Stuck between a rock and a hard place

The pleasures of practicing OR in a contract research organization

Geir Hasle
SINTEF ICT, Oslo, Norway

LANCS Initiative Advisory Board Meeting
London, 18 May 2010

Outline

- Personal background
- Contract research organisations
- OR at SINTEF
- VRP Research and Technology Development (RTD)
- Important challenges
- Reflections

Career

- 31 years at SINTEF ...
- The Medal for Long and Faithful Service
  The Royal Norwegian Society for Development

- Harassment

Technology for a better society

SINTEF

- An Independent Multi-Disciplinary Contract R&D Organisation
- Established in 1950
- Among the Largest CRO in Europe

Vision:

- Technology for a better Society

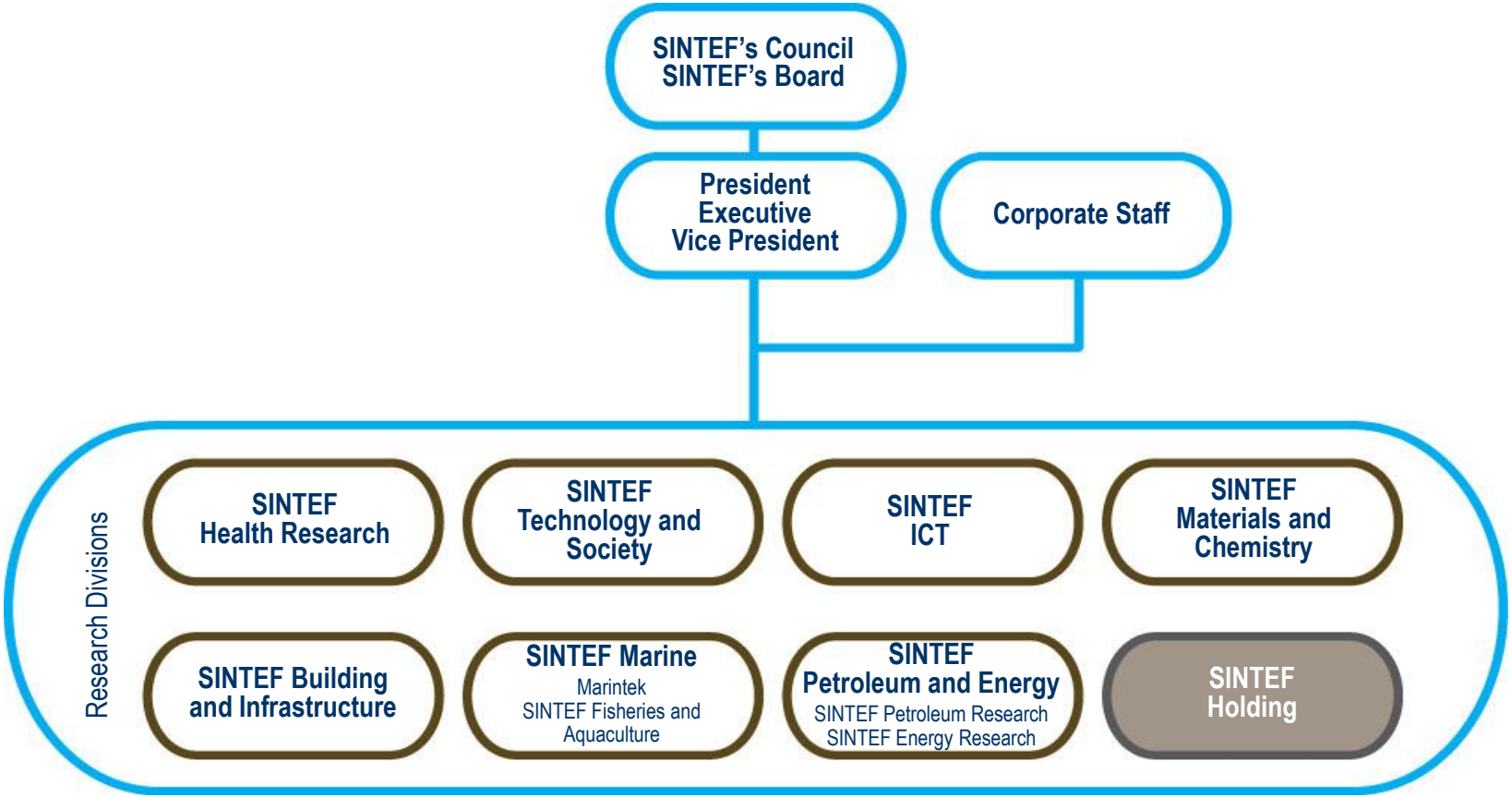
Business Concept:

- To meet the needs for Research-Based Innovation and Development for the Private and Public Sectors

SINTEF - A Norwegian Contract Research Institute

- Science and engineering – social sciences, health care
- Connected with
  - The Norwegian University of Science and Technology, Trondheim
  - The University of Oslo, Faculty of mathematics and natural sciences
- > 90 % of turnover from industry and public sector contracts
- Annual turnover ~ 270 M£
- Activities
  - Strategic, long term, basic research
  - Contract Research
  - Consultancy
  - Commercialization and spin-offs

The SINTEF Group



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Bridging the gap between academia and industry

Life at a CRO

- Almost a real job
- Not (publish or perish)
- Acquire contracts
- Build networks and consortia
- Keep clients happy
- Manage projects
- Deliver project results, on time, on budget
- Economical success
- Keep employees happy
- Recruit good people
- Range of activities in the RTD value chain
- Publish, to be attractive

- Different from academia, or industry?

Stuck between a rock and a hard place

Not as bad

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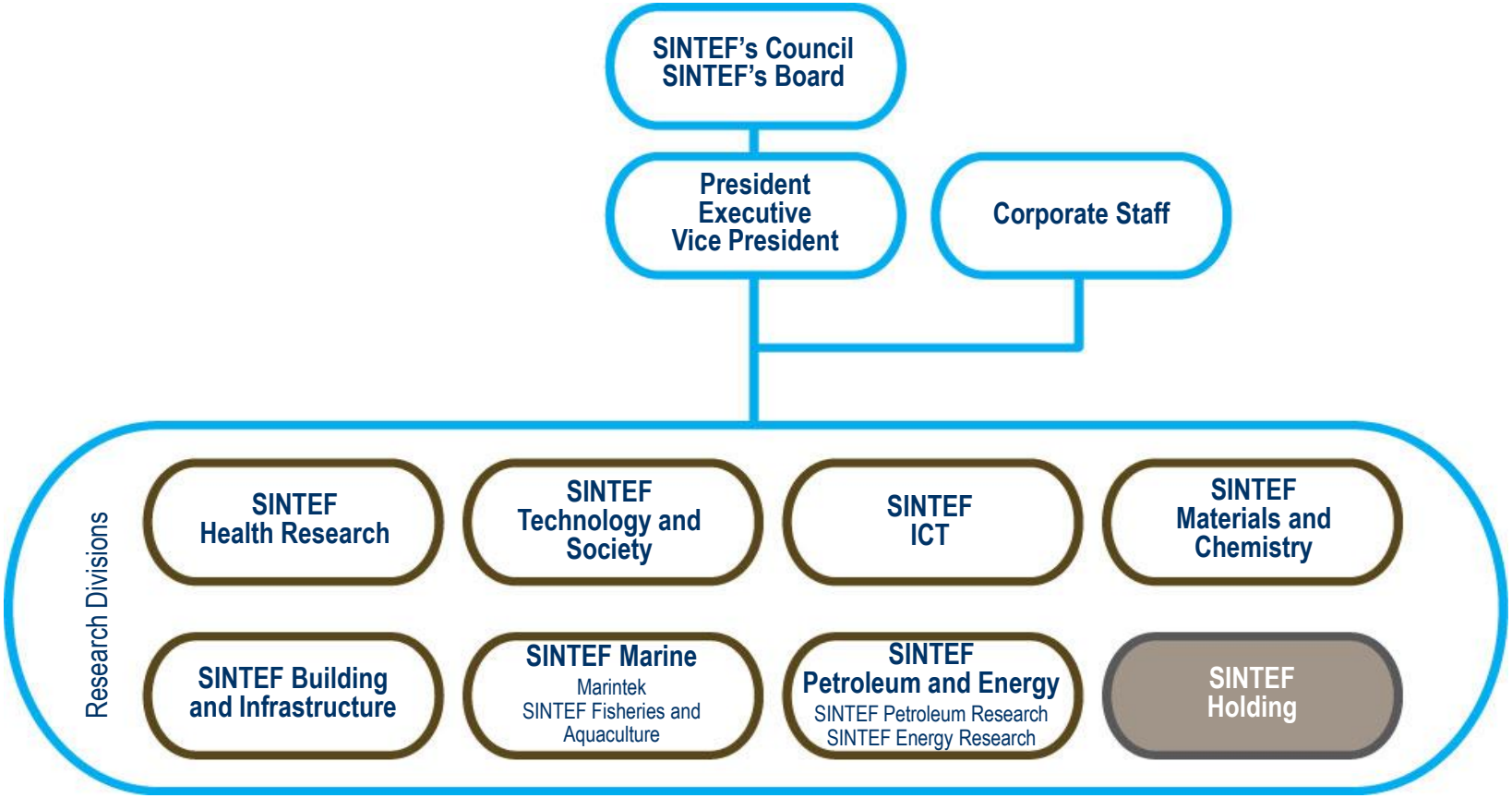

Main objective

To improve the performance of core business processes in industry and the public sector through tailored, high performance optimisation tools

Products and Services

- Optimisation kernels, components
- Prototypes
- Analyses
- Development of methods, techniques, algorithms
- Generic software libraries
- Focus
  - scheduling
  - routing
  - sequencing

The Way We Work

- Understanding the end user requirements
- Specification of optimisation kernel
- Analysis, identification of alternative approaches
- Detailed design
- Coding and module testing
- Empirical investigation
- Selection and tuning of optimisation technique
- Testing

- Reuse, generic sw libraries
- Understanding the problem
  - literature
  - collaboration

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Research on Rich VRPs & related problems at SINTEF

- Industrial Contracts since 1995
- Strategic Research
  - European Commission FP III, IV, V (e.g., GreenTrip 1996-1999)
  - Norwegian Research Council (RCN)
  - Internal Projects, students
- Generic VRP Solver - Spider (1995→)
  - Commercialization from 1999
  - GreenTrip AS → Spider Solutions AS
- TOP Programme 2001-2004 (RCN) http://www.top.sintef.no/
  - Basic Research on Rich VRP and related problems
  - VRPTW
  - Shortest Path Problem in Dynamic Road Topologies
- Innovation Projects supported by Research Council of Norway
  - "I Rute" (2001 – 2004) Bulk transportation
  - "DOiT" (2004 – 2007) Stochastic and Dynamic Routing
  - "EDGE" (2005 – 2008) Large Scale Routing
  - "Effekt" (2008 – 2011) Media Product Distribution Routing
- Ship routing
  - TurboRouter 1995 ->
  - SINTEF Internal Strategic Project (2005-2008)
  - LNGShipping

VRP in Operations Research

- General, idealized formulations
- Extensions studied in isolation
  - time windows
  - multiple depots
  - inventory constraints
  - ....
- Very fruitful for
  - understanding VRP variants
  - developing highly targeted algorithms
- Not always relevant to real-life problems
- Some application specific work
- Recently: More holistic approach: ”Rich VRPs”
  - General model, many aspects of industrial problems
  - Robust algorithms

Industrial aspects – VRP tool

- Adequate model of the applications
- Wide range of applications
- High quality information
  - addresses
  - distances, times, costs
  - orders
  - fleet and driver information
- Manual planning, user interface
- Ease of use
- Software issues
  - Integration with ERP etc.
  - Extendability
  - Maintainability
  - Documentation
- High quality solution in short time – powerful VRP solver

Industry needs rich VRP models

- Type of service and operation
  - multiple depots, no depot
  - different order types (delivery, pickup, direct, service, ...)
  - order splitting, flexible order volumes
  - node routing, arc routing, mixed
  - multiple tours per day
  - periodic problems
  - connection to inventory and manufacturing
- Constraints
  - capacity, several dimensions, hard and soft
  - time windows, multiple, hard and soft
  - precedences
  - (in)compatibilities
- Realistic distances, times, costs
- Cost components
  - multiple criteria
  - soft constraints and penalties
- Uncertainty and Dynamics

Typical Development Process

- Requirements from broad set of applications
- General conceptual model
- Develop solver
- Efficient and robust algorithms
- Assessment vs real life applications and literature benchmarks
- Extensions and improvements

Spider - A Generic VRP Solver

- Designed to be widely applicable
- Based on generic, rich model
- Predictive route planning
- Plan repair, reactive planning
- Dynamic planning with stochastic model

- Framework for VRP research

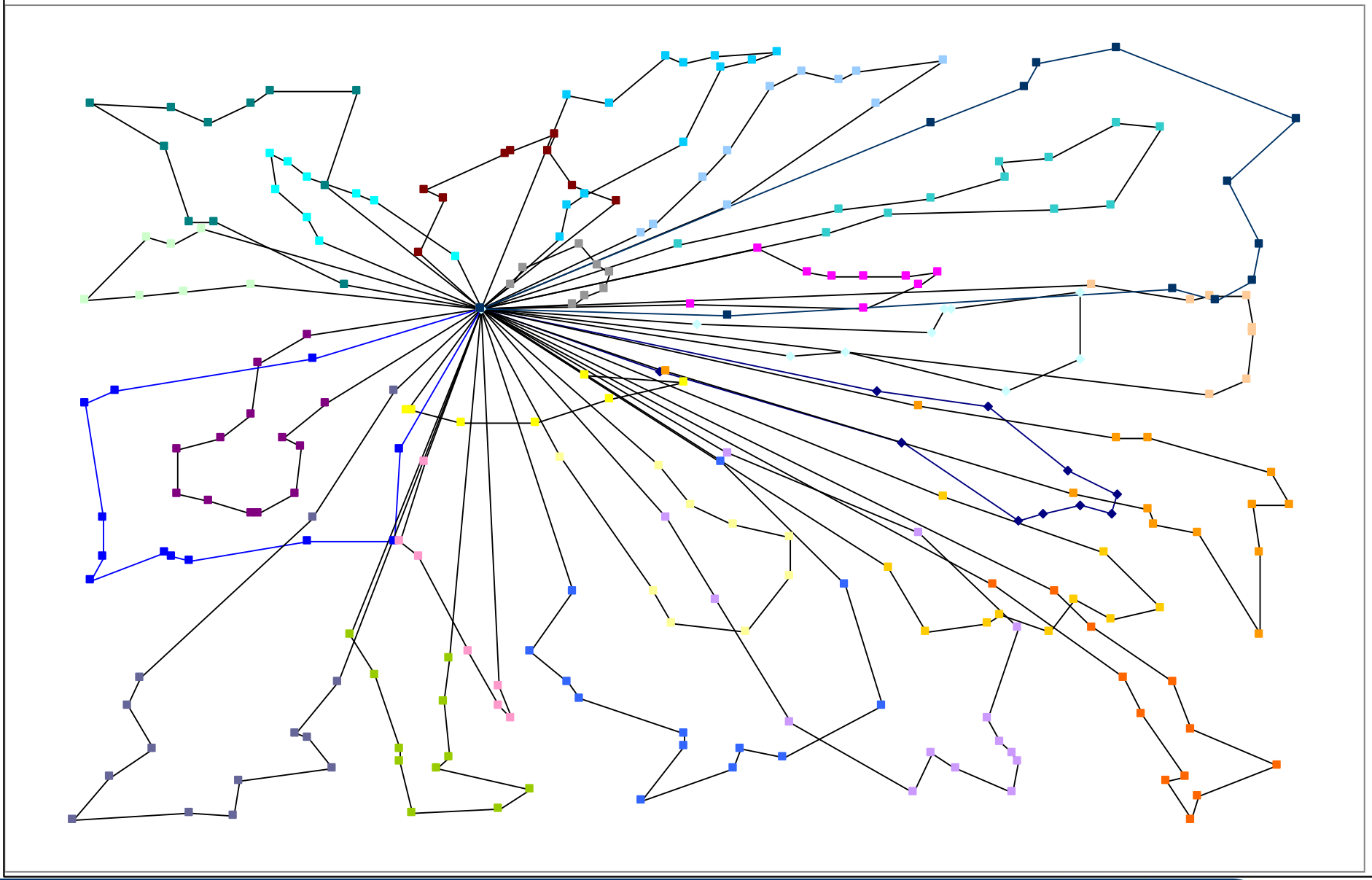
SPIDER - Generalisations of CVRP

- 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, mixed problems and aggregation of node orders
- Alternative time periods
- Non-Euclidean, asymmetric, time-varying travel times
- Compatibility constraints
- A variety of cost components and soft constraints
  - driving time restrictions
  - visual beauty of routing plan, non-overlapping routes
  - levelling

Uniform Algorithmic Approach

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

G-n262-k25: 5685 vs. 6119

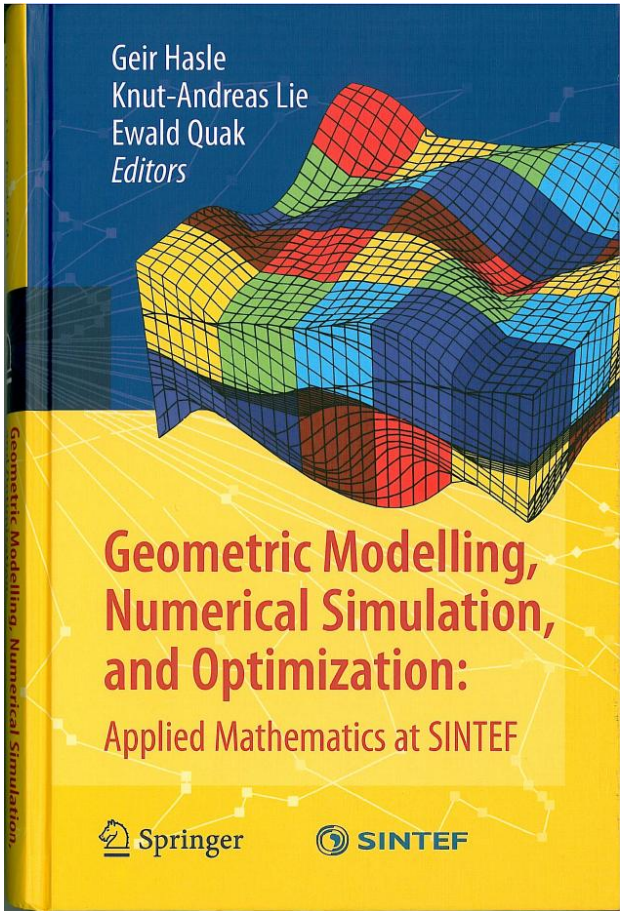


Spider Designer - Applications

- Distribution of bread (Bakers)
- Mail collection and distribution (Posten Norge)
- Local pickup and delivery (Schenker)
- Newspaper distribution, 1st tier (Aftenposten, Dagbladet)
- Newspaper distribution, last mile (Aftenposten, Stavanger Aftenblad)
- Collection of milk from farms (TINE)
- Distribution of fodder to farms (Landbruksdistribusjon)
- Distribution of fuel oil (Hydro Texaco)
- Location analyses, depot (obnoxious facility location, Norsk Gjenvinning AS)
- Distribution of blood (Ullevål sykehus)
- Distribution of groceries (REMA 1000)
- Distribution of magazines (Bladcentralen)
- Distribution of ice cream (Diplom Is; Hennig Olsen)
- Dial-a-ride, elderly, hospital patients (Nor-Link)

- Savings 2-35%, depending on application

Geir Hasle and Oddvar Kloster: *Industrial Vehicle Routing*.
Chapter (pp 397-435) in
Hasle, Geir; Lie, Knut-Andreas; Quak, Ewald (Eds.)
Geometric Modelling, Numerical Simulation, and Optimization:
Applied Mathematics at SINTEF
2007, XI, 558 p. 162 illus., 59 in color., Hardcover. ISBN: 978-3-540-68782-5
http://www.springer.com/



Invent – A generic solver for maritime inventory routing problems

Invent is a software library that can model and solve a wide class of maritime routing problems. This includes both traditional tramp shipping and industrial shipping problems with inventory management.

Vessels can be modeled at tank level with the possibility of detailed tank stowage and cleaning operations.

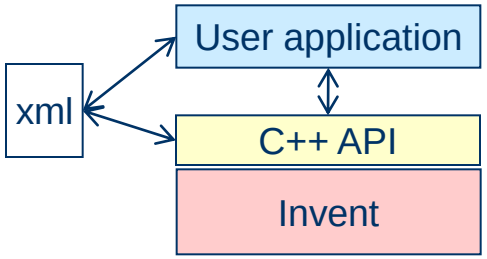
Inventories can have a time varying production or consumption profile together with an upper and lower limit on the inventory level.

The inventories can be combined with traditional orders with laycan and quantity intervals for a pair of pickup and delivery locations.

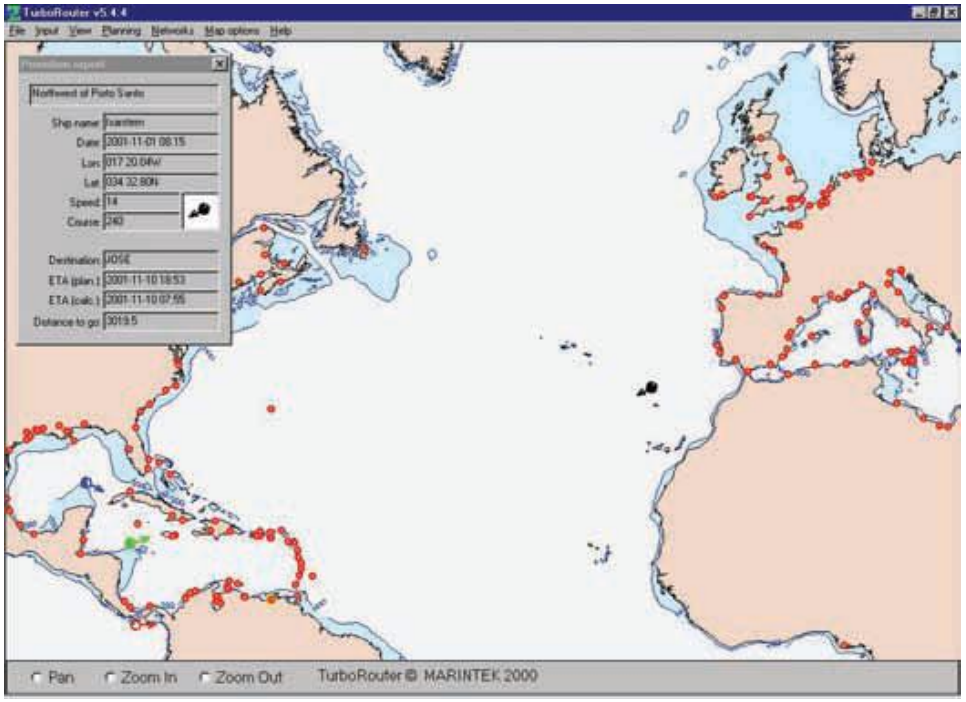
It is also possible to include contracts with details on required pickup or delivery in given periods, and time varying price curves for income and cost.

Problem instances are described in a general XML format that can be used as input for the automatic planning process.

Invent generates optimized plans for the problems based on advanced heuristic methods that are able to provide high quality solutions in short time.

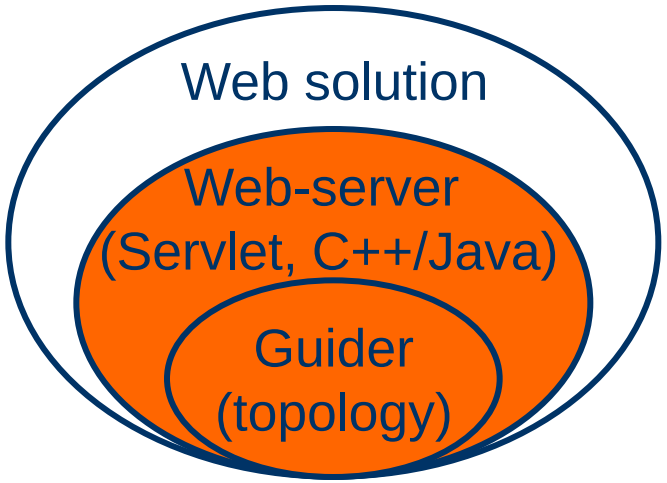


TurboRouter

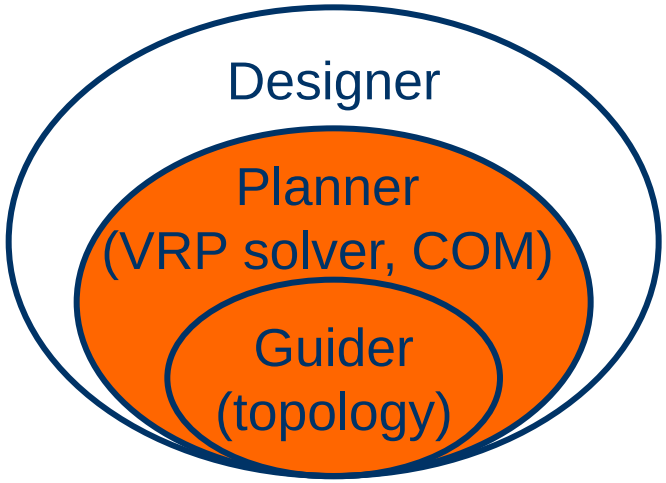


Products - architecture

Geomatikk AS

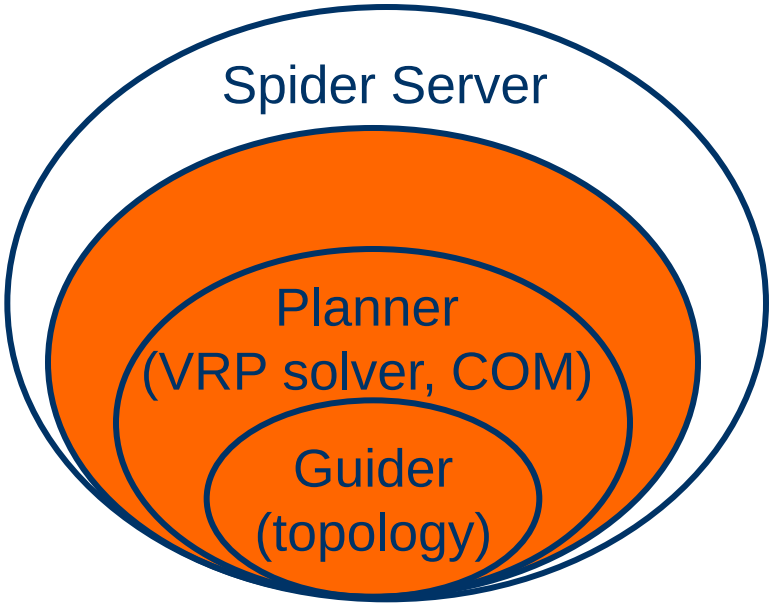


SPIDER Solutions AS

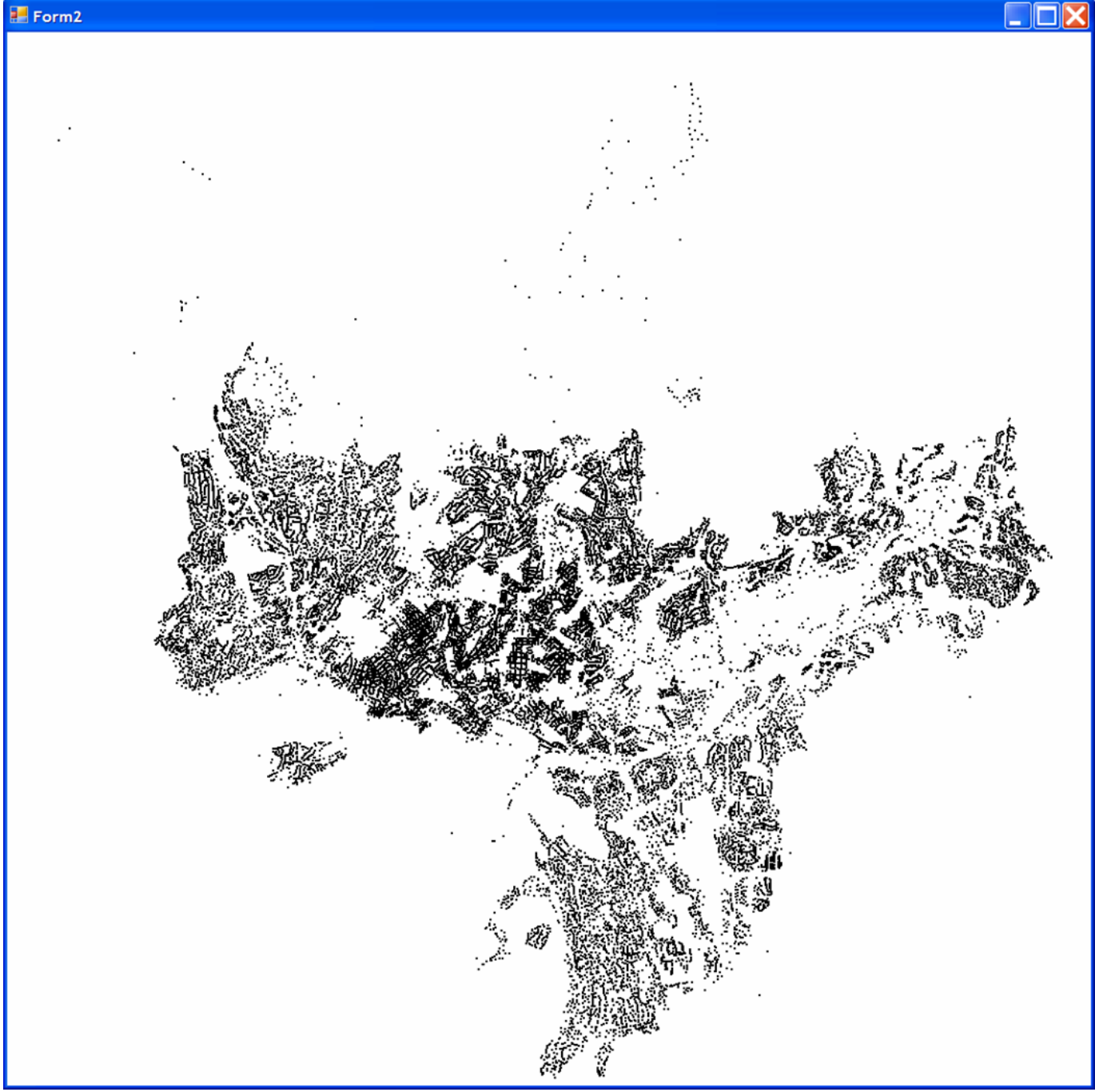


Distribution Innovation AS

DI web solution



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



Problem description

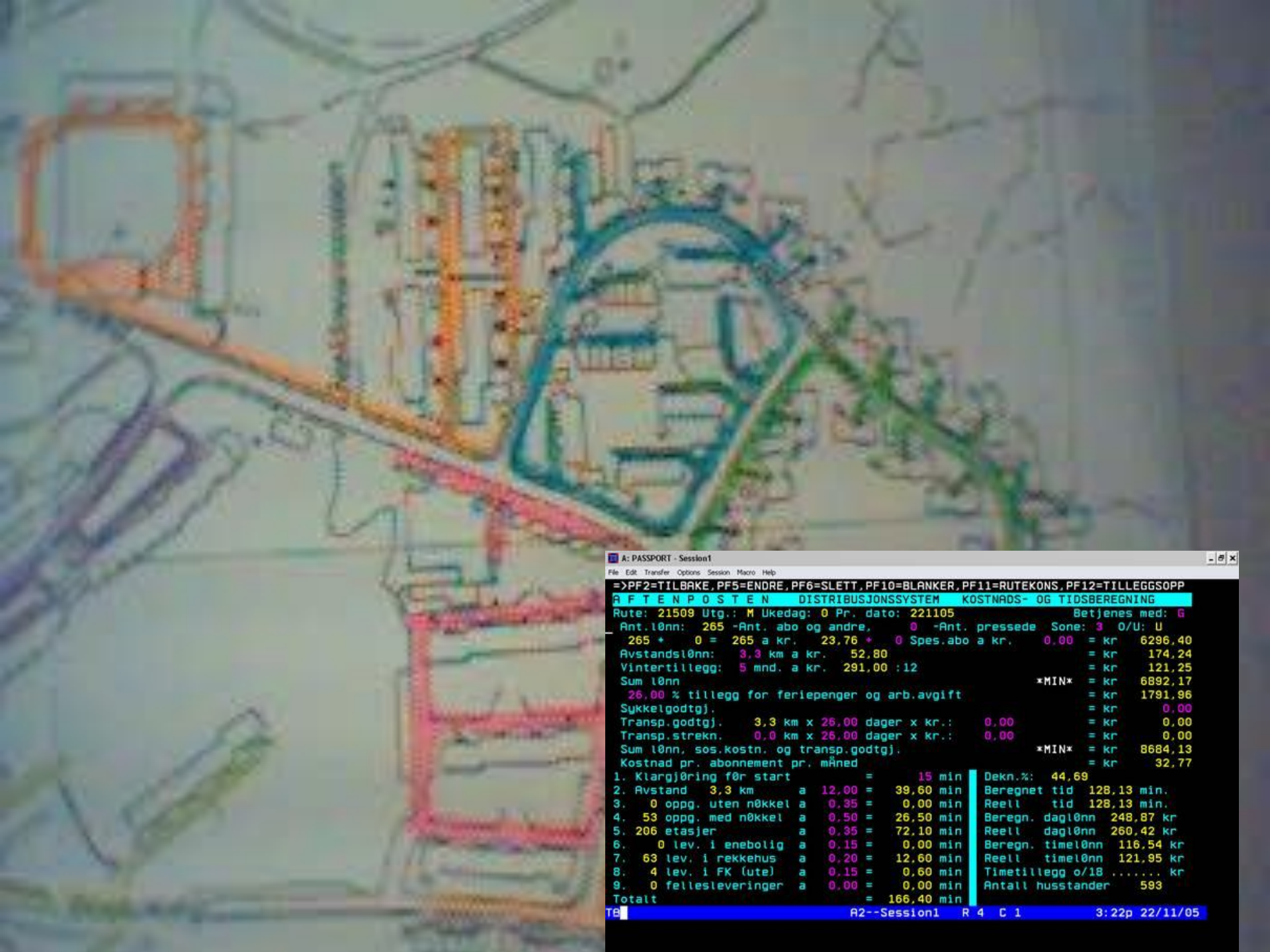
- Last mile part of two-echelon distribution
- (Open) DVRP with extensions
- Objectives
  - total duration
  - route balancing
  - clustering, route separation, ”visual beauty”
- Constraints
  - route duration
  - # routes

Additional niceties

- Determination of vehicle type (pedestrian, car)
- Combined routes
- Links that may be used by one route only
- ...

Extended problem

- Integrated problem
- Distribution from print shop to subscriber
- Location routing: Determination of pickup points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AFTENPOSTEN DISTRIBUSJONSSYSTEM KOSTNADS- OG TIDSBEREGNING
Rute: 21509 Utg.: M Ukedag: 0 Pr. dato: 221105 Betjenes med: G
Ant.lønn: 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
Avstandslønn: 3,3 km a kr. 52,80 = kr 174,24
Vintertillegg: 5 mnd. a kr. 291,00 :12 = kr 121,25
Sum lønn *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 lønn, sos.kostn. og transp.godtgj. *MIN* = kr 8684,13
Kostnad pr. abonnement pr. måned = kr 32,77
1. Klargjøring før start = 15 min
2. Avstand 3,3 km a 12,00 = 39,60 min
3. 0 oppg. uten nøkkel a 0,35 = 0,00 min
4. 53 oppg. med nøkkel 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
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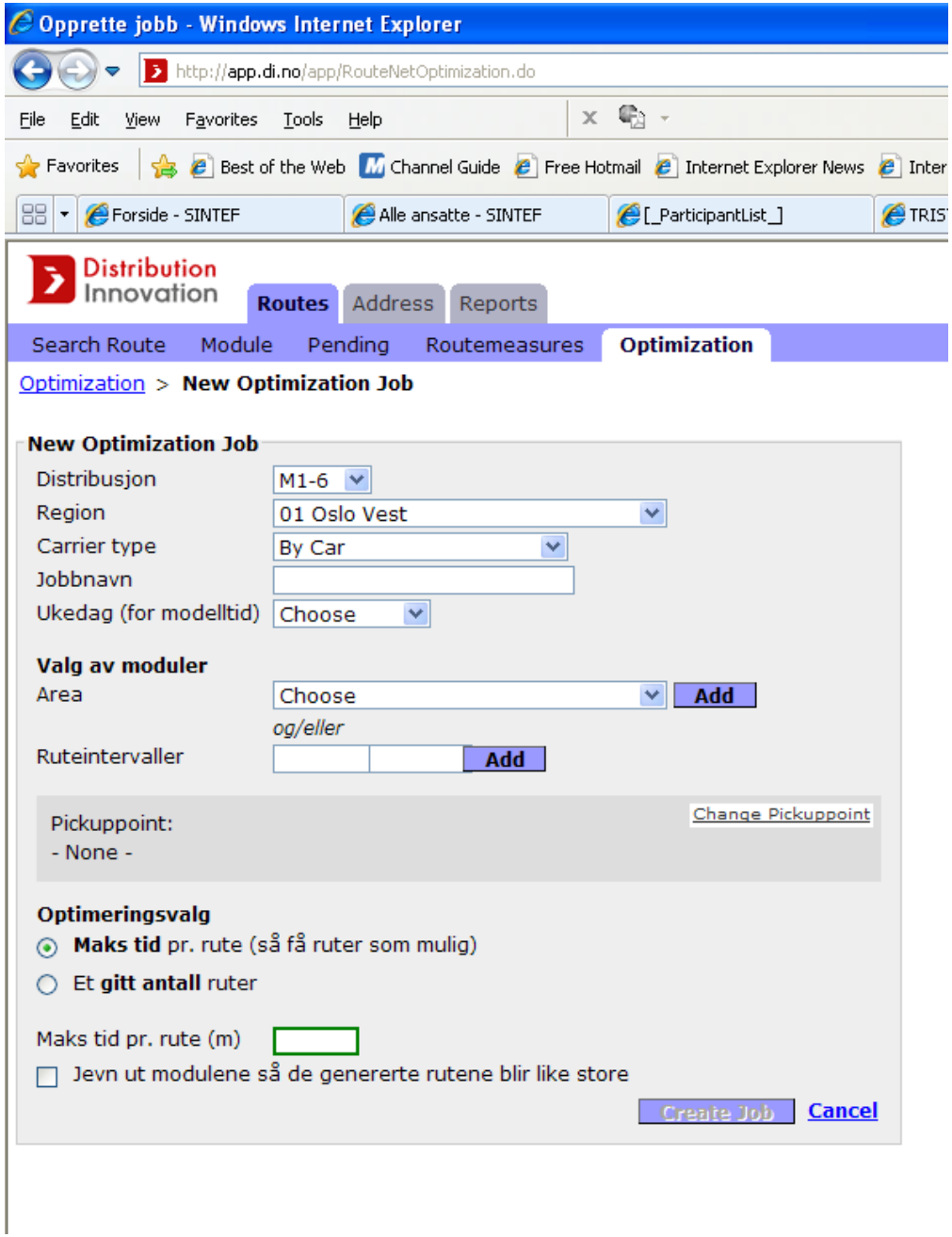
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Change Pickuppoint
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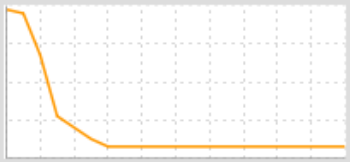
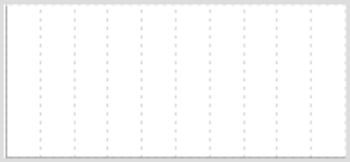
Maks tid pr. rute (så få ruter som mulig)
Et gitt antall ruter
Maks tid pr. rute (m)
Jevn ut modulene så de genererte rutene blir like store
Create Job
Cancel

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	**Eksportért til forfall** Ant. ruter 3 CPU-tid 27 min Iterasjoner 674051	
1219	Geografi 02 Oslo Nord, M1-6 **Gr.4D2 -20747-751** **H/3R/K/J v.3.1** 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 18:39 Ferdig 18:59	**Eksportért til forfall** Ant. ruter 3 CPU-tid 20 min Iterasjoner 562608	
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	**Eksportért til forfall** Ant. ruter 2 CPU-tid 15 min Iterasjoner 270674	
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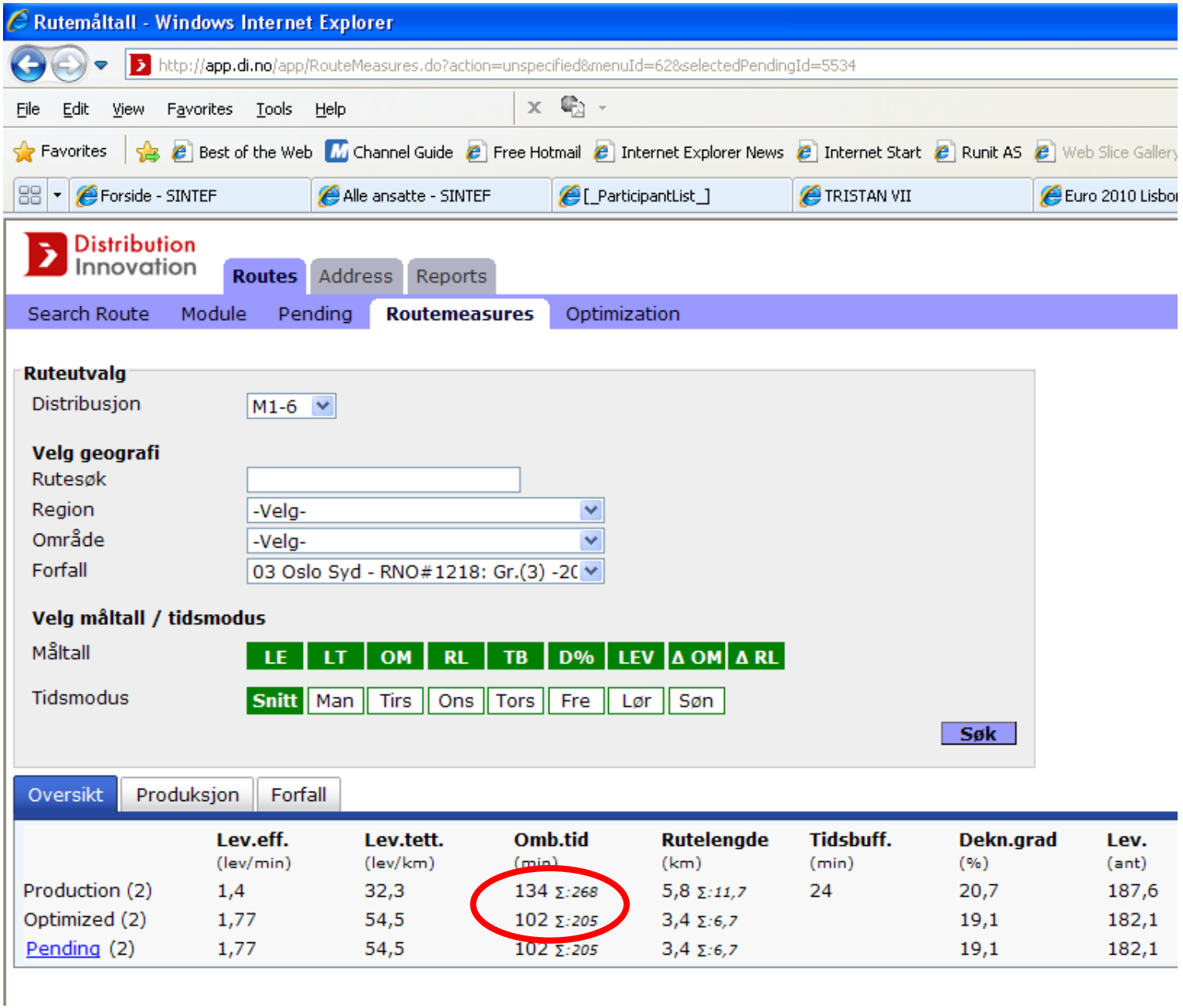
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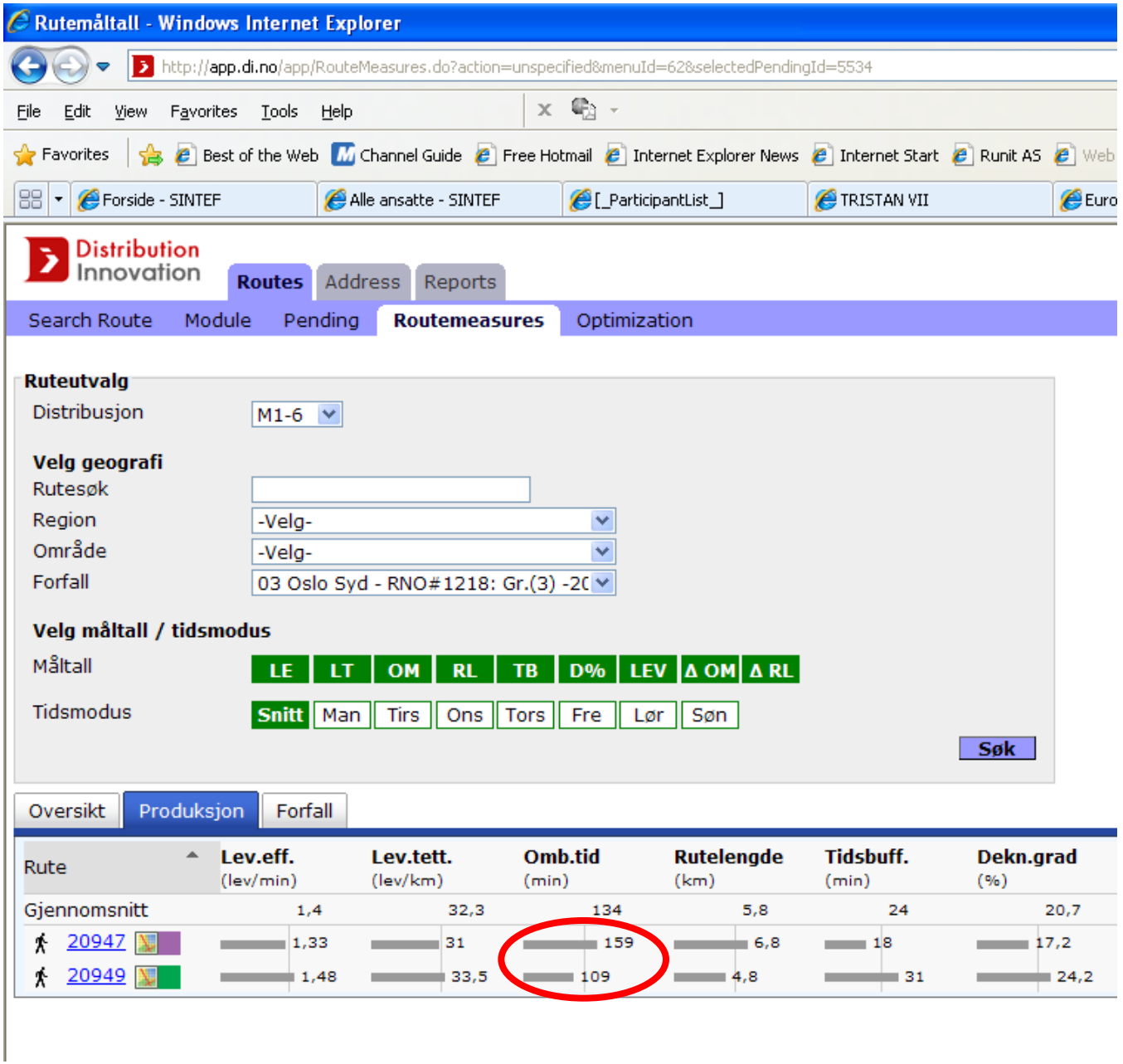
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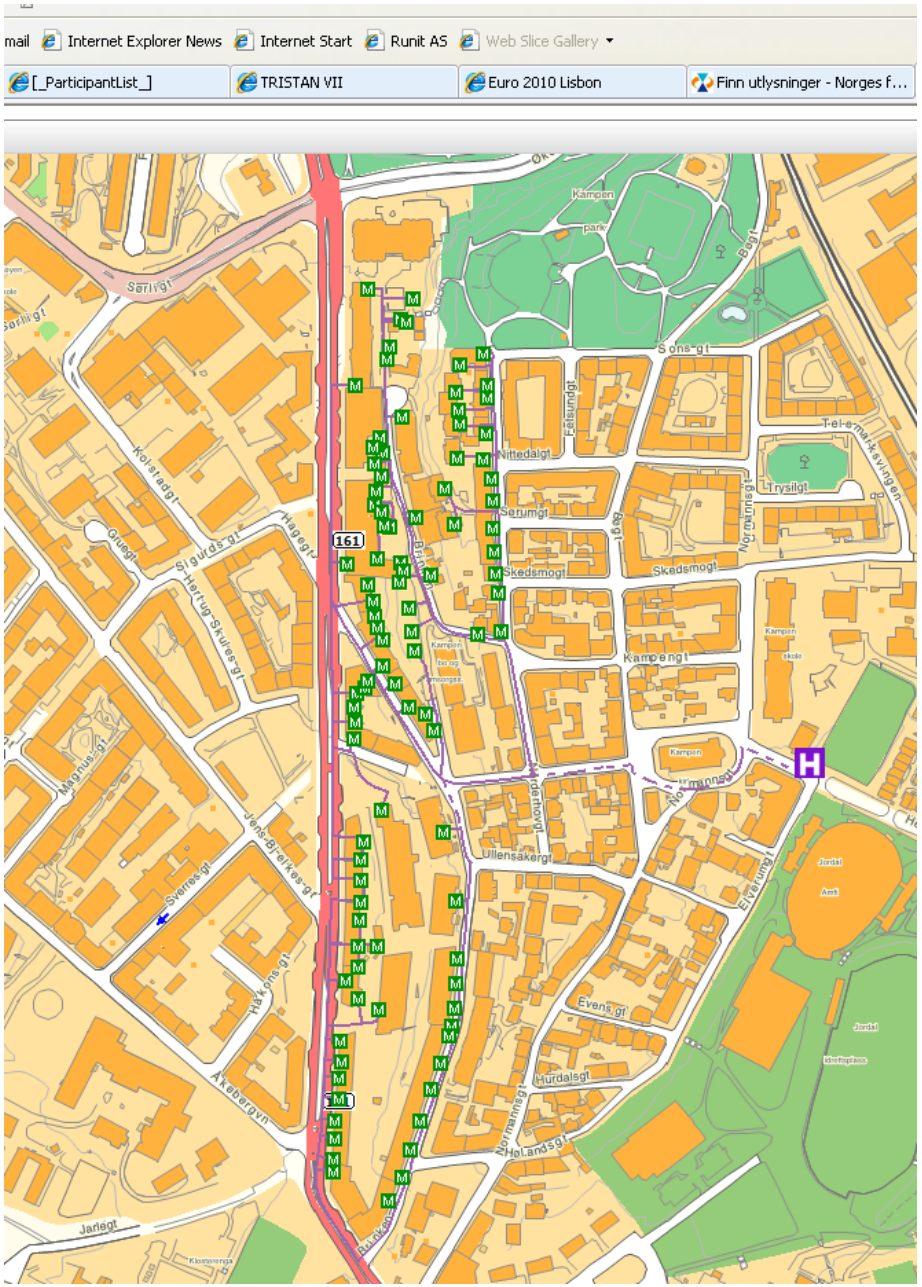
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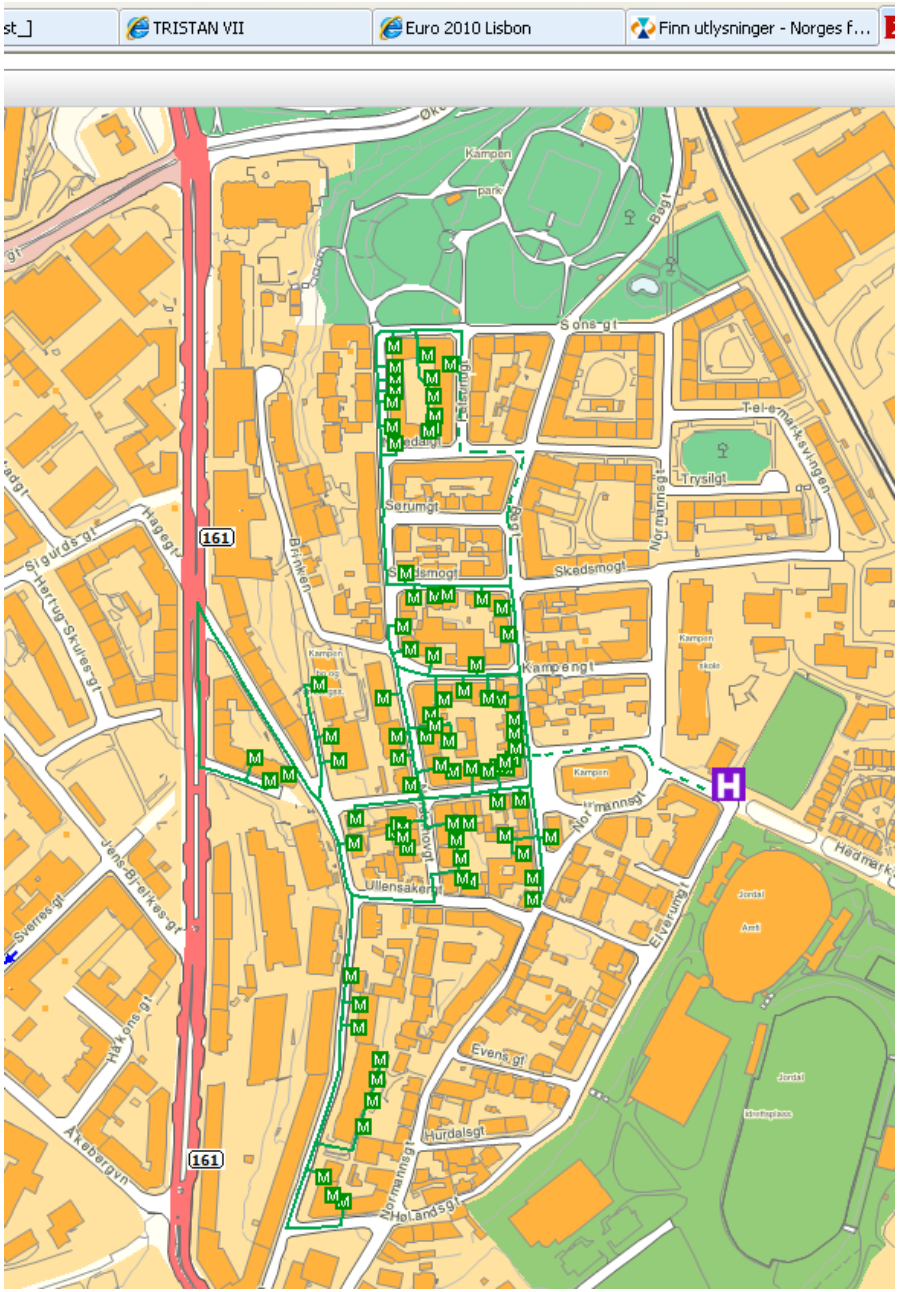
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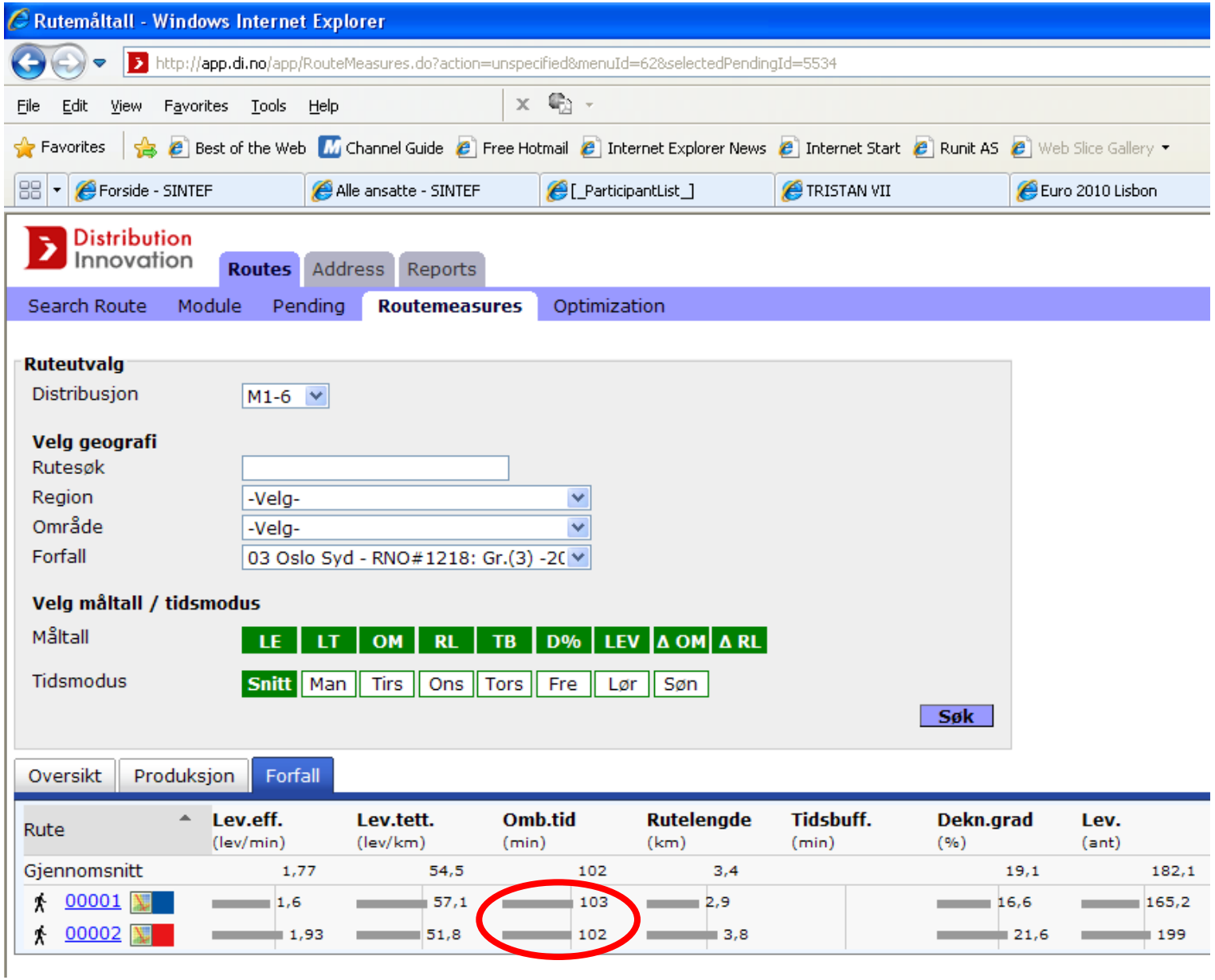
Rutemåltall - Windows Internet Explorer
http://app.di.no/app/RouteMeasures.do?action=unspecified&menuId=62&selectedPendingId=5534
File Edit View Favorites Tools Help
Favorites Best of the Web Channel Guide Free Hotmail Internet Explorer News Internet Start Runit AS Web Slice Gallery
Forside - SINTEF
Alle ansatte - SINTEF
[_ParticipantList_]
TRISTAN VII
Euro 2010 Lisbon
Distribution Innovation
Routes
Address
Reports
Search Route
Module
Pending
Routemeasures
Optimization
Ruteutvalg
Distribusjon
M1-6
Velg geografi
Rutesøk
Region
-Velg-
Område
-Velg-
Forfall
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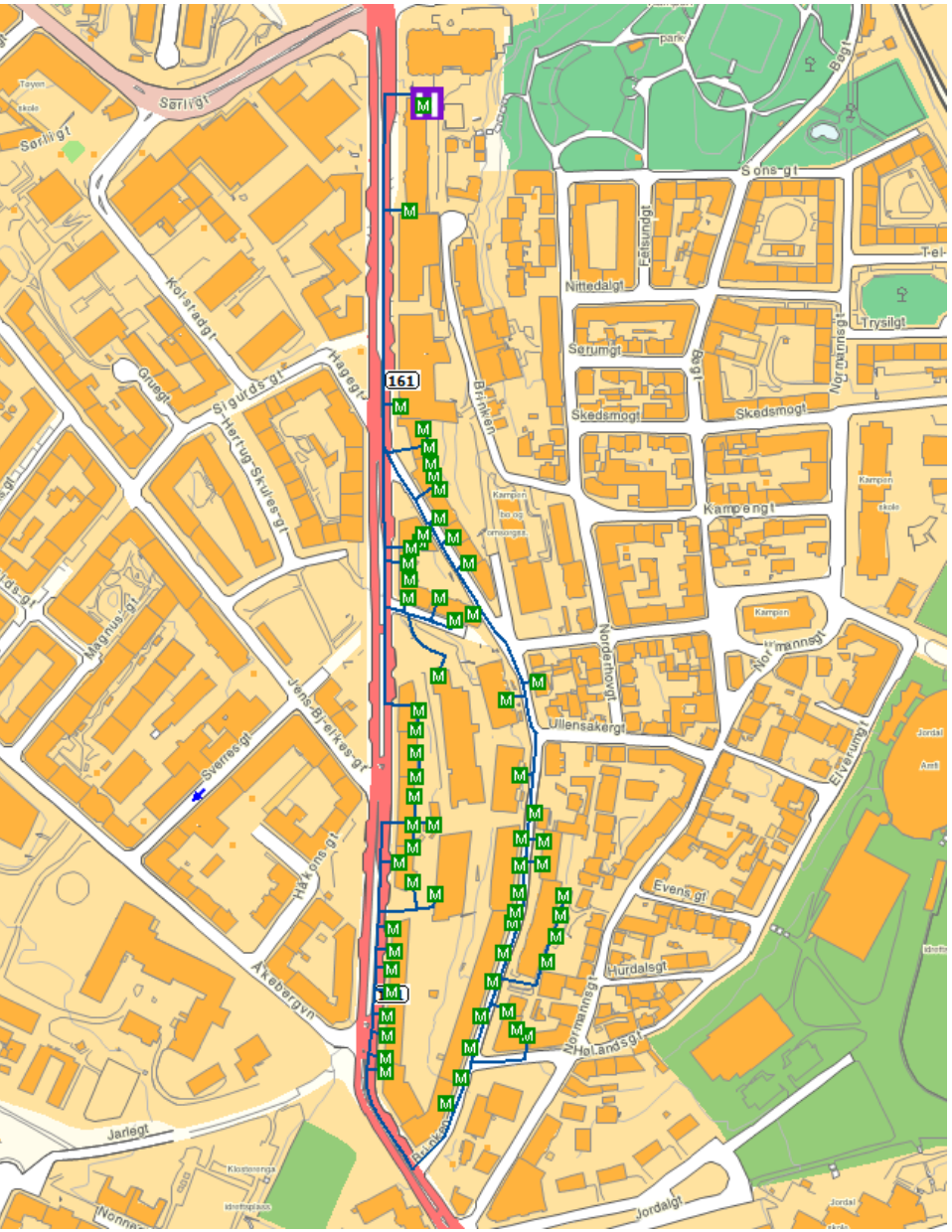
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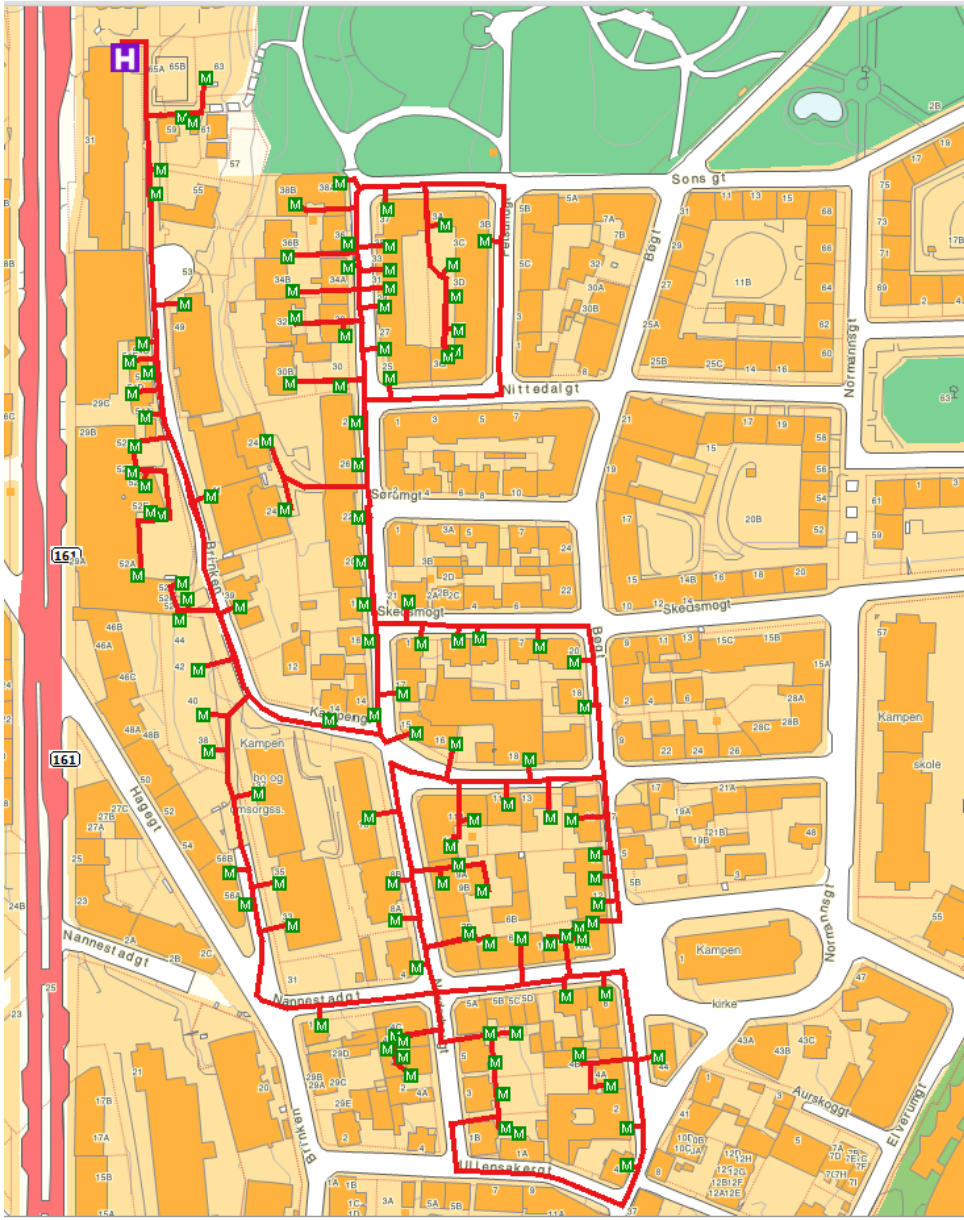
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Normannsgt
Begt
Aurskoggt
Elverumgt
Kampen
skole
kirke
161

Outline

- Personal background
- Contract research organisations
- OR at SINTEF
- VRP Research and Technology Development (RTD)
- Important challenges
- Reflections

Challenges for routing technology

- Industrial awareness
- Range of applications
- Information availability and quality – e.g. GIS
- User interfaces
- Software engineering
- Model adequacy and flexibility
- Robustness of solution method
- Solution quality for large-size and complex problems
- Integration along the value chain

Challenges

- Adequate models
- Cost function?
- Instance robustness
  - all kinds of instances
- Robustness towards uncertainty
- Scalability
  - very large size problems
- Exploiting modern commodity computers
  - multi-core, heterogeneous, GPUs
  - sequential algorithms will not benefit from hw developments

Important trends in VRP research

- Richer models, larger instances, more integrated problems
- Exact methods
- Self-adaptation
- Hybrid and collaborative methods
- Parallel and heterogeneous computing

Special Issue Transportation Science

- Advances in Vehicle Routing
- TRISTAN VII, Tromsø, Norway June 20-25 2010
- Guest editors
  - Marielle Christiansen
  - Arne Løkketangen
  - Geir Hasle
- Deadline October 15, 2010

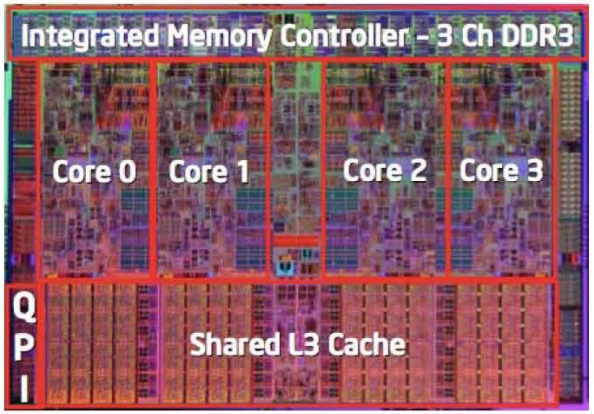
- See May issue of Transportation Science for call

Parallel and heterogeneous computing

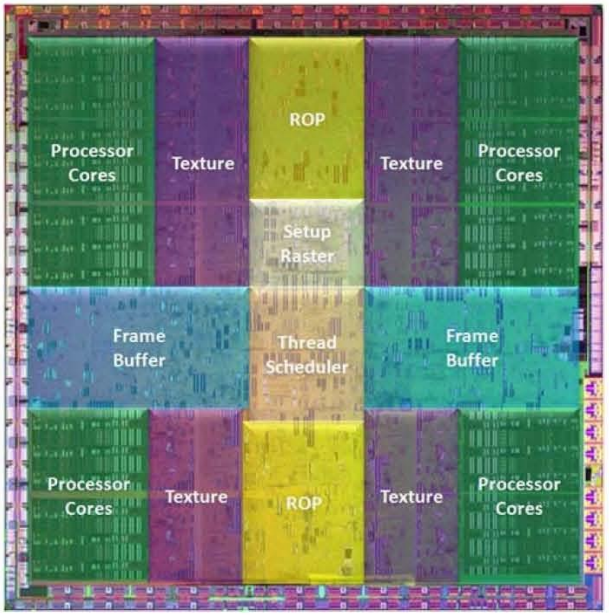
- CPU Clock frequency has stagnated
  (The Beach Law does not hold anymore ...)
- Moore's Law still valid
- But you need parallel algorithms to exploit it
- Multi-core and heterogeneous commodity computers
- Fine-grained and coarse-grained parallelism

Heterogeneous Computer

- A *heterogeneous computer* is a tightly coupled system of processing units with distinct characteristics.
- A modern desktop or laptop computer is an example of such a system, as most systems include both a task-parallel, multi-core CPU and one or more data-parallel processors in the form of programmable graphics processing units(GPUs).



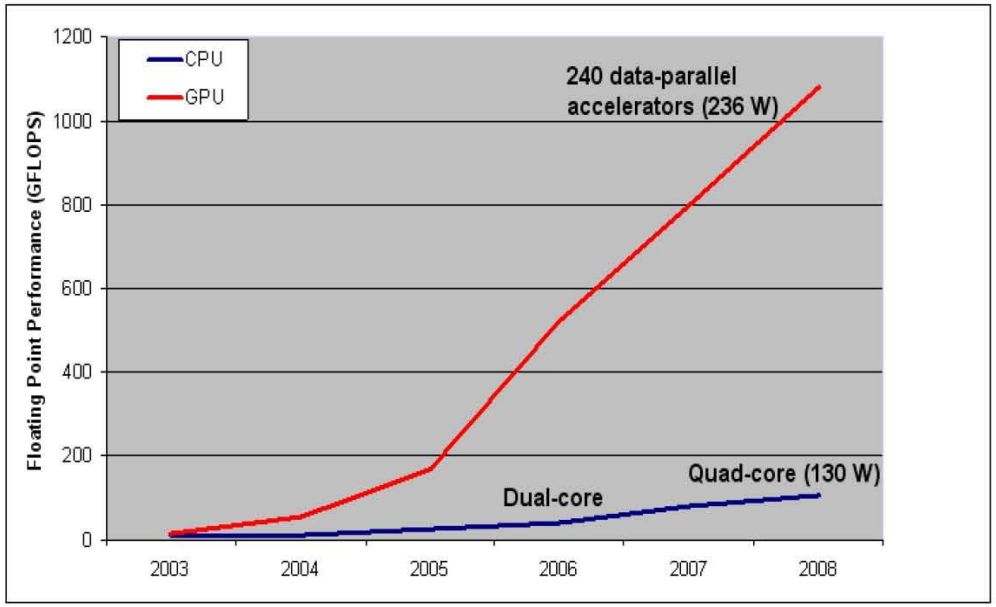
CPU (Intel Nehalem)



GPU (NVIDIA GeForce 280)

Graphics Processing Unit (GPU)

- Background: Game industry
- Massive parallel architecture (>500 cores per chip)
- Typically 10-50 times speedup compared to CPU applications



NVIDIA Fermi GPU

- 3 billion transistors
- 512 cores
- Up to 1 Terabyte of GPU memory
- 1.5 Teraflops performance
- 40 nm manufacturing process

NVIDIA GTX 480

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How do you do great OR research which has real applied impact?

- Value chain / network of RTD based innovation
- Academia /CRO/ SW Tool vendors / Users
- Communication
- Exchange of people
- Clusters of innovation
- Real challenges
- Mission, vision, call ...
- Financial resources
- Good management

- Most importantly: the people

The Indispensable Users

- They are different ...
- They may or may not understand what
  - they need
  - is possible
- They are inconsistent ...
- Listen carefully
- ... but do not trust

We need OR people that are

- highly skilled
- different

- motivated, proud
- brave, willing to take on new challenges
- able to carry heavy burdens

Thank you for your attention!

Stuck between a rock and a hard place

The pleasures of practicing OR in a contract research organization

Geir Hasle
SINTEF ICT, Oslo, Norway

LANCS Initiative Advisory Board Meeting
London, 18 May 2010