ROUTE2000

IMM/CTT - DTU

INTERNATIONAL WORKSHOP ON VEHICLE ROUTING

August 16th – 19th 2000

Rolighed, Skodsborg
Denmark

Contents

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Welcome

Transportation is a very important area in modern societies. In most western countries transportation occupies around 5-10 percent of the GNP. Within transportation vehicle routing forms an important part of the subject.

Also within the operations research scientific community vehicle routing is an important area leading to many journal articles and applications, and leading to many developments within optimization.

ROUTE2000 aims to provide a forum for scientific exchange and cooperation in the field of vehicle routing and related areas. The 18 presentations range from theoretical contributions to real-life implementations and cases, and cover areas as the traveling salesman problem, dynamic vehicle routing, vehicle routing with time windows, and crew scheduling.

It is my hope that the very interesting presentations, the informal workshop form, the single stream of presentations, and the nice surroundings will result in a very constructive and enriching meeting.

Finally I would like to thank the Danish Social Science Foundation and The Technical University of Denmark for supporting the workshop.

Oli B.G. Madsen
Chairman of ROUTE2000

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Organizing committee

Chairman **Oli B. G. Madsen** (*email: ogm@imm.dtu.dk*)
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Program

	Wednesday Aug. 16th
14.00 - 17.30	**Coffee Break** & Registration
18.00 - 19.00	**Dinner**
	Chairman: Oli B. G. Madsen
19.30 - 20.30	Welcome & Gilbert Laporte *Classical and modern heuristics for the vehicle routing problem*

	Thursday Aug. 17th
08.00 - 09.00	**Breakfast**
	Chairman: Jacques Desrosiers
09.00 - 09.30	Torsten Fahle *Scheduling of ambulant nursing staff*
09.30 - 10.00	Jean-Yves Potvin *Vehicle dispatching with time dependent travel times*
10.00 - 10.30	Allan Larsen *The dynamic vehicle routing problem with a priori information*
10.30 - 11.00	**Coffee break**
11.00 - 12.00	Carlos Daganzo *Coordinated vehicle routing with uncertain demand*
12.00 - 13.00	**Lunch**
13.00 - 17.30	**Excursion North Zealand**
18.00 - 19.00	**Dinner**
	Chairman: Jean-Yves Potvin
19.30 - 20.00	Michel Gendreau *Using constraint-based operators with variable neighborhood search to solve the vehicle routing problem with time windows*
20.00 - 20.30	Oli B. G. Madsen *Vehicle routing with time windows - status and recent developments*

	Friday Aug. 18th
08.00 - 09.00	**Breakfast**
	Chairman: Geir Hasle
09.00 - 09.30	Bertrand Le Cun *Optimizing Constrained Shortest Path for a Vehicle Routing Problem*
09.30 - 10.00	Mikael Rönnqvist *Forwarding operations in forestry*
10.00 - 10.30	Annette Vainer *Heuristics in vehicle routing - from theory to practice*
10.30 - 11.00	**Coffee break**
11.00 - 12.00	Ole Kessel *Real time vehicle scheduling - challenges and experiences from real life large scale implementations*
12.00 - 13.00	**Lunch**
	Chairman: Mikael Rönnqvist
13.00 - 13.30	Kjetil Fagerholt *Robust ship scheduling with multiple Time Windows*
13.30 - 14.00	Olli Bräysy *A new hybrid evolutionary algorithm for the vehicle routing problem with time windows*
14.00 - 14.30	Brian Kallehauge *A hybrid optimal method to the vehicle routing problem with time windows*
14.30 - 15.00	**Coffee Break**

	Friday Aug. 18th
	Chairman: Gilbert Laporte
15.00 - 16.00	Jacques Desrosiers *Airline fleet assignment with homogeneity*
16.00 - 16.30	Frederic Semet *A bilevel approach to the travelling salesman problem*
16.30 - 17.00	Niels Christian Petersen *Extensions of a two-commodity flow formulation for the symmetric TSP*
18.00 - 20.00	**Conference dinner**

	Saturday Aug. 19th
08.00 - 09.00	**Breakfast**
	Chairman: Oli B. G. Madsen
09.00 - 10.00	Geir Hasle *Issues in dynamic fleet management*
10.00 - 10.30	Marco Lübbecke *Pickup and delivery paths of restricted combinatorial structure*
10.30 - 11.00	**Coffee break**
11.00 - 12.00	Summing up and closing
12.00 - 13.00	**Lunch**
13.00 - 13.30	Goodbye

The North Zealand Excursion

The excursion on Thursday starts at 1:30pm where we will be picked up by a bus and head north along the coast. Our first stop is "Louisiana", the world-famous museum of modern art in Humlebæk. Its permanent exhibition is Danish and international art from after 1945. The museum is situated in a spacious, old park with a fine view across the Øresund (the small strait between Zealand and Sweden). It houses an exquisite collection of modern art by international artists such as Arp, Francis Bacon, Calder, Max Ernst, Henry Moore, Picasso and Warhol.

Louisiana is not merely an experience in modern and contemporary art, but a congenial reflection of the interplay between art, architecture and landscape. The magnificent park serves as an ideal setting for displaying the collection of modern sculptures.

Coffee and pastry is served at 3pm in the cafeteria of the museum, and 3:30pm we will leave the museum and continue the trip north along the beautiful coastline.

As we reach the "northern gate" of Øresund we will make a small stop at the castle of "Kronborg". Kronborg Castle is one of the most important renaissance castles in the north of Europe. Every year, several hundred thousand tourists visit the magnificent castle on the seaward approach to the Øresund.

The many foreign guests mainly associate Kronborg with Shakespeare's drama about Hamlet, Prince of Denmark. For Danish visitors the castle is a national and historic monument.

Kronborg was built in the years between 1574-1585 by the King of Denmark Frederik II. At the entrance of the Øresund,

the bright castle grew out of the medieval fortress "Krogen".

During the years, the various kings built other castles, and Kronborg ended up having to be content with the humble role as "Keeper of the Øresund".

In the beginning of the twentieth century Kronborg was restored and opened for public access.

From Kronborg our bus will take us back to Rolighed.

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Invited Presentations

4.1 Coordinated vehicle routing with uncertain demand

Carlos F. Daganzo (Department of Civil and Environmental Engineering, University of California, Berkeley)
Alan L. Erera

Numerical optimization methods have been developed and applied successfully to many deterministic variants of the so-called vehicle routing problem (VRP). Unfortunately, existing numerical methodologies are not as effective for planning and design problems when uncertainty is a significant issue. In view

of this, this presentation will show how approximation models for large-scale uncertain VRP's can complement conventional optimization methods and allow for the exploration of a broader set of design and operating strategies than is currently possible. The presentation will consider vehicle routing problems where vehicles have a finite capacity and demand is uncertain, focusing on strategies that coordinate the actions of all vehicles in the fleet in real time as information becomes available.

When uncertainty exists, systems should be designed with degrees of flexibility that allow for efficient control in real time. In the case of "single-period" vehicle routing problems we should determine two things: (i) the system configuration, including the fleet size and composition and an initial set of vehicle routes, and (ii) a dynamic control plan (algorithm) which specifies how vehicle routes are modified in real time as information becomes available. Uncertainty should be considered when designing both the system configuration and its control algorithm. Furthermore, configuration decisions should be made with both the flow of information and the control method in mind. For the capacitated VRP with uncertain demand, the desirability and feasibility of specific designs will depend on how and when lot size information becomes available and the degree of control that a dispatcher can exert over en-route vehicles.

Researchers have attempted to obtain optimal designs minimizing expected operating costs for problems in which customer lot size information becomes known only after the arrival of a vehicle. Unfortunately, all the solutions proposed to date are based either on configurations that are unlikely to be feasible in practice, such as single-vehicle fleets, or on feasible operating plans that are too restrictive to be appealing in practice. A possible alternative system design that may be more practical and efficient would allow tour failures to be consolidated into secondary "sweeper" routes. The approach here would be to plan initial routes as if the vehicle capacity were smaller ($q- < q$) to ensure that few primary tours would fail, and then to serve the overflow customers with a set of secondary tours where vehicles are allowed to cooperate. Unfortunately, although this configuration is simple to describe, it is already too difficult to optimize exactly. More promising designs where vehicles would be allowed to cooperate during the primary tours are even more difficult to treat exactly.

The presentation will show how a system in which vehicles are allowed to cooperate during the primary phase can be designed and operated by minimizing and approximate "logistic cost function" of key design parameters. The effectiveness of the proposed strategies is compared against (a) current strategies in which there is little or no coordination, and (b) against deterministic strategies for equivalent problems without uncertainty. It is shown that the introduction of coordination in proper ways lowers the operation cost from the best levels that can be achieved without coordination (a) to levels close to (b).

4.2 Airline Fleet Assignment with Homogeneity

Jacques Desrosiers (École des Hautes Études Commerciales & GERAD)

In the usual sequential process of planning the operations for an airline, the fleet assignment problem arises between the problem of determining a flight schedule given the passenger demand curves for each pair of origin and destination, and the problem of routing individual aircraft to cover all scheduled flight legs while satisfying maintenance requirements. It consists of determining the aircraft type to assign to each flight leg of a given flight schedule. These decisions must be made in order to maximize the sum of the expected profits for each leg (which depend on the chosen aircraft type), while satisfying a certain number of constraints described later on. The sequential planning process is then completed by computing crew rotations and monthly schedules for individual crew members that minimize crew costs while satisfying government regulations and collective agreement working rules.

This research addresses the fleet assignment problem for a weekly flight schedule where it is desirable to assign the same type of aircraft to the legs operating on different days of the week but with the same flight number. Even though it reduces schedule profitability, aircraft type homogeneity is sought in order to improve customer service and the planning of operations. Indeed, when the same aircraft type is assigned to legs with the same flight number, the same gate can be used for these legs, which is considered as more convenient for regular passengers. Also, the ground equipment needed to service and resupply the aircraft can remain near that gate. Finally, when crews are assigned to one-day rotations, as it is often the case for regional carriers, homogeneous assignments allow building the same crew rotations day after day. Such rotations are appreciated by the crew members, which usually prefer regular working days.

To our knowledge, no papers have been published on this extension of the airline fleet assignment problem. However, several papers addressing the classical version can be found in the literature. The problem is often formulated as a mixed integer, linear, multicommodity flow problem with side constraints defined on a time-space network (see Abara (1989), Subramanian *et al.* (1994) and Hane *et al.* (1995)). In Desaulniers *et al.* (1997) and Rexing *et al.* (2000), a variant of the problem is tackled where some flexibility on the flight departure times is allowed. These departure times must fall within given time intervals called time windows. Such flexibility opens up new feasible flight connection opportunities and, thus, can yield a more profitable fleet assignment. Formulating the problem as a special case of the unified formulation for time constrained vehicle and crew scheduling problems subsequently presented in Desaulniers *et al.* (1998), Desaulniers *et al.* (1997) solve it using a column generation approach embedded in a branch-and-bound search tree. Based on a discretization of the time windows, Rexing *et al.* (2000) formulate the problem as an integer linear program similar to the one proposed for the case with fixed departure times and solve it using a preprocessor, an LP solver and a branch-and-bound scheme.

Sometimes, solving the fleet assignment problem for a single day of the week can be a good starting point to obtain a fleet assignment for the whole week. Indeed, if the daily schedules are sufficiently similar from one day to the other, one can obtain an initial (perhaps infeasible) solution by duplicating the one-

day solution over the week. This initial weekly solution often needs to be adapted to take into account the minor differences existing between the days (for instance, when a flight is not flown every day of the week or when the passenger demand of a flight varies substantially over the week). In the latter case, it might be advantageous to assign different aircraft types to flight legs having quite different demands.

A weekly assignment derived from a daily solution tends to be homogeneous. However, in most cases, it is not optimal since the aircraft type assignment is determined from the schedule of a given day rather than from the whole week schedule. This is all the more true when the differences between the days are important. In particular, significant differences can often be observed between weekdays and weekend days.

On the other hand, when the problem size allows it, one may solve the problem (without homogeneity) considering the whole week schedule by using a model similar to that of Hane *et al.* (1995). Such an approach can produce optimal solutions in terms of profits but does not favor homogeneity since it is not taken into account.

The first contribution of this research is to propose a model for the fleet assignment problem with homogeneity that can be used to yield high profitable homogeneous solutions. Its second contribution consists of developing different heuristic solution approaches for this model that provide solutions of various qualities in various solution times. Third, these methodologies can be used to evaluate the impact of trading-off profits for homogeneity. Finally, this research shows that optimization tools can be used to produce solutions directly usable in practice by introducing elements that facilitate the operations.

Computational results obtained on Air Canada instances involving up to 4400 flight legs are reported. The system produces realistic solutions arising from a trade-off between profits and homogeneity, and solves large-scale instances in short times.

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4.3 Issues in Dynamic Fleet Management

Geir Hasle (DEPARTMENT OF OPTIMIZATION, SINTEF APPLIED MATHEMATICS)

In local pick-up and delivery, there is a huge potential for improvement of logistics performance. For operations of some size, dynamic, real-time routing is a very complex co-ordination task. Despite this fact, logistics management of local distribution, is predominantly performed by human dispatchers, even for large companies. Commercial VRP software is predominantly used for generation of static routes. Very few cases of real-life, real-time, dynamic routing supported by ICT tools based on VRP optimization are known to this author. The major VRP software vendors claim that their VRP tools support dynamic routing. What are the reasons for this mismatch?

There are a number of plausible reasons. Firstly, fleet management systems for real-time routing must be based on a rich VRP model. Generally, existing VRP tools are inflexible, and based on an idealized model. Configuration to the application at hand may be impossible or very costly. Secondly, there are very strong response time versus plan quality demands, both for plan generation and plan maintenance. VRP tools of today (to the extent that we know their workings) seem to be based on fairly old and simple construction heuristics, or, general techniques for solving MIP-formulations of the VRP. Such techniques are not powerful enough, or they find the optimal solution to an irrelevant question due to inadequacy of their underlying VRP model. Also, there are important software engineering issues. Real time fleet management systems need to be tightly integrated with order handling systems, systems for vehicle position tracking, and communication systems. Availability and quality of information on transportation orders, road network, vehicle positions, and traffic situation is crucial for Finally, a possible explanation are related with organizational issues such as lack of education, resistance from employees, lack of support from management, and bad project management. Recent and current research at our Department aims at resolving the technical part of the issues alluded to above. A major goal for us is to develop VRP technology for resolution of real-life applications in transportation management, for different transportation modalities, and for supply-chain coordination.

A major part our recent research has concentrated on the development of generic tools for VRPs with focus on local distribution. This entails development of a rich VRP model and corresponding efficient algorithms for construction, optimization and repair of routing plans. A crucial, basic component of this technology is a highly efficient cheapest path calculator for road networks, which takes driving restrictions into consideration. We have developed such a component based on transformation of the road network graph, and a variant of Dijkstra's algorithm extended with hash-tables. A second component is functionality for last minute optimization of tours before a vehicle is loaded or dispatched. Here, we have investigated exact methods for TSPs with side constraints based on branch and bound. The last part is effective algorithms for construction,

iterative improvement, and repair of routing plans for dynamic, rich VRP models. Our research and development has focused on insertion-based construction techniques, coupled with iterative improvement methods based on local search, constraint propagation and meta-heuristics. Based on our research efforts in VRP, the Department develops a generic VRP software toolkit. The toolkit includes functionality for automated configuration, a client-server architecture that supports multiple users and "organic" planning, as well as standardized interfaces to external systems.

Another part of our current research and technology development related with VRP deals with methods for solving complex vessel routing problems with additional constraints related with supply-chain coordination. One case is shipment of ammonia between producer and consumer ports of raw materials in process industries, where there are hard stock level constraints. For this case we have developed a hybrid method which combines a heuristic method for the combinatorial part with an LP solver for feasibility checking and detailed decisions on timing and volumes.

The Department also conducts more fundamental research on solving non-standard constraint satisfaction problems, i.e., problems with preferential constraints, over-constrained problems, and problems with multiple optimization criteria.

In this talk, the author shall describe the status of ongoing research and technology development related with VRP within the Department. He shall also point to challenges that will set the agenda for future research.

4.4 Real time vehicle scheduling - challenges and experiences from real life large scale implementations

Ole Kessel (PwC Centre of Excellence in Distribution Planning Systems, PriceWaterhouseCoopers)

PwC has in Copenhagen a Centre of Excellence in Distribution Planning Systems, that during the last decade has developed and implemented a series of state of the art real-time vehicle scheduling systems. The challenges in making such systems work in a real life environment are huge - technical as organisational. But the real life transportation planning is about making real time decisions, so the challenges must be overcomed. And they are ! During the speach, I'll give examples from running applications, covering their background and vision, solutions to and experiences from using event-driven optimisation in transportation order-booking as well as in the concurrently running re-scheduling based on GPS positioning and status-reports from the individual trucks.

4.5 Classical and modern heuristics for the vehicle routing problem

Gilbert Laporte (École des Hautes Études Commerciales and Centre for Research on Transportation)

The *Vehicle Routing Problem* (VRP) holds a central place in distribution management. It is also an important combinatorial optimization problem that has stimulated several powerful exact and approximate solution methodologies. The most studies version is the capacitated VRP on an undirected graph which can be defined as follows. Let $G = (V, E)$ be a graph where $V = \{v_o, v_1, \ldots, v_n\}$ is the vertex set and $E = \{(v_i, v_j) : v_i, v_j \in V, i < j\}$ is the edge set. Vertex v_0 represents a depot at which are based m identical vehicles of capacity Q. In some versions of the problems, m is a know value, in others it is a decision variable. The remaining vertices represent cities or customers. With every vertex v_i is associated a non-negative demand q_i. Also, a non-negative cost or distance c_{ij} is associated with every edge (v_i, v_j). The VRP consists of determining a set of m vehicle routes i) starting and ending at the depot; ii) such that every customer is visited exactly once by one vehicle; iii) such that the total demand of each vehicle route does not exceed Q; iv) having minimum total cost.

The VRP is an NP-hard problem that is exceedingly difficult to solve to optimality. To this day, no exact algorithm can consistently solve VRP instance in excess of 50 cities, although several larger instance, some involving more than 100 cities, have been solved optimally. Thus, the only practical approach is the use of heuristics. These belong to two broad classes: classical heuristics and modern heuristics heuristics (or metaheuristics).

Classical VRP heuristics can be broadly classified into three categories. *Constructive heuristics* gradually build a feasible solution while keeping an eye on the solution cost, but do not contain an improvement phase *per se*. In *two-phase heuristics*, the problem is decomposed into its two natural components: clustering of vertices into feasible routes and actual route construction, with possible feedback loops between the two stages. Two-phase heuristics can be divided into two classes: *cluster-first, route-second* methods and *route-first, cluster-second*. In the first case, vertices are first organized into feasible clusters, and a vehicle route is constructed for each of them. In the second case, a tour is first built on all vertices and is then segmented into feasible vehicle routes. Finally, *improvement methods* attempt to upgrade any feasible solution by performing a sequence of edge or vertex exchanges within or between vehicle routes. The distinction between constructive and improvements methods is, however, often blurred since most constructive algorithms incorporate improvement steps (typically 3-opt) at various stages.

As far as we are aware, six main types of metaheuristics have been applied to the VRP: 1) Simulated Annealing (SA), 2) Deterministic Annealing (DA), 3) Tabu Search (TS), 4) Genetic Algorithms (GA), 5) Ant Systems (AS), and 6) Neural Networks (NN). The first three algorithms, SA, DA and TS, start from an initial solution x_1, and move at each iteration t from x_t to a solution x_{t+1} in the neighbourhood $N(x_t)$ of x_t, until a stopping condition is satisfied. If $f(x)$ denotes the cost of x, then $f(x_{t+1})$ is not necessary less than $f(x_t)$. As a result, care must be taken to avoid cycling. GA examines at each step a population of solutions. Each population is derived from the preceding one by combining its best elements and discarding the worst. AS is a constructive approach in which several new solutions are created at each iteration using some of the information gathered at previous iterations. As was pointed out by

Taillard *et al.*, TS, GA and AS are methods that record, as the search proceeds, information on solutions encountered and use it to obtain improved solution. NN is a learning mechanism that gradually adjusts a set of weights until an acceptable solution is reached. The rules governing the search differ in each case and these must also be tailored to the shape of the problem at hand. Also, a fair amount of creativity and experimentation is required.

The purpose of this talk is to provide an overview of the most important classical and modern heuristics for the VRP. Several comparative computational results will be presented. Some future research directions will be outlined.

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Contributed Presentations

From kjefag@enter.vg Tue Aug 15 08:35:46 2000 Date: Mon, 14 Aug 2000 11:19:17 +0200 (CEST) From: kjefag@enter.vg To: Jesper Larsen <jla@imm.dtu.dk> Subject: New subject for presentation on ROUTE2000

Hello Jesper,

according to our conversation on the phone earlier today, I send you the title and abstract of my new presentation on ROUTE2000. I hope this change in presentation does not make any trouble to you. I look forward to seeing you in Rolighed on Wednesday.

Best regards

Kjetil

Ship scheduling with soft time windows

Abstract

This paper considers a real ship scheduling problem that can be considered as a multi-ship pickup and delivery problem with soft time windows. The motivation for introducing soft time windows instead of hard is that by allowing controlled time window violations for some customers, it may be possible to obtain better schedules and significant reductions in the transportation costs. To control the time window violations, inconvenience costs for servicing customers outside their time windows are imposed. An optimisation based approach based on a set partitioning formulation is proposed to solve the problem. First, all (or a number of promising) feasible routes are enumerated. Second, the various possible schedules of each route are computed as well as the corresponding operating and inconvenience costs. Finally, the schedules are given as input to a set partitioning problem. The solution method also determines the optimal speeds for the ships on the various sailing legs. The computational results show that the proposed approach works on the real ship scheduling problem.

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Practical information

- **Activities**

  Billiard, dart, table tennis, outdoor volleyball, TV and video (VHS), library, public accessible wood and a beach from where is is possible to go for a swim.

- **Address**

  The address of Rolighed is Skodsborg Strandvej 303, DK-2942 Skodsborg. Phone: 45 89 17 00, fax 45 89 17 68.

- **Departure**

  Rooms have to be vacated before 9am at departure. Keys must be returned at the reception. The reception will show you where to place your luggage.

  If you have used the phone in your room you must also pay for the usage at the reception.

- **Facilities**

  Whiteboard, flip-over, overhead-projector, TV and video (VHS), slide projector, sound system, fax, photocopier, PC with Microsoft Powerpoint and StarOffice Presentation.

- **Meeting rooms**

  Beside the large conference room that can hold up to 60 persons there are small rooms available. A large meeting room that has a capacity of 16 persons is also available. Additionally there are 4 meeting rooms where there is room for up 12 persons, and 1 small room that can hold up to 8 persons.

- **Phone**

  There are phones in the rooms. It is possible to get a direct line out of Rolighed, but all incoming calls are handles by the reception. Therefore it is not possible to receive incoming calls on the rooms after 7pm.

  It is more expensive to make phone calls from the room than from the coin phone available for the guests in the reception area (the number of the phone is 45 89 16 29). The phone in the hall has number 45 89 16 54, and is available for receiving calls after 7pm.

- **Public transportation**

  From Copenhagen Airport (Kastrup) and from the Copenhagen Main Station there is a regional train going to Vedbæk (Vedbaek) station - direction: Helsingør (Elsinore).

  Between 4:46am and 0:26am there are trains to/from the Airport (via the Copenhagen Main Station) and Elsinore every 20 minutes. Departure from the Airport is 06, 26 and 46. Arrival at the Copenhagen Main Station 19, 39 and 59. Departure from the Copenhagen Main Station 21, 41 and 01. Arrival at Vedbæk station 47, 07 and 27.

  At the airport tickets can be purchased at the DSB Ticket Office in terminal 3. A ticket from the Airport to Vedbæk costs 42 Danish Crowns, from the Copenhagen Main Station to Vedbæk the price will be 36 Danish Crowns.

  From Vedbæk station there is about 2 kilometers to walk. Alternatively a taxi from Vedbæk station to Rolighed costs approx. 45 Danish Crowns.

  Taxis can be called on 45 83 83 83.

- **Questions**

  If you have further questions about the workshop, Rolighed etc. you are welcome to ask the members of the organizing committee: Oli Madsen is in room 31, Jesper Larsen is in room 13 and René Munk Jørgensen is in room 14.

- **Reception**

  The reception is open on arrival and departure and from 8am to 7pm. In the reception it is possible to buy tobacco, candy, toilet requisites, postcards etc.

  Mail can be sent from the reception. All mail handed in before 4pm will be processed on the same day.

  The reception accepts the following credit cards: VISA, Eurocard/Mastercard, Eurocheck and JCB.

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Roligheden

Rolighed is beautifully situated in the middle of a large park, with a view of both forest and sea. The interior is characterized by a quiet modern elegance, in which it is impossible not to feel comfortable. As a conference hotel, Roligheden is also used for family events, receptions and meetings. The name Rolighed is Danish for peace and quiet.

The story of Rolighed can be dated at least 200 years back. The buildings might be even older, but in 1780 the land was bought by a Norwegian, Carsten Tank Anker. Back then there were already several large country estates around the small town Vedbæk, which makes it likely that Rolighed was once part of one of the neighbouring estates Sølyst and Enrum.

The Anker family was very close friends to the Duke of Wellington, which saved Rolighed when the English in 1807

went on shore and took over the large estates along the coastline. The Duke protected Rolighed, which is why his portrait is still displayed at Rolighed today.

In 1813 Carsten Anker sold Rolighed to captain John Christmas, and when he died in 1826 the estate was bought by the well know merchant William Dunzfeld, who again in 1841 sold Rolighed to the English diplomat Peter Browne. After Browne returned to England, the estate was sold to the Danish merchant L.J.T. Grøn, who lived on the estate with his wife for a long period until it was passed on to his son Howard Grøn. Howard rebuilt the estate in the 1920's, where the old wooden main building was torn down and replaced with the present beautiful brick building.

Several members of the Grøn family has lived on Rolighed, until the Foundation of May 28th. 1948 bought the estate. In 1960-61 Rolighed was slightly modified to its present look. A modern conference centre in elegant old surroundings.

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The Technical University of Denmark

The Technical University of Denmark

The Technical University of Denmark (DTU) was founded in 1829 by the famous Danish scientist H. C. Ørsted. Today it is one of the leading European technical universities and it is the largest research and teaching center within engineering in Northern Europe. DTU has 7000 bachelor and master students and 650 Ph.D. students. Research is performed by approx. 1250 researchers and 600 Ph.D. students employed at 33 departments. There is an extensive cooperation with industry, country-wide and internationally. More than half of the research performed at

DTU is financed by external resources. For further information see `http://www.dtu.dk`.

Department of Mathematical Modelling

The Department of Mathematical Modelling (IMM), which is one of DTU's largest departments, consists of a number of research sections focusing on applied mathematics and numerical computations. Presently the research staff number more than 50 researchers and 60 Ph.D. students. IMM focuses on mathematical and statistical modelling of e.g., physical, technical, biological or social systems. Teaching and research are carried out under the following headlines: Numerical Analysis and Scientific Computing, Mathematical Physics and Non-Linear Dynamics, Operations Research, Mathematical Statistics, Image Analysis, and Digital Signal Processing.

One of the research sections is the Operations Research Section presently consisting of 5 researchers and 4 Ph.D. students.

For the Operations Research section it is important, that the group covers the whole spectrum from the collection of data and problem analysis in the one end, to the practical implementation in the other end.

The areas, which the section is focusing on, can be divided according to the specific application or according to the tools which are used or developed. One of the main research areas for the Operations Research Section is transport, logistics, inventory and distribution systems, and crew scheduling. Of specific tools one can mention methods for solving continuous and discrete optimization problems (branch and bound, Lagrange relaxation and decomposition, sub-gradient optimization, dynamic programming), development of metaheuristics (simulated annealing, tabu search, genetic algorithms and neural networks) and the use of parallel computers. Many projects are carried out in cooperation with private or public companies. For further information about IMM see `http://www.imm.dtu.dk`. You can also visit the website of the Operations Research section at `http://www.imm.dtu.dk/or/`.

Centre for Traffic and Transportation Research

The Centre for Traffic and Transport Research (CTT) at DTU was established on January 1. 1999 in order to strengthen the research within traffic and transport. The main research areas are traffic models, traffic informatics, risc- and evaluation models, logistics, and transport optimization. Further information can be obtained from the DTU-webserver at the link `http://www.adm.dtu.dk/institutter/trafik/side1_d.htm`.