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Publications:

A study of traceability and quality assurance in fish supply chains

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Pricing and Capacity Planning Problems in Energy Transmission Networks
Efficient use of energy is an increasingly important topic. Environmental and climate concerns as well as concerns for security of supply has made renewable energy sources a viable alternative to traditional energy sources. However, the intermittent nature of for instance wind and solar energy necessitates a radical change in the way we plan and operate energy systems. Another paradigm change which began in the 1990’s for electricity systems is that of deregulation. This has led to a variety of different market structures implemented across the world. In this thesis we discuss capacity planning and transmission pricing problems in energy transmission networks. Although the modelling framework applies to energy networks in general, most of the applications discussed concern the transmission of electricity. A number of the problems presented involves transmission switching, which allows the operator of an electricity transmission network to switch lines in and out in an operational context in order to optimise the network flow. We show that transmission switching in systems with large-scale wind power may alleviate network congestions and reduce curtailment of wind power leading to higher utilisation of installed wind power capacity. We present formulations of — and efficient solution methods for— the transmission line capacity expansion problem and the unit commitment problem with transmission switching. We also show that transmission switching may radically change the optimal line capacity expansion strategy. In the Nordic
electricity system a market with zonal prices is adopted. We consider the problem of designing zones in an optimal way explicitly considering uncertainty. Finally, we formulate the integrated problem of pipeline capacity expansion planning and transmission pricing in natural gas transmission networks.

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**Modelling and Analysis of Distributed Energy Systems with Respect to Sustainable Energy: Focus on Electric Drive Vehicles**
Climate change and CO2 emissions is an important issue on the agenda of many politicians. Trying to decrease CO2 emissions, influences transportation, power production, etc. The power system is characterised by an increasing amount of renewables, with one of the most expanding renewable power sources being wind. Wind energy is fluctuating by nature, calling for increasing flexibility elsewhere in the energy system. For Denmark, hydro power from Norway help stabilizing the system, as does export of excess wind to Germany, although the latter is decreasing in use because of large correlations between high wind production in northern Germany and western Denmark. To decrease CO2 emissions through a decrease in the use of fossil fuelled plants, along with an increase the amount of renewable energy, the power system needs more flexibility such as flexible demands, storage etc. Flexibility could also come from the road transport system. Counting for 24% of the CO2 emissions in Denmark in 2009, the road transport system needs to move towards, e.g. electric drive vehicles. However, the electric drive vehicles are also demanding electricity from the power system. This brings both challenges and opportunities to the power system. One challenge is, that intelligence is needed unless peak-load is to increase drastically. With intelligent charging of the vehicles, though, the electric drive vehicles can be of great benefit providing flexible demand and charging at night time, instead of being regarded as yet another load and challenge for the energy system. Furthermore, discharging of vehicles can provide services to the power system. The batteries in the electric drive vehicles are batteries invested in anyway. Hence, why not use these actively for cheap storage by the energy system? Furthermore, the use of vehicles is opposite to the remaining demand for energy; e.g. while people are making dinner their vehicles will often be parked, being able to deliver back-up power - again, a great opportunity for the power system. In this PhD project I have focussed on modelling and analysis of a future integrated transport and power system. An integrated power and transport system enables analyses of the interactions between different parts of the energy system. The object of interest is an optimal configuration of an integrated power and transport system as well as I will be focussing on the drawbacks and benefits for the power system incorporating an electrified transport system. I have performed analyses in terms of integrating more renewable energy, for both Denmark as an isolated country, and for the northern European countries including Denmark, Sweden, Norway, Finland, and Germany. The analyses are performed using the deterministic energy systems analysis model, Balmorel. Furthermore, analyses have been made for the Irish power system on the influence of introducing electric drive vehicles in a predefined power system, using the stochastic energy systems analysis model, Wilmar. Interesting is, that it turns out to be most profitable to invest in enough wind to more than cover the electrified transport in Denmark. This holds, both when modelling Denmark as an isolated country, and when including the interactions between the Nordic countries. Furthermore, analyses show that fuel cell electric vehicles are not yet ready for competing with the other vehicle types. This is, among other things, due the technologies not being cheap enough, thus, the development is not expected to have reached a competitive stage. Another interesting finding is the results showing that it is beneficial for Ireland to have electric drive vehicles in terms of both costs and CO2 emissions. However, introducing the electric drive vehicles in Ireland, imply an increase in both costs and CO2 in the Great British side, as most of the power for the vehicles is produced on British coal power plants. Thus, focusing nationally, Ireland should invest in the electric drive vehicles, although, on an international level, the investments are costly.

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**Organisations:** Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy, Department of Management Engineering, Operations Research, Intelligent Energy Systems Programme
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Rostering and Task Scheduling: Applications in Manpower Planning

In a modern society, manpower can be both a scarce and an expensive resource. Skilled personnel is usually in high demand and accounts for a significant part of total expenses in many companies. When the work is divided in shifts, a roster is compiled to allocate these to the employees. The rostering process is non-trivial and especially when service is required around the clock, rostering may involve considerable effort from a designated planner. Therefore, in order to minimize costs and overstaffing, to maximize the utilization of available staff, and to ensure a high level of satisfaction among the employees, sophisticated scheduling methods are required. When approaching the day of operation, the detail level of the planning becomes finer. With a given allocation of shifts to employees, the focus is turned to tasks scheduling within those shifts. The objective is to assign as much work as possible to the available staff, while respecting various requirements and rules and while including possible transportation time between tasks. This thesis presents a number of industrial applications in rostering and task scheduling. The applications exist within various contexts in health care, the aviation industry, transportation, and production. The focus regarding rostering is both on a generalized rostering problem, which captures most realistic settings, and also on a more specific case, where particular issues and extensions are examined. In task scheduling, the focus is restricted to scheduling problems with temporal dependencies between tasks. However, these problems appear in various contexts and with different properties. A group of the problems considered are related to vehicle routing problems, where transportation and time windows are important factors that must be accounted for. Mathematical and logic-based models are presented for the problems considered. Novel components are added to existing models and the modeling decisions are justified. In one case, the model is solved by a simple, but efficient greedy construction heuristic. In the remaining cases, column generation is applied. Column generation is an iterative exact solution method based on the theory of linear programming and is capable of providing provably optimal solutions. In some of the applications, the approach is modified to provide feasible solutions of high-quality in less time. The exceptional solution quality of column generation is maintained, but the certificate of optimality is compromised. The contribution of this thesis is partly in the introduction, extension, and refinement of mathematical models for practical planning problems. Further, the contribution is in the proposed solution methods, which produce applicable and superior results to a range of realistic manpower planning problems. The contributions are presented in six scientific papers, which are compiled in the thesis. These include the development of a versatile approach to generalized rostering, building on an idea of compile-time customization. Several extensions of practical rostering problems are presented. For task scheduling, a general modeling of temporal dependencies is introduced and included in the methodology of column generation. The approach is applied to several practical problems with promising results. Lastly, a novel approach to crane scheduling with superior results is presented.
Rich Vehicle Routing Problems and Applications

The Vehicle Routing Problem (VRP) is one of the most important and challenging optimization problems in the field of Operations Research. It was introduced by Dantzig and Ramser (1959) and defined as the problem of designing the optimal set of routes for a fleet of vehicles in order to serve a given set of customers. The VRP is a computationally hard combinatorial problem and has been intensively studied by numerous researchers in the last fifty years. Due to the significant economic benefit that can be achieved by optimizing the routing problems in practice, more and more attention has been given to various extensions of the VRP that arise in real life. These extensions are often called Rich Vehicle Routing Problems (RVRPs). In contrast to the research of classical VRP that focuses on the idealized models with unrealistic assumptions, the research of RVRPs considers those complicated constraints encountered in the real-life planning and provides solutions that are executable in practice. In this thesis, we investigated the models and algorithms of three practical vehicle routing problems. Each of them involves special practical issues that are only considered in very few papers. Our study of these problems was motivated by our cooperation with industrial companies, particularly Transvision A/S and its client distributors, and Danish Crown. The models and methods proposed in the thesis are general and can be applied to practical routing problems arising in many other distribution companies as well. We first consider a vehicle routing problem with cross-docking options, in which products are picked up from suppliers by vehicles, consolidated at the depot and immediately delivered to customers by the same set of vehicles. It is more complex than the traditional vehicle routing problems in the sense that consolidation decisions have to be made at the depot and these decisions interact with the planning of pickup and delivery routes. We presented a mathematical model and proposed a Tabu Search based heuristic to solve it. It is shown that the approach can produce near-optimal solutions within very short computational time on real-life data involving up to 200 pairs of suppliers and customers. The second problem we consider is a dynamic vehicle routing problem with multiple objectives over a planning horizon that consists of multiple periods. In this problem, customer orders are revealed incrementally over the planning horizon. The delivery plan must be made and executed in every period without knowing the future orders. We modeled the problem as a mixed integer linear program and solved it by means of a three-phase heuristic that works over a rolling planning horizon. The method improves the company’s solution in terms of all the objectives, including the travel time, customer waiting and daily workload balances, under the given constraints considered in the work. Finally, we address an integrated vehicle routing and driver scheduling problem, in which a large number of practical constraints are considered, such as the multi-period horizon, the time windows for the delivery, the heterogeneous vehicles, the drivers' predefined working regulations, the driving rule etc. The problem is formulated as a mixed integer linear program and treated by a multilevel variable neighborhood search algorithm. The method is implemented and tested on real-life data involving up to 2000 orders. It is shown that the method is able to provide solutions of good quality within reasonable running time.
Disruption management in the airline industry—Concepts, models and methods
This paper provides a thorough review of the current state-of-the-art within airline disruption management of resources, including aircraft, crew, passenger and integrated recovery. An overview of model formulations of the aircraft and crew scheduling problems is presented in order to emphasize similarities between solution approaches applied to the planning and recovery problems. A brief overview of research within schedule robustness in airline scheduling is included in the review, since this proactive measure is a natural complement to disruption management.

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In this paper, we present the Slab Yard Planning and Crane Scheduling Problem. The problem has its origin in steel production facilities with a large throughput. A slab yard is used as a buffer for slabs that are needed in the upcoming production. Slabs are transported by cranes and the problem considered here is concerned with the generation of schedules for these cranes. The problem is decomposed and modeled in two parts, namely a planning problem and a scheduling problem. In the planning problem, a set of crane operations is created to take the yard from its current state to a desired goal state. In the scheduling problem, an exact schedule for the crane is generated, where each operation is assigned to a crane and is given a specific time of initiation. For both models, a thorough description of the modeling details is given along with a specification of objective criteria. Preliminary tests are run on a generic setup with simulated data. The test results are very promising. The production delays are reduced significantly in the new solutions compared with the corresponding delays observed in a simulation of manual planning.
Scheduling of inspectors for ticket spot checking in urban rail transportation

A central issue for operators of passenger transportation in urban rail is balancing the income from tickets against the cost of the operation. The main part of the income except for governmental subsidies comes from sales of tickets. There are various ways to ensure that all passengers carry valid tickets, i.e. to avoid so called fare evasion. Many European companies use spot checking of passengers and among these is DSB S-tog. The current paper describes a decision support tool developed at DSB S-tog. Based on historical data regarding when penalty fares are claimed and based on the schedules of the inspectors, this tool enables the construction of new schedules for ticket inspectors, such that the income from penalty fares claimed from passengers without a valid ticket is maximised. Other tools to increase income from ticket sales and penalty fares are also discussed.

The fish industry - toward supply chain modelling

Mathematical models for simulating and optimizing aspects of supply chains such as distribution, planning, and optimal handling of raw materials are widely used. However, modeling based on a holistic chain view including several or all supply chain agents is less studied, and food-related aspects such as quality and shelf-life issues enforce additional requirements onto the chains. In this article, we consider the supply chain structure of the fish industry. We discuss and illustrate the potential of using mathematical models to identify quality and value-adding activities. The article provides a first step toward innovative supply chain modeling aimed to identify benefits for all agents along chains in the fish industry.
Decision Support for Planning of Multimodal Transportation with Multiple Objectives
This thesis treats two different planning problems from the transportation industry; one from freight transport and one from passenger transport. Each problem emerges as a combination of problems that are already known from the operational research literature, and introduces a new view of well-known issues. They both originate in the world of multimodality, and
deal with problems that arise as a consequence of the combined use of several modes. The thesis introduces the Double Travelling Salesman Problem with Multiple Stacks (DTSPMS), which is a problem that combines routing and last-in-first-out loading constraints. After giving an introduction to the problem, a range of related problems from the literature are discussed. Some considerations are made regarding the combinatorial problems for the DTSPMS compare to solutions of the regular Travelling Salesman Problem. Next, two papers are presented, introducing respectively heuristic and exact solution procedures for the problem. The heuristic approach tests a variety of metaheuristic solution approaches, of which a large number of problems presents the best results. Results are provided for real-life instance sizes, for smaller instances for which the optimal solution value is known, and for some larger instances, which can also be justified from a real-life perspective. The purpose of solving the DTSPMS is optimality, different mathematical formulation are presented and tested in the second paper. The most promising approach is based on a decomposition of the problem into a routing part and a loading feasibility part, and all tested instances with 15 orders can be solved using this approach. The Simultaneous Vehicle Scheduling and Passenger Service Problem (SVSPSP) is an integration of two problems that are usually solved separately and sequentially, namely the timetabling problem and the Vehicle Scheduling Problem. The SVSPSP allows for the solution of the timetabling problem to be reoptimised when considering the vehicle scheduling phase, and considers passenger inconvenience at transfers at the same time. The paper presents a mathematical model of the problem, and the implementation of a large neighbourhood search solution procedure. The problem is solved for a real-life based problem instance, containing eight bus lines in the Greater Copenhagen area, and the results are promising.

**General information**

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**The Train Driver Recovery Problem - Solution Method and Decision Support System Framework**

In this thesis we consider the train driver recovery problem (TDRP). The problem occurs when the daily train driver schedule becomes infeasible due to irregular operations on the railway network. Unforeseen disruptions such as signalling problems or rolling stock failures prevent the train drivers from following the originally scheduled sequence of activities in their duties. The real-time re-scheduling of the disrupted train driver duties is currently performed manually by the train driver dispatchers. If the disruption is severe and many train driver duties are disturbed, this is a very complicated task to carry out. The interest of the passenger railway operator DSB S-tog A/S in introducing automated decision support for the train driver dispatchers is a key motivation for this project. We propose an optimization-based solution method for solving the TDRP and develop a prototype for the decision support system. The framework is based on solving restricted TDRP instances with a rolling time horizon, aiming at modifying the original duty schedule as little as possible. We formulate TDRP as a set partitioning model, where variables represent train driver recovery duties, and describe why the proposed model and solution method is suitable for solving in real-time. Recovery duties are generated as resource constrained paths in duty networks, and the set partitioning problem is solved with a linear programming based branch-and-price algorithm. Dynamic column generation and problem space expansion at each node of the branch-and-price tree together with a constraint branching strategy convivially contribute to the solution method. Real-life operational data is provided by DSB S-tog A/S in order to test the implemented solution method. Based on the computational experiments presented in this thesis, we conclude that the proposed approach is indeed applicable for implementation in a decision support system for train driver dispatchers in practice. DSB S-tog A/S is working on using the research results obtained during this thesis and the programming code of the prototype to develop and implement the train driver decision support system in their operational environment. Besides solving a particular optimization problem, this thesis contributes with a description of the railway planning process, tactical crew scheduling and the real-time dispatching solutions, taking a starting point in DSB S-tog’s operations. Furthermore, we present comprehensive reviews of operations research applications within railway crew...

Agent Based Individual Traffic Guidance

This thesis investigates the possibilities in applying Operations Research (OR) to autonomous vehicular traffic. The explicit difference to most other research today is that we presume that an agent is present in every vehicle - hence Agent Based Individual Traffic guidance (ABIT). The next evolutionary step for the in-vehicle route planners is the introduction of two-way communication. We presume that the agent is capable of exactly this. Based on this presumption we discuss the possibilities and define a taxonomy and use this to discuss the ABIT system. Based on a set of scenarios we conclude that the system can be divided into two separate constituents. The immediate dispersion, which is used for small areas and quick response, and the individual alleviation, which considers the longer distance decision support. Both of these require intricate models and cost functions which at the beginning of the project were not previously considered. We define a special inseparable cost function and develop a solution complex capable of using this cost function. In relation to calibration and estimation of statistical models used for dynamic route guidance we worked with generating random number sequences. During this work we made significant findings related to random numbers.
Decision Support for the Rolling Stock Dispatcher

Real-time recovery is receiving a fast growing interest in an increasingly competitive railway operation market. This thesis considers the area of rolling stock dispatching which is one of the typical real-time railway dispatching problems. All work of the thesis is based on the network and planning processes of the railway operator DSB S-tog a/s. In the thesis the problems existing in the railway planning process from the strategic to real-time level are briefly sketched. Network planning, line planning, timetabling, crew and rolling stock planning is outlined and relevant references are given. Specifically the thesis references the operation research studies based on the railway operation of DSB S-tog a/s. Subsequently the process of dispatching is outlined with a specific emphasis on rolling stock. The rolling stock recovery problem is the problem of assigning train units to train departures in a disrupted rolling stock schedule so that operation returns quickly to the originally planned schedule. Different network structures and mathematical formulations for the problem are discussed. Based on prior work on network structures a decomposed approach for the rolling stock recovery problem is put forward. The main contributions of the thesis are contained in four papers included as appendices. The papers deal with respectively an analysis of robustness in timetables, the mathematical model behind a decision support tool for reinsertion of a train line, a survey on the dispatching problems of passenger railway transportation and the decomposed solution process of the rolling stock recovery problem. The paper on the robustness analysis has been accepted for submission in the International Journal of Operations Research. Two of the papers have been submitted to journals and are being reviewed. The last paper will be submitted. Furthermore, the work of the two papers on the robustness analysis respectively the reinsertion model have formed the basis of practical projects in DSB S-tog. The applicability of the decomposed process will be further investigated in the future.

Disruption Management in Passenger Railway Transportation

This paper deals with disruption management in passenger railway transportation. In the disruption management process, many actors belonging to different organizations play a role. In this paper we therefore describe the process itself and the roles of the different actors. Furthermore, we discuss the three main subproblems in railway disruption management: timetable adjustment, and rolling stock and crew re-scheduling. Next to a general description of these problems, we give an overview of the existing literature and we present some details of the specific situations at DSB S-tog and NS. These are the railway operators in the suburban area of Copenhagen, Denmark, and on the main railway lines in The Netherlands, respectively. Finally, we address the integration of the re-scheduling processes of the timetable, and the resources rolling stock and crew.

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Solving the Turbine Positioning Problem for Large Offshore Wind Farms by Simulated Annealing
The current paper is concerned with determining the optimal layout of the turbines inside large offshore wind farms by means of an optimization algorithm. We call this the Turbine Positioning Problem. To achieve this goal a simulated annealing algorithm has been devised, where three types of local search operations are performed recursively until the system converges. The effectiveness of the proposed algorithm is demonstrated on a suite of real life test cases, including Horns Rev offshore wind farm. The results are verified using a commercial wind resource software indicating that this method represents an effective strategy for the wind turbine positioning problem. The findings enable the comparison of the optimized and the grid layouts and the study of the wake differences between these configurations. It is seen that for very large offshore wind farms the difference in wake losses is negligible while, as the wind farm's size reduces, the differences start becoming significant. A sensitivity analysis is also performed showing that greater density of turbines in
the perimeter of the optimized wind farm reduces the wake losses even if the wind climate changes.

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The fishing industry - toward supply chain modelling
Mathematical models for simulating and optimizing supply chain aspects such as distribution planning and optimal use of raw materials are widely used. However, modelling based on a holistic chain view is less studied, and food-related aspects such as quality and shelf life issues enforce additional requirements onto the chains. In this paper, we consider the supply chain structure of the Danish fishing industry and illustrate the potential of using mathematical models to identify quality and value-adding activities. This is a first step toward innovative supply chain modelling aimed to identify benefits for actors along chains in the fishing industry.

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Organisations: Operations Research, Department of Management Engineering, Technical University of Denmark
Authors: Jensen, T. K. (Intern), Nielsen, J. (Ekstern), Larsen, E. P. (Ekstern), Clausen, J. (Intern)
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The Manpower Allocation Problem with Time Windows and Job-Teaming Constraints: A Branch-and-Price Approach
In this paper, we consider the Manpower Allocation Problem with Time Windows, Job-Teaming Constraints and a limited number of teams (m-MAPTWTC). Given a set of teams and a set of tasks, the problem is to assign to each team a sequential order of tasks to maximize the total number of assigned tasks. Both teams and tasks may be restricted by time windows outside which operation is not possible. Some tasks require cooperation between teams, and all teams cooperating must initiate execution simultaneously. We present an IP-model for the problem, which is decomposed using Dantzig-Wolfe decomposition. The problem is solved by column generation in a Branch-and-Price framework. Simultaneous execution of tasks is enforced by the branching scheme. To test the efficiency of the proposed algorithm, 12 realistic test instances are introduced. The algorithm is able to find the optimal solution in 11 of the test instances. The main contribution of this article is the addition of synchronization between teams in an exact optimization context.

General information
Vehicle routing with cross-docking

Over the past decade, cross-docking has emerged as an important material handling technology in transportation. A variation of the well-known Vehicle Routing Problem (VRP), the VRP with Cross-Docking (VRPCD) arises in a number of logistics planning contexts. This paper addresses the VRPCD, where a set of homogeneous vehicles are used to transport orders from the suppliers to the corresponding customers via a cross-dock. The orders can be consolidated at the cross-dock but cannot be stored for very long because the cross-dock does not have long-term inventory-holding capabilities. The objective of the VRPCD is to minimize the total travel time while respecting time window constraints at the nodes and a time horizon for the whole transportation operation. In this paper, a mixed integer programming formulation for the VRPCD is proposed. A tabu search heuristic is embedded within an adaptive memory procedure to solve the problem. The proposed algorithm is implemented and tested on data sets provided by the Danish consultancy Transvision, and involving up to 200 pairs of nodes. Experimental results show that this algorithm can produce high-quality solutions (less than 5% away from optimal solution values) within very short computational time.
Optimization of the raw material use at Danish slaughterhouses

General information
State: Published
Organisations: Operations Research, Department of Management Engineering, Operations Management
Authors: Kjærsgaard, N. C. (Intern), Clausen, J. (Intern), Jacobsen, P. (Intern)
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Mathematical models and methods for analysis of distributed power generation on market conditions
The liberalisation of electricity markets around the world which has taken place in recent years – and is still ongoing – has had several consequences for the various players in the markets affected. Typically, the tasks of production, transmission, and distribution of electricity which were often handled by so-called vertically integrated monopolies have been separated to varying degrees and are in liberalised systems handled by different players. In the Nordic system, electricity is traded as a commodity on a day-ahead spot market where suppliers and consumers submit their bids for the following day and a common hourly electricity spot price is found. Intra-day markets for balancing power also exist. The raison d’etre for this type of market is that although supply and demand are balanced on a day-ahead basis, actual demand is impossible to forecast with complete accuracy. Thus on the day of operation actual demand and planned supply never match precisely. The system operator must then procure so-called balancing power in the intra-day market to maintain the physical balance...
of the system at all times. The present thesis considers the effects of large amounts of distributed electricity generation in a power system subject to a liberalised market. In particular, the Danish electricity system is analysed in terms of four different focus topics which are considered in the six research papers presented and commented on in the thesis. The analyses range from planning the operation and/or bidding of single-technology units such as wind power turbines and local combined heat and power plants to analyses from a system point of view such as the interaction between the natural gas, district heating, and electricity systems, and the system operator dilemma of procuring reserve power well in advance as opposed to purchasing the needed volumes in the intra-day balancing market. The thesis itself provides an introduction to the Nordic power system and market with emphasis on the Danish situation. After presenting a few classic topics in power system operation, the situation post-liberalisation of the electricity markets is analysed and a literature review is given of the major topics of the thesis, setting the contributions of the thesis into perspective of previous work on related topics. Subsequently, the papers included in the thesis are summarised and commented upon and the main contributions are listed, before the thesis is concluded upon.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Operations Research, Department of Management Engineering
Authors: Schaumburg-Müller, C. (Intern), Clausen, J. (Intern), Ravn, H. V. (Intern)
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Mathematical models and heuristic solutions for container positioning problems in port terminals
This PhD thesis is concerned with the container positioning problem (CPP) which consists in determining optimal sequences of positions and moves for containers in a single storage block of a terminal yard. The purpose of the thesis is to apply Operations Research (OR) methods for optimizing the CPP by constructing mathematical programming formulations of the problem and developing an efficient heuristic algorithm for its solution. The thesis consists of an introduction, two main chapters concerning new mathematical formulations and a new heuristic for the CPP, technical issues, computational results, and conclusive remarks. The introduction provides a basis for appreciating the presented work and sets out the scope, motivation, purpose, and contributions of the thesis. Furthermore, the CPP is defined and described, an overview of port container terminal issues in general is provided, and relevant literature concerning the subject is reviewed. The research presented in this thesis is divided into two main parts: Construction and investigation of new mathematical programming formulations of the CPP and development and implementation of a new event-based heuristic for the problem. The first part presents three mathematical programming formulations. First, a conceptual mixed integer linear programming (MIP) model for the entire port container terminal is presented. Subsequently, two models for the CPP are suggested: A MIP model and a binary integer linear programming (BIP) model. The models provide a basis for analyzing the CPP, demonstrating its complexity, and investigating potentials in model-based exact solution approaches. The models are solved by standard optimization software and the results as well as perspectives for alternative solution methods, making use of the models, are discussed. The second part presents an efficient solution algorithm for the CPP. Based on a number of new concepts, an event-based construction heuristic is developed and its ability to solve real-life problem instances is established. The backbone of the algorithm is a list of events, corresponding to a sequence of operations in the storage block. This concept enables a representation of the time dimension of the problem which is very efficient. Furthermore, introducing a range of criteria for evaluating and selecting positions for containers makes both a highly effective and very flexible algorithm which is also robust to changes in parameters and input data. Two improvement routines are presented, one imbedded in the basic heuristic and the other constituting a repair algorithm with the purpose of improving an initial heuristic solution. The heuristic algorithm performance and a wide range of different planning strategies are investigated by solving a large number of test instances and real-life problems. A total of 60 small-scale, 60 medium-scale, and 288 large-scale instances are introduced and used in the conduction of the computational experiments on the models and the heuristic algorithm. Results from the model runs show that it is difficult to obtain optimal solutions to the CPP by solving the mathematical formulations using standard optimizers. Furthermore, investigation of the potential of applying a relaxation approach indicates that this may not be a fruitful direction. Results from the heuristic runs prove the proposed algorithm very suitable for the CPP as good solutions are obtained within very short run times. Some important issues for further improvement of the heuristic algorithm are presented. Conclusively it may be stated that the proposed mathematical models are complex and hard to solve by standard optimization software and that the presented heuristic algorithm is very robust and scalable and constitutes a highly efficient solution method for
the CPP. The conclusive remarks are followed by some interesting perspectives for future research.

**Technical Report: Optimizing the Slab Yard Planning and Crane Scheduling Problem using a Two-Stage Approach**

In this paper, we present The Slab Yard Planning and Crane Scheduling Problem. The problem has its origin in steel production facilities with a large throughput. A slab yard is used as a buffer for slabs that are needed in the upcoming production. Slabs are transported by cranes and the problem considered here, is concerned with the generation of schedules for these. The problem is decomposed and modeled in two parts, namely a planning problem and a scheduling problem. In the planning problem a set of crane operations is created to take the yard from its current state to a desired goal state. The aim of the planning problem is twofold. A number of compulsory operations are generated, in order to comply with short term planning requirements. These operations are mostly moves of arriving and leaving slabs in the yard. A number of non-compulsory operations with a long term purpose are also created. A state of the yard may be more or less suited for future operations. It is desirable to keep the yard in a state, where it lends itself well to the future requests. Partial knowledge of future requests may exist and hence the yard can be prepared for those. In the scheduling problem, an exact schedule for the cranes is generated, where each operation is assigned to a crane and is given a specific time of initiation. For both models, a thorough description of the modeling details is given along with a specification of objective criteria. Variants of the models are presented as well. Preliminary tests are run on a generic setup with artificially generated data. The test results are very promising. The production delays are reduced significantly in the new solutions compared to the corresponding delays observed in a simulation of manual planning. The work presented in this paper is focused on a generic setup. In future research, the model and the related methods should be adapted to a practical setting, to prove the value of the proposed model in real-world circumstances.

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**Decision Support System for Fighter Pilots**

During a mission over enemy territory a fighter aircraft may be engaged by ground based threats. The pilot can use different measures to avoid the aircraft from being detected by e.g. enemy radar systems. If the enemy detects the aircraft a missile may be fired to seek and destroy the aircraft. Such a missile will almost always be either radar guided or heat seeking. It will be launched from a permanent launch pad, or it will be man portable and small enough to fit in the boot of a car. The probability of a missile being detected by onboard sensors depends on the type of missile. If a missile is detected the pilot may choose to deploy electronic countermeasures to avoid the impact of the missile. The countermeasures to choose depends on e.g. the type of missile and guidance system, distance and direction between the missile and the aircraft, an assessment of the environment hostility, aircraft altitude and airspeed, and the availability of countermeasures. Radar systems, guidance of missiles, and electronic countermeasures are all parts of the electronic warfare domain. A brief description of this domain is given. It contains an introduction to both systems working on-board the aircraft and countermeasures that can be applied to mitigate threats. This work is concerned with finding proper evasive actions when a fighter aircraft is engaged by ground based threats. To help the pilot in deciding on these actions a decision support system may be implemented. The environment in which such a system must work is described, as are some general requirements to the design of the system. Decisions suggested by the system are based on information acquired from different sources. The process of providing information from sources such as intelligence, on-board sensor systems, and tactical data from other platforms (aircraft, ships, etc.) is described. Different approaches to finding the combination of countermeasures and manoeuvres improving the pilots survivability is investigated. During training a fighter pilot will learn a set of rules to follow when threat occurs. For the pilot these rules will be formulated in natural language. An expert system can be build by translating these rules into a language understandable by a computer program. This is done in the development of a Prolog based decision support system. A decision support system will base its decisions on input from non-perfect sources. Warnings from on-board sensor can be false and intelligence reports deficient. A Bayesian net is modelled to address this. Building the dependency tables of a Bayesian net requires a large number of cells to be filled with relevant probabilities. Not having sufficient knowledge about these probabilities makes the work with developing a Bayesian net cumbersome. Therefore a method for structural learning is investigated. Here a Bayesian net is build using a set of sample data from a number of missile flight simulations. Knowledge about threats in the current combat scenario may influence the choice of evasive manoeuvres and proper countermeasures. If at any given time more expendables are dispensed than necessary, and none is left for a later necessity, the pilots survivability may decrease. A mathematical model is developed to describe this problem. It is solved to optimality using solver software. When new threats occur the decision support system must be able to provide suggestions within a fraction of a second. Since the time it takes to find an optimal solution to the mathematical model can not comply with this requirement solutions are sought using a metaheuristic.

**General information**

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Authors: Randleff, L. R. (Intern), Clausen, J. (Intern)
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**Applied Railway Optimization in Production Planning at DSB-S-tog - Tasks, Tools and Challenges**

Efficient public transportation is becoming increasingly vital for modern capitals. DSB S-tog a/s is the major supplier of rail traffic on the infrastructure of the city-rail network in Copenhagen. S-tog has experienced a demand for increasing volume and quality of the transportation offered to the customers, and has concurrently been met with demands for higher efficiency in the daily operation. The plans of timetable, rolling stock and crew must hence allow for a high level of customer service, be efficient, and be robust against disturbances of operations. It is a highly non-trivial task to meet these conflicting goals. S-tog has therefore on the strategic level decided to use software with optimization capabilities in the
planning processes. We describe the current status for each activity using optimization or simulation as a tool: Timetable evaluation, rolling stock planning, and crew scheduling. In addition we describe on-going efforts in using mathematical models in activities such as timetable design and work-force planning. We also identify some organizational key factors, which have paved the way for extended use of optimization methods in railway production planning.

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Authors: Clausen, J. (Intern)
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Disruption Management in Passenger Railway Transportation
This paper deals with disruption management in passenger railway transportation. In the disruption management process, many actors belonging to different organizations play a role. In this paper we therefore describe the process itself and the roles of the different actors. Furthermore, we discuss the three main subproblems in railway disruption management: timetable adjustment, rolling stock and crew re-scheduling. Next to a general description of these problems, we give an overview of the existing literature and we present some details of the specific situations at DSB S-tog and NS. These are the railway operators in the suburban area of Copenhagen, Denmark, and on the main railway lines in the Netherlands, respectively. Since not much research has been carried out yet on Operations Research models for disruption management in the railway context, models and techniques that have been developed for related problems in the airline world are discussed as well. Finally, we address the integration of the re-scheduling processes of the timetable, and the resources rolling stock and crew.

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Jespersen-Groth, J. (Ekstern), Potthoff, D. (Ekstern), Clausen, J. (Intern), Huisman, D. (Ekstern), Kroon, L. (Ekstern), Maroti, G. (Ekstern), Nielsen, M. N. (Ekstern)
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Disruption Management in Passenger Transportation - from Air to Tracks
Over the last 10 years there has been a tremendous growth in air transportation of passengers. Both airports and airspace are close to saturation with respect to capacity, leading to delays caused by disruptions. At the same time the amount of vehicular traffic around and in all larger cities of the world has show a dramatic increase as well. Public transportation by e.g. rail has come into focus, and hence also the service level provided by suppliers ad public transportation. These transportation systems are likewise very vulnerable to disruptions. In the airline industry there is a long tradition for using advanced mathematical models as the basis for planning of resources as aircraft and crew. These methods are now also coming to use in the process of handling disruptions, and robustness of plans has received much interest. Commercial IT-systems supplying decision support for recovery of disrupted operations are becoming available. The use of advanced planning and recovery methods in the railway industry currently gains momentum. The current paper gives a short overview over the methods used for planning and disruption management in the airline industry. The situation regarding
railway optimization is then described and discussed. The issue of robustness of timetables and plans for rolling stock and crew is also addressed.

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**Mortgage Loan Portfolio Optimization Using Multi-Stage Stochastic Programming**
We consider the dynamics of the Danish mortgage loan system and propose several models to reflect the choices of a mortgagor as well as his attitude towards risk. The models are formulated as multi stage stochastic integer programs, which are difficult to solve for more than 10 stages. Scenario reduction and LP relaxation are used to obtain near optimal solutions for large problem instances. Our results show that the standard Danish mortgagor should hold a more diversified portfolio of mortgage loans, and that he should rebalance the portfolio more frequently than current practice.

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Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Rasmussen, K. M. (Intern), Clausen, J. (Intern)
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BFI (2014): BFI-level 2
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BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.557 SNIP 1.421 CiteScore 1.42
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
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BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.922 SNIP 1.38 CiteScore 1.24
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Optimization and Simulation in the Danish Fishing Industry

We consider the Danish fishing industry from a holistic viewpoint, and give a review of the main aspects, and the important actors. We also consider supply chain theory, and identify both theoretically, and based on other application areas, e.g. other fresh food industries, how optimization and simulation can be applied in a holistic modeling framework. Using the insights into supply chain theory and the Danish fishing industry, we investigate how the fishing industry as a whole may benefit from the formulation and use of mathematical optimization and simulation models. Finally, an appendix illustrates how a mathematical programming model may be designed to improve the planning of the fishing efforts for a group of fishermen.
Optimizing the Steel Plate Storage Yard Crane Scheduling Problem Using a Two Stage Planning/Scheduling Approach
This paper presents the Steel Plate Storage Yard Crane Scheduling Problem. The task is to generate a schedule for two gantry cranes sharing tracks. The schedule must comply with a number of constraints and at the same time be cost efficient. We propose some ideas for a two stage planning/scheduling solution approach to the problem.

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Authors: Hansen, A. D. (Intern), Clausen, J. (Intern)
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Main Research Area: Technical/natural sciences
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Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2007

The Manpower Allocation Problem with Time Windows and Job-Teaming Constraints

General information
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Authors: Hansen, A. D. (Intern), Kolind, E. (Intern), Clausen, J. (Intern)
Publication date: 2007

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Conference: International Conference on Automated Planning and Scheduling, 01/01/2007
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Publication: Research - peer-review › Article in proceedings – Annual report year: 2007

In this paper, we consider the Manpower Allocation Problem with Time Windows, Job-Teaming Constraints and a limited number of teams (m-MAPTWTC). Given a set of teams and a set of tasks, the problem is to assign to each team a sequential order of tasks to maximize the total number of assigned tasks. Both teams and tasks may be restricted by time windows outside which operation is not possible. Some tasks require cooperation between teams, and all teams cooperating must initiate execution simultaneously. We present an IP-model for the problem, which is decomposed using Dantzig-Wolfe decomposition. The problem is solved by column generation in a Branch-and-Price framework. Simultaneous execution of tasks is enforced by the branching scheme. To test the efficiency of the proposed algorithm, 12 realistic test instances are introduced. The algorithm is able to find the optimal solution in 11 of the test instances. The main contribution of this article is the addition of synchronization between teams in an exact optimization context.

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A hybrid algorithm for solving the economic lot and delivery scheduling problem in the common cycle case

The ELDSP problem is a combined lot sizing and sequencing problem. A supplier produces and delivers components of different types to a consumer in batches. The task is to determine the cycle time, i.e., the time between deliveries, which minimizes the total cost per time unit. This includes the determination of the production sequence of the component types within each cycle.

We investigate the computational behavior of two published algorithms, a heuristic and an optimal algorithm. With large number of component types, the optimal algorithm has long running times. We devise a hybrid algorithm, which is both optimal and efficient. (c) 2005 Elsevier B.V. All rights reserved.
Risk Assessments of Minefields in Humanitarian Mine Action - a Bayesian Approach

During the last 10-15 years, the international community has become aware of the devastating mine contamination problems experienced in many post-conflict countries. As a consequence, a considerable amount of money and time is spent on research and development in new ways of locating buried mines and unexploded ordnance in a fast and secure way. A major breakthrough is however still waiting, and a large fraction of the mine clearance, which still remains to be done, will therefore hinge on slow and dangerous procedures based on prodders and metal detectors. Realizing that landmine contamination is a phenomenon which cannot be eliminated overnight but is a problem which has to managed in several years to come, it is essential that the resources a national government in a mine affected country spends on mine clearance are used on the right projects. However, the identification of the mine clearance projects with the greatest impact is a delicate task. More systematic approaches to the ranking of minefields with respect to mine clearance can be found in the literature, but these methods are either founded on simple scoring rules or are of a more qualitative nature. Thus nobody seems yet to have examined the usefulness of the analytical tools which might be provided by operations research and statistics in order to support decision makers involved in national mine clearance programmes. In February 2002, the Danish Defence Research Establishment initiated in collaboration with the Technical University of Denmark a Ph.D.-project to investigate whether the application of operations research and statistics can support decision makers in Humanitarian Mine Action to make the prioritization of mine clearance operations more effective. The main part of that project, which is presented in the enclosed thesis, has concentrated on the development of a risk model quantifying to what extent a minefield poses a risk to a society. The risk model is derived in two steps: First, a general model, which requires detailed information about the mined area in question, is derived. Secondly, by the introduction of two additional assumptions, the general model is turned into a simple binomial model depending on two parameters m and q. In this context the integer m denotes the number of so-called functional mines in the minefield under consideration, and the parameter q denotes the probability of a randomly selected mine being encountered by a person, a vehicle, etc. during a predefined observation period. The true values of the binomial parameters, which jointly characterize the state of the mined area, will rarely be known in advance, but beliefs about these based on whatever information is available can conveniently be expressed in terms of probability distributions p(m) and p(q). This prepares the way for the introduction of Bayesian data analysis by which updates of the probability distributions can be generated from incoming accident statistics. The major obstacle to a real-life application of the derived risk model seems to be the lack of actual information about the binomial parameter q. A considerable part of the enclosed thesis focuses therefore on ways to provide information about q through statistical modelling. Depending on the level of historical information available to a hypothetical decision maker, two different proposed models are examined as ways of extracting information about q: 1) A simple hierarchical model which as input requires accident statistics and clearance reports from already cleared minefields; 2) A finite mixture model where only accident statistics and the specification of certain prior distributions are needed as input data. Common to both models is the generation of posterior distributions of the parameter q. To extract information about q from these distributions various simulation techniques are applied including importance sampling and Markov Chain simulation. The possibility of making updates of the entering probability distributions p(m) and p(q) through incoming accident statistics by the use of Bayes' rule makes the suggested risk model dynamic. Moreover, the application of Bayesian data analysis gives the derived risk model a very flexible structure which allows an accommodation to the varied circumstances found in Humanitarian Mine Action with respect to the amount of accessible information. The present thesis closes with an overall prescription for the synthesis of different pieces of information based on the concept of reference priors.
Constructing Periodic Timetables using MIP - a case study from DSB S-train

We describe a mathematical model to create operational timetable alternatives in DSB S-tog a/s. The model is a mixed integer program implemented in GAMS and solved by CPLEX. We investigate the impact of automatic merges of lines and perform scenario analysis for a subset of the parameters in the model.

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BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.416 SNIP 0.555 CiteScore 0.89
BFI (2014): BFI-level 1
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BFI (2013): BFI-level 1
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ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.518 SNIP 0.717 CiteScore 1.41
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.326 SNIP 0.458 CiteScore 0.89
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.506 SNIP 0.714
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BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.288 SNIP 0.474
Finding the best visualization of an ontology

An ontology is a classification model for a given domain. In information retrieval, ontologies are used to perform broad searches. An ontology can be visualized as nodes and edges. Each node represents an element and each edge a relation between a parent and a child element. Working with an ontology becomes easier with a visual representation. An idea is to use the expressive power that a 3D representation provides to provide visualization for the user. In this paper, we propose a new method for positioning the elements of the visualized concept lattice in the 3D world based on Operations Research (OR) methods. One method uses a discrete location model to create an initial solution and we propose heuristic methods to further improve the visual result. We evaluate the visual results according to our success criteria and the feedback from users. Running times of the heuristic indicate that an improved version should be feasible for on-line processing and what-if analysis of ontologies.

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State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Fabritius, C. (Ekstern), Madsen, N. (Ekstern), Clausen, J. (Intern), Larsen, J. (Intern)
Pages: 1482-1490
Publication date: 2006
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of the Operational Research Society
Volume: 57
Issue number: 12
ISSN (Print): 0160-5682
Ratings:
BFI (2018): BFI-level 2
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): SJR 1.004 SNIP 1.052 CiteScore 1.59
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 0.938 SNIP 0.912 CiteScore 1.43
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.045 SNIP 1.112 CiteScore 1.34
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.242 SNIP 1.201 CiteScore 1.42
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.279 SNIP 1.081 CiteScore 1.24
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.37 SNIP 1.17 CiteScore 1.27
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.531 SNIP 1.137
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.352 SNIP 1.124
Optimal Reinsertion of Cancelled Train Lines

One recovery strategy in case of a major disruption in rail network is to cancel all trains on a specific line of the network. When the disturbance has ended, the cancelled line must be reinserted as soon as possible. In this article we present a mixed integer programming (MIP) model for calculating the best way to reinsert cancelled train lines in a rail network covered by a periodic timetable. Using a high abstraction level it has been possible to incorporate the temporal aspect in the model only relying on the information embedded in the train identification numbers of each departure. The model finds the optimal solution in an average of 0.5 CPU seconds in each test case.
Proceedings of the 1st Nordic Optimization Symposium - 10th Nordic MPS meeting, Copenhagen 2006

On behalf of the Technical University of Denmark, the Danish Operations Research Society and the Nordic Section of the Mathematical Programming Society we welcome you to Copenhagen and the 1st Nordic Optimization Symposium - the 10th meeting of the Nordic MPS. The meetings of the Nordic MPS have evolved to be more that just a meeting on Mathematical Programming. They are a forum for discussing a wide range of related areas and practical cases. In the organizing committee we wanted the name of the meeting to reflect this. We have therefore in agreement with the board of the Nordic MPS suggested to add a new title, that reflects the much broader field that is our playground at these meetings. Still the odd trustworthy title “Meeting of the Nordic MPS” has been maintained to demonstrate the origin of the symposium. It is our hope that future Nordic MPS meetings will carry on using this "double name". The program includes 2 plenary lectures by Leo Kroon and Arne Drud and more than 50 contributed presentations. The symposium has this time expanded beyond our Nordic boundaries with participants from eg. the Netherlands, Italy and New Zealand. As a consequence the original 2 parallel streams we had in mind have extended to 3 throughout the symposium. It is our firm belief that this symposium will - like all the previous Nordic MPS meetings - be a fruitfull ground for collaboration and networking and thereby further tighten the ties between the Nordic countries in relation to optimization, Operations Research and Mathematical Programming. Finally we would like to thank our sponsors and supporter for their contributions. It has among other things made it possible to give free registration to a number of researchers from the Baltic countries and Ph.D. students in general. We wish you all an enjoyable 1st Nordic Optimization Symposium (10th Nordic MPS meeting) in Copenhagen.

Robustness and Recovery in Train Scheduling - a simulation study from DSB S-tog a/s

This paper presents a simulation model to study the robustness of timetables of DSB S-tog a/s, the city rail of Copenhagen. Dealing with rush hour scenarios only, the simulation model investigates the effects of disturbances on the S-tog network. Several timetables are analyzed with respect to robustness. Some of these are used in operation and some are generated for the purpose of investigating timetables with specific alternative characteristics.

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling, Department of Transport, Logistics & ITS
Authors: Clausen, J. (Intern), Jørgensen, R. M. (Intern), Kohl, N. (Intern), Larsen, J. (Intern), Madsen, O. B. (Intern)
Publication date: 2006

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions: imm4517.pdf
Source: orbit
Source-ID: 191717
Publication: Research - peer-review › Report – Annual report year: 2006

Robustness and Recovery in Train Scheduling - a simulation study from DSB S-tog a/s

This paper presents a simulation model to study the robustness of timetables of DSB S-tog a/s, the city rail of Copenhagen. Dealing with rush hour scenarios only, the simulation model investigates the effects of disturbances on the S-tog network. Several timetables are analyzed with respect to robustness. Some of these are used in operation and some are generated for the purpose of investigating timetables with specific alternative characteristics.

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Hofman, M. A. (Ekstern), Madsen, L. (Ekstern), Groth, J. J. (Intern), Clausen, J. (Intern), Larsen, J. (Intern)
Publication date: 2006

Publication information
Hierarchical Network Design

Communication networks are immensely important today, since both companies and individuals use numerous services that rely on them. This thesis considers the design of hierarchical (communication) networks. Hierarchical networks consist of layers of networks and are well-suited for coping with changing and increasing demands. Two-layer networks consist of one backbone network, which interconnects cluster networks. The clusters consist of nodes and links, which connect the nodes. One node in each cluster is a hub node, and the backbone interconnects the hub nodes of each cluster and thus the clusters. The design of hierarchical networks involves clustering of nodes, hub selection, and network design, i.e. selection of links and routing of flows. Hierarchical networks have been in use for decades, but integrated design of these networks has only been considered for very special types of networks. The thesis investigates models for hierarchical network design and methods used to design such networks. In addition, ring network design is considered, since ring networks commonly appear in the design of hierarchical networks. The thesis introduces hierarchical networks, including a classification scheme of different types of hierarchical networks. This is supplemented by a review of ring network design problems and a presentation of a model allowing for modeling most hierarchical networks. We use methods based on linear programming to design the hierarchical networks. Thus, a brief introduction to the various linear programming based methods is included. The thesis is thus suitable as a foundation for study of design of hierarchical networks. The major contribution of the thesis consists of seven papers which are included in the appendix. The papers address hierarchical network design and/or ring network design. The papers have all been submitted for journals, and except for two papers, are awaiting review. The papers are mostly concerned with optimal methods and, in a few cases, heuristics for designing hierarchical and ring networks. All papers develop bounds which are used in the optimal methods and for comparison. Finally, computational results are reported. In Danish: Kommunikationsnetværk har enorm betydning i dag, da enkeltpersoner og virksomheder anvender utallige tjenester, som afhænger af kommunikationsnetværkene. Denne afhandling omhandler design af hierarkiske (kommunikations-) netværk. Hierarkiske netværk er lagdelte og er varegode til at håndtere ændringer og gede i krav til båndbredde. Netværk med to niveauer består af et backbone netværk som forbinder klynger af netværksknuder. Klyngerne består af netværksknuder og forbindelser mellem netværksknuderne.
Risk and investment management in liberalized electricity markets

Electricity markets around the world are currently undergoing a liberalization process that changes the way electricity is traded and priced as a commodity. The electricity system has unique technical characteristics and the importance of electricity as a good in today's informational society is significant. Liberalization does not change the fact that politicians and regulators will be held responsible for keeping the lights on at reasonable costs. What changes is the tool used by regulators to accomplish this task. The introduction of competitive markets implies that market participants will be held financially responsible for their decisions. Regulated system operators remain responsibility for the physical balancing and electricity markets will therefore remain strongly regulated even after liberalization. The combination of strongly regulated but competitive trading arrangements creates an environment where market participants will face a new set of financial risks comprising elements of competition, physical electricity characteristics and potential political regulatory intervention. On the other side of the market regulators and politicians will face the complex task of designing an electricity market that can outperform the previously regulated monopolies with respect to the three main requirements of security of supply, economical efficiency and environmental protection. The economic theory of electricity markets forms an essential basis for decision making in a liberalized setting. The effect of financial risk on decision making is becoming an increasingly important topic within this field of electricity economics, due to the significant elements of uncertainty in electricity markets. A primary goal of the thesis is to increase the understanding of how the introduction of competitive markets affects the nancial risk related to different decision problems within the areas of risk management and investments in liberalized electricity markets. Focus is on applied microeconomics and analyzes of the interplay between market design parameters and the technical characteristics of the electricity system. Theory, literature and introduction to speci c problem areas related to risk management and investments is provided in two separate introductory chapters. Contributions to research within specific problems areas is then subsequently provided by five research papers. The two topics are relatively broad, however the two chapters and ve papers all share analyzes of nancial risk in liberalized electricity markets as a common underlying theme. The risk management part of the thesis focuses on modelling and measurement of financial risk in electricity markets. Key topics are electricity price modelling and the development of risk measures suitable for electricity market portfolios. Risk management tools used for nancial assets have until recently largely been transferred more or less directly to electricity market portfolios which include physical assets such as power plants and retail contracts. The hypothesis of this thesis is that the relevance of nancial tools for electricity market risk management, depends critically on the technical characteristics of electricity assets and on the demands placed by the stakeholders in the electricity sector. In many cases such technical characteristics and stakeholder demands will imply a need for revised and renewed tools compared to those used for portfolios of nancial assets. Chapter 2 in the thesis discuss such developments and provides a
literature review of risk management modelling theory and applications in electricity markets.

**General Information**

State: Published  
Organisations: Department of Informatics and Mathematical Modeling, Operations Research, Department of Management Engineering, Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy  
Authors: Lemming, J. K. (Intern), Clausen, J. (Intern), Morthorst, P. E. (Intern), Ravn, H. V. (Intern)  
Publication date: Feb 2005

**Publication information**

Original language: English  
Main Research Area: Technical/natural sciences  
Electronic versions: imm2823.pdf  
Links:  
http://www2.imm.dtu.dk/pubdb/p.php?2823  
Source: orbit  
Source-ID: 185928  
Publication: Research › Ph.D. thesis – Annual report year: 2005

**An exact algorithm for Aircraft Landing Problem**

**General Information**

State: Published  
Organisations: Operations Research, Department of Informatics and Mathematical Modeling  
Authors: Wen, M. (Intern), Larsen, J. (Intern), Clausen, J. (Intern)  
Publication date: 2005

**Publication information**

Original language: English  
Main Research Area: Technical/natural sciences  
Electronic versions: imm4001.pdf  
Links:  
http://www2.imm.dtu.dk/pubdb/p.php?4001  
Source: orbit  
Source-ID: 185965  
Publication: Research - peer-review › Report – Annual report year: 2005

**Disruption Management in the Airline Industry - Concepts, Models and Methods**

**General Information**

State: Published  
Organisations: Operations Research, Department of Informatics and Mathematical Modeling  
Authors: Clausen, J. (Intern), Larsen, A. (Intern), Larsen, J. (Intern)  
Publication date: 2005

**Publication information**

Original language: English  
Main Research Area: Technical/natural sciences  
Electronic versions: imm3763.pdf  
Links:  
http://www2.imm.dtu.dk/pubdb/p.php?3763  
Source: orbit  
Source-ID: 185941  
Publication: Research - peer-review › Report – Annual report year: 2005

**Når uheldet er ude**

**General Information**

State: Published  
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Clausen, J. (Intern), Jespersen, J. (Ekstern), Rezanova, N. J. (Intern)
Pages: 26-28
Publication date: 2005
Main Research Area: Technical/natural sciences

Publication information
Journal: Effektivitet
Issue number: 5
Original language: English
Links:
http://www2.imm.dtu.dk/pubdb/p.php?4355
Source: orbit
Source-ID: 185643
Publication: Research › Journal article – Annual report year: 2005

Teknikker i IT-støttet beslutningstagning

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Clausen, J. (Intern)
Pages: 12-15
Publication date: 2005
Main Research Area: Technical/natural sciences

Publication information
Journal: Effektivitet
Issue number: 5
Original language: Danish
Links:
http://www2.imm.dtu.dk/pubdb/p.php?4354
Source: orbit
Source-ID: 185642
Publication: Research › Journal article – Annual report year: 2005

Using Heuristics to Solve the Dedicated Aircraft Recovery Problem

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Løve, M. (Ekstern), Sørensen, K. R. (Ekstern), Larsen, J. (Intern), Clausen, J. (Intern)
Pages: 189-207
Publication date: 2005
Main Research Area: Technical/natural sciences

Publication information
Journal: Central European Journal of Operations Research
Volume: 13
Issue number: 2
ISSN (Print): 1435-246X
Ratings:
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BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.465 SNIP 0.798 CiteScore 0.85
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.755 SNIP 1.086 CiteScore 1.08
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.627 SNIP 1.076 CiteScore 0.99
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.775 SNIP 1.204 CiteScore 1.12
A Hybrid Algorithm for Solving the Economic Lot and Delivery Scheduling Problem in the Common Cycle Case

The ELDSP problem is a combined lot sizing and sequencing problem. A supplier produces and delivers components of different component types to a consumer in batches. The task is to determine the cycle time, i.e., that time between deliveries, which minimizes the total cost per time unit. This includes the determination of the production sequence of the component types within each cycle. We investigate the computational behavior of two published algorithms, a heuristic and an optimal algorithm. With a large number of component types, the optimal algorithm has long running times. We devise a hybrid algorithm, which is both optimal and efficient.

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Ju, S. (Ekstern), Clausen, J. (Intern)
Number of pages: 16
Publication date: 2004

Finding the best visualization of an ontology
An ontology is a classification model for a given domain. In information retrieval ontologies are used to perform broad searches. An ontology can be visualized as nodes and edges. Each node represents an element and each edge a relation between a parent and a child element. Working with an ontology becomes easier with a visual representation. An idea is to use the expressive power that a 3D representation to provide visualization for the user. In this paper we propose a new method for positioning the elements of the visualized concept lattice in the 3D world based on Operations Research (OR) methods. One method uses a discrete location model to create an initial solution and we propose heuristic methods to further improve the visual result. We evaluate the visual results according to our success criteria and the feedback from users. Running times of the heuristic indicate that an improved version should be feasible for on-line processing and what-if analysis of ontologies.

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Fabritius, C. V. (Ekstern), Madsen, N. L. (Ekstern), Clausen, J. (Intern), Larsen, J. (Intern)
Industrialised application of combinatorial optimization
This thesis is one of the results of CIAMM (Center for Industrialised Application of Mathematical Modelling). The center is composed of industrial companies e.g. Odense Steel Shipyard (OSS), Bang & Olufsen (B&O), Danish Technological Institute and 4 departments from 3 universities including Informatics and Mathematical Modelling at Technical University of Denmark.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Authors: Hansen, J. (Intern), Clausen, J. (Intern)
Publication date: Oct 2003

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
imm2513.pdf
Links:
Source: orbit
Source-ID: 58678
Publication: Research › Ph.D. thesis – Annual report year: 2003

ISMP 2003

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Tind, J. (ed.) (Ekstern), Clausen, J. (Intern)
Publication date: 2003

Publication information
Publisher: Springer Verlag
Original language: English
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 58590
Publication: Research - peer-review › Book – Annual report year: 2003

Optimization and Simulation in Drug Development - Review and Analysis
We give a review of pharmaceutical R&D and mathematical simulation and optimization methods used to support decision making within the pharmaceutical development process. The complex nature of drug development is pointed out through a description of the various phases of the pharmaceutical development process. A part of the paper is dedicated to the use of simulation techniques to support clinical trials. The paper ends with a section describing portfolio modelling methods in the context of the pharmaceutical industry.

General information
State: Published
Disruption Management for an Airline - Rescheduling of aircraft

The Aircraft Recovery Problem (ARP) involves decisions concerning aircraft to flight assignments in situations where unforeseen events have disrupted the existing flight schedule, e.g. bad weather causing flight delays. The aircraft recovery problem aims to recover these flight schedules through a series of reassignments of aircraft to flights, delaying of flights and cancellations of flights. This article demonstrates an effective method to solve ARP. A heuristic is implemented, which is able to generate feasible revised flight schedules of a good quality in less than 10 seconds. This article is a product of the DESCARTES project, a project funded by the European Union between the Technical University of Denmark, British Airways and Carmen.

General information
Hierarchical Network Design Using Simulated Annealing

We consider the problem of optimizing a Lipschitzian function. The branch and bound technique is a well-known solution method, and the key components for this are the subdivision scheme, the bound calculation scheme, and the initialization. For Lipschitzian optimization, the bound calculations are based on the sampling of function values.

We propose a branch and bound algorithm based on regular simplexes. Initially, the domain in question is covered with regular simplexes, and our subdivision scheme maintains this property. The bound calculation becomes both simple and efficient, and we describe two schemes for sampling points of the function: midpoint sampling and vertex sampling.

The convergence of the algorithm is proved, and numerical results are presented for the two dimensional case, for which also a special initial covering is presented. (C) 2002 Elsevier Science Ltd. All rights reserved.

Subdivision, Sampling, and Initialization Strategies for Simplical Branch and Bound in Global Optimization

We consider the problem of optimizing a Lipschitzian function. The branch and bound technique is a well-known solution method, and the key components for this are the subdivision scheme, the bound calculation scheme, and the initialization. For Lipschitzian optimization, the bound calculations are based on the sampling of function values.

We propose a branch and bound algorithm based on regular simplexes. Initially, the domain in question is covered with regular simplexes, and our subdivision scheme maintains this property. The bound calculation becomes both simple and efficient, and we describe two schemes for sampling points of the function: midpoint sampling and vertex sampling.

The convergence of the algorithm is proved, and numerical results are presented for the two dimensional case, for which also a special initial covering is presented. (C) 2002 Elsevier Science Ltd. All rights reserved.
Disruption management

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling, Department of Transport
Authors: Clausen, J. (Intern), Hansen, J. (Intern), Larsen, J. (Intern), Larsen, A. (Intern)
Pages: 40-43
Using heuristics to solve the dedicated aircraft recovery problem

The Dedicated Aircraft Recovery Problem (DARP) involves decisions concerning aircraft to flight assignments in situations where unforeseen events have disrupted the existing flight schedule, e.g. bad weather causing flight delays. The dedicated aircraft recovery problem aims to recover these flight schedules through a series of reassignments of aircraft to flights, delaying of flights and cancellations of flights. This article describes an effective method to solve DARP. A heuristic is implemented, which is able to generate feasible revised flight schedules of good quality in less than 10 seconds when applied to real flight schedules with disruptions from British Airways. The heuristic is able to consider delays, cancellations and reassignments simultaneously and balance the trade-off between these options. It is also demonstrated that different strategies can be applied to prioritize these options when generating the revised flight schedules without affecting the solution time required.

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling, COOP, Carmen System A.B.
Authors: Løve, M. (Ekstern), Sørensen, K. R. (Ekstern), Larsen, J. (Intern), Clausen, J. (Intern)
Publication date: 2001
Large Steel Plate Storage Optimization

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Authors: Stidsen, T. K. (Intern), Hansen, J. (Intern), Clausen, J. (Intern)
Publication date: 2000

Host publication information
Title of host publication: COMPIT
Place of publication: Berlin
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 176524
Publication: Research - peer-review › Article in proceedings – Annual report year: 2000

Solving Graph Bisection Problems with Semidefinite Programming Bounds

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Clausen, J. (Intern), Karisch, S. E. (Intern), Rendl, F. (Ekstern)
Pages: 177 - 191
Publication date: 2000
Main Research Area: Technical/natural sciences

Publication information
Journal: INFORMS Journal on Computing
Volume: 12
ISSN (Print): 0899-1499
Ratings:
Web of Science (2000): Indexed yes
Original language: English
Branch and Bound, Semidefinite Programming, Graph Bisection
Links:
http://www2.imm.dtu.dk/pubdb/p.php?569
Source: orbit
Source-ID: 199541
Publication: Research - peer-review › Journal article – Annual report year: 2000

Using Parallel Computers to solve the Vehicle Routing Problem with Time Windows

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling, Logistics & ITS, Department of Transport
Authors: Larsen, J. (Intern), Clausen, J. (Intern), Madsen, O. B. (Intern)
Publication date: 2000

Publication information
Publisher: Informatics and Mathematical Modelling, Technical University of Denmark, DTU
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 200948
Publication: Research - peer-review › Report – Annual report year: 2000

A dual framework for lower bounds of the quadratic assignment problem based on linearization
A dual framework allowing the comparison of various bounds for the quadratic assignment problem (QAP) based on linearization, e.g. the bounds of Adams and Johnson, Carraresi and Malucelli, and Hahn and Grant, is presented. We discuss the differences of these bounds and propose a new and more general bounding procedure based on the dual of the linearization of Adams and Johnson. The new procedure has been applied to problems of dimension up to
On the Best Search Strategy in Parallel|Branch-and-Bound - Best-First-Search vs. Lazy Depth-First-Search

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Clausen, J. (Intern), Perregaard, M. (Intern)
Pages: 1 - 17
Publication date: 1999
Main Research Area: Technical/natural sciences

Publication information
Journal: Annals of OR
Issue number: 90
ISSN (Print): 0254-5330
Ratings:
BFI (2018): BFI-level 1
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.44 SJR 1.009 SNIP 1.211
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.037 SNIP 1.108 CiteScore 1.29
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.971 SNIP 1.203 CiteScore 1.21
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.26 SNIP 1.457 CiteScore 1.57
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.063 SNIP 1.082 CiteScore 1.17
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.887 SNIP 1.071 CiteScore 0.96
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.861 SNIP 1.257
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.935 SNIP 1.32
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.884 SNIP 1.129
Scopus rating (2007): SJR 1.164 SNIP 1.505
Scopus rating (2006): SJR 0.656 SNIP 0.951
Pushing the limit of solvable QAP problems using parallel processing -- is Nugent 30 within reach?

**General information**
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Clausen, J. (Intern)
Pages: 59-74
Publication date: 1999
Main Research Area: Technical/natural sciences

**Publication information**
Journal: The IMA Volumes in Mathematics and its Applications
Volume: 106
Original language: English
Quadratic Assignment, Branch and bound
Links:
http://www2.imm.dtu.dk/pubdb/p.php?556
Source: orbit
Source-ID: 199542
Publication: Research - peer-review › Journal article – Annual report year: 1999

Ruteoptimering - modeller og løsningsmetoder

**General information**
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Clausen, J. (Intern)
Publication date: 1999

**Host publication information**
Title of host publication: GIS i Danmark 2
Main Research Area: Technical/natural sciences
Links:
http://www2.imm.dtu.dk/pubdb/p.php?562
Source: orbit
Source-ID: 200632
Publication: Research - peer-review › Book chapter – Annual report year: 1999

A dual framework for lower bounds of the quadratic assignment problem based on linearization

**General information**
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Authors: Karisch, S. E. (Intern), Cela, E. (Ekstern), Clausen, J. (Intern), Espersen, T. G. (Intern)
Number of pages: 44
Publication date: 1998

Publication information
Place of publication: Kgs. Lyngby
Publisher: Informatics and Mathematical Modelling
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 170490
Publication: Research - peer-review › Report – Annual report year: 1998

Center for Kombinatorisk Optimering - et muligt center i Øresundsregionen, i E. Skarback (ed):

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, University of Copenhagen
Authors: Clausen, J. (Intern), Thorup, M. (Ekstern), Pisinger, D. (Ekstern)
Publication date: 1998

Publication information
Place of publication: Alnarp - Sverige
Publisher: proceedings fra Øresundssymposium 98
Original language: Danish
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 169946
Publication: Research - peer-review › Book – Annual report year: 1998

Global Optimization by Means of Branch and Bound with Simplex Based Covering

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Vytautas Magnus University
Authors: Clausen, J. (Intern), Zilinskas, A. (Ekstern)
Number of pages: 14
Publication date: 1998

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 170233
Publication: Research - peer-review › Report – Annual report year: 1998

Kompleksitet, i Den Store Danske Encyklopædi

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Authors: Clausen, J. (Intern)
Number of pages: 107
Publication date: 1998

Publication information
Publisher: Den Store Danske Encyklopædi
Original language: Danish
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 169948
Publication: Research - peer-review › Book – Annual report year: 1998
On the Applicability of Lower Bounds for Solving Rectilinear

The quadratic assignment problem (QAP) belongs to the hard core of NP-hard optimization problems. After almost forty years of research only relatively small instances can be solved to optimality. The reason is that the quality of the lower bounds available for exact methods is not sufficient. Recently, lower bounds based on decomposition were proposed for the so called rectilinear QAP that proved to be the strongest for a large class of problem instances. We investigate the strength of these bounds when applied not only at the root node of a search tree but as the bound function used in a Branch-and-Bound code solving large scale QAPs.

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling, University of Copenhagen, University of Graz
Authors: Clausen, J. (Intern), Karisch, S. E. (Intern), Perregaard, M. (Ekstern), Rendl, F. (Ekstern)
Pages: 127-147
Publication date: 1998
Main Research Area: Technical/natural sciences

Publication information
Journal: Computational Optimization and Applications
Volume: 10
Issue number: 2
ISSN (Print): 0926-6003
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- BFI (2018): BFI-level 1
- BFI (2017): BFI-level 1
- Web of Science (2017): Indexed Yes
- BFI (2016): BFI-level 1
- Scopus rating (2016): SJR 1.365 SNIP 1.323 CiteScore 1.74
- BFI (2015): BFI-level 1
- Scopus rating (2015): SJR 1.32 SNIP 1.485 CiteScore 1.56
- Web of Science (2015): Indexed yes
- BFI (2014): BFI-level 1
- Scopus rating (2014): SJR 1.065 SNIP 1.612 CiteScore 1.61
- BFI (2013): BFI-level 1
- Scopus rating (2013): SJR 0.862 SNIP 1.624 CiteScore 1.37
- ISI indexed (2013): ISI indexed yes
- BFI (2012): BFI-level 1
- Scopus rating (2012): SJR 1.159 SNIP 1.568 CiteScore 1.48
- ISI indexed (2012): ISI indexed yes
- BFI (2011): BFI-level 1
- Scopus rating (2011): SJR 1.216 SNIP 1.864 CiteScore 1.45
- ISI indexed (2011): ISI indexed yes
- BFI (2010): BFI-level 1
Parallel Branch-and-Bound Methods for the Job Shop Scheduling

Job-shop scheduling (JSS) problems are among the more difficult to solve in the class of NP-complete problems. The only successful approach has been branch-and-bound based algorithms, but such algorithms depend heavily on good bound functions. Much work has been done to identify such functions for the JSS problem, but with limited success. Even with recent methods, it is still not possible to solve problems substantially larger than 10 machines and 10 jobs. In the current study, we focus on parallel methods for solving JSS problems. We implement two different parallel branch-and-bound algorithms for JSS on a 16-processor MEIKO computing surface with Intel i860 processors and perform extensive computational testing using classical publicly available benchmark problems. The parallel part of one of the implementations is based on a similar parallel code for quadratic assignment problems. Results are reported for different branching rules proposed in the literature.

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Clausen, J. (Intern), Perregaard, M. (Intern)
Pages: 137-160
Publication date: 1998
Main Research Area: Technical/natural sciences

Publication information
Journal: Annals of OR
Volume: 83
ISSN (Print): 0254-5330
Ratings:
BFI (2018): BFI-level 1
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.44 SJR 1.009 SNIP 1.211
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.037 SNIP 1.108 CiteScore 1.29
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.971 SNIP 1.203 CiteScore 1.21
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.26 SNIP 1.457 CiteScore 1.57
ISI indexed (2013): ISI indexed yes
Solving Large-Scale QAP Problems in Parallel with the Search

Program libraries are one tool to make the cooperation between specialists from various fields successful: the separation of application-specific knowledge from application-independent tasks ensures portability, maintenance, extensibility, and flexibility. The current paper demonstrates the success in combining problem-specific knowledge for the quadratic assignment problem (QAP) with the raw computing power offered by contemporary parallel hardware by using the library of parallel search algorithms ZRAM. Solutions of previously unsolved large standard test-instances of the QAP are presented.
Parallel Branch and Bound - Principles and Personal experiences

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Clausen, J. (Intern)
Publication date: 1997

Host publication information
Title of host publication: Parallel Computing in Optimization
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 200633
Publication: Research - peer-review › Book chapter – Annual report year: 1997

Solving Large Quadratic Assignment Problems in Parallel
Quadratic Assignment problems are in practice among the most difficult to solve in the class of NP-complete problems. The only successful approach hitherto has been Branch-and-Bound-based algorithms, but such algorithms are crucially dependent on good bound functions to limit the size of the space searched. Much work has been done to identify such functions for the QAP, but with limited success. Parallel processing has also been used in order to increase the size of problems solvable to optimality. The systems used have, however, often been systems with relatively few, but very
powerful vector processors, and have hence not been ideally suited for computations essentially involving non- 
vectorizable computations on integers. In this paper we investigate the combination of one of the best bound functions for a 
Branch-and-Bound algorithm (the Gilmore-Lawler bound) and various testing, variable binding and recalculation of bounds 
between branchings when used in a parallel Branch-and-Bound algorithm. The algorithm has been implemented on a 16- 
processor MEIKO Computing Surface with Intel i860 processors. Computational results from the solution of a number of 
large QAPs, including the classical Nugent 20 are reported.

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Clausen, J. (Intern), Perregaard, M. (Intern)
Pages: 111 - 128
Publication date: 1997
Main Research Area: Technical/natural sciences

Publication information
Journal: Computational Optimization and Applications
Volume: 8
Issue number: 2
ISSN (Print): 0926-6003
Ratings:
BFI (2018): BFI-level 1
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 1.365 SNIP 1.323 CiteScore 1.74
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.32 SNIP 1.485 CiteScore 1.56
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.065 SNIP 1.612 CiteScore 1.61
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.862 SNIP 1.624 CiteScore 1.37
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.159 SNIP 1.568 CiteScore 1.48
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.216 SNIP 1.864 CiteScore 1.45
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.009 SNIP 1.471
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.178 SNIP 1.539
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.072 SNIP 1.158
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.279 SNIP 1.392
Scopus rating (2006): SJR 0.894 SNIP 1.422
Scopus rating (2005): SJR 1.388 SNIP 1.594
Scopus rating (2004): SJR 0.734 SNIP 1.302
Scopus rating (2003): SJR 0.846 SNIP 1.225
Scopus rating (2002): SJR 1.524 SNIP 1.084
Scopus rating (2001): SJR 1.833 SNIP 0.808
Scopus rating (2000): SJR 1.568 SNIP 0.944
Scopus rating (1999): SJR 1.934 SNIP 1.725
An $O(|V|^*|E|)$ Algorithm for Finding Immediate Multiple-Vertex Dominators

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Alstrup, S. (Ekstern), Jørgensen, K. (Ekstern), Clausen, J. (Intern)
Pages: 9 - 11
Publication date: 1996
Main Research Area: Technical/natural sciences

Publication information
Journal: Information Processing Letters
Volume: 59
ISSN (Print): 0020-0190
Ratings:
BFI (2018): BFI-level 2
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): SJR 0.57 SNIP 0.967 CiteScore 1.02
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 0.602 SNIP 1.167 CiteScore 0.93
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 0.593 SNIP 0.934 CiteScore 0.94
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 0.609 SNIP 1.047 CiteScore 0.95
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 0.603 SNIP 1.037 CiteScore 0.92
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 0.612 SNIP 0.929 CiteScore 0.85
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 0.625 SNIP 1.016
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 0.708 SNIP 1.062
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.837 SNIP 1.161
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 0.76 SNIP 1.144
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.699 SNIP 1.193
Scopus rating (2005): SJR 0.614 SNIP 1.189
Parallel Search-Based Methods in Optimization", in "Applied Parallel Computing - Industrial Computation and Optimization

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Clausen, J. (Intern)
Publication date: 1996

Host publication information
Title of host publication: PARA96
Main Research Area: Technical/natural sciences
Conference: PARA96, 01/01/1996
Source: orbit
Source-ID: 200443
Publication: Research › Article in proceedings – Annual report year: 1996

A Family of Bipartite Cardinality Matching Problems Solvable in $O(n^2)$ Time
For a given, unweighted bipartite graph $G$ with $2n$ non isolated vertices, we consider the so called bipartite cardinality matching problem (BCMP) for which the time complexity of the fastest exact algorithm available is $O(n^{5/2})$. We devise a greedy algorithm which either finds a perfect matching in $O(n^2)$ time or identifies cycle of length 4 in the complement $G$ of $G$

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Clausen, J. (Intern), Krarup, J. (Ekstern)
Pages: 496 - 501
Publication date: 1995
Main Research Area: Technical/natural sciences

Publication information
Journal: Nordic Journal of Computing
Volume: 2
ISSN (Print): 1236-6064
Ratings:
BFI (2016): BFI-level 1
BFI (2015): BFI-level 1
BFI (2014): BFI-level 1
BFI (2013): BFI-level 1
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
ISI indexed (2011): ISI indexed no
Integer Programming and Combinatorial Optimization

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Balas, E. (ed.) (Ekstern), Clausen, J. (ed.) (Intern)
Publication date: 1995

Publication Information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 200593
Publication: Research - peer-review › Book – Annual report year: 1995

Parallel Algorithms for the Assignment Problem - Experimental Evaluation of Three Distributed Algorithms

General information
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling
Authors: Schutt, C. (Ekstern), Clausen, J. (Intern)
Pages: 337 - 351
Publication date: 1995
Main Research Area: Technical/natural sciences

Publication Information
Journal: AMS DIMACS Series in Discrete Mathematics and Theoretical Computer Science
Volume: 22
Original language: English
Links:
http://www2.imm.dtu.dk/pubdb/p.php?582
Source: orbit
Source-ID: 199793
Publication: Research - peer-review › Journal article – Annual report year: 1995

EDB-Miniordbog

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Authors: Clausen, J. (Intern)
Publication date: 1987

Publication Information
Publisher: Fremad
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 200563
Publication: Research - peer-review › Book – Annual report year: 1987
Projects:

**Beslutningsproblemer for energitransmissionsnetværk i et samfundsøkonomisk perspektiv**

Department of Management Engineering  
Period: 01/09/2008 → 22/02/2012  
Number of participants: 5  
Phd Student: Villumsen, Jonas Christoffer (Intern)  
Supervisor: Clausen, Jens (Intern)  
Main Supervisor: Pisinger, David (Intern)  
Examiner: Rasmussen, Kouros Marjani (Intern)  
Bjørndal, Mette Helene (Ekstern)  

**Financing sources**  
Source: Internal funding (public)  
Name of research programme: Institut stipendie (DTU) Samf.  
Project: PhD

**A Framework for Constraint-Programming based Configuration**

Department of Informatics and Mathematical Modeling  
Period: 01/03/2008 → 28/09/2011  
Number of participants: 7  
Phd Student: Queva, Matthieu Stéphane Benoit (Intern)  
Supervisor: Clausen, Jens (Intern)  
Ricci, Laurent (Ekstern)  
Main Supervisor: Probst, Christian W. (Intern)  
Examiner: Fischer, Paul (Intern)  
Felfernig, Alexander (Ekstern)  
Hotz, Lothar (Ekstern)  

**Financing sources**  
Source: Internal funding (public)  
Name of research programme: ErhvervsPhD-ordningen VTU  
Project: PhD

**Analyse og modellering af distribuerede elsystemer med høj andel vedvarende energi**

Department of Management Engineering  
Period: 01/05/2007 → 01/06/2011  
Number of participants: 6  
Phd Student: Juul, Nina (Intern)  
Supervisor: Clausen, Jens (Intern)  
Meibom, Peter (Intern)  
Main Supervisor: Pisinger, David (Intern)  
Examiner: Stidsen, Thomas Jacob Riis (Intern)  
Söder, Lennart (Ekstern)
**Financing sources**
Source: Internal funding (public)
Name of research programme: Institut/centerfinansieret
Project: PhD

**Modeller og Metoder for optimeringsproblemer med kombineret resourceplanlægning og skedulering**

Department of Management Engineering
Period: 01/12/2006 → 01/09/2010
Number of participants: 5
Phd Student:
Dohn, Anders Høeg (Intern)
Supervisor:
Larsen, Jesper (Intern)
Main Supervisor:
Clausen, Jens (Intern)
Examiner:
Rönnqvist, Mikael (Ekstern)
von den Akker, J. M. (Ekstern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: DTU-lønnet stipendie
Project: PhD

**Models and Algorithms for the Vehicle Routing Problem with Cross Docking**

Department of Management Engineering
Period: 01/02/2006 → 24/03/2010
Number of participants: 6
Phd Student:
Wen, Min (Intern)
Supervisor:
Clausen, Jens (Intern)
Main Supervisor:
Larsen, Jesper (Intern)
Examiner:
Larsen, Allan (Intern)
Hasle, Geir (Ekstern)
Nielsen, Jakob Birkedal (Intern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: DTU-lønnet stipendie
Project: PhD

**Beslutningsstøtte til genopretning ved uregelmæssigheder i togdrift**

Department of Management Engineering
Period: 01/10/2005 → 22/04/2009
Number of participants: 6
Phd Student:
Groth, Julie Jespersen (Intern)
Supervisor:
Clausen, Jens (Intern)
Main Supervisor:
Larsen, Jesper (Intern)
Examiner:
Stidsen, Thomas Jacob Riis (Intern)
Abbink, Erwin Jan W. (Ekstern)
Liebchen, Christian (Ekstern)

Financial sources
Source: Internal funding (public)
Name of research programme: ErhvervsPhD-ordningen VTU
Project: PhD

Decision Support for Planning of Multi-modal Transportation with Multiple Objectives
Department of Transport
Period: 01/03/2005 → 02/12/2009
Number of participants: 6
Phd Student:
Petersen, Hanne Løhmann (Intern)
Supervisor:
Clausen, Jens (Intern)
Main Supervisor:
Madsen, Oli B.G. (Intern)
Examiner:
Larsen, Jesper (Ekstern)
Laporte, Gilbert (Ekstern)
Lysgaard, Jens (Ekstern)

Financial sources
Source: Internal funding (public)
Name of research programme: Programbevilling
Project: PhD

Operationsanalyse i jernbanedrift
Department of Management Engineering
Period: 01/02/2005 → 21/10/2009
Number of participants: 4
Phd Student:
Rezanova, Natalia Jurjevna (Intern)
Main Supervisor:
Clausen, Jens (Intern)
Examiner:
Pisinger, David (Intern)
Huisman, Dennis (Ekstern)

Financial sources
Source: Internal funding (public)
Name of research programme: DTU, Samfinansiering
Project: PhD

Optimal råvareanvendelse og ordreafvikling på svineslagterier
Department of Management Engineering
Period: 01/10/2004 → 24/09/2008
Number of participants: 7
Phd Student:
Kjærsgaard, Niels Christian (Intern)
Supervisor:
Hagdrup, Claus (Ekstern)
Jacobsen, Peter (Intern)
Main Supervisor:
Clausen, Jens (Intern)
Examiner:
Juel, Henrik (Intern)
Rasmussen, Svend (Ekstern)
van Betteray, Klemens (Ekstern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: ErhvervsPhD-ordningen VTU
Project: PhD

**Optimering af containeroperationer i havne**
Department of Management Engineering
Period: 01/09/2004 → 11/04/2008
Number of participants: 5
Phd Student:
Kallehauge, Louise Sibbesen (Intern)
Main Supervisor:
Clausen, Jens (Intern)
Examiner:
Juel, Henrik (Intern)
Jensen, Rune M. (Ekstern)
Voss, Stefan (Ekstern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: DTU-lønnet stipendie
Project: PhD

**Stochastic Scheduling in Production Planning**
Department of Informatics and Mathematical Modeling
Period: 01/04/2004 → 31/01/2008
Number of participants: 5
Phd Student:
Rasmussen, Kourosh Marjani (Intern)
Main Supervisor:
Clausen, Jens (Intern)
Examiner:
Stidsen, Thomas Jacob Riis (Intern)
Sørensen, Peter Norman (Ekstern)
Vladimirou, Hercules (Ekstern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: DTU-lønnet stipendie
Project: PhD

**Beslutningsstøttesystem til jagerpiloter**
Department of Informatics and Mathematical Modeling
Number of participants: 7
Phd Student:
Randleff, Lars Rosenberg (Ekstern)
Supervisor:
Jensen, Gert Hvedstrup (Intern)
Søndergaard, Steen (Ekstern)
Main Supervisor:
Clausen, Jens (Intern)
Examiner:
Stidsen, Thomas Jacob Riis (Intern)
Birkemark, Christian M. (Ekstern)
Wright, George A. (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Ansat eksternt
Project: PhD

Modeller og metoder til analyse af decentral produktion på markedsvilkår

Department of Informatics and Mathematical Modeling
Period: 15/09/2003 → 02/07/2008
Number of participants: 5
Phd Student:
Schaumburg-Müller, Camilla (Intern)
Supervisor:
Ravn, Hans V. (Intern)
Main Supervisor:
Clausen, Jens (Intern)
Examiner:
Stidsen, Thomas Jacob Riis (Intern)
Holttinene, Hannele K. (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Eksternt finansieret virksomhed
Project: PhD

Disruption Management i transportsektoren

Department of Informatics and Mathematical Modeling
Period: 01/04/2003 → 01/07/2009
Number of participants: 6
Phd Student:
Wanscher, Jørgen (Intern)
Supervisor:
Larsen, Jesper (Intern)
Main Supervisor:
Clausen, Jens (Intern)
Examiner:
Stidsen, Thomas Jacob Riis (Intern)
Davidsson, Paul (Ekstern)
Liu, Ronghui (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD

Design af hierarkiske netværk

Department of Informatics and Mathematical Modeling
Period: 01/03/2002 → 05/08/2005
Number of participants: 5
Phd Student:
Thomadsen, Tommy (Intern)
Main Supervisor:
Clausen, Jens (Intern)
Examiner:
Hansen, Per Christian (Intern)
Optimal rydning af landminer og ammunition

Department of Informatics and Mathematical Modeling
Period: 01/02/2002 → 13/03/2006
Number of participants: 6
Phd Student:
Vistisen, Jan Bastholm (Intern)
Supervisor:
Christensen, Torben (Ekstern)
Main Supervisor:
Clausen, Jens (Intern)
Examiner:
Larsen, Jan (Ekstern)
Clausen, Svend (Ekstern)
Haugstad, Bjarne (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Anden sektorministeriel finans
Project: PhD

DESCARTES - Decision Support for Integrated Crew and Aircraft Recovery

DESCARTES addresses the problem of disruption management for large airlines. This is considered one of the most important and hardest problems to deal with in todays planning procedures in the airline industry. The goal of the project has been to develop a prototype tool enabling the airlines to integrate the management of aircrafts and staff when replanning immediately before a flight due to last minute changes. The project has progressed in an incremental fashion developing a number of individual recovery systems for aircraft, crew, and passengers as well as a system enabling these to collaborate when generation potential solutions for a disruption. Each of the individual systems are useful as a stand-alone system enabling the project to give early business benefit to the industrial partner and to the software vendor participating. A number of different approaches has been tested in the development process: heuristics, constraint programming, and traditional mathematical programming methods. Also, different approaches to solution techniques for the integration of recovery systems has been tested: the Integrated Sequential Recovery method consisting of the individual subsystems collaboration through a well-defined interface to retrieve options, and the Tailored Integration approach, in which the generation of potential solutions is influenced by the current situation for crew and aircraft concurrently. The results of the project now form the basis of a number of commercial products marketed by Carmen System AB.

Department of Informatics and Mathematical Modeling
British Airways
Carmen System A.B.
Period: 01/11/2000 → 31/12/2002
Number of participants: 8
Project participant:
Madsen, Oli B.G. (Intern)
Saxtorph, Jesper (Intern)
Hultberg, Tim Helge (Intern)
Larsen, A (Ekstern)
Larsen, J. (Ekstern)
Project Manager, organisational:
Clausen, Jens (Intern)
Bundock, Nicki (Ekstern)
Tiourine, Sergey (Ekstern)
Håndtering af Risiko forbundet med investeringer i et liberaliseret El-marked

Department of Informatics and Mathematical Modeling
Period: 15/07/2000 → 11/02/2005
Number of participants: 7
Phd Student:
Lemming, Jacob (Intern)
Supervisor:
Morthorst, Poul Erik (Intern)
Ravn, Hans V. (Intern)
Main Supervisor:
Clausen, Jens (Intern)
Examiner:
Larsen, Jesper (Ekstern)
Bunn, Derek (Ekstern)
Wallace, Stein William (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Risø (Løn)
Project: PhD

CIAMM - Center for Industrialised Application of Mathematical Modelling
CIAMM started its activity in late 1999. The goal has been to develop planning tools based on mathematical modelling, which can be used in everyday planning and replanning in larger companies. The planning problems are usually so complex, that a human planner cannot take into account all possible solutions. During the three project years the main case study has been the steel plate storage at Odense Steel Shipyard. The storage consists of 250 stacks containing more than 3000 types of steel plates. The plates are lifted by two gantry cranes sharing tracks and hence unable to pass each other. When a specific plate is needed in the production, all plates above this in the stack has to be moved to get access to the plate. Hence each plate is lifted unproductively a number times before it is actually removed from the storage. The problem addressed is how to organize the storage in order to minimize the number of superfluous lifts. The project has developed methods both for planning the daily sequences of lifts and for on-line dispatch strategy for operating the cranes. Saving of 50 - 60 % on the current practice has been achieved. In addition, a packing system has been developed based on a real-life case from Bang & Olufs, in which boxed are packed into containers taking into account also constraints regarding loads on the items and support of these. Finally, a methodology for IT-system development with a large optimization content has been developed and described - the technique resembles the DSDM method, and much attention is given to rapid prototype developments and to knowledge exchange between end users and developers, since this ah has turned out to be a major obstacle in the development process.

Department of Informatics and Mathematical Modeling
Department of Management Engineering
Aalborg University
Copenhagen Business School
Odense Steel Shipyard Ltd.
Bang & Olufsen A/S
Teknologisk Institut
Period: 01/01/2000 → 31/12/2002
Number of participants: 8
Project participant:
Hansen, Jesper (Intern)
Project Manager, organisational:
Clausen, Jens (Intern)
Vesterager, Johan (Intern)
Holm, Hans (Ekstern)
Mouritsen, Jan (Ekstern)
Tuxen, Jan (Ekstern)
Industrialiseret anvendelse af matematiske optimeringsmodeller

Department of Informatics and Mathematical Modeling
Period: 01/01/2000 → 06/10/2003
Number of participants: 4
Phd Student:
Hansen, Jesper (Intern)
Main Supervisor:
Clausen, Jens (Intern)
Examiner:
Juel, Henrik (Intern)
Labbé, Martine (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Ansat eksternt CAMP
Project: PhD

Optimerings algoritmer til netværks planlægning

Department of Informatics and Mathematical Modeling
Period: 01/06/1999 → 26/01/2003
Number of participants: 6
Phd Student:
Stidsen, Thomas Jacob Riis (Intern)
Supervisor:
Madsen, Oli B.G. (Intern)
Main Supervisor:
Clausen, Jens (Intern)
Examiner:
Juel, Henrik (Intern)
Holmberg, Kaj Evert Ragnar (Ekstern)
Maculan, Nelson F. (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Offentlig finansiering
Project: PhD

EXPLAIN - Explorative Net Planning
EXPLAIN is concerned with strategic planning of communication networks in the telecommunication sector. The goal has been to construct a planning tool to be used both on an operational and a strategic level by net planners. The tool will have a visual user interface for both in- and output, underlying modules dealing with traffic analysis and network construction under varying assumptions on objectives (such as cost and fail-safeness) and constraints, and the ability to handle also scenarios with uncertainty regarding central parameters. The project resulted in three Ph.D.-theses adressing the issues of traffic, physical net planning, and optimization methods in network design. The project part regarding user interface was left unsolved due to recruitment problems. Regarding the optimization methods, the key result was the ability to take into account not only links and their costs, but also nodes and costs of these when designing a communication network in the greenfield case. Also, optimization of the ring architecture for communication networks with protection was considered, and new results questioning the current practice in design of this type of networks was achieved.

Department of Informatics and Mathematical Modeling
Department of Telecommunication
Ericsson Telecom AB
TDC A/S
PARELLELIZATION OF THE VEHICLE ROUTING PROBLEM WITH TIME WINDOWS

Department of Informatics and Mathematical Modeling
Period: 01/01/1998 → 30/09/1999
Number of participants: 2
Phd Student:
Larsen, Jesper (Intern)
Main Supervisor:
Clausen, Jens (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD

Parallelle Algoritmer til Lineær Programmering

Department of Informatics and Mathematical Modeling
Period: 01/01/1997 → 14/12/2001
Number of participants: 7
Phd Student:
Hultberg, Tim Helge (Intern)
Supervisor:
Hansen, Per Christian (Intern)
Nielsen, Hans Bruun (Intern)
Main Supervisor:
Clausen, Jens (Intern)
Examiner:
Madsen, Oli B.G. (Intern)
Drud, Arne (Intern)
Powell, Susan (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: DTU-Su Stipendium, Eksperiment
Project: PhD

The dynamic vehicle routing problem

Department of Transport
Period: 01/01/1997 → 17/04/2001
Number of participants: 5
Phd Student:
Larsen, Allan (Intern)
Main Supervisor:
Madsen, Oli B.G. (Intern)
Examiner:
Clausen, Jens (Intern)
Gendreau, Michel (Ekstern)
**Vehicle routing with time windows.**

The purpose of the project is to develop and test optimal solution methods to vehicle routing problems with customer time windows. A method based on Dantzig-Wolfe decomposition, generation of valid inequalities, and branch and bound is developed. The results are very promising and the algorithm turns out to be faster than other algorithms considered in the literature, and several previously unsolved problems has been solved to optimality. For the time being we are improving the branch and bound procedure and implementing a parallel branch and bound.

**EPOS: Efficient Parallel algorithms for Optimization and Simulation**

The goal is to develop efficient and reliable parallel algorithms that can utilize supercomputers for solving large-scale optimization and simulation problems.

**Financing sources**

Source: Internal funding (public)
Name of research programme: Anden Sektorministeriel Fin-SU
Project: PhD

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**Financing sources**

Source: Unknown
Name of research programme: Ukendt
Amount: 5,758,000.00 Danish Kroner
Project