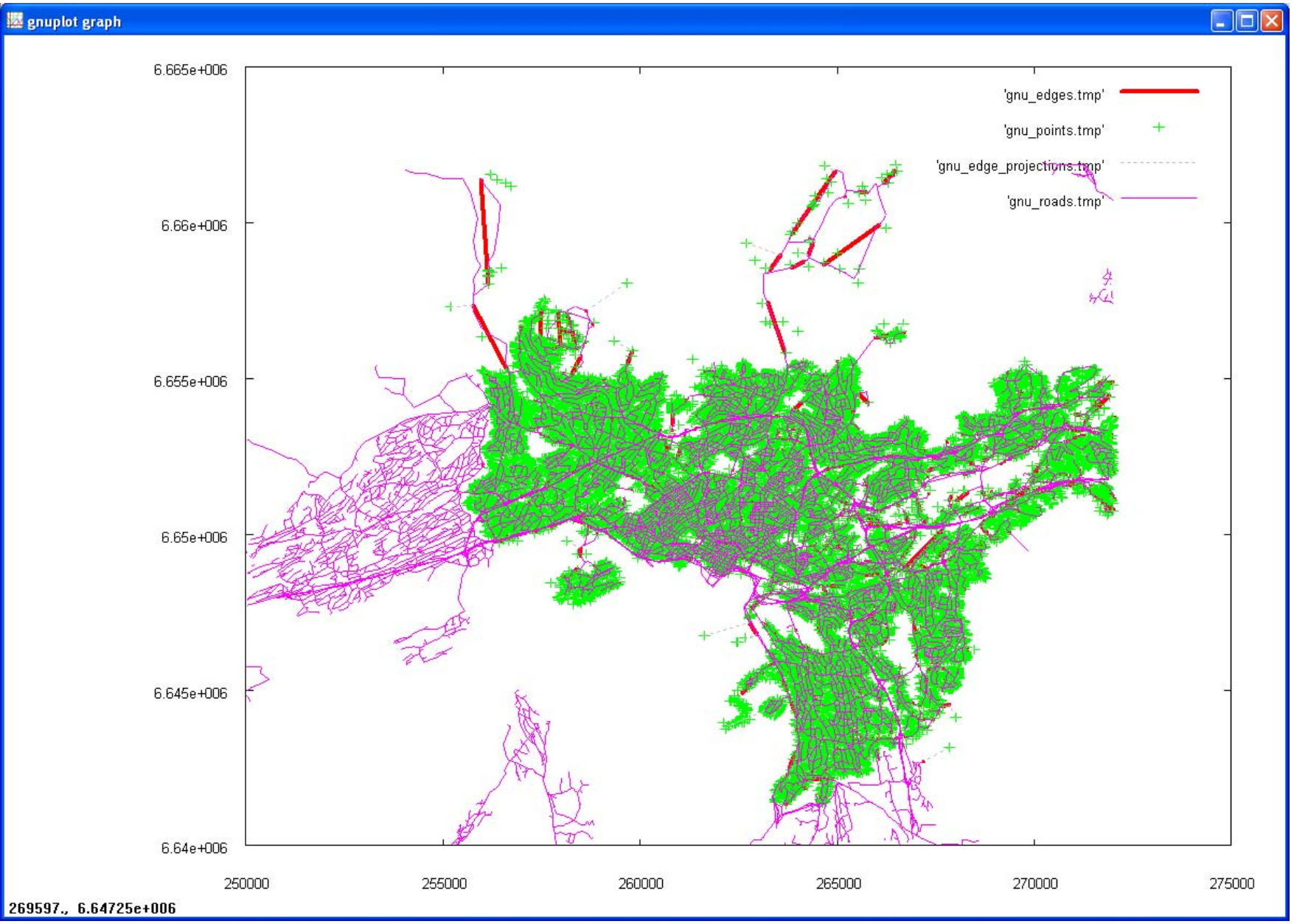
Produksjon
Forfall
Lev.eff. (lev/min)
Lev.tett. (lev/km)
Omb.tid (min)
Rutelengde (km)
Tidsbuff. (min)
Dekn.grad (%)
Lev. (ant)
Production (5) 3,12 34,3 70 Σ:348 7,8 Σ:39,2 106 22,7 240,8
Optimized (5) 3,85 133,2 49 Σ:247 2,3 Σ:11,4 23,3 224,2

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

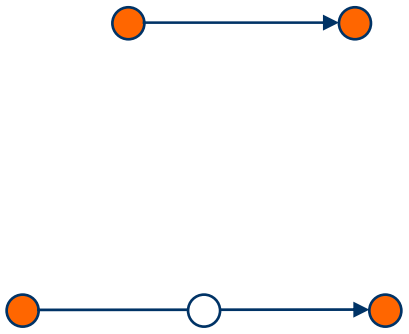


VRP solver - Spider

- 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

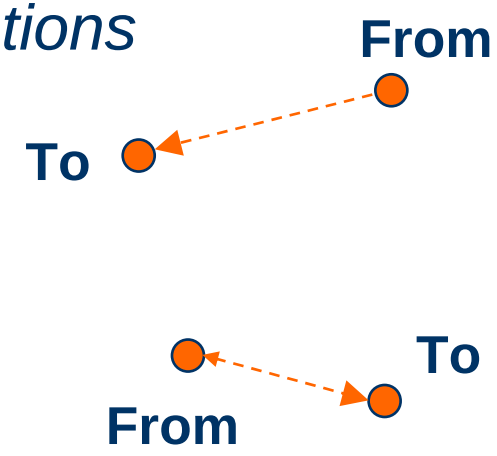
- Every task (pickup, delivery, tour start/end...) has a *location*
- Topology Module (Guider) provides distance, cost and time services:
  - $d(l_1, l_2)$, $c(l_1, l_2)$, $t(l_1, l_2)$
  - Possibly time dependent
  - Not necessarily symmetric
  - Triangle inequality holds



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

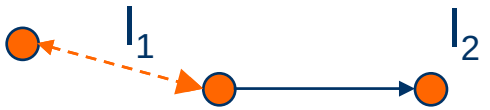
Extending locations

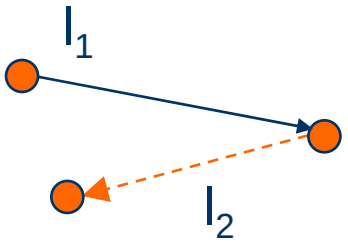
- Previously: Only *Node Locations*
- New type of locations: *Edge Locations*
- **From**: Node location
- **To**: Node location
- **Reversible**: bool

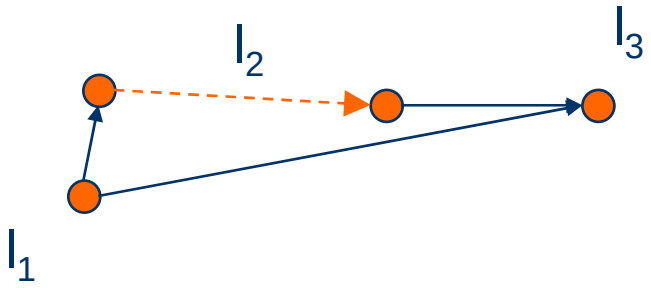


Impact on topology

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

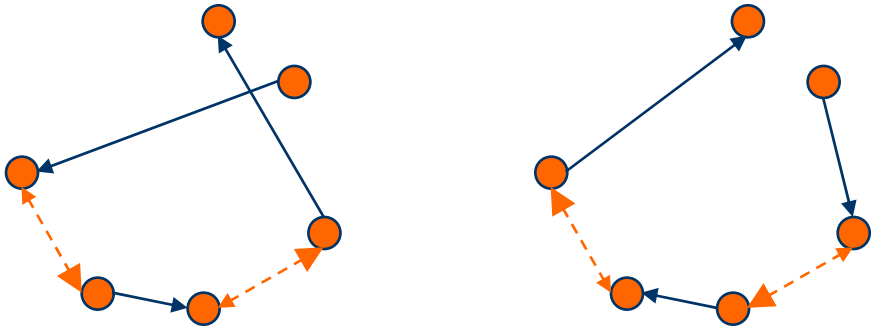






Impact on operators

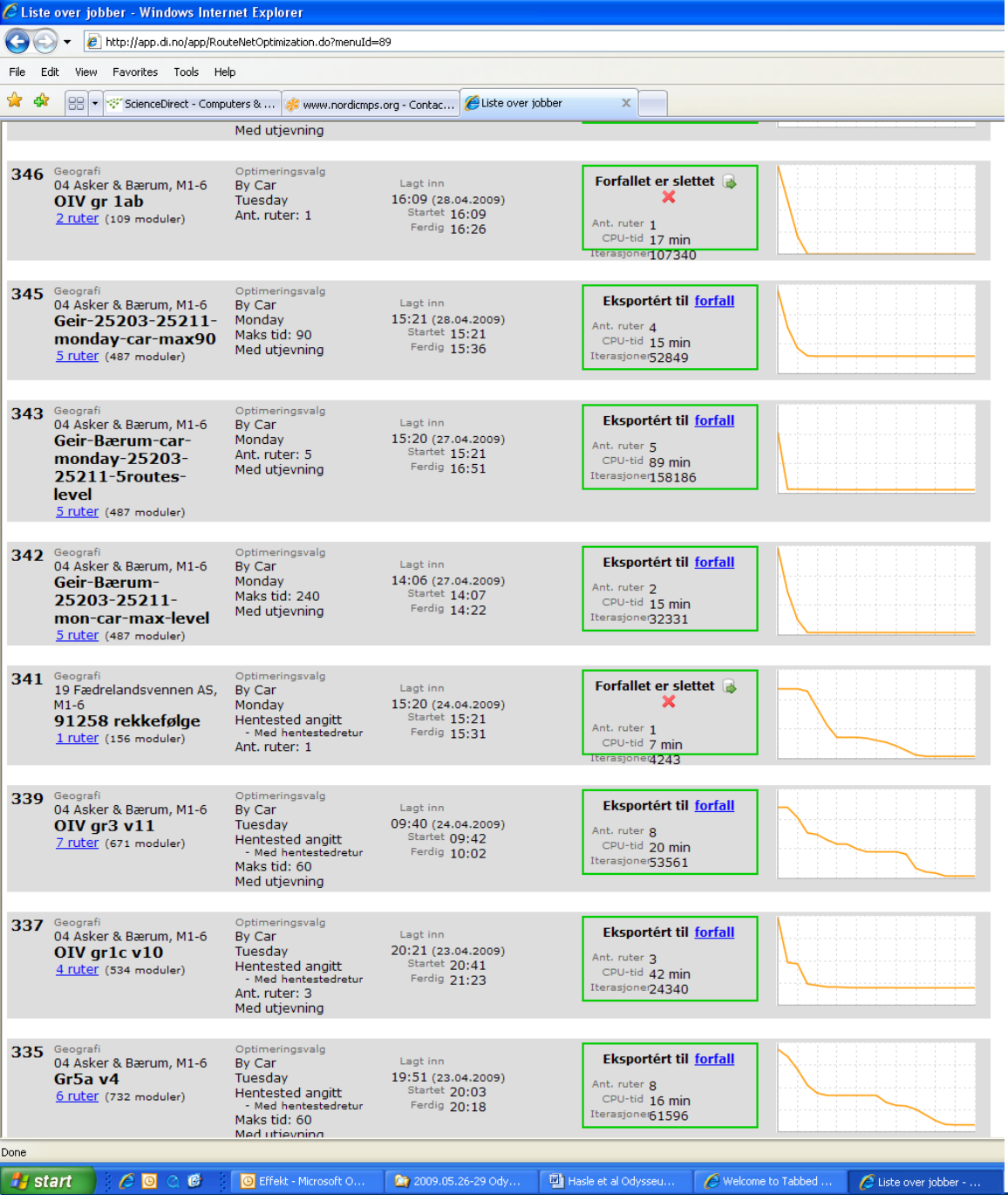
- When reversing subtours (2-opt, 3-opt), we reverse all reversible edge locations

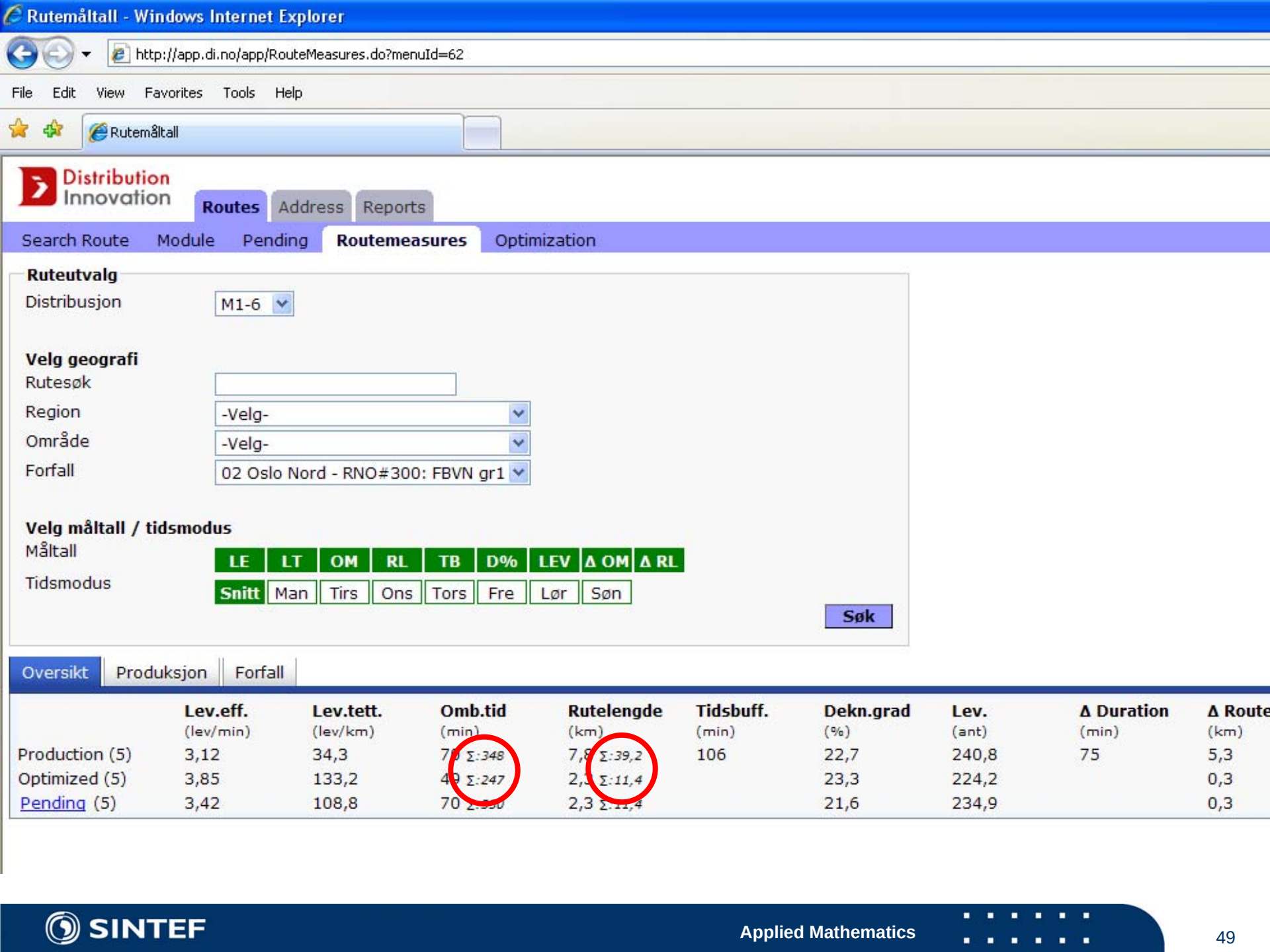


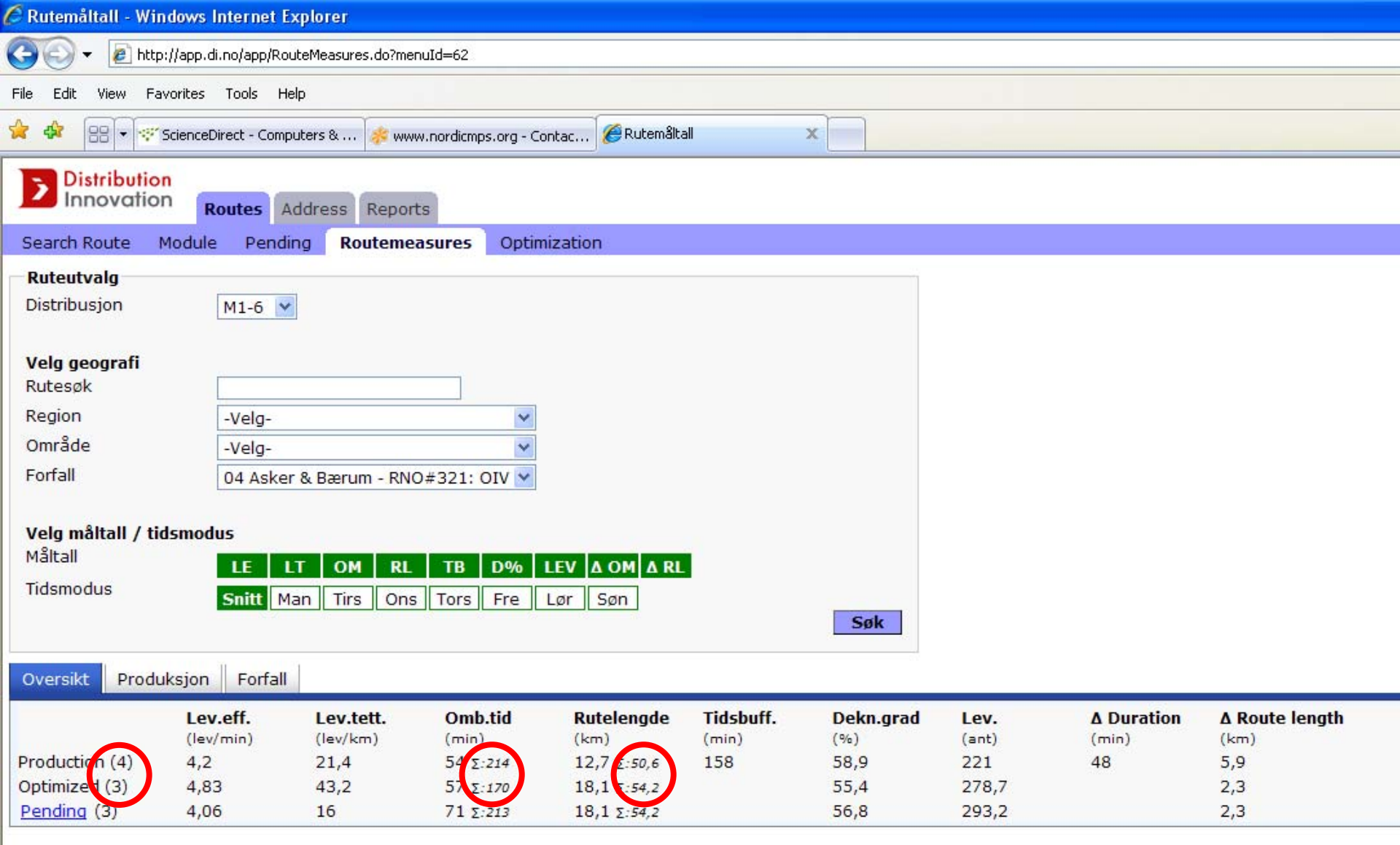
- That's it

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?


Liste over jobber - Windows Internet Explorer
http://app.di.no/app/RouteNetOptimization.do?menuId=89
File Edit View Favorites Tools Help
ScienceDirect - Computers & ...
www.nordicmps.org - Contac...
Liste over jobber
Med utjevning
346 Geografi 04 Asker & Bærum, M1-6 OIV gr 1ab 2 ruter (109 moduler) Optimeringsvalg By Car Tuesday Ant. ruter: 1 Lagt inn 16:09 (28.04.2009) Startet 16:09 Ferdig 16:26 Forfallet er slettet 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 Lagt inn 15:20 (27.04.2009) Startet 15:21 Ferdig 16:51 Eksportert til forfall Ant. ruter 5 CPU-tid 89 min Iterasjoner 158186
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 Lagt inn 14:06 (27.04.2009) Startet 14:07 Ferdig 14:22 Eksportert til forfall Ant. ruter 2 CPU-tid 15 min Iterasjoner 32331
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 Forfallet er slettet 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 Lagt inn 09:40 (24.04.2009) Startet 09:42 Ferdig 10:02 Eksportert til forfall Ant. ruter 8 CPU-tid 20 min Iterasjoner 53561
337 Geografi 04 Asker & Bærum, M1-6 OIV gr1c v10 4 ruter (534 moduler) Optimeringsvalg By Car Tuesday Hentested angitt - Med hentestedretur Ant. ruter: 3 Med utjevning Lagt inn 20:21 (23.04.2009) Startet 20:41 Ferdig 21:23 Eksportert til forfall Ant. ruter 3 CPU-tid 42 min Iterasjoner 24340
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 Ant. ruter 8 CPU-tid 16 min Iterasjoner 61596
Done
start
Effekt - Microsoft O...
2009.05.26-29 Ody...
Hasle et al Odysseu...
Welcome to Tabbed ...
Liste over jobber - ...


Rutemåltall - Windows Internet Explorer
http://app.di.no/app/RouteMeasures.do?menuId=62
File Edit View Favorites Tools Help
Rutemåltall
Distribution Innovation
Routes Address Reports
Search Route Module Pending Routemeasures Optimization
Ruteutvalg
Distribusjon M1-6
Velg geografi
Rutesøk
Region -Velg-
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
Tidsmodus Snitt Man Tirs Ons Tors Fre Lør Søn
Søk
Oversikt Produksjon Forfall
Lev.eff. (lev/min) Lev.tett. (lev/km) Omb.tid (min) Rutelengde (km) Tidsbuff. (min) Dekn.grad (%) Lev. (ant) Δ Duration (min) Δ Route (km)
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


Rutemåltall - Windows Internet Explorer
http://app.di.no/app/RouteMeasures.do?menuId=62
File Edit View Favorites Tools Help
ScienceDirect - Computers & ...
www.nordicmps.org - Contac...
Rutemåltall
Distribution Innovation
Routes
Address
Reports
Search Route
Module
Pending
Routemeasures
Optimization
Ruteutvalg
Distribusjon
M1-6
Velg geografi
Rutesøk
Region
-Velg-
Område
-Velg-
Forfall
04 Asker & Bærum - RNO#321: OIV
Velg måltall / tidsmodus
Måltall
LE LT OM RL TB D% LEV Δ OM Δ RL
Tidsmodus
Snitt Man Tirs Ons Tors Fre Lør Søn
Søk
Oversikt
Produksjon
Forfall
Lev.eff. (lev/min)
Lev.tett. (lev/km)
Omb.tid (min)
Rutelengde (km)
Tidsbuff. (min)
Dekn.grad (%)
Lev. (ant)
Δ Duration (min)
Δ Route length (km)
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

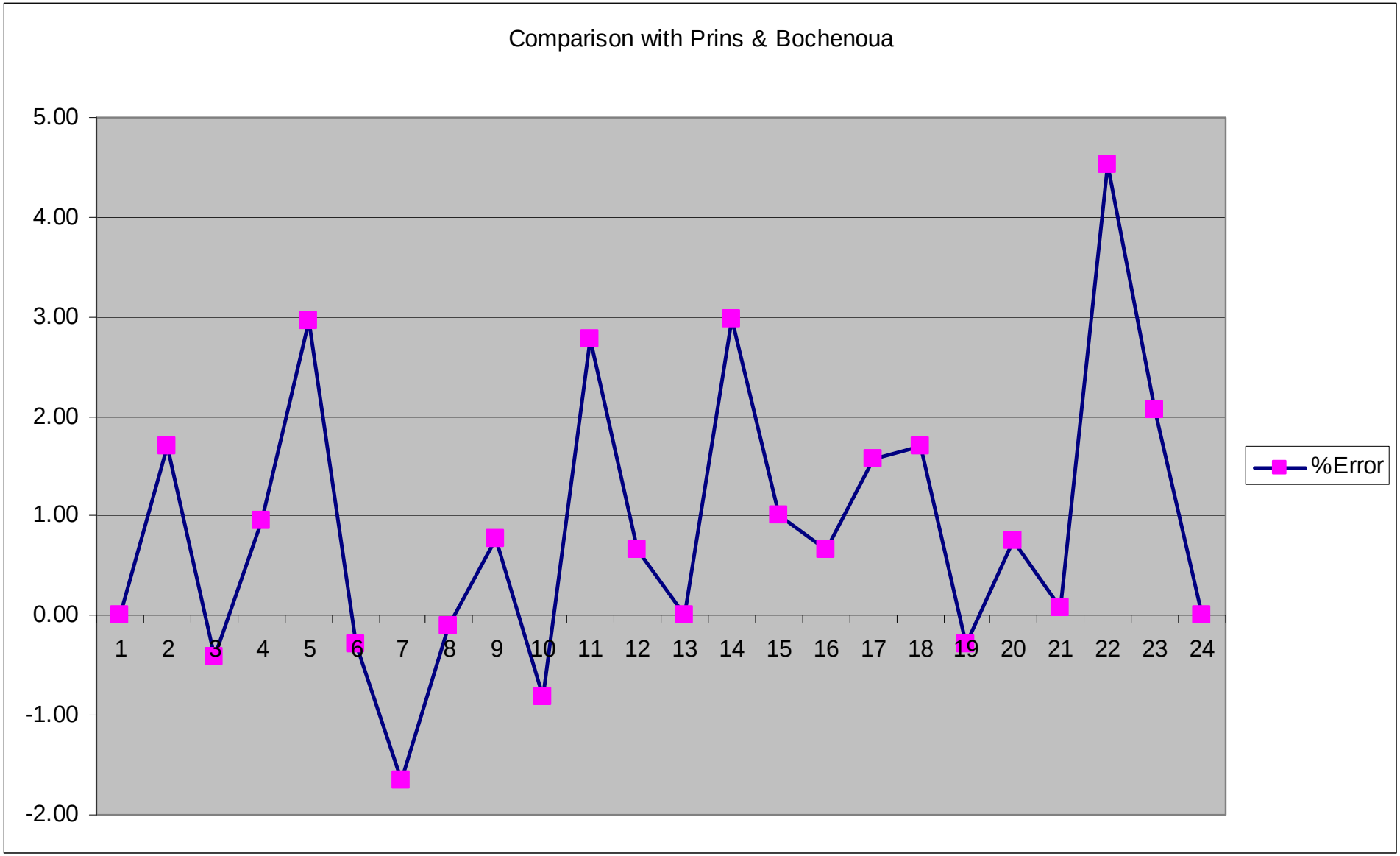
NEARP experiments

- 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
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

Media Product Distribution

Decomposition and aggregation heuristics for solving large-scale multi-criteria DVRPs

Rich VRP

Geir Hasle

1st Collab workshop

Holmen fjordhotel, Asker, April 11-13, 2010