A fix-and-optimize matheuristic for university timetabling

University course timetabling covers the task of assigning rooms and time periods to courses while ensuring a minimum violation of soft constraints that define the quality of the timetable. These soft constraints can have attributes that make it difficult for mixed-integer programming solvers to find good solutions fast enough to be used in a practical setting. Therefore, metaheuristics have dominated this area despite the fact that mixed-integer programming solvers have improved tremendously over the last decade. This paper presents a matheuristic where the MIP-solver is guided to find good feasible solutions faster. This makes the matheuristic applicable in practical settings, where mixed-integer programming solvers do not perform well. To the best of our knowledge this is the first matheuristic presented for the University Course Timetabling problem. The matheuristic works as a large neighborhood search where the MIP solver is used to explore a part of the solution space in each iteration. The matheuristic uses problem specific knowledge to fix a number of variables and create smaller problems for the solver to work on, and thereby iteratively improves the solution. Thus we are able to solve very large instances and retrieve good solutions within reasonable time limits. The presented framework is easily extendable due to the flexibility of modeling with MIPs; new constraints and objectives can be added without the need to alter the algorithm itself. At the same time, the matheuristic will benefit from future improvements of MIP solvers. The matheuristic is benchmarked on instances from the literature and the 2nd International Timetabling Competition (ITC2007). Our algorithm gives better solutions than running a state-of-the-art MIP solver directly on the model, especially on larger and more constrained instances. Compared to the winner of ITC2007, the matheuristic performs better. However, the most recent state-of-the-art metaheuristics outperform the matheuristic.
A flow-first route-next heuristic for liner shipping network design

Having a well-designed liner shipping network is paramount to ensure competitive freight rates, adequate capacity on trade-lanes, and reasonable transportation times. The most successful algorithms for liner shipping network design make use of a two-phase approach, where they first design the routes of the vessels, and then flow the containers through the network in order to calculate how many of the customers' demands can be satisfied, and what the imposed operational costs are. In this article, we reverse the approach by first flowing the containers through a relaxed network, and then design routes to match this flow. This gives a better initial solution than starting from scratch, and the relaxed network reflects the ideas behind a physical internet of having a distributed multi-segment intermodal transport. Next, the initial solution is improved by use of a variable neighborhood search method, where six different operators are used to modify the network. Since each iteration of the local search method involves solving a very complex multi-commodity flow problem to route the containers through the network, the flow problem is solved heuristically by use of a fast Lagrange heuristic. Although the Lagrange heuristic for flowing containers is 2–5% from the optimal solution, the solution quality is sufficiently good to guide the variable neighborhood search method in designing the network. Computational results are reported, showing that the developed heuristic is able to find improved solutions for large-scale instances from LINER-LIB, and it is the first heuristic to report results for the biggest WorldLarge instance.
A framework for dynamic rescheduling problems

Academic scheduling problems usually assume deterministic and known in advance data. However, this situation is not often met in practice, since data may be subject to uncertainty and it may change over time. In this paper, we introduce a general rescheduling framework to address such dynamic scheduling problems. The framework consists mainly of a controller that makes use of a solver. The solver can assume deterministic and static data, whereas the controller deals with the uncertain and dynamic aspects of the problem and it is in charge of triggering the solver when needed and when possible. Extensive tests are carried out for the job shop problem, and we demonstrate that the framework can be used to ascertain the benefit of using rescheduling over static methods, decide between rescheduling policies, and finally we show that it can be applied in real-life applications due to a low time overhead. The framework is general enough to be applied to any scheduling environment where a fast enough deterministic solver exists.
A hybrid approach for biobjective optimization

A large number of the real world planning problems which are today solved using Operations Research methods are actually multiobjective planning problems, but most of them are solved using singleobjective methods. The reason for converting, i.e. simplifying, multiobjective problems to singleobjective problems is that no standard multiobjective solvers exist and specialized algorithms need to be programmed from scratch. In this article we will present a hybrid approach, which operates both in decision space and in objective space. The approach enables massive efficient parallelization and can be used to a wide variety of biobjective Mixed Integer Programming models. We test the approach on the biobjective extension of the classic traveling salesman problem, on the standard datasets, and determine the full set of nondominated points. This has only been done once before (Florios and Mavrotas, 2014), and in our approach we do it in a fraction of the time.

General information
State: Accepted/In press
Organisations: Department of Management Engineering, Management Science, Operations Research, Aarhus University
Authors: Stidsen, T. J. R. (Intern), Andersen, K. A. (Ekstern)
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Scopus rating (2017): SNIP 0.924 SJR 0.539 CiteScore 0.82
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.04 SJR 0.67 SNIP 1.093
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.81 SNIP 1.036 CiteScore 1.18
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.098 SNIP 1.098 CiteScore 1.39
Web of Science (2014): Indexed yes
A hybrid Constraint Programming/Mixed Integer Programming framework for the preventive signaling maintenance crew scheduling problem

A railway signaling system is a complex and interdependent system which should ensure the safe operation of trains. We introduce and address a mixed integer optimisation model for the preventive signal maintenance crew scheduling problem in the Danish railway system. The problem contains many practical constraints, such as temporal dependencies between crew schedules, the splitting of tasks across multiple days, crew competency requirements and several other managerial constraints. We propose a novel hybrid framework using Constraint Programming (CP) to generate initial feasible solutions to feed as ‘warm start’ solutions to a Mixed Integer Programming (MIP) solver for further optimisation. We apply the CP/MIP framework to a section of the Danish rail network and benchmark our results against both direct application of a MIP solver and modelling the problem as a Constraint Optimisation Problem (COP). Whereas the current practice of using a general purpose MIP solver is only able to solve instances over a two-week planning horizon, the hybrid framework generates good results for problem instances over an eight-week period. In addition, the use of a MIP solver to improve the initial solutions generated by CP is shown to be vastly superior to solving the problem as a COP.

General information
State: Published
Organisations: Management Science, Department of Management Engineering, Operations Research, Queen Mary University of London, Banedanmark
Authors: Pour, S. M. (Intern), Drake, J. H. (Ekstern), Ejlertsen, L. S. (Ekstern), Rasmussen, K. M. (Intern), Burke, E. K. (Ekstern)
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Scopus rating (2017): CiteScore 4.08 SJR 2.437 SNIP 2.375
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.83 SJR 2.489 SNIP 2.433
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.225 SNIP 2.364 CiteScore 3.59
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.143 SNIP 2.444 CiteScore 3.21
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.238 SNIP 2.691 CiteScore 3.25
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.328 SNIP 2.567 CiteScore 3.01
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 2.352 SNIP 2.422 CiteScore 3.02
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 2.383 SNIP 2.426
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 2.236 SNIP 2.564
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.715 SNIP 1.944
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.623 SNIP 2.027
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.217 SNIP 2.007
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.092 SNIP 1.897
Scopus rating (2004): SJR 1.192 SNIP 1.869
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.977 SNIP 1.528
Scopus rating (2002): SJR 0.899 SNIP 1.348
Scopus rating (2001): SJR 1.03 SNIP 1.291
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 1.14 SNIP 1.133
Web of Science (2000): Indexed yes
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A matheuristic for transfer synchronization through integrated timetabling and vehicle scheduling

Long transfer times often add unnecessary inconvenience to journeys in public transport systems. Synchronizing relevant arrival and departure times through small timetable modifications could reduce excess transfer times, but may also directly affect the operational costs, as the timetable defines the set of feasible vehicle schedules. Therefore better results in terms of passenger service, operational costs, or both, could be obtained by solving these problems simultaneously.

General information
State: Published
Organisations: Department of Management Engineering, Management Science, Operations Management, Transport DTU, Operations Research, University of Amsterdam
Authors: Fonseca, J. P. (Intern), van der Hurk, E. (Intern), Roberti, R. (Ekstern), Larsen, A. (Intern)
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Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.09 SJR 3.109 SNIP 2.607
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.57 SJR 2.844 SNIP 2.477
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 3.149 SNIP 2.84 CiteScore 5.15
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 3.054 SNIP 3 CiteScore 4.21
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 3.223 SNIP 3.47 CiteScore 4.64
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 3.22 SNIP 3.181 CiteScore 3.3
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.93 SNIP 3.536 CiteScore 3.82
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2 SNIP 2.832
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.383 SNIP 3.049
Web of Science (2009): Indexed yes
A Strategic View of University Timetabling

University Timetabling has traditionally been studied as an operational problem where the goal is to assign lectures to rooms and timeslots and create timetables of high quality for students and teachers. Two other important decision problems arise before this can be solved: what rooms are necessary, and in which teaching periods? These decisions may have a large impact on the resulting timetables and are rarely changed or even discussed. This paper focuses on solving these two strategic problems and investigates the impact of these decisions on the quality of the resulting timetables.

The relationship and differences between operational, tactical and strategic timetabling problems are reviewed. Based on the formulation of curriculum-based course timetabling and data from the Second International Timetabling Competition (ITC 2007), three new bi-objective mixed-integer models are formulated. We propose an algorithm based on the -constraint method to solve them. The algorithm can be used to analyze the impact of having different resources available on most timetabling problems. Finally, we report results on how the three objectives - rooms, teaching periods and quality - influence one another.

General information

State: Published
Organisations: Department of Management Engineering, Management Science, Operations Research, University of Auckland
Authors: Lindahl, M. (Intern), Mason, A. (Ekstern), Stidsen, T. J. R. (Intern), Sørensen, M. (Intern)
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BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 4.08 SJR 2.437 SNIP 2.375
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.83 SJR 2.489 SNIP 2.433
Web of Science (2016): Indexed yes
A Survey on Robustness in Railway Planning

Planning problems in passenger railway range from long term strategic decision making to the detailed planning of operations. Operations research methods have played an increasing role in this planning process. However, recently more attention has been given to considerations of robustness in the quality of solutions to individual planning problems, and of operations in general. Robustness in general is the capacity for some system to absorb or resist changes. In the context of railway robustness it is often taken to be the capacity for operations to continue at some level when faced with a disruption such as delay or failure. This has resulted in more attention given to the inclusion of robustness measures and objectives in individual planning problems, and to the providing of tools to ensure operations continue under disrupted situations. In
this paper we survey the literature on robustness in railway planning problems, considering how robustness is conceptualized and modelled for the individual problems of railway, the degree to which an overall railway robustness concept is present, and consider the future directions of robustness in railway planning.

**General information**

State: Published
Organisations: Department of Management Engineering, Management Science, Operations Research, Transport DTU
Authors: Lusby, R. M. (Intern), Larsen, J. (Intern), Bull, S. H. (Intern)
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- Web of Science (2018): Indexed yes
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- Web of Science (2017): Indexed yes
- BFI (2016): BFI-level 1
- Scopus rating (2016): CiteScore 3.83 SJR 2.489 SNIP 2.433
- Web of Science (2016): Indexed yes
- BFI (2015): BFI-level 1
- Scopus rating (2015): SJR 2.225 SNIP 2.364 CiteScore 3.59
- Web of Science (2015): Indexed yes
- BFI (2014): BFI-level 1
- Scopus rating (2014): SJR 2.143 SNIP 2.444 CiteScore 3.21
- Web of Science (2014): Indexed yes
- BFI (2013): BFI-level 1
- Scopus rating (2013): SJR 2.238 SNIP 2.691 CiteScore 3.25
- ISI indexed (2013): ISI indexed yes
- Web of Science (2013): Indexed yes
- BFI (2012): BFI-level 1
- Scopus rating (2012): SJR 2.328 SNIP 2.567 CiteScore 3.01
- ISI indexed (2012): ISI indexed yes
- Web of Science (2012): Indexed yes
- BFI (2011): BFI-level 1
- Scopus rating (2011): SJR 2.352 SNIP 2.422 CiteScore 3.02
- ISI indexed (2011): ISI indexed yes
- Web of Science (2011): Indexed yes
- BFI (2010): BFI-level 1
- Scopus rating (2010): SJR 2.383 SNIP 2.426
- Web of Science (2010): Indexed yes
- BFI (2009): BFI-level 1
- Scopus rating (2009): SJR 2.236 SNIP 2.564
- Web of Science (2009): Indexed yes
- BFI (2008): BFI-level 1
- Scopus rating (2008): SJR 1.715 SNIP 1.944
- Web of Science (2008): Indexed yes
- Scopus rating (2007): SJR 1.623 SNIP 2.027
- Web of Science (2007): Indexed yes
- Scopus rating (2006): SJR 1.217 SNIP 2.007
- Web of Science (2006): Indexed yes
Benders' Decomposition for Curriculum-Based Course Timetabling

In this paper we applied Benders' decomposition to the Curriculum-Based Course Timetabling (CBCT) problem. The objective of the CBCT problem is to assign a set of lectures to time slots and rooms. Our approach was based on segmenting the problem into time scheduling and room allocation problems. The Benders' algorithm was then employed to generate cuts that connected the time schedule and room allocation. We generated only feasibility cuts, meaning that most of the solutions we obtained from a mixed integer programming solver were infeasible, therefore, we also provided a heuristic in order to regain feasibility.

We compared our algorithm with other approaches from the literature for a total of 32 data instances. We obtained a lower bound on 23 of the instances, which were at least as good as the lower bounds obtained by the state-of-the-art, and on eight of these, our lower bounds were higher. On two of the instances, our lower bound was an improvement of the currently best-known. Lastly, we compared our decomposition to the model without the decomposition on an additional six instances, which are much larger than the other 32. To our knowledge, this was the first time that lower bounds were calculated for these six instances.

General information
State: Published
Organisations: Department of Management Engineering, Management Science, Operations Research, Department of Applied Mathematics and Computer Science, MaCom A/S
Authors: Bagger, N. F. (Intern), Sørensen, M. (Ekstern), Slidsen, T. R. (Intern)
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BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 3.75 SJR 1.916 SNIP 2.094
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.77 SJR 2.299 SNIP 2.192
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.924 SNIP 2.048 CiteScore 3.09
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.225 SNIP 2.309 CiteScore 3.12
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.527 SNIP 2.93 CiteScore 3.62
Centralised horizontal cooperation and profit sharing in a shipping pool

Horizontal cooperation in logistics has attracted an increasing amount of attention in both industry and the research community. The most common form of cooperation in the tramp shipping market is the shipping pool, formed by a fleet of ships from different ownerships operated by a centralised administration. This paper studies such a centralised horizontal cooperation, a product tanker pool in Denmark, and addresses the operational challenges, including how to maximise the pool profit and how to allocate it fairly. We apply discrete event simulation and dynamic ship routing and speed optimisation in order to maximise the pool profit in a highly dynamic environment and apply methods derived from cooperative game theory when allocating the total profit. Through a large number of experiments on realistic data, we evaluate the benefit of cooperation under different scenarios, present the results from the profit allocation and analyse the effect of pool size on the total profit and ship utilisation rate.

General information
State: Accepted/In press
Organisations: Department of Management Engineering, Transport DTU, Transport Modelling, Management Science, Operations Research, Xi'an Jiaotong-Liverpool University
Authors: Wen, M. (Ekstern), Larsen, R. (Intern), Røpke, S. (Intern), Petersen, H. L. (Intern), Madsen, O. B. (Intern)
Number of pages: 15
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Dantzig-Wolfe Decomposition of the Daily Course Pattern Formulation for Curriculum-Based Course Timetabling

In this paper, we considered the problem of Curriculum-Based Course Timetabling, i.e., assigning weekly lectures to a time schedule and rooms. We developed a Column Generation algorithm based on a pattern formulation of the time scheduling part of the problem by Bagger et al. (2016). The pattern formulation is an enumeration of all schedules by
which each course can be assigned on each day; it is a lower bounding model. Pattern enumeration has also been considered in Burke et al. (2008), where the authors enumerated all schedules to which each curriculum can be assigned on each day. We applied the Dantzig-Wolfe reformulation, so each column corresponded to a schedule for an entire day. We solved the reformulation with the Column Generation algorithm, where each pricing problem generated a full schedule for a single day. We provided a pre-processing technique that, on average, removed approximately 45% of the pattern variables in the pricing problems. We then extended the pre-processing technique into inequalities that we added to the model. Lastly, we describe how we applied Local Branching to the pricing problem by using the columns generated in previous iterations. We compare the lower bounds we obtained, with other methods from literature, on 20 data instances of real-world applications. For 16 instances the optimal solutions are known, but the remaining four are still open. Our approach improved the best-known lower bound for all four open instances, and decreased the average gap from 24% to 11%.

General information
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Organisations: Department of Management Engineering, Management Science, Operations Research
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Scopus rating (2017): CiteScore 4.08 SJR 2.437 SNIP 2.375
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.83 SJR 2.489 SNIP 2.433
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.225 SNIP 2.364 CiteScore 3.59
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.143 SNIP 2.444 CiteScore 3.21
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.238 SNIP 2.691 CiteScore 3.25
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.328 SNIP 2.567 CiteScore 3.01
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 2.352 SNIP 2.422 CiteScore 3.02
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 2.383 SNIP 2.426
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 2.236 SNIP 2.564
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.715 SNIP 1.944
Web of Science (2008): Indexed yes
Editorial: Operational Research – Making an Impact

The origins of Operational Research are well known. OR developed – in particular in the UK - in the early 1940s as an area in which science was applied and new research inspired by real-world challenges, primarily in military analysis and in industrial production. As OR developed, a community of academic OR scholars became established alongside OR practitioners and this has led quite naturally to the situation that, over time, much of the OR academic literature is inspired by theoretical development rather than by immediate application.

General information
State: Published
Organisations: Department of Management Engineering, Management Science, Operations Research, University of Strathclyde
Authors: Belton, V. (Ekstern), Bedford, T. (Ekstern), Pisinger, D. (Intern)
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Scopus rating (2017): CiteScore 4.08 SJR 2.437 SNIP 2.375
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.83 SJR 2.489 SNIP 2.433
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.225 SNIP 2.364 CiteScore 3.59
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.143 SNIP 2.444 CiteScore 3.21
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Electric bus fleet size and mix problem with optimization of charging infrastructure

Battery electric buses are seen as a well-suited technology for the electrification of road-based public transport. However, the transition process from conventional diesel to electric buses faces major hurdles caused by range limitations and required charging times of battery buses. This work addresses these constraints and provides a methodology for the cost-optimized planning of depot charging battery bus fleets and their corresponding charging infrastructure. The defined problem covers the scheduling of battery buses, the fleet composition, and the optimization of charging infrastructure in a joint process. Vehicle schedule adjustments are monetized and evaluated together with the investment and operational costs of the bus system. The resulting total cost of ownership enables a comparison of technical alternatives on a system level, which makes this approach especially promising for feasibility studies comprising a wide range of technical concepts. Two scenarios of European cities are analyzed and discussed in a case study, revealing that the cost structure is influenced significantly by the considered bus type and its technical specifications. For example, the total energy consumption of the considered lightweight bus is up to 32% lower than the total consumption of the high range bus, although the deadheading mileage increases. However, the total costs of ownership for operating both bus types are relatively close, due to the increased fleet size and driver expenses required for the lightweight bus system. The case study furthermore reveals that a mixed fleet of different bus types could be advantageous depending on the operational characteristics of the bus route.

General information
Flexible ship loading problem with transfer vehicle assignment and scheduling
This paper presents the flexible containership loading problem for seaport container terminals. The integrated management of loading operations, planning of the transport vehicles to use and their scheduling is what we define as the Flexible Ship Loading Problem (FSLP). The flexibility comes from a cooperative agreement between the terminal operator and the liner shipping company, specifying that the terminal has the right to decide which specific container to load for each slot obeying the class-based stowage plan received from the liner. We formulate a mathematical model for the problem. Then we present various modelling enhancements and a mathematical model to obtain strong lower bounds. We also propose a heuristic algorithm to solve the problem. It is shown that enhancements improve the performance of formulation significantly, and the heuristic efficiently generates high-quality solutions. Results also point out that substantial cost savings can be achieved by integrating the ship loading operations.

General information
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Organisations: Department of Management Engineering, Management Science, Operations Research, Transport DTU
Authors: Iris, Ç. (Intern), Christensen, J. (Intern), Pacino, D. (Intern), Repke, S. (Intern)
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Main Research Area: Technical/natural sciences

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BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.09 SJR 3.109 SNIP 2.607
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.57 SJR 2.844 SNIP 2.477
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 3.149 SNIP 2.84 CiteScore 5.15
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 3.054 SNIP 3 CiteScore 4.21
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 3.223 SNIP 3.47 CiteScore 4.64
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 3.22 SNIP 3.181 CiteScore 3.3
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.93 SNIP 3.536 CiteScore 3.82
ISI indexed (2011): ISI indexed yes
Mixed Integer Linear Programming for new trends in wind farm cable routing

The efficient production of green energy plays an important role in modern economies. In this paper we address the optimization of cable connections between turbines in an offshore wind park. Different versions of this problem have been studied recently. In a previous joint project with Vattenfall BA Wind (a global leader in energy production) we have studied and modeled the main constraints arising in practical cases. Building on that model, in the present paper we address new features that have been recently proposed by Vattenfall's experts. Turbines are becoming still more customized, therefore it is important to be able to evaluate the impact of new technologies with a flexible optimization tool. We here show how some new features can effectively be modeled and solved using a Mixed-Integer Linear Programming paradigm. Computational results on a real-world case are briefly presented.

General information
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Organisations: Department of Management Engineering, Management Science, Operations Research, Transport DTU
Authors: Fischetti, M. (Intern), Pisinger, D. (Intern)
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BFI (2018): BFI-level 1
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Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
On the Impact of Considering Power Losses in Offshore Wind Farm Cable Routing

Wind energy is a field of main importance in the transition away from fossil fuels. In order to achieve this goal, reducing production cost of wind energy is of primary importance, especially for offshore wind parks. In the present paper we illustrate optimization models to achieve this goal for the cable routing problem. In particular we focus on the economical impact of considering power losses in the optimization. The resulting optimization problem considers both minimizing immediate costs (CAPEX) and minimizing costs due to power losses in the park lifetime. Thanks to the close collaboration with a leading energy company, we have been able to conduct different what-if analyses on a set of existing wind parks. Having a fast and reliable tool to optimize cable routing considering or not power losses, we have been able, for the first time, to quantify the impact of these kinds of decisions at design phase. Our results illustrates the importance of considering power losses already at the design phase, as well as the importance of having a sophisticated optimization tool, compared with the traditional manual design.

General information
State: Published
Organisations: Department of Management Engineering, Management Science, Operations Research, Transport DTU
Authors: Fischetti, M. (Intern), Pisinger, D. (Intern)
Number of pages: 26
Pages: 267-292
Publication date: 2018

Host publication information
Optimal wind farm cable routing: Modeling branches and offshore transformer modules

Many EU countries aim at reducing fossil fuels in the near future, hence an efficient production of green energy is very important to reach this goal. In this article, we address the optimization of cable connections between turbines in an offshore wind park. Different versions of the problem have been studied in the recent literature. As turbines are becoming still more customized, it is important to be able to evaluate the impact of new technologies with a flexible optimization tool for scenario evaluation. In a previous joint project with Vattenfall BA Wind (a global leader in energy production) we have studied and modeled the main constraints arising in practical cases. Building on that model, in the present article, we address new technological features that have been recently proposed by Vattenfall's experts. We show how some new features can be modeled and solved using a Mixed-Integer Linear Programming paradigm. We report and discuss computational results on the performance of our new models on a set of real-world instances provided by Vattenfall.
Planning and scheduling operating rooms for elective and emergency surgeries with uncertain duration

In this paper we investigate the planning of operating rooms at Rigshospitalet, a large Danish hospital. Each operation must be assigned to a specific operating room and also be scheduled for a specific time while taking into account clinical guidelines. Both elective and emergency operations are included, such that the elective operations are planned while still taking potential emergency operations into consideration. Furthermore, the duration of each operation is uncertain. The aim is to construct robust operating room schedules that minimise overtime work and release unused capacity.

Due to the uncertainty associated with arrival of emergency patients and also the duration of each operation, a deterministic model is not suitable for this problem. Therefore, we develop a stochastic model where operation duration can vary and where the arrivals of emergency patients are unknown. The stochastic model is computationally heavy, so two mixed integer programming based heuristics denoted 2-Step Relax-and-Fix and All Open Relax-and-Fix are developed to solve the problem.

The computational study is based on an extensive dataset compromising 304 days. The heuristics give good results with half of the operating rooms having less than 8 min of overtime work. To test the robustness of the solutions we carry out a simulated implementation of the operation plans. The simulation shows that the heuristic solutions are fairly robust. In general, results show a clear potential for implementing the method for planning and scheduling of operating rooms at Rigshospitalet.

General information
State: Accepted/In press
Organisations: Department of Management Engineering, Management Science, Operations Research, Office for Study Programmes and Student Affairs, Transport DTU, Technical University of Denmark
Authors: Kroer, L. R. (Ekstern), Foverskov, K. (Ekstern), Vilhelmsen, C. (Intern), Hansen, A. S. (Intern), Larsen, J. (Intern)
Publication date: 2018
Main Research Area: Technical/natural sciences

Publication information
Journal: Operations Research for Health Care
ISSN (Print): 2211-6923
Ratings:
Web of Science (2018): Indexed yes
Scopus rating (2017): CiteScore 1.65 SJR 0.95 SNIP 0.826
Scopus rating (2016): CiteScore 1.9 SJR 0.861 SNIP 1.262
Scopus rating (2015): CiteScore 2.08 SNIP 1.629 SJR 0.964
Simultaneous Optimization of Container Ship Sailing Speed and Container Routing with Transit Time Restrictions

We introduce a decision support tool for liner shipping companies to optimally determine the sailing speed and needed fleet for a global network. We incorporate cargo routing decisions with tight transit time restrictions on each container such that we get a realistic picture of the utilization of the network. Furthermore, we show that it is possible to extend the model to include optimal time scheduling decisions such that the time associated with transhipments is also reflected accurately. To solve the speed optimization problem, we propose an exact algorithm based on Benders decomposition and column generation that exploits the separability of the problem. Computational results show that the method is applicable to liner shipping networks of realistic size and that it is important to incorporate cargo routing decisions when optimizing speed.

General information
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Organisations: Department of Management Engineering, Management Science, Transport DTU, Operations Research
Authors: Karsten, C. V. (Intern), Røpke, S. (Intern), Pisinger, D. (Intern)
Number of pages: 19
Publication date: 2018
Main Research Area: Technical/natural sciences

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Journal: Transportation Science
ISSN (Print): 0041-1655
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BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4.27 SJR 3.312 SNIP 2.56
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.69 SJR 2.564 SNIP 2.345
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 2.65 SNIP 2.532 CiteScore 3.9
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.937 SNIP 2.3 CiteScore 3.11
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.657 SNIP 2.872 CiteScore 3.34
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.65 SNIP 2.451 CiteScore 2.86
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.149 SNIP 2.254 CiteScore 2.4
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.36 SNIP 2.354
Web of Science (2010): Indexed yes
The impact of socioeconomic and behavioural factors for purchasing energy efficient household appliances: A case study for Denmark

Increasing the share of evermore energy efficient household electric appliances is one strategy to address environmental impacts arising from residential electricity demand. Hence, governments and energy actors are interested in the determining factors behind the consumer choice of conventional versus high efficiency labelled appliances. This study employs empirical survey data from the Danish Energy Agency to model influential factors behind Danish consumer choice of energy efficient appliances. To estimate consumer propensities, we use a logistic regression model over a set of socioeconomic, demographic, and behavioural variables. The study regresses over this unique combination of end-use behavioural variables by creating an energy efficiency index. Statistical results show that housing type, quantity of inhabitants, age, and end-use behaviour are strong predictors for choosing energy efficient appliances. Interestingly, income is a weaker predictor. Despite a relatively wealthy national income and well-educated population, information campaigns have been largely ineffective in driving high efficiency investments. In light of this study's results and exogenous factors such as urbanising demographics and shifting Danish housing stock towards apartments, the study suggests improved information campaigns by targeting key demographics.

General information

State: Published
Organisations: Department of Management Engineering, Systems Analysis, Management Science, Operations Research
Authors: Baldini, M. (Intern), Trivella, A. (Intern), Wente, J. W. (Intern)
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Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4.97 SJR 1.994 SNIP 2.094
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.49 SJR 2.197 SNIP 1.985
Tramp ship routing and scheduling with voyage separation requirements

This presentation addresses a tramp routing and scheduling problem. Tramp ships operate like taxies by following the available demand, as opposed to liner ships that operate like busses on a fixed route network according to a published...
timetable. Tramp operators determine some of the demand in advance by ensuring long-term contracts. The rest of the demand comes from optional voyages found in the spot market. Routing and scheduling a tramp fleet to best utilize feet capacity according to the current demand is therefore an ongoing and complicated problem. We add further complexity by incorporating voyage separation requirements that enforce a minimum time spread between some voyages. We developed a new and exact Branch-and-Price procedure for this problem. A dynamic programming algorithm generates columns, while a novel time window branching scheme is used to enforce the voyage separation requirements. Computational results show that the algorithm finds optimal solutions very quickly for the vast majority of test instances. We compare the results with two earlier published methods and show that our Branch-and-Price approach outperforms both an a priori path generation method and an Adaptive Large Neighbourhood Search heuristic.

A Branch-and-Price algorithm for railway rolling stock rescheduling

How to best reschedule their fleet of rolling stock units during a disruption is an optimization problem regularly faced by railway operators. Despite the problem's high complexity, it is still usually solved manually. In this paper we propose a path based mathematical formulation and solve it using a Branch-and-Price algorithm. We demonstrate that, unlike flow based approaches, our formulation is more easily extended to handle certain families of constraints, such as train unit maintenance restrictions. The proposed algorithm is benchmarked on several real-life instances provided by the suburban railway operator in Copenhagen, DSB S-tog. When used in combination with a lower bound method taken from the literature we show that near-optimal solutions to this rescheduling problem can be found within a few seconds. Furthermore, we show that the proposed methodology can be used, with minor modification, on a tactical planning level, where it produces near-optimal rolling stock schedules in minutes of CPU time.
### A Branch-and-Price Approach to the Feeder Network Design Problem

In this paper, we consider the problem of designing a container liner shipping feeder network. The designer has to choose which port to serve during many rotations that start and end at a central hub. Many operational characteristics are considered, such as variable leg-by-leg speeds and cargo transit times. Realistic instances are generated from the LinerLib benchmark suite. The problem is solved with a branch-and-price algorithm, which can solve most instances to optimality within one hour. The results also provide insights on the cost structure and desirable features of optimal routes. These insights were obtained by means of an analysis where scenarios are generated varying internal and external conditions, such as fuel costs and port demands.

### General information

State: Published

Organisations: Department of Management Engineering, Management Science, Operations Research, Transport DTU, RWTH Aachen University, Maersk Line

Authors: Santini, A. (Ekster), Plum, C. E. M. (Ekster), Røpke, S. (Intern)

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Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 4.08 SJR 2.437 SNIP 2.375
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.83 SJR 2.489 SNIP 2.433
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.225 SNIP 2.364 CiteScore 3.59
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.143 SNIP 2.444 CiteScore 3.21
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.238 SNIP 2.691 CiteScore 3.25
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.328 SNIP 2.567 CiteScore 3.01
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 2.352 SNIP 2.422 CiteScore 3.02
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 2.383 SNIP 2.426
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 2.236 SNIP 2.564
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.715 SNIP 1.944
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.623 SNIP 2.027
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.217 SNIP 2.007
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.092 SNIP 1.897
Scopus rating (2004): SJR 1.192 SNIP 1.869
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.977 SNIP 1.528
Scopus rating (2002): SJR 0.899 SNIP 1.348
Scopus rating (2001): SJR 1.03 SNIP 1.291
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 1.14 SNIP 1.133
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 1.091 SNIP 1.084
Original language: English
DOIs:
10.1016/j.ejor.2017.06.063
A dynamic programming approach for optimizing train speed profiles with speed restrictions and passage points
This paper considers a novel solution method for generating improved train speed profiles with reduced energy consumption. The solution method makes use of a time-space graph formulation which can be solved through Dynamic Programming. Instead of using uniform discretization of time and space as seen previously in the literature, we rely on an event-based decomposition that drastically reduces the search space. This approach is very flexible, making it easy to handle, e.g., speed limits, changes in altitude, and passage points that need to be crossed within a given time window. Based on solving an extensive number of real-life problem instances, our benchmarks show that the proposed solution method is able to satisfy all secondary constraints and still be able to decrease energy consumption by 3.3% on average compared to a commercial solver provided by our industrial collaborator, Cubris. The computational times are generally very low, making it possible to recompute the train speed profile in case of unexpected changes in speed restrictions or timings. This is a great advantage over static offline lookup tables. Also, the framework is very flexible, making it possible to handle a number of additional constraints on robustness, passenger comfort etc. Selected details of the method and benchmark are only described at a high level for confidentiality reasons.

General information
State: Published
Organisations: Department of Management Engineering, Management Science, Operations Research, Cubris ApS
Authors: Haahr, J. T. (Intern), Pisinger, D. (Intern), Sabbaghian, M. (Ekstern)
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Journal: Transportation Research Part B: Methodological
Volume: 99
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Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.09 SJR 3.109 SNIP 2.607
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.57 SJR 2.844 SNIP 2.477
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 3.149 SNIP 2.84 CiteScore 5.15
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 3.054 SNIP 3 CiteScore 4.21
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 3.223 SNIP 3.47 CiteScore 4.64
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 3.22 SNIP 3.181 CiteScore 3.3
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.93 SNIP 3.536 CiteScore 3.82
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2 SNIP 2.832
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
A matheuristic approach for solving the Integrated Timetabling and Vehicle Scheduling Problem

The Integrated Timetabling and Vehicle Scheduling Problem (IT-VSP) is a generalization of the well-known Vehicle Scheduling Problem (VSP). In the IT-VSP the trips in the original timetables may be modified in terms of arrival and departure times in order to minimize a new objective function that considers both operational costs and passenger transfer costs. Starting from a base timetable, the allowed modifications include shifting the departure time from the first station of each trip and also the extension of dwell times at important stops where large flows of passengers are expected to transfer between different trips. We consider transfers between bus trips scheduled by the model, but also transfers to other fixed lines that intersect the lines considered in the IT-VSP. We present a MIP formulation of the IT-VSP able to solve small instances of the problem, and a matheuristic approach that uses the compact MIP to solve larger instances of the problem. The idea is to iteratively solve restricted versions of the MIP selecting at each step a subset of trips where modifications are allowed, while all other trips remain fixed. The performance of the proposed matheuristic is shown on a case study with real-life instances provided by the main service provider in the greater Copenhagen area. The effect of allowing dwell times is compared to previous approaches to the problem where trips are only allowed to be shifted in time.

General information
State: Published
Authors: Fonseca, J. F. P. (Intern), Larsen, A. (Intern), van der Hurk, E. (Intern), Røpke, S. (Intern), Roberti, R. (Ekstern)
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Main Research Area: Technical/natural sciences
Electronic versions:
AbstractIT_VSP.pdf
Source: PublicationPreSubmission
Source-ID: 142996085
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2018

A multiple ship routing and speed optimization problem under time, cost and environmental objectives

The purpose of this paper is to investigate a multiple ship routing and speed optimization problem under time, cost and environmental objectives. A branch and price algorithm as well as a constraint programming model are developed that consider (a) fuel consumption as a function of payload, (b) fuel price as an explicit input, (c) freight rate as an input, and (d) in-transit cargo inventory costs. The alternative objective functions are minimum total trip duration, minimum total cost and minimum emissions. Computational experience with the algorithm is reported on a variety of scenarios.

General information
Bin-packing problems with load balancing and stability constraints

The Bin-Packing Problem (BPP) is one of the most investigated and applicable combinatorial optimization problems. The problem consists of packing objects of different sizes into a finite number of similar bins, such that the number of used bins is minimized. Applications of the bin-packing problem appear in a wide range of disciplines, including transportation and logistics, computer science, engineering, economics and manufacturing. The problem is well-known to be NP-hard and difficult to solve in practice, especially when dealing with the multi-dimensional cases. Closely connected to the BPP is the Container Loading Problem (CLP), which addresses the optimization of a spatial arrangement of cargo inside a container or transportation vehicle, with the objective to maximize the value of the cargo loaded or the volume utilization. The CLP focuses on a single container, and has been extended in the literature to handle a variety of different constraints arising from real-world problems. Consider for example the problem of arranging items into an aircraft cargo area such that the barycenter of the loaded plane is as close as possible to an ideal point given by the aircraft’s specifications. The position of the barycenter has an impact on the flight performance in terms of safety and efficiency, and even a minor displacement from the ideal barycenter can lead to a high increase of fuel consumption [1]. Similar considerations apply when loading trucks and container ships. The aim of this work is to integrate realistic constraints related to e.g. load balancing, cargo stability and weight limits, in the multi-dimensional BPP. The BPP poses additional challenges compared to the CLP due to the supplementary objective of minimizing the number of bins. In particular, in section 2 we discuss how to integrate bin-packing and load balancing of items. The problem has only been considered in the literature in simplified versions, e.g. balancing a single bin or introducing a feasible region for the barycenter. In section 3 we generalize the problem to handle cargo stability and weight constraints.

Competitive Liner Shipping Network Design

We present a solution method for the liner shipping network design problem which is a core strategic planning problem faced by container carriers. We propose the first practical algorithm which explicitly handles transshipment time limits for all demands. Individual sailing speeds at each service leg are used to balance sailing speed against operational costs, hence ensuring that the found network is competitive on both transit time and cost. We present a matheuristic for the problem where a MIP is used to select which ports should be inserted or removed on a route. Computational results are presented showing very promising results for realistic global liner shipping networks. Due to a number of algorithmic enhancements, the obtained solutions can be found within the same time frame as used by previous algorithms not handling time constraints. Furthermore, we present a sensitivity analysis on fluctuations in bunker price which confirms the applicability of the algorithm.
Considering passenger and operator inconvenience in the scheduling of large railway projects

The continued development and renewal of railway infrastructure and technology is necessary to enable railway operators to provide high quality services subject to ever increasing demand. However, the execution of large infrastructure projects causes disturbances in the network due to the occupation of infrastructure over extended periods of time. In this paper we propose a multiobjective project scheduling optimization model for railway infrastructure projects that takes inconvenience caused to users of the infrastructure into account. We illustrate how the model can be used in an interactive way by planners based on their preferences, and we show that Pareto optimal solutions can be found in reasonable time using instances with realistic features. The result is a decision support model to aid infrastructure project planners in ensuring that passenger and operator inconvenience are also taken into account.

General information
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Organisations: Department of Management Engineering, Management Science, Operations Management, Operations Research, Transport DTU
Authors: Kidd, M. P. (Intern), Lusby, R. M. (Intern), Larsen, J. (Intern)
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BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
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Scopus rating (2017): CiteScore 5.09 SJR 3.109 SNIP 2.607
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.57 SJR 2.844 SNIP 2.477
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 3.149 SNIP 2.84 CiteScore 5.15
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 3.054 SNIP 3 CiteScore 4.21
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 3.223 SNIP 3.47 CiteScore 4.64
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 3.22 SNIP 3.181 CiteScore 3.3
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.93 SNIP 3.536 CiteScore 3.82
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2 SNIP 2.832
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.383 SNIP 3.049
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 2.407 SNIP 2.904
Scopus rating (2007): SJR 2.245 SNIP 3.071
Consumer’s Attitude Towards Investments in Residential Energy-Efficient Appliances: How End-User Choices Contribute to Change Future Energy Systems

The proliferation of increasingly energy-efficient (EE) appliances is a key strategy to address the impacts of rising residential electricity demand (Danish Energy Agency 2017). To this end, governments and institutions are interested in understanding the drivers of consumer choice between conventional and environmentally friendly alternatives when purchasing new household electric appliances. This study employs empirical data from a survey conducted by the Danish Energy Agency to model the decision criteria behind Danish consumer investment in energy-efficient labeled appliances. The analysis uses logistic regression over a set of socioeconomic, demographic, and behavioral variables to predict purchase propensities. The findings are relevant for policy makers interested in targeting consumers in the appliance market, particularly for a relatively wealthy national context. The study concludes by integrating the predicted propensities with an energy-systems model to assess the nation-wide impact of efficient appliances’ uptake in terms of electricity, emissions and economic savings.

Flow Formulations for Curriculum-based Course Timetabling

In this paper we present two mixed-integer programming formulations for the Curriculum based Course Timetabling Problem (CTT). We show that the formulations contain underlying network structures by dividing the CTT into two separate models and then connect the two models using flow formulation techniques. The first mixed-integer programming formulation is based on an underlying minimum cost flow problem, which decreases the number of integer variables significantly and improves the performance compared to an intuitive mixed-integer programming formulation. The second formulation is based on a multi-commodity flow problem which in general is NP-hard, however, we prove that it suffices to solve the linear programming relaxation of the model. The formulations show competitiveness with other approaches based on mixed-integer programming from the literature and improve the currently best known lower bound on one data instance in the benchmark data set from the second international timetabling competition. Regarding upper bounds, the
formulation based on the minimum cost flow problem performs better on average than other mixed integer programming approaches for the CTT.

General information
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Organisations: Department of Management Engineering, Management Science, Operations Research, MaCom A/S, RHA Software Group
Authors: Bagger, N. F. (Intern), Kristiansen, S. (Ekstern), Sørensen, M. (Ekstern), Stidsen, T. J. R. (Intern)
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http://www.optimization-online.org/DB_HTML/2016/12/5786.html
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Improved formulations and an Adaptive Large Neighborhood Search heuristic for the integrated berth allocation and quay crane assignment problem
This paper focuses on the integrated berth allocation and quay crane assignment problem in container terminals. We consider the decrease in the marginal productivity of quay cranes and the increase in handling time due to deviation from the desired position. We consider a continuous berth, discretized in small equal-sized sections. A number of enhancements over the state-of-the-art formulation and an Adaptive Large Neighborhood Search (ALNS) heuristic are presented. Computational results reveal that the enhancements improve many of the best-known bounds, and the ALNS outperforms the state-of-the-art heuristics for many instances. We also conduct further analysis on a new larger benchmark.

General information
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Organisations: Department of Management Engineering, Management Science, Operations Research, Transport DTU
Authors: Iris, C. (Intern), Pacino, D. (Intern), Røpke, S. (Intern)
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Main Research Area: Technical/natural sciences
Publication information
Journal: Transportation Research. Part E: Logistics and Transportation Review
Volume: 105
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BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4.03
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.68
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.51
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.59
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.64
Integer programming techniques for educational timetabling

Educational timetabling problems require the assignment of times and resources to events, while sets of required and desirable constraints must be considered. The XHSTT format was adopted in this work because it models the main features of educational timetabling and it is the most used format in recent studies in the field. This work presents new cuts and reformulations for the existing integer programming model for XHSTT. The proposed cuts improved hugely the linear relaxation of the formulation, leading to an average gap reduction of 32%. Applied to XHSTT-2014 instance set, the alternative formulation provided four new best known lower bounds and, used in a matheuristic framework, improved eleven best known solutions. The computational experiments also show that the resulting integer programming models from the proposed formulation are more effectively solved for most of the instances.

General information

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Organisations: Department of Management Engineering, Management Science, Operations Research, Universidade Federal de Minas Gerais, Universidade Federal de Ouro Preto
Authors: Fonseca, G. H. (Ekstern), Santos, H. G. (Ekstern), Carrano, E. G. (Ekstern), Stidsen, T. J. R. (Intern)
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Integrated Rolling Stock Planning for Suburban Passenger Railways

One of the core issues for operators of passenger railways is providing sufficient number of seats for passengers while keeping operating costs at a minimum. The process a railway operator undertakes in order to achieve this is called rolling stock planning. Rolling stock planning deals with deciding how to utilise the fleet of available train units in space and time. In this thesis, rolling stock planning has been studied, using as case study DSB S-tog, the suburban passenger railway operator of the City of Copenhagen. At DSB S-tog, the rolling stock planning process is subdivided according to time horizon into two subprocesses. Firstly, there is the long-term circulation planning process, in which planning is conducted for anonymous, virtual train units months in advance. Secondly, there is the short-term train unit dispatching process, which covers the execution of the long term circulation plan. In the train unit dispatching process, the anonymous, virtual train units from the circulation planning process will have real, physical train units assigned to them. The train unit dispatching process has a short-term time horizon of days, hours and minutes and makes sure the actual, real-world train services are performed. Disruptions are also handled in this process. In the long term circulation planning phase of rolling stock planning, a large number of railway-specific requirements must be taken into account: The physical railway
In the short-term train unit dispatching phase of rolling stock planning, additional railway-specific requirements include: Exterior graffiti removal and unscheduled maintenance on demand and sometimes within a given time frame; Make available train units to meet surveillance video recording requests from the police within a given time frame. Due to the large number of railway-specific requirements and their nature, rolling stock planning is traditionally conducted in a step-by-step manner, in which the individual planning processes are not integrated with each other. Needless to say, this yields rolling stock plans that are either suboptimal or infeasible with regard to the requirements. In this thesis it is shown that it is possible to design and implement a rolling stock planning model integrating into one planning process all the railway-specific requirements of DSB S-tog, all at the same time. This integrated rolling stock planning model is implemented using a greedy heuristic and makes use of the novel (train) unit order conservation principle, implemented as special side constraints to a resource constrained shortest path algorithm. The integrated rolling stock planning model is tested extensively on 15 real-world, manually constructed rolling stock plan data instances. When run on these instances, the greedy heuristic can achieve an average economic gain of approx. 2% with processing times in all cases less than 1 hour 20 minutes. In addition to this, the greedy heuristic can make typically infeasible rolling stock plans feasible within just a few minutes of processing time. Moreover, in this thesis a number of different economic net value upper bound calculation models are designed, implemented and tested. The net value upper bound calculation models implement the railway-specific requirements to a varying degree and consequently expose different properties with regard to tightness of bounds and processing times. The net value upper bound model having the highest degree of requirements integration adheres to 47% of the requirements by count. Using this tightest net value upper bound calculation model, it is shown that the greedy heuristic mentioned before is able to gain approx. 1/3 of the relative gap between the net value of the original, manual plans and the net value upper bound. Moreover, it is shown that in most cases, the net value of the original, manual plans already lie close to the upper bound.

Furthermore, a branch-and-price based matheuristic integrated rolling stock planning model is designed, implemented and tested. It is shown that this type of matheuristic model is able to adhere fully to all railway-specific requirements, and that the vast majority of requirements can be integrated into the optimisation steps of the matheuristic algorithm. The branch-and-price matheuristic model can solve small instances (e.g., in the form of matheuristic iterations) to optimality. Used in conjunction with the greedy heuristic, the two methods combined can achieve an additional small gain in objective value not achievable using each method by itself. With a yearly cost of the rolling stock operation in the hundreds of million DKK, the potential benefit of a real-world application of the models to DSB S-tog is in the order of several million DKK per year. In addition to this, a substantial benefit can be gained by the way the models can automate the current, manual planning procedures. This will enable planners to invest more creativity and meticulousness into the planning process as a result of being liberated from manual planning procedures. For these reasons, DSB S-tog is eager to proceed with the real-world application of the models developed in this thesis.

General information
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Integrating robust timetabling in line plan optimization for railway systems
We propose a heuristic algorithm to build a railway line plan from scratch that minimizes passenger travel time and operator cost and for which a feasible and robust timetable exists. A line planning module and a timetabling module work iteratively and interactively. The line planning module creates an initial line plan. The timetabling module evaluates the line plan and identifies a critical line based on minimum buffer times between train pairs. The line planning module proposes a...
new line plan in which the time length of the critical line is modified in order to provide more flexibility in the schedule. This flexibility is used during timetabling to improve the robustness of the railway system. The algorithm is validated on the DSB S-tog network of Copenhagen, which is a high frequency railway system, where overtakings are not allowed. This network has a rather simple structure, but is constrained by limited shunt capacity. While the operator and passenger cost remain close to those of the initially and (for these costs) optimally built line plan, the timetable corresponding to the finally developed robust line plan significantly improves the minimum buffer time, and thus the robustness, in eight out of ten studied cases.

**General information**

State: Published
Organisations: Department of Management Engineering, Management Science, Operations Research, Transport DTU, KU Leuven
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- Web of Science (2016): Indexed yes
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- Scopus rating (2015): SJR 2.026 SNIP 2.714 CiteScore 4.23
- Web of Science (2015): Indexed yes
- BFI (2014): BFI-level 2
- Scopus rating (2014): SJR 2.045 SNIP 3.169 CiteScore 3.84
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- Web of Science (2012): Indexed yes
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- Web of Science (2011): Indexed yes
- BFI (2010): BFI-level 2
- Scopus rating (2010): SJR 0.937 SNIP 2.356
- BFI (2009): BFI-level 2
- Scopus rating (2009): SJR 1.088 SNIP 2.369
- BFI (2008): BFI-level 2
- Scopus rating (2008): SJR 0.977 SNIP 2.523
- Scopus rating (2007): SJR 0.901 SNIP 1.581
- Scopus rating (2006): SJR 1.915 SNIP 2.76
- Scopus rating (2005): SJR 1.49 SNIP 3.074
Mathematical Programming Approaches for Optimal University Timetabling

Every semester universities are faced with the challenge of creating timetables for the courses. Creating these timetables is an important task to ensure that students can attend the courses they need for their education. Creating timetables that are feasible can be challenging, and when different preferences are taken into account, the problems become even more challenging. Therefore, automating the processes of generating these timetables is a great help for the planners and the universities. Scheduling and timetabling has been studied before in the literature, and two international conferences are dedicated to this research field. This thesis considers a University Timetabling problem, more specifically the Curriculum-based Course Timetabling (CTT) problem. The objective of the CTT problem is to assign a set of lectures to time slots and rooms. The literature has focused mainly on heuristic applications which are also apparent in the different surveys. The drawback of the heuristics is that they are problem specific and do not provide any information on the quality of the solutions they generate. The objective of this thesis is to minimize the gap between the best-known upper bounds and the best-known lower bounds for CTT by using Mixed Integer Programming (MIP) based approaches. We present a total of 15 different MIP based approaches that we have implemented, ranging from Cutting Plane techniques and Lagrangian Relaxation to Benders’ Decomposition and Dantzig-Wolfe Decomposition. Most of these implementations did not provide satisfying results. However, they provide valuable insights into the difficulties of the problem. We discuss all the approaches, the difficulties we have encountered, and suggestions on how to bring research further. Four of the implementations have led to articles submitted to international peer-reviewed journals. The last two focus on generating high-quality lower bounds by applying an extended formulation, which is then decomposed. The articles in this thesis have brought us closer to the goal of closing the gap between the best-known upper and lower bounds for CTT. Though CTT was the problem in focus, the methods implemented here are general enough to be applied for other scheduling problems as well.
Models and Methods for the Design and Support of Liner Shipping Networks

The modern economy relies on cheap and reliable transportation of goods all around the globe. Liner shipping networks represent an important link in the global supply chain, as they connect countries and continents over long distances at comparatively low transportation costs. In largeliner shipping networks, several hundred container vessels operate more than a hundred shipping routes. The individual routes are linked through ports, where containers can be loaded, unloaded but also be transshipped between shipping routes. The resulting networks constitute inherently complex systems. In this thesis we present mathematical modeling and optimization tools that help decision makers in the liner shipping industry to find solutions to complex decision problems. The decision problems we address involve questions like: Which ports shall be covered by the network? How shall each single shipping route be designed to achieve a well-connected but cost-efficient network? How shall port calls be scheduled and synchronized between shipping routes to offer the most economical and fastest transportation between ports? On which route shall containers be transported, if multiple options exist? The articles in this thesis contribute to the field of Operations Research with application in maritime optimization. More particularly, the first two articles present models and solution methods to (re-)design and (re-)schedule large liner shipping networks. The articles combine and substantially extend modeling features of previous contributions and narrow the gap to the economic and operational reality of liner shipping. The results obtained from solving the models shed light on previously unexamined issues. The developed solution algorithms cannot only handle the increased complexity inherent to the models, but improve over existing methods proposed in the literature. The third article addresses a strategic infrastructure and tanker fleet sizing problem as part of an industrial case study with a large liner shipping company. The case study is motivated by recent changes in environmental regulations that may substantially change the way liner vessels are operated in the future. The article addresses the establishment of a large-scale liquefied natural gas supply chain along a major trade lane. It analyzes the interaction between long-term investment and operational costs, derives basic decision rules and evaluates the robustness of the solutions.

General information
State: Published
Organisations: Department of Management Engineering, Management Science, Transport DTU, Operations Research
Authors: Koza, D. F. (Intern)
Number of pages: 162
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On the impact of using Mixed Integer Programming Techniques on Real-world Offshore Wind Parks

Wind power is a leading technology in the transition to sustainable energy. Being a new and still more competitive field, it is of major interest to investigate new techniques to solve the design challenges involved. In this paper, we consider optimization of the inter-array cable routing for offshore wind farms, taking power losses into account. Since energy losses in a cable depend on the load (i.e. wind), cable losses are estimated by considering a possibly large number wind scenarios. In order to deal with different wind scenarios efficiently we used a precomputing strategy. The resulting optimization problem considers two objectives: minimizing immediate costs (CAPEX) and minimizing costs due to power losses. This makes it possible to perform various what-if analyses to evaluate the impact of different preferences to
CAPEX versus reduction of power losses. Thanks to the close collaboration with a leading energy company, we have been able to report results on a set of real-world instances, based on six existing wind parks, studying the economical impact of considering power losses in the cable routing design phase.

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Optimization in liner shipping
Seaborne trade is the lynchpin in almost every international supply chain, and about 90% of non-bulk cargo worldwide is transported by container. In this survey we give an overview of data-driven optimization problems in liner shipping. Research in liner shipping is motivated by a need for handling still more complex decision problems, based on big data sets and going across several organizational entities. Moreover, liner shipping optimization problems are pushing the limits of optimization methods, creating a new breeding ground for advanced modelling and solution methods. Starting from liner shipping network design, we consider the problem of container routing and speed optimization. Next, we consider empty container repositioning and stowage planning as well as disruption management. In addition, the problem of bunker purchasing is considered in depth. In each section we give a clear problem description, bring an overview of the existing literature, and go in depth with a specific model that somehow is essential for the problem. We conclude the survey by giving an introduction to the public benchmark instances LINER-LIB. Finally, we discuss future challenges and give directions for further research.

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Scopus rating (2017): SNIP 0.999 SJR 0.825 CiteScore 1.47
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Scopus rating (2016): SJR 1.463 SNIP 1.564 CiteScore 1.83
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.974 SNIP 1.022 CiteScore 1.19
BFI (2014): BFI-level 1
Optimization of hospital ward resources with patient relocation using Markov chain modeling

Overcrowding of hospital wards is a well-known and often revisited problem in the literature, yet it appears in many different variations. In this study, we present a mathematical model to solve the problem of ensuring sufficient beds to hospital wards by re-distributing beds that are already available to the hospital. Patient flow is modeled using a homogeneous continuous-time Markov chain and optimization is conducted using a local search heuristic. Our model accounts for patient relocation, which has not been done analytically in literature with similar scope. The study objective is to ensure that patient occupancy is reflected by our Markov chain model, and that a local optimum can be derived within a reasonable runtime. Using a Danish hospital as our case study, the Markov chain model is statistically found to reflect occupancy of hospital beds by patients as a function of how hospital beds are distributed. Furthermore, our heuristic is found to efficiently derive the optimal solution. Applying our model to the hospital case, we found that relocation of daily arrivals can be reduced by 11.7% by re-distributing beds that are already available to the hospital.
Railway capacity and expansion analysis using time discretized paths

When making investments in railway infrastructure it is important to be able to identify the limits for freight transportation in order to not only use the infrastructure in the best possible way, but to also guide future capacity investments. This paper presents a model to assess the capacity of railway freight transportation on a long term strategic level. The model uses an hourly time discretization and analyses the impact of railway network expansions based on future demand forecasts. It provides an optimal macroscopic freight train schedule and can indicate the time and place of any congestion. In addition, two expansions of the primary model are developed. The first can be used to determine the minimal number of expansions needed to ensure all freight can be feasibly routed, while the second can be used to schedule freight trains at hours not congested by passenger trains using variable penalties for the different passenger busy time slots. As part of a European Union project, all models are applied to a realistic case study that focuses on analyzing the capacity of railway network, in Denmark and Southern Sweden using demand forecasts for 2030. Results suggest that informative solutions can be found quickly with the proposed approach.

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Authors: Reinhardt, L. B. (Ekstern), Pisinger, D. (Intern), Lusby, R. M. (Intern)
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Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.274 SNIP 1.409 CiteScore 2.21
BFI (2014): BFI-level 1
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BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.204 SNIP 1.68 CiteScore 1.48
ISI indexed (2013): ISI indexed yes
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BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.807 SNIP 0.524 CiteScore 0.79
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.551 SNIP 0.783 CiteScore 0.5
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.402 SNIP 0.81
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.332 SNIP 1.162
Scheduling EURO-k Conferences

EURO-k conferences are among the largest Operations Research conferences in the world, typically including more than 2000 presentations. As opposed to many other conferences, EURO-k conferences are hierarchically organized, and the conference schedule should reflect this structure to make navigation easier and more logical. In this article we present a scheduling tool that has been developed during the EURO2015 and EURO2016 conferences to schedule the streams, sessions and talks. A schedule is obtained by solving a number of optimization models, each addressing a specific objective. First, areas are assigned to buildings, making sure that related research areas are located close to each other. Next, the goal is to allocate each stream to only one room, and to ensure that the stream consists of a sequence of consecutive time slots. Finally, we optimize the assignment of room sizes. We illustrate the process by showing results from the scheduling of the EURO2016 conference, which took place in Poznan (Poland), July 3–6, 2016.

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Organisations: Department of Management Engineering, Management Science, Operations Research, Transport DTU, University of Bologna
Authors: Stidsen, T. J. R. (Intern), Pisinger, D. (Intern), Vigo, D. (Ekstern)
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Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.83 SJR 2.489 SNIP 2.433
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.225 SNIP 2.364 CiteScore 3.59
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.143 SNIP 2.444 CiteScore 3.21
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.238 SNIP 2.691 CiteScore 3.25
ISI indexed (2013): ISI indexed yes
We present a novel solution approach to the container pre-marshalling problem using the A* and IDA* algorithms combined with several novel branching and symmetry breaking rules that significantly increases the number of pre-marshalling instances that can be solved to optimality. A* and IDA* are graph search algorithms that use heuristics combined with a complete graph search to find optimal solutions to problems. The container pre-marshalling problem is a key problem for container terminals seeking to reduce delays of inter-modal container transports. The goal of the container pre-marshalling problem is to find the minimal sequence of container movements to shuffle containers in a set of stacks such that the resulting stacks are arranged according to the time each container must leave the stacks. We evaluate our approach on three well-known datasets of pre-marshalling problem instances, solving over 500 previously unsolved instances to optimality, which is nearly twice as many instances as the current state-of-the-art method solves.
Strategic, Tactical and Operational University Timetabling

University education is delivered via lectures and classes that are attended by students. When and where these classes are taught is determined by the timetable. A timetable has many stakeholders, and it is the task of planners to accommodate their needs as far as possible, as it has a significant influence on the daily life of both staff and students.
Furthermore, it has a large impact on the use of the university’s resources. Rooms are a significant cost, and as many are allocated specifically to teaching it is important that the planners optimize their use. Creating a high-quality timetable is, therefore, essential to providing an excellent education, while at the same time using the university’s resources efficiently. This thesis presents an introduction to the university course timetabling problem and its different formulations. Although university timetabling has been widely studied in the literature, work has focused on the creation of a schedule once all of the available resources have been determined, called the course assignment problem. This thesis broadens the perspective by also investigating the decision problems that must be solved before and after the course assignment problem. One important problem is to determine the necessary resources. This thesis formulates the room planning problem that determines which rooms are available, and the teaching periods problem that determines timeslots for teaching. It then analyzes how the available resources affect the quality of the timetable. Once the timetable has been generated, there can be disruptions. This thesis investigates the quality recovering problem, which addresses this issue. In this case, an important constraint is that the new solution must be similar to the initial one, but not degrade the quality of the timetable. Solution methods are presented to these four problems. These are based on mixed integer programming, and the same underlying model is used in different ways to solve decision problems that occur at different levels of the organization. All methods are tested on the curriculum-based course timetabling problem used for the Second International Timetabling Competition, which is the most-studied problem formulation in the literature. Finally, this thesis suggests potential directions for future research, which aims to ensure that there are tangible benefits for planners and universities.

General information
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Authors: Lindahl, M. (Intern), Stidsen, T. J. R. (Intern), Sørensen, M. (Intern)
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The liquefied natural gas infrastructure and tanker fleet sizing problem
We consider a strategic infrastructure and tanker fleet sizing problem in the liquefied natural gas business. The goal is to minimize long-term on-shore infrastructure and tanker investment cost combined with interrelated expected cost for operating the tanker fleet. A non-linear arc-based model and an exact solution method based on a set-partitioning formulation are developed. The latter approach allows very fast solution times. Computational results for a case study with a liner shipping company are presented, including an extensive sensitivity analysis to account for limited predictability of key parameter values, to analyze the solutions’ robustness and to derive basic decision rules.

General information
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Organisations: Department of Management Engineering, Management Science, Operations Research, Transport DTU, L’Oréal Danmark A/S
Authors: Koza, D. F. (Intern), Røpke, S. (Intern), Molas, A. B. (Ekstern)
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On-road electric vehicle recharging infrastructure is essential in the transformation of electric vehicles into a practical transportation option. This study focuses upon assessing the need for recharging infrastructure for long distance travel for a large market share of electric vehicles, finding the optimal infrastructure deployment, and understanding the economic, social and environmental costs and benefits associated with the optimal infrastructure deployment. The analysis considers quick-charging and battery-switching as plausible recharging technologies. Results show: (i) the promotion of electric vehicles is beneficial when considering economic costs and benefits for operators and users, tax redistribution, and environmental externalities, even with a relatively modest market share; (ii) the number of required recharging stations for satisfaction of the travel demand is at the magnitude of 1–2% of the current gasoline infrastructure, under the assumption of wide availability of off-road recharging at home and the workplace; (iii) the optimal deployment of the recharging stations is along the main national highways outside of urban conurbations, under the assumption of wide availability of home recharging; (iv) the battery-switching technology is far more attractive to the consumer than the quick-charging technology for long-distance travel requiring more than one recharging visit.

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Organisations: Office for Finance and Accounting, Transport Modelling, Department of Management Engineering, Transport DTU, Management Science, Operations Research, Systems Analysis
Authors: Christensen, L. (Intern), Jensen, T. C. (Intern), Kaplan, S. (Intern), Røpke, S. (Intern), Olsen, A. (Intern)
Number of pages: 21
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Publication date: 2017
Time constrained liner shipping network design

We present a mathematical model and a solution method for the liner shipping network design problem. The model takes into account coordination between vessels and transit time restrictions on the cargo flow. The solution method is an improvement heuristic, where an integer program is solved iteratively to perform moves in a large neighborhood search. Our improvement heuristic is applicable as a real-time decision support tool for a liner shipping company. It can be used to find improvements to the network when evaluating changes in operating conditions or testing different scenarios. Computational results on the benchmark suite LINER-LIB are reported. (C) 2016 Elsevier Ltd. All rights reserved.
Tolerance analysis for 0–1 knapsack problems
Post-optimal analysis is the task of understanding the behavior of the solution of a problem due to changes in the data. Frequently, post-optimal analysis is as important as obtaining the optimal solution itself. Post-optimal analysis for linear programming problems is well established and widely used. However, for integer programming problems the task is much more computationally demanding, and various approaches based on branch-and-bound or cutting planes have been presented. In the present paper, we study how much coefficients in the original problem can vary without changing the optimal solution vector, the so-called tolerance analysis. We show how to perform exact tolerance analysis for the 0–1 knapsack problem with integer coefficients in amortized time \( O(c \log n) \) for each item, where \( n \) is the number of items, and \( c \) is the capacity of the knapsack. Amortized running times report the time used for each item, when calculating tolerance limits of all items. Exact tolerance limits are the widest possible intervals, while approximate tolerance limits may be suboptimal. We show how various upper bounds can be used to determine approximate tolerance limits in time \( O(\log n) \) or \( O(1) \) per item using the Dantzig bound and Dembo–Hammer bound, respectively. The running times and quality of the tolerance limits of all exact and approximate algorithms are experimentally compared, showing that all tolerance limits can be found in less than a second. The approximate bounds are of good quality for large-sized instances, while it is worth using the exact approach for smaller instances.
In this paper we explore tramp ship routing and scheduling. Tramp ships operate much like taxis following the available demand. Tramp operators can determine some of their demand in advance by entering into long-term contracts and then try to maximise profits from optional voyages found in the spot market. Routing and scheduling a tramp fleet to best utilise fleet capacity according to current demand is therefore an ongoing and complicated problem. Here we add further complexity to the routing and scheduling problem by incorporating voyage separation requirements that enforce a minimum time spread between some voyages. The incorporation of these separation requirements helps balance the conflicting objectives of maximising profit for the tramp operator and minimising inventory costs for the charterer, since...
these costs increase if similar voyages are not performed with some separation in time. We have developed a new and exact branch-and-price procedure for this problem. We use a dynamic programming algorithm to generate columns and describe a time window branching scheme used to enforce the voyage separation requirements which we relax in the master problem. Computational results show that our algorithm in general finds optimal solutions very quickly and performs much faster compared to an earlier a priori path generation method. Finally, we compare our method to an earlier adaptive large neighbourhood search heuristic and find that on similar-sized instances our approach generally uses less time to find the optimal solution than the adaptive large neighbourhood search method uses to find a heuristic solution.

General information
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Authors: Vilhelmsen, C. (Intern), Lusby, R. M. (Intern), Larsen, J. (Intern)
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Scopus rating (2008): SJR 0.832 SNIP 0.878
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.093 SNIP 1.158
Scopus rating (2006): SJR 1.34 SNIP 1.41
Web of Science (2006): Indexed yes
Tramp ship routing and scheduling with voyage separation requirements

This presentation addresses a tramp routing and scheduling problem. Tramp ships operate like taxies by following the available demand, as opposed to liner ships that operate like busses on a fixed route network according to a published timetable. Tramp operators determine some of the demand in advance by ensuring long-term contracts. The rest of the demand comes from optional voyages found in the spot market. Routing and scheduling a tramp feet to best utilize feet capacity according to the current demand is therefore an ongoing and complicated problem. We add further complexity by incorporating voyage separation requirements that enforce a minimum time spread between some voyages. We developed a new and exact Branch-and-Price procedure for this problem. A dynamic programming algorithm generates columns, while a novel time window branching scheme is used to enforce the voyage separation requirements. Computational results show that the algorithm finds optimal solutions very quickly for the vast majority of test instances. We compare the results with two earlier published methods and show that our Branch-and-Price approach outperforms both an a priori path generation method and an Adaptive Large Neighbourhood Search heuristic.

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Authors: Larsen, J. (Intern), Lusby, R. M. (Intern), Vilhelmsen, C. (Intern)
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Source-ID: 132393302
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Using OR + AI to Predict the Optimal Production of Offshore Wind Parks: A Preliminary Study

In this paper we propose a new use of Machine Learning together with Mathematical Optimization. We investigate the question of whether a machine, trained on a large number of optimized solutions, can accurately estimate the value of the optimized solution for new instances. We focus on instances of a specific problem, namely, the offshore wind farm layout optimization problem. In this problem an offshore site is given, together with the wind statistics and the characteristics of the turbines that need to be built. The optimization wants to determine the optimal allocation of turbines to maximize the park power production, taking the mutual interference between turbines into account. Mixed Integer Programming models and other state-of-the-art optimization techniques, have been developed to solve this problem. Starting with a dataset of 2000+ optimized layouts found by the optimizer, we used supervised learning to estimate the production of new wind parks. Our results show that Machine Learning is able to well estimate the optimal value of offshore wind farm layout problems.

General information
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Organisations: Department of Management Engineering, Management Science, Operations Research, Department of Applied Mathematics and Computer Science, Cognitive Systems
Authors: Fischetti, M. (Intern), Fraccaro, M. (Intern)
Pages: 203-211
Inter-array cable routing optimization for big wind parks with obstacles

The optimization problem we study here consists in finding an optimal cable routing to connect a given number of offshore turbines to one (or more) offshore substation(s). Different constraints have to be respected, such as cable capacity, cable prices, crossing restrictions, limits on connections to substation(s), and possible presence of obstacles in the site. To solve this large-scale optimization problem we use a matheuristic approach, that is an hybridization of mathematical programming techniques and heuristics. First, a Mixed-Integer Linear Programming (MILP) model is defined. The MILP model is able to solve smaller instances to optimality but for large wind parks it fails in even finding a feasible solution. Therefore we investigate various matheuristics to handle this situation: the heuristics are used to decrease the number of variables in the optimization model by fixing some of them at each iteration. We propose and compare three different fixing strategy: “random fixing”, “distance based fixing” and “sector fixing”. Each of the three matheuristics has been tuned to find a proper trade-off between neighborhood size and solution time. Finally, we compare the solutions from the matheuristic framework with solutions from the initial MILP model on a number of real world instances, demonstrating the effectiveness of our approach when optimizing inter-array cable routing of big parks.
Planning of Midwives
At a hospital in Denmark around 40 midwives support the pregnancy of approx. 6000 pregnant women every year. Their role is to monitor the pregnancies and prepare the women for labour. Based on the due date of a woman, authority guidelines prescribe specific and mostly rather narrow time windows within which the pregnant woman should have consultations with a midwife. Therefore, once a pregnant woman enters the system, her sequence of consultations for the time period until labour is fairly fixed. There is a clear goal that, as far as possible, each pregnant woman should see the same midwife at every consultation. Every week the newly arrived pregnant women are assigned an arbitrary free time slot belonging to a specific midwife. In turn this midwife is expected to have consultations with this woman in specific weeks according to the authority guidelines. This random assignment of pregnant women to specific midwives, without any concern to the midwives' future schedules, means that each midwife has a very unbalanced workload over the year. Furthermore, it means that there is an imbalance between the workloads of the different midwives.

The aim of this project is therefore to devise a method that can make a fair distribution of pregnant women among the midwives. The distribution should result in a balanced workload for each midwife and a balanced workload among the midwives while at the same time making sure that the time windows for consultations are not violated.

A Branch and Cut algorithm for the container shipping network design problem
The network design problem in liner shipping is of increasing importance in a strongly competitive market where potential cost reductions can influence market share and profits significantly. In this paper the network design and fleet assignment problems are combined into a mixed integer linear programming model minimizing the overall cost. To better reflect the real-life situation we take into account the cost of transshipment, a heterogeneous fleet, route dependant capacities, and butterfly routes. To the best of our knowledge it is the first time an exact solution method to the problem considers transshipment cost. The problem is solved with branch-and-cut using clover and transshipment inequalities. Computational results are reported for instances with up to 15 ports.
A column generation-based heuristic for rostering with work patterns

This paper addresses the Ground Crew Rostering Problem with Work Patterns, an important manpower planning problem arising in the ground operations of airline companies. We present a cutting stock-based integer programming formulation of the problem and describe a powerful heuristic decomposition approach, which utilizes column generation and variable fixing, to construct efficient rosters for a six-month time horizon. The time horizon is divided into smaller blocks, where overlaps between the blocks ensure continuity. The proposed methodology is able to circumvent one step of the conventional roster construction process by generating rosters directly based on the estimated workload. We demonstrate that this approach has the additional advantage of being able to easily incorporate robustness in the roster. Computational results on real-life instances confirm the efficiency of the approach.
Efficient use of energy is an increasingly important topic. Environmental and climate concerns as well as concerns for security of supply have 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.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Villumsen, J. C. (Intern), Clausen, J. (Intern), Pisinger, D. (Intern)
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Cutting Planes for Branch-and-Price Algorithms
This article presents a general framework for formulating cutting planes in the context of column generation for integer programs. Valid inequalities can be derived using the variables of an equivalent compact formulation (i.e., the subproblem variables) or the master problem variables. In the first case, cuts are added to the compact formulation, either at the master level or the subproblem level, and the decomposition process is reapplied. In the second case, we show that it is possible to model inequalities defined on the master problem variables by adding new variables and constraints to the subproblem formulation. The augmented subproblem indirectly indicates that there exists an augmented compact formulation that includes these new variables and constraints. Three examples on how to apply this framework are presented: the vehicle routing problem with time windows, the edge coloring problem, and the cutting stock problem. © 2011 Wiley Periodicals, Inc. NETWORKS, Vol. 58(4), 301–310 2011

General information
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Organisations: Operations Research, Department of Management Engineering, Ecole Polytechnique de Montreal, HEC Montreal
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Optimisation-Based Solution Methods for Set Partitioning Models

The scheduling of crew, i.e. the construction of work schedules for crew members, is often not a trivial task, but a complex puzzle. The task is complicated by rules, restrictions, and preferences. Therefore, manual solutions as well as solutions from standard software packages are not always sufficient with respect to solution quality and solution time. Enhancement of the overall solution quality as well as the solution time can be of vital importance to many organisations. The fields of operations research and mathematical optimisation deal with mathematical modelling of difficult scheduling problems (among other topics). The fields also deal with the development of sophisticated solution methods for these mathematical models.

This thesis describes the set partitioning model which has been widely used for modelling crew scheduling problems. Integer properties for the set partitioning model are shown, and exact and optimisation-based heuristic solution methods for the model are described. All these methods are centered around the wellknown column generation technique. Different practical applications of crew scheduling are presented, and some of these applications are considered in detail in four included scientific papers. It is shown how these applications all fit into a generalisation of the set partitioning model. Each of the four papers contribute a novel solution method for the specific application treated in the paper.

Routing and scheduling problems

In today's globalized society, transport contributes to our daily life in many different ways. The production of the parts for a shelf ready product may take place on several continents and our travel between home and work, vacation travel and business trips has increased in distance the last couple of decades. To deliver competitive service and price, transportation today needs to be cost effective. A company requiring for things to be shipped will aim at having the freight shipped as cheaply as possible while often satisfying certain time constraints. For the transportation company, the effectiveness of the network is of importance aiming at satisfying as many customer demands as possible at a low cost.

Routing represent a path between locations such as an origin and destination for the object routed. Sometimes routing has a time dimension as well as the physical paths. This may be that the objects routed have an availability time window and a delivery time window or that locations on the path have a service time window. When routing moving transportation objects such as vehicles and vessels schedules are made in connection with the routing. Such schedules represent the time for the presence of a connection between two locations. This could be an urban bus schedule where busses are routed and this routing creates a bus schedule which the passengers between locations use. In this thesis various routing
and scheduling problems will be presented. The topics covered will be routing from an origin to a destination on a predefined network, the routing and scheduling of vessels in a liner shipping network given a demand forecast to be covered, the routing of manpower and vehicles transporting disabled passengers in an airport and the vehicle routing with time windows where one version studied includes edge set cost making the cost of the individual vehicle routes inter-dependant. Depending on the problem type, the size of the problems and time available for solving, different solution methods can be applicable. In this thesis both heuristic methods and several exact methods are investigated depending on the problems needed to be solved. The solution methods applied to the problems cover dynamic programming for multi constrained shortest paths, Branch-and-cut for liner shipping, Simulated annealing for transporting assisted passengers in airports, branch-cut-and-price for vehicle routing with time windows and edges set costs.

**General information**
State: Published
Organisations: Operations Research, Department of Management Engineering, Logistics & ITS, Department of Transport
Authors: Reinhardt, L. B. (Intern), Pisinger, D. (Intern), Madsen, O. B. (Intern), Kallehauge, B. (Intern)
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**Robust long-term production planning**

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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, hydropower 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 are 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 system 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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Shortest Paths and Vehicle Routing
This thesis presents how to parallelize a shortest path labeling algorithm. It is shown how to handle Chvátal-Gomory rank-1 cuts in a column generation context. A Branch-and-Cut algorithm is given for the Elementary Shortest Paths Problem with Capacity Constraint. A reformulation of the Vehicle Routing Problem based on partial paths is presented. Finally, a practical application of finding shortest paths in the telecommunication industry is shown.

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Organisations: Operations Research, Department of Management Engineering
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A multilevel variable neighborhood search heuristic for a practical vehicle routing and driver scheduling problem

The world's second largest producer of pork, Danish Crown, also provides a fresh meat supply logistics system within Denmark. This is used by the majority of supermarkets in Denmark. This article addresses an integrated vehicle routing and driver scheduling problem arising at Danish Crown in their fresh meat supply logistics system. The problem consists of a 1-week planning horizon, heterogeneous vehicles, and drivers with predefined work regulations. These regulations include, among other things, predefined workdays, fixed starting time, maximum weekly working duration, and a break rule. The objective is to minimize the total delivery cost that is a weighted sum of two kinds of delivery costs. A multilevel variable neighborhood search heuristic is proposed for the problem. In a preprocessing step, the problem size is reduced through an aggregation procedure. Thereafter, the aggregated weekly planning problem is decomposed into daily planning problems, each of which is solved by a variable neighborhood search. Finally, the solution of the aggregated problem is expanded to that of the original problem. The method is implemented and tested on real-life data consisting of up to 2,000 orders per week. Computational results show that the aggregation procedure and the decomposition strategy are very effective in solving this large scale problem, and our solutions are superior to the industrial solutions given the constraints considered in this work.

General information
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Scopus rating (2013): SJR 1.083 SNIP 1.233 CiteScore 1.24
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BFI (2012): BFI-level 2
Scopus rating (2012): SJR 0.757 SNIP 1.009 CiteScore 0.85
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
A Multi-mode RCPSP with Stochastic Nonrenewable Resource Consumption

Many processes within production scheduling and project management involve the scheduling of a number of activities, each activity having a certain duration and requiring a certain amount of limited resources. The duration and resource requirements of activities are commonly the result of estimations, and thus generally subject to uncertainty. If this uncertainty is not taken into account the resulting schedules may not be robust in the sense that, when executed, the uncertainty may cause the schedules to take longer than expected, consume more resources, or be outright infeasible.

We propose a new variant of the Multi-mode Resource-Constrained Project Scheduling Problem, where the nonrenewable resource requirements of each mode is given by a Gaussian distribution, and the nonrenewable resource constraints must be satisfied with a certain probability $p$. Such constraints are also known as chance constraints. We present a Conic Quadratic Integer Program model of the problem, and describe and experiment with a branch-and-cut algorithm for solving the problem. In each node of the branch-and-bound tree, the branching decisions are propagated in order to remove variables from the problem, and thus improve bounds. In addition we experiment with cutting on the conic quadratic resource constraints. Computational experiments show that the branch-and-cut algorithm outperforms CPLEX 12.1. We finally examine the “cost of uncertainty” by investigating the relation between values of $p$, the makespan, and the solution time.

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Authors: Müller, L. F. (Intern)
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An Adaptive Large Neighborhood Search Algorithm for the Multi-mode RCPSP

We present an Adaptive Large Neighborhood Search algorithm for the Multi-mode Resource-Constrained Project Scheduling Problem (MRCPSP). We incorporate techniques for deriving additional precedence relations and propose a new method, so-called mode-diminution, for removing modes during execution. These techniques make use of bound arguments, and we propose and experiment with three new bounds for the MRCPSP, in addition to bounds found in the literature. We propose a simple technique, so-called opportunistic mode-flipping, which can be applied whenever a schedule is generated, and which significantly improves the results of the algorithm. Computational experiments are performed on a set of standard benchmark instances from the PSPLIB, and a comparison is made with other algorithms found in the literature. The experiments show that the algorithm is competitive, but can not beat the best algorithms. Even so, some of the elements of the algorithm perform well, that is the bound arguments, the mode-removal procedure, and in particular opportunistic mode-flipping, and these elements may perhaps be used to improve the results of other algorithms for this problem.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Muller, L. F. (Intern)
Number of pages: 25
Publication date: 2011

An IP Framework for the Crew Pairing Problem Using Subsequence Generation

In this paper we consider an important problem for the airline industry. The widely studied crew pairing problem is typically formulated as a set partitioning problem and solved using the branch-and-price methodology. Here we develop a new integer programming framework, based on the concept of subsequence generation, for solving the set partitioning formulation. In subsequence generation one restricts the number of permitted subsequent flights, that a crew member can turn to after completing any particular flight. By restricting the number of subsequences, the number of pairings in the problem decreases. The aim is then to dynamically add attractive subsequences to the problem, thereby increasing the number of possible pairings and improving the solution quality. Encouraging results are obtained on 19 real-life instances supplied by Air New Zealand and show that the described methodology is a viable alternative to column generation.

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Organisations: Operations Research, Department of Management Engineering
Authors: Rasmussen, M. S. (Intern), Lusby, R. M. (Intern), Ryan, D. (Intern), Larsen, J. (Intern)
Number of pages: 19
Publication date: 2011
A path based model for a green liner shipping network design problem
Liner shipping networks are the backbone of international trade providing low transportation cost, which is a major driver of globalization. These networks are under constant pressure to deliver capacity, cost effectiveness and environmentally conscious transport solutions. This article proposes a new path based MIP model for the Liner shipping Network Design Problem minimizing the cost of vessels and their fuel consumption facilitating a green network. The proposed model reduces problem size using a novel aggregation of demands. A decomposition method enabling delayed column generation is presented. The subproblems have similar structure to Vehicle Routing Problems, which can be solved using dynamic programming.

Column Generation for Transmission Switching of Electricity Networks with Unit Commitment
This paper presents the problem of finding the minimum cost dispatch and commitment of power generation units in a transmission network with active switching. We use the term active switching to denote the use of switches to optimize network topology in an operational context. We propose a Dantzig-Wolfe reformulation and a novel column generation framework to solve the problem efficiently. Preliminary results are presented for the IEEE-118 bus network with 19 generator units. Active switching is shown to reduce total cost by up to 15% for a particular 24-hour period. Furthermore, the need for generator startups is reduced by 1. Instances with limited switching, some of which are intractable for commercial solvers, are shown to solve to optimality in reasonable time.
Elective course planning
Efficient planning increasingly becomes an indispensable tool for management of both companies and public organizations. This is also the case for high school management in Denmark, because the growing individual freedom of the students to choose courses makes planning much more complex. Due to reforms, elective courses are today an important part of the curriculum, and elective courses are a good way to make high school education more attractive for the students. In this article, the problem of planning the elective courses is modeled using integer programming and three different solution approaches are suggested, including a Branch-and-Price framework using partial Dantzig–Wolfe decomposition. Explicit Constraint Branching is used to enhance the solution process, both on the original IP model and in the Branch-and-Price algorithm. To the best of our knowledge, no exact algorithm for the Elective Course Planning Problem has been described in the literature before. The proposed algorithms are tested on data sets from 98 of the 150 high schools in Denmark. The tests show that for the majority of the problems, the optimal solution can be obtained within the one hour time bound. Furthermore the suggested algorithms achieve better results than the currently applied meta-heuristic.
Fleet deployment, network design and hub location of liner shipping companies

A mixed integer linear programming formulation is proposed for the simultaneous design of network and fleet deployment of a deep-sea liner service provider. The underlying network design problem is based on a 4-index (5-index by considering capacity type) formulation of the hub location problem which are known for their tightness. The demand is elastic in the sense that the service provider can accept any fraction of the origin–destination demand. We then propose a primal decomposition method to solve instances of the problem to optimality. Numerical results confirm superiority of our approach in comparison with a general-purpose mixed integer programming solver.

**General information**

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- Authors: Gelareh, S. (Intern), Pisinger, D. (Intern)
- Pages: 947–964
Hub location problems in transportation networks

In this paper we propose a 4-index formulation for the uncapacitated multiple allocation hub location problem tailored for urban transport and liner shipping network design. This formulation is very tight and most of the tractable instances for MIP solvers are optimally solvable at the root node. While the existing state-of-the-art MIP solvers fail to solve even small size instances of problem, our accelerated and efficient primal (Benders) decomposition solves larger ones. In addition, a...
very efficient greedy heuristic, proven to be capable of obtaining high quality solutions, is proposed. We also introduce fixed cost values for Australian Post (AP) dataset.

Improved exact method for the double TSP with multiple stacks

The Double TSP with Multiple Stacks is a logistics problem where one must, using a container, transport a given number of orders from a set of pickup customers to a set of delivery customers at minimum cost. Each order corresponds to the
movement of one pallet, all pickups must be completed before the first delivery, and the container cannot be repacked once packed. In this paper we improve the previously proposed exact method of Lusby et al. (Int Trans Oper Res 17 (2010), 637–652) through an additional preprocessing technique that uses the longest common subsequence between the respective pickup and delivery problems. The results suggest an impressive improvement, and we report, for the first time, optimal solutions to several unsolved instances from the literature containing 18 customers. Instances with 28 customers are also shown to be solvable within a few percent of optimality. © 2011 Wiley Periodicals, Inc. NETWORKS, Vol. 58(4), 290–300 2011

General information
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Organisations: Operations Research, Department of Management Engineering
Authors: Lusby, R. M. (Intern), Larsen, J. (Intern)
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BFI (2015): BFI-level 2
Scopus rating (2015): SJR 0.896 SNIP 0.974 CiteScore 1.21
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 0.941 SNIP 1.349 CiteScore 1.03
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.083 SNIP 1.233 CiteScore 1.24
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 0.757 SNIP 1.009 CiteScore 0.85
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 0.924 SNIP 1.297 CiteScore 1.18
ISI indexed (2011): ISI indexed yes
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BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.348 SNIP 1.266
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.082 SNIP 1.486
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 0.843 SNIP 1.224
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Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.71 SNIP 1.631
Scopus rating (2005): SJR 0.874 SNIP 1.27
Scopus rating (2004): SJR 0.586 SNIP 1.107
Scopus rating (2003): SJR 0.623 SNIP 1.246
Liner Shipping Cargo Allocation with Repositioning of Empty Containers

General information
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Organisations: Operations Research, Department of Management Engineering
Authors: Brouer, B. D. (Intern), Pisinger, D. (Intern), Spoorendonk, S. (Intern)
Pages: 109-124
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Main Research Area: Technical/natural sciences

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Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 0.21 SJR 0.161 SNIP 0.177
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.28 SNIP 0.324 CiteScore 0.28
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.631 SNIP 0.32 CiteScore 0.67
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.397 SNIP 0.242 CiteScore 0.53
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.476 SNIP 0.507 CiteScore 0.55
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.285 SNIP 0.613 CiteScore 0.47
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.472 SNIP 0.421
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.473 SNIP 0.777
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Scopus rating (2008): SJR 0.582 SNIP 0.776
Scopus rating (2007): SJR 0.238 SNIP 0.346
Scopus rating (2006): SJR 0.166 SNIP 0.468
Scopus rating (2005): SJR 0.304 SNIP 0.334
Scopus rating (2004): SJR 0.374 SNIP 0.592
Scopus rating (2003): SJR 0.238 SNIP 0.342
Scopus rating (2002): SJR 0.591 SNIP 0.852
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Scopus rating (2000): SJR 0.195 SNIP 0.309
Scopus rating (1999): SJR 0.213 SNIP 0.456
Original language: English
empty repositioning, Liner shipping, column generation, multicommodity flow
DOIs:
Locating a general minisum 'circle' on a plane
We approximate a set of given points in the plane by the boundary of a convex and symmetric set which is the unit circle of some norm. This generalizes previous work on the subject which considers Euclidean circles only. More precisely, we examine the problem of locating and scaling the unit circle of some given norm $k$ with respect to given points on the plane such that the sum of weighted distances (as measured by the same norm $k$) between the circumference of the circle and the points is minimized. We present general results and are able to identify a finite dominating set in the case that $k$ is a polyhedral norm.
Long-term home care scheduling
In several countries, home care is provided for certain citizens living at home. The long-term home care scheduling problem is to generate work plans spanning several days such that a high quality of service is maintained and the overall cost is kept as low as possible. A solution to the problem provides detailed information on visits and visit times for each employee on each of the covered days. We propose a branch-and-price algorithm for the long-term home care scheduling problem. The pricing problem generates one-day plans for an employee, and the master problem merges the plans with respect to regularity constraints. The method solves instances with up to 99 visits during one week. This truly illustrates the complexity of the problem.

Modelling Zonal Pricing Design under Uncertainty in Electricity Markets

Modelling Zonal Pricing Design under Uncertainty in Electricity Markets
Models for the discrete berth allocation problem: A computational comparison
In this paper we consider the problem of allocating arriving ships to discrete berth locations at container terminals. This problem is recognized as one of the most important processes for any container terminal. We review and describe three main models of the discrete dynamic berth allocation problem, improve the performance of one model, and, through extensive numerical tests, compare all models from a computational perspective. The results indicate that a generalized set-partitioning model outperforms all other existing models.

General information
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Organisations: Logistics & ITS, Department of Transport, Operations Research, Department of Management Engineering, Technical University of Denmark
Authors: Buhrkal, K. F. (Intern), Zuglian, S. (Ekstern), Røpke, S. (Intern), Larsen, J. (Intern), Lusby, R. M. (Intern)
Pages: 461-473
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Main Research Area: Technical/natural sciences

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BFI (2015): BFI-level 2
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Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.59
Web of Science (2014): Indexed yes
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Scopus rating (2013): CiteScore 3.64
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
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Scopus rating (2012): CiteScore 2.91
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BFI (2011): BFI-level 2
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ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
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Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Multi-Objective and Multi-Constrained Non-Additive Shortest Path Problems

Shortest path problems appear as subproblems in numerous optimization problems. In most papers concerning multiple objective shortest path problems, additivity of the objective is a de-facto assumption, but in many real-life situations objectives and criteria, can be non-additive. The purpose of this paper is to give a general framework for dominance tests for problems involving a number of non-additive criteria. These dominance tests can help to eliminate paths in a dynamic programming framework when using multiple objectives. Results on real-life multi-objective problems containing non-additive criteria are reported. We show that in many cases the framework can be used to efficiently reduce the number of generated paths.

General Information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Reinhardt, L. B. (Intern), Pisinger, D. (Intern)
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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.924 SNIP 2.048 CiteScore 3.09
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.225 SNIP 2.309 CiteScore 3.12
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.527 SNIP 2.93 CiteScore 3.62
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.727 SNIP 2.775 CiteScore 3.36
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 2.41 SNIP 2.449 CiteScore 3.05
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 2.316 SNIP 2.449
Optimal Wafer Cutting in Shuttle Layout Problems

A major cost in semiconductor manufacturing is the generation of photo masks which are used to produce the dies. When producing smaller series of chips it can be advantageous to build a shuttle mask (or multi-project wafer) to share the startup costs by placing different dies on the same mask. The shuttle layout problem is frequently solved in two phases: first, a floorplan of the shuttle is generated. Then, a cutting plan is found which minimizes the overall number of wafers needed to satisfy the demand of each die type. Since some die types require special production technologies, only compatible dies can be cut from a given wafer, and each cutting plan must respect various constraints on where the cuts may be placed. We present an exact algorithm for solving the minimum cutting plan problem, given a floorplan of the dies. The algorithm is based on delayed column generation, where the pricing problem becomes a maximum vertex-weighted clique problem in which each clique consists of cutting compatible dies. The resulting branch-and-price algorithm is able to solve realistic cutting problems to optimality in a couple of seconds.
Railway Track Allocation: Models and Methods

Efficiently coordinating the movement of trains on a railway network is a central part of the planning process for a railway company. This paper reviews models and methods that have been proposed in the literature to assist planners in finding train routes. Since the problem of routing trains on a railway network entails allocating the track capacity of the network (or part thereof) over time in a conflict-free manner, all studies that model railway track allocation in some capacity are considered relevant. We hence survey work on the train timetabling, train dispatching, train platforming, and train routing problems, group them by railway network type, and discuss track allocation from a strategic, tactical, and operational level.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering, University of Auckland
Authors: Lusby, R. M. (Intern), Larsen, J. (Intern), Ehrgott, M. (Ekstern), Ryan, D. (Ekstern)
Pages: 843-883
Publication date: 2011
Routing trains through railway junctions: A new set-packing approach

The problem of routing trains through railway junctions is an integral part of railway operations. Large junctions are highly interconnected networks of track where multiple railway lines merge, intersect, and split. The number of possible routings makes this a very complicated problem. We show how the problem can be formulated as a set-packing model with a resource-based constraint system. We prove that this formulation is tighter than the conventional node-packing model, and develop a branch-and-price algorithm that exploits the structure of the set-packing model. A discussion of the variable generation phase, as well as a pricing routine in which these variables are represented by tree structures, is also described. Computational experiments on 25 random timetables show this to be an efficient approach. © 2011 INFORMS.
Separation and extension of cover inequalities for second-order conic knapsack constraints with GUBs

We consider the second-order conic equivalent of the classic knapsack polytope where the variables are subject to generalized upper bound constraints. We describe and compare a number of separation and extension algorithms which make use of the extra structure implied by the generalized upper bound constraints in order to strengthen the second-order conic equivalent of the classic cover cuts. We show that determining whether a cover can be extended with a variable is NP-hard. Computational experiments are performed comparing the proposed separation and extension algorithms. These experiments show that applying these extended cover cuts can greatly improve solution time of second-order cone programs.

Solving a Vehicle Routing Problem with a non-linear load dependant cost function

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Atamtürk, A. (Intern), Muller, L. F. (Intern), Pisinger, D. (Intern)
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**Subsequence Generation for the Airline Crew Pairing Problem**

Good and fast solutions to the airline crew pairing problem are highly interesting for the airline industry, as crew costs are the biggest expenditure after fuel for an airline. The crew pairing problem is typically modelled as a set partitioning problem and solved by column generation. However, the extremely large number of possible columns naturally has an impact on the solution time. In the solution method of this work we severely limit the number of allowed subsequent flights, i.e. the subsequences, thereby significantly decreasing the number of possible columns. Set partitioning problems with limited subsequence counts are known to be easier to solve, resulting in a decrease in solution time. The problem though, is that a small number of deep subsequences might be needed for an optimal or near-optimal solution and these might not have been included by the subsequence limitation. Therefore, we try to identify or generate such subsequences that potentially can improve the solution value. We benchmark the subsequence generation approach against a classical column generation approach on real-life test instances. We consider the LP relaxation and compare the quality and the integrality of the solutions. The LP solutions from the subsequence generation approach are less fractional, but it comes at the cost of a worse solution quality. The approach in the present paper is novel. To our knowledge generation of subsequences have not been described and tested previously in the literature.

**The vehicle routing problem with edge set costs**

We consider an important generalization of the vehicle routing problem with time windows in which a fixed cost must be paid for accessing a set of edges. This fixed cost could reflect payment for toll roads, investment in new facilities, the need for certifications and other costly investments. The certifications and contributions impose a cost for the company while they also give unlimited usage of a set of roads to all vehicles belonging to the company. Different versions for defining the edge sets are discussed and formulated. A MIP-formulation of the problem is presented, and a solution method based on branch-and-price-and-cut is applied to the problem. The computational results show that instances with up to 50 customers can be solved in reasonable time, and that the branch-cut-and-price algorithm generally outperforms CPLEX. It also seems that instances get more difficult when the penalized edge sets form a spanning tree, compared to when they are randomly scattered.
The vehicle routing problem with time windows and temporal dependencies

In this article, we formulate the vehicle routing problem with time windows and temporal dependencies. The problem is an extension of the well studied vehicle routing problem with time windows. In addition to the usual constraints, a scheduled time of one visit may restrain the scheduling options of other visits. Special cases of temporal dependencies are synchronization and precedence constraints. Two compact formulations of the problem are introduced and the Dantzig–Wolfe decompositions of these formulations are presented to allow for a column generation-based solution approach. Temporal dependencies are modeled by generalized precedence constraints. Four different master problem formulations are proposed and it is shown that the formulations can be ranked according to the tightness with which they describe the solution space. A tailored time window branching is used to enforce feasibility on the relaxed master problems. Finally, a computational study is performed to quantitatively reveal strengths and weaknesses of the proposed formulations. It is concluded that, depending on the problem at hand, the best performance is achieved either by relaxing the generalized precedence constraints in the master problem, or by using a time-indexed model, where generalized precedence constraints are added as cuts when they become severely violated. © 2011 Wiley Periodicals, Inc.

Train shunting at a workshop area

We consider the problem of planning the shunting of train units at a railway workshop area. Before and after the maintenance check, a train unit is parked at a depository track. The problem is to schedule the trains to workshops and depot tracks in order to complete the repairs as soon as possible, while avoiding train blockings at the tracks. We give a formal definition of the problem and present three heuristic approaches based on, respectively, Guided Local Search (GLS), Guided Fast Local Search (GFLS) and Simulated Annealing (SA). Computational experiments are reported for realistic instances. It turns out, that both GLS and SA find within a few minutes solutions that are a few percent from the best MIP solution found.

General information

State: Published
Organisations: Operations Research, Department of Management Engineering, University of Copenhagen
Authors: Jacobsen, P. M. (Ekstern), Pisinger, D. (Intern)
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Airport Ground Staff Scheduling

Modern airports are centers of transportation that service a large number of aircraft and passengers every day. To facilitate this large volume of transportation, airports are subject to many logistical and decision problems that must continuously be solved to make sure each flight and passenger travels safely and efficiently through the airport. When an aircraft lands, a significant number of tasks must be performed by different groups of ground crew, such as fueling, baggage handling and cleaning. These tasks must be complete before the aircraft is able to depart, as well as check-in and security services. These tasks are collectively known as ground handling, and are the major source of activity with airports. The business environments of modern airports are becoming increasingly competitive, as both airports themselves and their ground handling operations are changing to private ownership. As airports are in competition to attract airline routes, efficient and reliable ground handling operations are imperative for the viability and continued growth
of both airports and airlines. The increasing liberalization of the ground handling market prompts ground handling operators to increase cost effectiveness and deliver fast and reliable service. This thesis presents models and algorithms for general optimization and decision problems arising within ground handling. The thesis contains an introductory part which provide an overview of the ground handling environment and reviews a series of optimization problems from the specific perspective of airport ground handling. In addition, the thesis contains five scientific papers, which consider specific optimization problems within ground handling in detail. The considered problems range from generalized approaches to workforce planning, to highly detailed scheduling problems arising in the highly dynamic environment of airports.

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Organisations: Operations Research, Department of Management Engineering
Authors: Clausen, T. (Intern), Pisinger, D. (Intern)
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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.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Dohn, A. H. (Intern), Larsen, J. (Intern), Clausen, J. (Intern)
Scheduling Network Traffic for Grid Purposes
This thesis concerns scheduling of network traffic in grid context. Grid computing consists of a number of geographically distributed computers, which work together for solving large problems. The computers are connected through a network.

When scheduling job execution in grid computing, data transmission has so far not been taken into account. This causes stability problems, because data transmission takes time and thus causes delays to the execution plan. This thesis proposes the integration of job scheduling and network routing. The scientific contribution is based on methods from operations research and consists of six papers. The first four considers data transmission in grid context. The last two solves the data transmission problem, where the number of paths per data connection is bounded from above. The thesis shows that it is possible to solve the integrated job scheduling and network routing problem to optimality for a grid, where computers are connected through a packet-switched network. When the network topology is optical, the routing problem becomes significantly more complex and the problem should thus be solved heuristically. Furthermore, the thesis proposes a number of new exact methods for the data transmission problem, where the number of paths is bounded from above. The new exact solution methods outperform existing methods from the literature.

Service Network Design and Management in Linear Container Shipping Applications
General information
State: Published
Organisations: Department of Transport, Logistics & ITS, Operations Research, Department of Management Engineering
Authors: Andersen, M. W. (Intern), Madsen, O. B. (Intern), Stidsen, T. R. (Intern)
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 investigate 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.
Clique inequalities applied to the vehicle routing problem with time windows
This work presents an exact branch-cut-and-price algorithm for the vehicle routing problem with time windows (VRPTW) where the well-known clique inequalities are used as cutting planes defined on the set partitioning master problem variables. It shows how these cutting planes affect the dominance criterion applied in the pricing algorithm, which is a labeling algorithm for solving resource-constrained elementary shortest path problems. The idea of using cutting planes defined on the master problem variables for the VRPTW has been recently developed: Chvátal-Gomory rank-1 cuts were applied. However, to our knowledge, this is a first attempt at incorporating for the VRPTW a set of valid inequalities specialized for the set partitioning polytope. Computational results show that the use of clique inequalities improves the lower bound at the root node of the search tree and reduces the number of nodes in this tree.

General information
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Organisations: Operations Research, Department of Management Engineering, Ecole Polytechnique de Montreal
Authors: Spoorendonk, S. (Intern), Desaulniers, G. (Ekstern)
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BFI (2016): BFI-level 1
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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.28 SNIP 0.324 CiteScore 0.28
BFI (2014): BFI-level 1
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BFI (2013): BFI-level 1
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ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.476 SNIP 0.507 CiteScore 0.55
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.285 SNIP 0.613 CiteScore 0.47
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.472 SNIP 0.421
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.473 SNIP 0.777
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.582 SNIP 0.776
A Branch-and-Cut Algorithm for Elementary Shortest Path Problem with Resource Constraints
The elementary shortest path with resource constraints are commonly solved with dynamic programming algorithms. We present a branch-and-cut algorithm for the undirected version. Two types of resources are discussed: A capacity and a fixed charge resource. The former is the subproblem of the capacitated vehicle routing problem and the latter is for the split delivery version.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Jepsen, M. K. (Intern), Petersen, B. (Intern), Spoorendonk, S. (Intern)
Publication date: 2010
Event: Abstract from Optimization Days 2010, Montréal, Canada.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 251317
Publication: Research › Journal article – Annual report year: 2010

A Branch and Cut algorithm for the container shipping network design problem
The network design problem in liner shipping is of increasing importance in a strongly competitive market where potential cost reductions can influence market share and profits significantly. In this paper the network design and fleet assignment problems are combined into a mixed integer linear programming model minimizing the overall cost. To better reflect the real-life situation we take into account the cost of transhipment, a heterogeneous fleet, route dependant capacities, and butterfly routes. To the best of our knowledge it is the first time an exact solution method to the problem considers transhipment cost. The problem is solved with branch-and-cut using clover and transhipment inequalities. Computational results are reported for instances with up to 15 ports.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Reinhardt, L. B. (Intern), Kallehauge, B. (Intern), Pisinger, D. (Intern)
Number of pages: 18
Publication date: 2010

Publication information
Place of publication: Kgs. Lyngby
Publisher: DTU Management
Original language: English
Series: DTU Management 2010
Number: 20
Main Research Area: Technical/natural sciences
Links:
A branch-and-cut algorithm for the elementary shortest path problem with resource constraints
The elementary shortest path with resource constraints have commonly been solved with dynamic programming algorithms. Assuming an undirected graph, we present a compact formulation of this problem and a branch-and-cut algorithm to solve it. Two types of resources are discussed: a capacity and a fixed charge resource. The former is the subproblem of the capacitated vehicle routing problem and the latter is from the split delivery version. Computational results are presented and compared to dynamic programming algorithms.

General information
State: Published
Organisations: Department of Management Engineering, Operations Research
Authors: Jepsen, M. K. (Intern), Petersen, B. (Intern), Spoorendonk, S. (Intern)
Publication date: 2010
Event: Abstract from 24th European Conference on Operational Research, Lisbon, Portugal.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 265190
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2010

A Dynamic Programming-Based Heuristic for the Shift Design Problem in Airport Ground Handling
We consider the heterogeneous shift design problem for a workforce with multiple skills, where work shifts are created to cover a given demand as well as possible while minimizing cost and satisfying a flexible set of constraints. We focus mainly on applications within airport ground handling where the demand can be highly irregular and specified on time intervals as short as five minutes. Ground handling operations are subject to a high degree of cooperation and specialization that require workers with different qualifications to be planned together. Different labor regulations or organizational rules can apply to different ground handling operations, so the rules and restrictions can be numerous and vary significantly. This is modeled using flexible volume constraints that limit the creation of certain shifts. We present a fast heuristic for the heterogeneous shift design problem based on dynamic programming that allows flexibility in modeling the workforce. Parameters allow a planner to determine the level of demand coverage that best fulfills the requirements of the organization. Results are presented from several diverse real-life ground handling instances.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Clausen, T. (Intern)
Number of pages: 26
Publication date: 2010

Publication information
Place of publication: Kgs. Lyngby
Publisher: DTU Management
ISBN (Print): 978-87-90855-76-5
Original language: English
Series: DTU Management 2010
Number: 7
Main Research Area: Technical/natural sciences
Electronic versions:
2010_7.pdf
Links:
http://www.man.dtu.dk/upload/institutter/ipl/publ/publikationer%202010/rap7.10.endelig.pdf
Source: orbit
Source-ID: 260121
Publication: Research › Report – Annual report year: 2010

A Generic Solution Approach to Nurse Rostering
In this report, we present a solution approach to the nurse rostering problem. The problem is defined by a generic model that is able to capture close to all of the problem characteristics that we have seen in the literature and in the realistic problems at hand. The model is used directly in the solution algorithm which gives a very versatile solution method. The method at the same time is constructed to exploit a number of problem specific features and thereby we have a both versatile and efficient solution method. The approach presented uses a set partitioning model of the rostering problem,
which is solved in a branch-and-price framework. Columns of the set partitioning problem are generated dynamically and branch-and-bound is used to enforce integrality. The column generating subproblem is modeled in three stages that utilize the inherent structure of roster-lines. Some important features of the implementation are described. The implementation builds on the generic model and hence the program can be setup for any problem that fits the model. The adaptation to a new problem is simple, as it requires only the input of a new problem definition. The solution method is internally adjusted according to the new definition. In this report, we present two different practical problems along with corresponding solutions. The approach captures all features of each problem and is efficient enough to provide optimal solutions. The solution time is still too large for the method to be immediately applicable in practice, but we suggest a number of ways to improve the method further.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering, University of Auckland
Authors: Hansen, A. D. (Intern), Mason, A. (Ekstern), Ryan, D. (Ekstern)
Number of pages: 36
Publication date: 2010

Publication information
Place of publication: Kgs. Lyngby
Publisher: DTU Management
ISBN (Print): 978-87-90855-72-7
Original language: English

Series: DTU Management 2010
Number: 5
Main Research Area: Technical/natural sciences
label setting, set partitioning problem, set covering problem, column generation, shortest path problem with resource constraints, linear programming, integer programming, generalized rostering problem, nurse scheduling, nurse rostering, branch-and-price, dynamic programming

Electronic versions:
2010_5.pdf
Links:
http://www.man.dtu.dk/upload/institutter/ipl/publ/publikationer%202010/rapport%205.pdf
Source: orbit
Source-ID: 258827
Publication: Research › Report – Annual report year: 2010

A greedy construction heuristic for the liner service network design problem
The Liner Service Network Design Problem (LSN-DP) is the problem of constructing a set of routes for a heterogeneous vessel fleet of a global liner shipping operator. Routes in the liner shipping context are non-simple, cyclic routes constructed for a specific vessel type. The problem is challenging due to the size of a global liner shipping operation and due to the hub-and-spoke network design, where a high percentage of the total cargo is transshipped. We present the first construction heuristic for large scale instances of the LSN-DP. The heuristic is able to find a solution for a real life case with 234 unique ports and 14000 demands in 33 seconds.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Brouer, B. D. (Intern)
Number of pages: 4
Publication date: 2010
Event: Abstract from Seventh Triennial Symposium on Transportation Analysis, Tromsø, Norway.
Main Research Area: Technical/natural sciences

Electronic versions:
abstract_tristan (4).pdf
Links:
http://www.sintef.no/Projectweb/TRISTAN/Program/
Source: orbit
Source-ID: 258226
Publication: Research › Conference abstract for conference – Annual report year: 2010

A Greedy Construction Heuristic for the Liner Shipping Network Design Problem

General information
A hybrid adaptive large neighborhood search algorithm applied to a lot-sizing problem

This paper presents a hybrid of a general heuristic framework that has been successfully applied to vehicle routing problems and a general purpose MIP solver. The framework uses local search and an adaptive procedure which choses between a set of large neighborhoods to be searched. A mixed integer programming solver and its built-in feasibility heuristics is used to search a neighborhood for improving solutions. The general reoptimization approach used for repairing solutions is specifically suited for combinatorial problems where it may be hard to otherwise design operations to define a neighborhood of a solution and to investigate the feasibility of elements in such a neighborhood. The hybrid heuristic framework is applied to the multi-item capacitated lot sizing problem with dynamic lot sizes, where experiments have been conducted on a series of instances from the literature. On average the heuristic solutions are within 0.2% of the previously best known solutions and we found new improved upper bounds for 3 out of 12 instances.
Analysis of internal network requirements for the distributed Nordic Tier-1

The Tier-1 facility operated by the Nordic DataGrid Facility (NDGF) differs significantly from other Tier-1s in several aspects: It is not located at one or a few locations but instead distributed throughout the Nordic, it is not under the governance of a single organisation but instead built from resources under the control of a number of different national organisations. Being physically distributed makes the design and implementation of the networking infrastructure a challenge. NDGF has its own internal OPN connecting the sites participating in the distributed Tier-1. To assess the suitability of the network design and the capacity of the links, we present a model of the internal bandwidth needs for the NDGF Tier-1 and its associated Tier-2 sites. The model takes the different type of workloads into account and can handle different kinds of data management strategies. It has already been used to dimension the internal network structure of NDGF. We also compare the model with real life data measurements.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering, Nordic DataGrid Facility, NORDUnet A/S, Aalborg University
Authors: Behrmann, G. (Ekstern), Fischer, L. (Ekstern), Gamst, M. (Intern), Grønager, M. (Ekstern), Kleist, J. (Ekstern)
Pages: 052001
Publication date: 2010
Conference: 17th International Conference on Computing in High Energy and Nuclear Physics : CHEP09, Prague, 01/01/2011
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Physics: Conference Series
Volume: 219
Issue number: 5
ISSN (Print): 1742-6596
Ratings:
BFI (2018): BFI-level 1
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 0.48 SJR 0.241 SNIP 0.447
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 0.45 SJR 0.24 SNIP 0.401
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.252 SNIP 0.374 CiteScore 0.35
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.264 SNIP 0.352 CiteScore 0.32
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.245 SNIP 0.293 CiteScore 0.25
ISI indexed (2013): ISI indexed no
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.293 SNIP 0.387 CiteScore 0.33
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.293 SNIP 0.356 CiteScore 0.43
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.288 SNIP 0.351
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
A new formulation for the 2-echelon capacitated vehicle routing problem
The 2-echelon capacitated vehicle routing problem (2E-CVRP) is a transportation and distribution problem where goods are transported from a depot to a set of customers possible via optional satellite facilities. The 2E-CVRP is relevant in city-logistic applications where legal restrictions make it infeasible to use large trucks within the center of large cities. We propose a new mathematical formulation for the 2E-CVRP with much fewer variables than the previously proposed but with several constraint sets of exponential size. The strength of the model is implied by the facts that many cutting planes proposed for the previous formulations are redundant and that many model symmetries can now be avoided. A branch-and-cut algorithm is developed to solve this model to optimality.

An Exact Method for the Double TSP with Multiple Stacks
The double travelling salesman problem with multiple stacks (DTSPMS) is a pickup and delivery problem in which all pickups must be completed before any deliveries can be made. The problem originates from a real-life application where a 40 foot container (configured as 3 columns of 11 rows) is used to transport up to 33 pallets from a set of pickup customers to a set of delivery customers. The pickups and deliveries are performed in two separate trips, where each trip starts and ends at a depot and visits a number of customers. The aim of the problem is to produce a stacking plan for the pallets that minimizes the total transportation cost (ignoring the cost of transporting the container between the depots of the two trips) given that the container cannot be repacked at any stage. In this paper we present an exact solution method based on matching k-best TSP solutions for each of the separate pickup and delivery TSP problems and show that previously unsolved instances can be solved within seconds using this approach.
An integer programming model and benchmark suite for liner shipping network design

Maritime transportation is accountable for 2.7% of the world's CO2 emissions and the liner shipping industry is committed to a slow steaming policy to provide low cost and environmentally conscious global transport of goods without compromising the level of service. The potential for making cost effective and energy efficient liner shipping networks using operations research is huge and neglected. The implementation of logistic planning tools based upon operations research has enhanced performance of both airlines, railways and general transportation companies, but within the field of liner shipping very little operations research has been done. We believe that access to domain knowledge and data is an entry barrier for researchers to approach the important liner shipping network design problem. This paper presents a thorough description of the liner shipping domain applied to network design along with a rich integer programming model based on the services, that constitute the fixed schedule of a liner shipping company. The model may be relaxed as well as decomposed. The design of a benchmark suite of data instances to reflect the business structure of a global liner shipping network is discussed. The paper is motivated by providing easy access to the domain and the data sources of...
liner shipping for operations researchers in general. A set of data instances with offset in real world data is presented and made available upon request. Future work is to provide computational results for the instances.

**General information**
State: Published
Organisations: Operations Research, Department of Management Engineering, Det Norske Veritas, Maersk Line
Authors: Løfstedt, B. (Intern), Alvarez, J. F. (Ekstern), Plum, C. E. M. (Intern), Pisinger, D. (Intern), Sigurd, M. M. (Ekstern)
Number of pages: 42
Publication date: 2010

**Publication information**
Place of publication: Kgs. Lyngby
Publisher: DTU Management
Original language: English

Series: DTU Management Engineering report
Number: 19.2010
Main Research Area: Technical/natural sciences
Network design, Iner shipping, Mathematical programming
Electronic versions: rapport_19_2010.pdf
Source: orbit
Source-ID: 271300
Publication: Research › Report – Annual report year: 2010

An Integrated Approach to the Ground Crew Rostering Problem with Work Patterns
This paper addresses the Ground Crew Rostering Problem with Work Patterns, an important manpower planning problem arising in the ground operations of airline companies. We present a cutting stock based integer programming formulation of the problem and describe a powerful decomposition approach, which utilizes column generation and variable fixing, to construct efficient rosters for a six month time horizon. The time horizon is divided into smaller blocks, where overlaps between the blocks ensure continuity. The proposed methodology is able to circumvent one step of the conventional roster construction process by generating rosters directly based on the estimated workload. We demonstrate that this approach has the additional advantage of being able to easy incorporate robustness in the roster. Computational results on real-life instances confirm the efficiency of the approach.

**General information**
State: Published
Organisations: Operations Research, Department of Management Engineering, University of Southern Denmark
Authors: Lusby, R. M. (Intern), Hansen, A. D. (Intern), Range, T. M. (Ekstern), Larsen, J. (Intern)
Number of pages: 22
Publication date: 2010

**Publication information**
Place of publication: Kgs. Lyngby
Publisher: DTU Management
ISBN (Print): 978-87-90855-78-9
Original language: English

Series: DTU Management 2010
Number: 9
Main Research Area: Technical/natural sciences
Cutting Stock Problem, Manpower Planning, Optimization
Electronic versions: 2010_10.pdf
Links: http://www.man.dtu.dk/upload/institutter/ipl/publ/publikationer%202010/rapport%209.pdf
Source: orbit
Source-ID: 260235
Publication: Research › Report – Annual report year: 2010

A Rule-Based Local Search Algorithm for General Shift Design Problems in Airport Ground Handling
We consider a generalized version of the shift design problem where shifts are created to cover a multiskilled demand and fit the parameters of the workforce. We present a collection of constraints and objectives for the generalized shift design
A local search solution framework with multiple neighborhoods and a loosely coupled rule engine based on simulated annealing is presented. Computational experiments on real-life data from various airport ground handling organization show the performance and flexibility of the proposed algorithm.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Clausen, T. (Intern)
Number of pages: 20
Publication date: 2010

Publication information
Place of publication: Kgs. Lyngby
Publisher: DTU Management
ISBN (Print): 978-87-90855-93-2
Original language: English

Series: DTU Management 2010
Number: 16
Main Research Area: Technical/natural sciences
Electronic versions:
2010_16.pdf
Links:
Source: orbit
Source-ID: 266311
Publication: Research › Report – Annual report year: 2010

A solution approach to the ROADEF/EURO 2010 challenge based on Benders’ Decomposition
We present a Benders’ decomposition based framework for solving a large scale energy management problem with varied constraints posed as the ROADEF/EURO 2010 challenge. Because of the nature of the problem, not all constraints can be modeled satisfactorily as linear constraints and the approach is therefore divided into two stages: in the first stage Benders feasibility and optimality cuts are added based on the linear programming relaxation of the Benders Master problem, and in the second stage feasible integer solutions are enumerated and procedure is applied to each solution in an attempt to make them satisfy the constraints not part of the mixed integer program. A number of experiments are performed on the available benchmark instances. These experiments show that the approach is competitive on the smaller instances, but not for the larger ones. We believe the exact approach gives insight into the problem and additionally makes it possible to find lower bounds on the problem, which is typically not the case for the competing heuristics.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Lusby, R. M. (Intern), Muller, L. F. (Intern), Petersen, B. (Intern)
Number of pages: 29
Publication date: 2010

Publication information
Place of publication: Kgs. Lyngby
Publisher: DTU Management
Original language: English

Series: DTU Management 2010
Number: 18
Main Research Area: Technical/natural sciences
Electronic versions:
2010_18.pdf
Links:
Source: orbit
Source-ID: 270613
Publication: Research › Report – Annual report year: 2010

Capacity efficiency of recovery request bundling
This paper presents a comparison of recovery methods in terms of capacity efficiency. In particular, a method where recovery requests are bundled towards the destination (Shortcut Span Protection) is evaluated against traditional recovery
methods. Our simulation results show that Shortcut Span Protection uses more capacity than the unbundled related methods, but this is compensated by easier control and management of the recovery actions.

**General information**
State: Published
Organisations: Networks Technology and Service Platforms, Department of Photonics Engineering, Operations Research, Department of Management Engineering
Authors: Ruepp, S. R. (Intern), Dittmann, L. (Intern), Berger, M. S. (Intern), Stidsen, T. R. (Intern), Lagakos, S. (Ekstern), Perlovsky, L. (Ekstern), Jha, M. (Ekstern), Covaci, B. (Ekstern), Zaharim, A. (Ekstern), Mastorakis, N. (Ekstern)
Publication date: 2010

**Host publication information**
Title of host publication: CISST’10: Proceedings of the 4th Wseas International Conference on Circuits, Systems, Signal and Telecommunications
Publisher: World Scientific and Engineering Acad and Soc
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 268011
Publication: Research - peer-review › Article in proceedings – Annual report year: 2010

**Cutting in branch-and-cut-and-price algorithms**
Given a Dantzig-Wolfe decomposition of an integer program, this talk presents a general framework for formulating, on the original formulation, valid inequalities derived on an equivalent master problem. It is possible to model these inequalities by adding new variables and constraints to the original formulation. We show how the additional inequalities may give rise to an augmented sub-problem. Examples on how to apply this framework are given for the vehicle routing problem with time windows.

**General information**
State: E-pub ahead of print
Organisations: Operations Research, Department of Management Engineering, Ecole Polytechnique de Montreal, HEC Montreal
Authors: Spoorendonk, S. (Intern), Desaulniers, G. (Ekstern), Desrosiers, J. (Ekstern)
Publication date: 2010
Event: Abstract from 4th Nordic Optimization Symposium, Aarhus, Denmark.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 269471
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2010

**Disruption Management - Foreword**

**General information**
State: Published
Organisations: Operations Research, Department of Management Engineering, Logistics & ITS, Department of Transport
Authors: Clausen, J. (Intern), Larsen, A. (Intern), Larsen, J. (Intern)
Pages: 807-808
Publication date: 2010
Main Research Area: Technical/natural sciences

**Publication information**
Journal: Computers & Operations Research
Volume: 37
Issue number: 5
ISSN (Print): 0305-0548
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 3.75 SJR 1.916 SNIP 2.094
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.
Dynamic Routing of Short Transfer Baggage

We consider a variant of the Vehicle Routing Problem that arises in airports when transporting baggage for passengers with connecting flights. Each bag can be delivered in two locations with disjunctive time windows. The task is to define multiple trips for the vehicles in order to deliver bags that arrive continuously during the day. We present an IP model of the problem and describe the problem as a case study from a real life setting. We present a weighted greedy algorithm for dispatching vehicles that works in an dynamic context, meaning that it only considers bags available at the time of dispatch. Computational results are presented for real-life passenger data with stochastic bag arrival times and travel times. The results indicate that the algorithm is able to dispatch the baggage considerably better than the manual delivery plans reported in the case study, and due to its fast running times, the algorithm is suitable for dynamic dispatching. Investigations on the impact of uncertainty and fleet size make it possible to support a trade-off between fleet size and expected service level.


General information
State: E-pub ahead of print
Organisations: Operations Research, Department of Management Engineering, Royal Military College of Canada, Georg-August-Universität Göttingen
Authors: Brimberg, J. (Ekstern), Juel, H. (Intern), Schöbel, A. (Ekstern)
Publication date: 2010
Main Research Area: Technical/natural sciences
Evaluating the efficiency of shortcut span protection

This paper presents a comparison of various recovery methods in terms of capacity efficiency with the underlying aim of reducing control plane load. In particular, a method where recovery requests are bundled towards the destination (Shortcut Span Protection) is evaluated can compared against traditional recovery methods. The optimization model is presented and our simulation results show that Shortcut Span Protection uses more capacity than the unbundled related methods, but this is compensated by easier control and management of the recovery actions.

General information
State: Published
Organisations: Networks Technology and Service Platforms, Department of Photonics Engineering, Operations Research, Department of Management Engineering
Authors: Ruepp, S. R. (Intern), Dittmann, L. (Intern), Berger, M. S. (Intern), Stidsen, T. R. (Intern)
Pages: 143-152
Publication date: 2010
Main Research Area: Technical/natural sciences

Publication Information
Journal: W S E A S Transactions on Communications
Volume: 9
Issue number: 2
ISSN (Print): 1109-2742
Ratings:
Scopus rating (2017): SNIP 0.331 SJR 0.116
Scopus rating (2016): SJR 0.12 SNIP 0.46
Scopus rating (2015): SJR 0.12 SNIP 0.609
Scopus rating (2014): SJR 0.181 SNIP 0.556
Scopus rating (2013): SJR 0.171 SNIP 0.498
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.157 SNIP 0.433
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.141 SNIP 0.209
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.196 SNIP 0.356
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.28 SNIP 0.384
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.221 SNIP 0.295
Scopus rating (2007): SJR 0.149 SNIP 0.064
Scopus rating (2006): SJR 0.114 SNIP 0.21
Original language: English
System recovery, Optimisation
Source: orbit
Source-ID: 259994
Publication: Research - peer-review › Journal article – Annual report year: 2010

Geometric fit of a point set by generalized circles

In our paper we approximate a set of given points by a general circle. More precisely, given two norms k 1 and k 2 and a set of points in the plane, we consider the problem of locating and scaling the unit circle of norm k 1 such that the sum of weighted distances between the circumference of the circle and the given points is minimized, where the distance is measured by a norm k 2. We present results for the general case. In the case that k 1 and k 2 are both polyhedral norms, we are able to solve the problem by investigating a finite candidate set.

General information
State: Published
Greedy and metaheuristics for the offline scheduling problem in grid computing

In grid computing a number of geographically distributed resources connected through a wide area network, are utilized as one computations unit. The NP-hard offline scheduling problem in grid computing consists of assigning jobs to resources in advance. In this paper, five greedy heuristics and two metaheuristics for solving the offline scheduling problem are introduced. Computationally evaluating the heuristics shows that all heuristics find useful solutions with a gap of 20% between upper and lower bounds. The metaheuristics give better results than the greedy heuristics, but also have larger time usage. All heuristics solve instances with up to 2000 jobs and 1000 resources, thus the results are useful both with respect to running times and to solution values.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Gamst, M. (Intern)
Number of pages: 26
Publication date: 2010

Publication information
Place of publication: Kgs. Lyngby
Publisher: DTU Management
ISBN (Print): 978-87-90855-65-9
Original language: English

Series: DTU Management 2010
Number: 2
Main Research Area: Technical/natural sciences
Electronic versions:
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Links:
Source: orbit
Source-ID: 256519
Publication: Research › Report – Annual report year: 2010

Hierachical Two-Layer Ring Network Design

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Spoorendonk, S. (Intern), Stidsen, T. R. (Intern), Jepsen, M. K. (Intern)
Publication date: 2010
Event: Abstract from 10th INFORMS Telecommunications Conference, Montreal, Canada.
Main Research Area: Technical/natural sciences
Electronic versions:
spoorendonk.pdf
Source: orbit
Source-ID: 262328
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2010

Integrating job scheduling and constrained network routing

This paper examines the NP-hard problem of scheduling jobs on resources such that the overall profit of executed jobs is maximized. Job demand must be sent through a constrained network to the resource before execution can begin. The problem has application in grid computing, where a number of geographically distributed resources connected through an optical network work together for solving large problems. A number of heuristics are proposed along with an exact solution approach based on Dantzig-Wolfe decomposition. The latter has some performance difficulties while the heuristics solve all instances within minutes and with an average solution value gap as low as 3%.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Integrating job scheduling and network routing

General information
State: Accepted/In press
Organisations: Operations Research, Department of Management Engineering
Authors: Gamst, M. (Intern)
Interactive Cost Configuration Over Decision Diagrams

In many AI domains such as product configuration, a user should interactively specify a solution that must satisfy a set of constraints. In such scenarios, offline compilation of feasible solutions into a tractable representation is an important approach to delivering efficient backtrack-free user interaction online. In particular, binary decision diagrams (BDDs) have been successfully used as a compilation target for product and service configuration. In this paper we discuss how to extend BDD-based configuration to scenarios involving cost functions which express user preferences. We first show that an efficient, robust and easy to implement extension is possible if the cost function is additive, and feasible solutions are represented using multi-valued decision diagrams (MDDs). We also discuss the effect on MDD size if the cost function is non-additive or if it is encoded explicitly into MDD. We then discuss interactive configuration in the presence of multiple cost functions. We prove that even in its simplest form, multiple-cost configuration is NP-hard in the input MDD. However, for solving two-cost configuration we develop a pseudo-polynomial scheme and a fully polynomial approximation scheme. The applicability of our approach is demonstrated through experiments over real-world configuration models and product-catalogue datasets. Response times are generally within a fraction of a second even for very large instances.
Large Neighborhood Search

Heuristics based on large neighborhood search have recently shown outstanding results in solving various transportation and scheduling problems. Large neighborhood search methods explore a complex neighborhood by use of heuristics. Using large neighborhoods makes it possible to find better candidate solutions in each iteration and hence traverse a more promising search path. Starting from the large neighborhood search method, we give an overview of very large scale neighborhood search methods and discuss recent variants and extensions like variable depth search and adaptive large neighborhood search.

Liner shipping hub network design in a competitive environment

A mixed integer programming formulation is proposed for hub-and-spoke network design in a competitive environment. It addresses the competition between a newcomer liner service provider and an existing dominating operator, both operating on hub-and-spoke networks. The newcomer company maximizes its market share—which depends on the service time and transportation cost—by locating a predefined number of hubs at candidate ports and designing its network. While general-purpose solvers do not solve instances of even small size, an accelerated Lagrangian method combined with a
A new mixed integer programming formulation is proposed for hub-and-spoke network design in a competitive environment. It addresses competition between a newcomer liner service provider and an alliance, both operating on hub-and-spoke networks. The newcomer company maximizes its market share — proportional to service time and transportation cost — by locating a predefined number of hubs at candidate ports and designing its network. While general-purpose solvers do not solve instances of even small size, an accelerated Lagrangian method coupled with a primal heuristic obtains very good bounds. Our computational experiments on real instances of practical size indicate superiority of our approach.
LP Duality and KKT Conditions for LP

General information
State: Accepted/In press
Organisations: Operations Research, Department of Management Engineering
Authors: Clausen, J. (Intern)
Number of pages: 14
Publication date: 2010

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Publisher: Louisiana Tech University
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Publication: Research - peer-review › Journal article – Annual report year: 2010

Multi-dimensional Bin Packing Problems with Guillotine Constraints
The problem addressed in this paper is the decision problem of determining if a set of multi-dimensional rectangular boxes can be orthogonally packed into a rectangular bin while satisfying the requirement that the packing should be guillotine cuttable. That is, there should exist a series of face parallel straight cuts that can recursively cut the bin into pieces so that each piece contains a box and no box has been intersected by a cut. The unrestricted problem is known to be NP-hard. In this paper we present a generalization of a constructive algorithm for the multi-dimensional bin packing problem, with and without the guillotine constraint, based on constraint programming.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering, IT University of Copenhagen
Authors: Amosson, R. R. (Ekstern), Pisinger, D. (Intern)
Network Survivability: End-to-End Recovery Using Local Failure Information

Algorithmic discrete mathematics plays a key role in the development of information and communication technologies, and methods that arise in computer science, mathematics and operations research – in particular in algorithms, computational complexity, distributed computing and optimization – are vital to modern services such as mobile telephony, online banking and VoIP. This book examines communication networking from a mathematical viewpoint. The contributing authors took part in the European COST action 293 – a four-year program of multidisciplinary research on this subject. In this book they offer introductory overviews and state-of-the-art assessments of current and future research in the fields of broadband, optical, wireless and ad hoc networks. Particular topics of interest are design, optimization, robustness and energy consumption. The book will be of interest to graduate students, researchers and practitioners in the areas of networking, theoretical computer science, operations research, distributed computing and mathematics.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering, Networks Technology and Service Platforms, Department of Photonics Engineering
Authors: Marzo, J. L. (Ekstern), Stidsen, T. R. (Intern), Ruepp, S. R. (Intern), Calle, E. (Ekstern), Tapolcai, J. (Ekstern), Segovia, J. (Ekstern)
Number of pages: 426
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Source: orbit
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Publication: Research - peer-review › Book chapter – Annual report year: 2010

On the Integrated Job Scheduling and Constrained Network Routing Problem
This paper examines the NP-hard problem of scheduling a number of jobs on a finite set of machines such that the overall profit of executed jobs is maximized. Each job demands a number of resources, which must be sent to the executing machine via constrained paths. Furthermore, two resource demand transmissions cannot use the same edge in the same time period. An exact solution approach based on Dantzig-Wolfe decomposition is proposed along with several heuristics. The methods are computationally evaluated on test instances arising from telecommunications with up to 500 jobs and 500 machines. Results show that solving the problem to optimality is very difficult. The proposed heuristics have good performance with an average solution value gap of 3% and with very small running times.

General information
State: Published
Optimal Routing with Failure-Independent Path Protection

Reliable communication has become crucial in today's information society. Modern communication networks are required to deliver reliable communication to their customers. Unfortunately, protection against network failures significantly hampers efficient utilization of network investments, because the associated routing problems become much harder. In this article we present a rigorous mathematical analysis of one of the most promising protection methods: Failure independent path protection. We present an LP model which is solved by column generation. The subproblem is proven to be strongly P-hard, but still solvable for medium sized networks through the use of specialized dynamic programming algorithms. This enables us to evaluate the performance of failure independent path protection for eight networks with up to 37 nodes and 57 links. The results indicate that only between 3% and 8% extra network capacity is necessary when compared with the capacity required by complete rerouting (which is the absolute lower bound for single link failure protection).
Optimering - et grundlag for bæredygtig IT

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Organisations: Operations Research, Department of Management Engineering
Authors: Pisinger, D. (Intern)
Number of pages: 156
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Links:
http://www.diku.dk/jubilee/dikus_jubilaeumsskrift/
Source: orbit
Source-ID: 267493
Publication: Research - peer-review › Book chapter – Annual report year: 2010
Optimising the Slab Yard Planning and Crane Scheduling Problem using a two-stage heuristic

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.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Hansen, A. D. (Intern), Clausen, J. (Intern)
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Main Research Area: Technical/natural sciences

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  Web of Science (2017): Indexed Yes
  BFI (2016): BFI-level 1
  Scopus rating (2016): CiteScore 2.67 SJR 1.435 SNIP 1.413
  BFI (2015): BFI-level 1
  Scopus rating (2015): SJR 1.306 SNIP 1.317 CiteScore 2.29
  Web of Science (2015): Indexed yes
  BFI (2014): BFI-level 1
  Scopus rating (2014): SJR 1.222 SNIP 1.33 CiteScore 2.15
  BFI (2013): BFI-level 1
  Scopus rating (2013): SJR 1.2 SNIP 1.53 CiteScore 2.09
  ISI indexed (2013): ISI indexed yes
  Web of Science (2013): Indexed yes
  BFI (2012): BFI-level 1
  Scopus rating (2012): SJR 1.238 SNIP 1.558 CiteScore 1.93
  ISI indexed (2012): ISI indexed yes
  BFI (2011): BFI-level 1
  Scopus rating (2011): SJR 1.138 SNIP 1.392 CiteScore 1.69
  ISI indexed (2011): ISI indexed yes
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  Scopus rating (2010): SJR 0.889 SNIP 1.119
  Web of Science (2010): Indexed yes
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  Scopus rating (2009): SJR 0.771 SNIP 1.097
  BFI (2008): BFI-level 2
  Scopus rating (2008): SJR 0.907 SNIP 1.272
  Scopus rating (2007): SJR 0.836 SNIP 1.194
  Web of Science (2007): Indexed yes
Planning of Shared Backup Path Protection

General information
State: Published
Organisations: Operations Research, Department of Management Engineering, Technical University of Munich, University of Copenhagen
Authors: Kiese, M. (Ekstern), Stidsen, T. R. (Intern), Spoorendonk, S. (Intern), Zachariasen, M. (Ekstern)
Publication date: 2010
Event: Abstract from 10th INFORMS Telecommunications Conference, Montreal, Canada.
Main Research Area: Technical/natural sciences

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Quadratic Assignment of Hubs in p-Hub Median Problem

We introduce Generalized p-Hub Median Problem (GpHMP) that seeks to locate p hub nodes and install p distinct hub facilities/operators on the hubs while discount factor resulted by consolidation of flow on the hub links depends on the facilities/operators that are installed/operating on both hub nodes end-point. In contrast, in traditional hub location problems it is commonly assumed that all the hub facilities share a similar characteristic and economy of scale resulted by consolidation of flow over hub edges is not directly relevant to the hub facilities being installed at both end-points. The mathematical model is presented and numerical results on the instances of CAB and AP data sets are reported.

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State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Gelareh, S. (Intern)
Number of pages: 9
Publication date: 2010
Raw material utilization in slaughterhouses – optimizing expected profit using mixed-integer programming

Slaughterhouses are major players in the pork supply chain, and supply and demand must be matched in order to generate the highest profit. In particular, carcasses must be sorted in order to produce the "right" final products from the "right" carcasses. We develop a mixed-integer programming (MIP) model for computing the optimal sorting of carcasses according to two parameters; slaughter weight and fat layer. Moreover, we consider a new approach for dealing with expected measurement errors. The results provide insight into how sorting groups should be designed in order to improve the profit at slaughterhouses. Finally, we comment on the expected effect of variations in the raw material supply and the demand as well as future research concerning joint modelling of supply chain aspects.

Route planning for airport personnel transporting passengers with reduced mobility

Major airports have an average throughput of more than 100,000 passengers per day, some of which will need special assistance. The largest airports have a daily average throughput of more than 500 passengers with reduced mobility. A significant number of people and busses are assigned to provide transportation for the passengers with reduced mobility. It is often necessary for a passenger with reduced mobility to use several different modes of transport during their journey through the airport. Synchronization occurs at the locations where transport modes are changed as to not leave passengers unattended. A description of the problem together with a mathematical model is presented. The objective is to maximize the quality of service by scheduling as many of the passengers as possible, while ensuring a smooth transport with short waiting times. A simulated annealing based heuristic for solving the problem is presented. The algorithm makes use of an abstract representation of a candidate solution which in each step is transformed to an actual schedule by use of a greedy heuristic. Local search is performed on the abstract representation using advanced neighborhoods which modify large parts of the candidate solution. Computational results are reported showing that the algorithm is able to find good solutions within a couple of minutes, making the algorithm applicable for dynamic scheduling. Moreover high-quality solutions can be obtained by running the algorithm for 15 minutes.
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 subsides 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.

Simultaneous Fleet Deployment and Network Design of Liner Shipping

A mixed integer linear programming formulation is proposed for the simultaneous design of network and fleet deployment of a liner service providers for deep-sea shipping. The underlying network design problem is based on a 4-index (5-index by considering capacity type) formulation of the hub location problem which are known for their tightness. The demand is considered to be elastic in the sense that the service provider can accept any fraction of the origin-destination demand. We then propose a primal decomposition method to solve instances of the problem to optimality. Numerical results confirm superiority of our approach in comparison with a general-purpose mixed integer programming solver.
Solving the Airline Crew Pairing Problem using Subsequence Generation

Good and fast solutions to the airline crew pairing problem are highly interesting for the airline industry, as crew costs are the biggest expenditure after fuel for an airline. The crew pairing problem is typically modelled as a set partitioning problem and solved by column generation. However, the extremely large number of possible columns naturally has an impact on the solution time. In this work in progress we severely limit the number of allowed subsequent flights, i.e. the subsequences, thereby significantly decreasing the number of possible columns. Set partitioning problems with limited subsequence counts are known to be easier to solve, resulting in a decrease in solution time. The problem though, is that a small number of deep subsequences might be needed for an optimal or near-optimal solution and these might not have been included by the subsequence limitation. Therefore, we try to identify or generate such subsequences that potentially can improve the solution value.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering, University of Auckland
Authors: Rasmussen, M. S. (Intern), Ryan, D. M. (Ekstern), Lusby, R. M. (Intern), Larsen, J. (Intern)
Pages: 539-541
Publication date: 2010
The dynamic multi-period vehicle routing problem
This paper considers the Dynamic Multi-Period Vehicle Routing Problem which deals with the distribution of orders from a depot to a set of customers over a multi-period time horizon. Customer orders and their feasible service periods are dynamically revealed over time. The objectives are to minimize total travel costs and customer waiting, and to balance the daily workload over the planning horizon. This problem originates from a large distributor operating in Sweden. It is modeled as a mixed integer linear program, and solved by means of a three-phase heuristic that works over a rolling planning horizon. The multi-objective aspect of the problem is handled through a scalar technique approach. Computational results show that the proposed approach can yield high quality solutions within reasonable running times.
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.

General information

State: Published
Organisations: Operations Research, Department of Management Engineering, Division of Seafood Research, National Food Institute, Section for Public Sector Consultancy, National Institute of Aquatic Resources
Authors: Jensen, T. K. (Intern), Nielsen, J. (Intern), Larsen, E. (Intern), Clausen, J. (Intern)
Pages: 214-226
Publication date: 2010
Main Research Area: Technical/natural sciences

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Scopus rating (2017): SNIP 0.386 SJR 0.309 CiteScore 0.64
Web of Science (2017): Indexed Yes
The Home Care Crew Scheduling Problem: Preference-Based Visit Clustering and Temporal Dependencies

In the Home Care Crew Scheduling Problem a staff of caretakers has to be assigned a number of visits to patients' homes, such that the overall service level is maximised. The problem is a generalisation of the vehicle routing problem with time windows. Required travel time between visits and time windows of the visits must be respected. The challenge when assigning visits to caretakers lies in the existence of soft preference constraints and in temporal dependencies between the start times of visits. We model the problem as a set partitioning problem with side constraints and develop an
exact branch-and-price solution algorithm, as this method has previously given solid results for classical vehicle routing problems. Temporal dependencies are modelled as generalised precedence constraints and enforced through the branching. We introduce a novel visit clustering approach based on the soft preference constraints. The algorithm is tested both on real-life problem instances and on generated test instances inspired by realistic settings. The use of the specialised branching scheme on real-life problems is novel. The visit clustering decreases run times significantly, and only gives a loss of quality for few instances. Furthermore, the visit clustering allows us to find solutions to larger problem instances, which cannot be solved to optimality.

The linearized simultaneous string-design and cargo-routing problem

A global liner shipping network, consists of a billion dollar investment in assets. Designing this network, to minimize costs, while considering operational constraints is thus of great relevance. Empirical studies of the cost structure of a networks strings (ship rotations), show linear relation to the capacity and length of the string, this is used in a formulation and solution method.

The Linearized Simultaneous String-Design and Cargo-Routing Problem

A global liner shipping network, consists of a billion dollar investment in assets. Designing this network, to minimize costs, while considering operational constraints is thus of great relevance. Empirical studies of the cost structure of a networks strings (ship rotations), show linear relation to the capacity and length of the string, this is used in a formulation and solution method.
The Off-line Group Seat Reservation Problem
In this paper we address the problem of assigning seats in a train for a group of people traveling together. We consider two variants of the problem. One is a special case of two-dimensional knapsack where we consider the train as having fixed size and the objective is to maximize the utilization of the seats in the train. The second is a special case of two-dimensional bin packing where all requests must be accommodated while trying to minimize the number of passenger cars needed. For both variants of the problem we present a number of bounds and develop exact algorithms. Computational results are presented for various instances based on realistic data, and from the packing literature adapted to the problems addressed.
The Train Driver Recovery Problem - a Set Partitioning Based Model and Solution Method

The need to recover a train driver schedule occurs during major disruptions in the daily railway operations. Based on data from the Danish passenger railway operator DSB S-tog A/S, a solution method to the train driver recovery problem (TDRP) is developed. The TDRP is formulated as a set partitioning problem. We define a disruption neighbourhood by identifying a small set of drivers and train tasks directly affected by the disruption. Based on the disruption neighbourhood, the TDRP model is formed and solved. If the TDRP solution provides a feasible recovery for the drivers within the disruption neighbourhood, we consider that the problem is solved. However, if a feasible solution is not found, the disruption neighbourhood is expanded by adding further drivers or increasing the recovery time period. Fractional solutions to the LP relaxation of the TDRP are resolved with a constraint branching strategy using the depth-first search of the Branch & Bound tree. The LP relaxation of the TDRP possesses strong integer properties. We present test scenarios generated from the historical real-life operations data of DSB S-tog A/S. The numerical results show that all but one tested instances produce integer solutions to the LP relaxation of the TDRP and solutions are found within a few seconds.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Rezanova, N. J. (Intern), Ryan, D. (Intern)
Pages: 845-856
Publication date: 2010
Main Research Area: Technical/natural sciences

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Scopus rating (2017): CiteScore 3.75 SJR 1.916 SNIP 2.094
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Two- and three-index formulations of the minimum cost multicommodity k-splittable flow problem

The multicommodity flow problem (MCFP) considers the efficient routing of commodities from their origins to their destinations subject to capacity restrictions and edge costs. Baier et al. [G. Baier, E. Köhler, M. Skutella, On the k-splittable flow problem, in: 10th Annual European Symposium on Algorithms, 2002, 101–113] introduced the maximum flow multicommodity k-splittable flow problem (MCKFP) where each commodity may use at most k paths between its origin and its destination. This paper studies the -hard minimum cost multicommodity k-splittable flow problem (MCMCKFP) in which a given flow of commodities has to be satisfied at the lowest possible cost. The problem has applications in transportation problems where a number of commodities must be routed, using a limited number of distinct transportation units for each commodity. Based on a three-index formulation by Truffot et al. [J. Truffot, C. Duhamel, P. Mahey, Branch and price pour le problème du multiflot k-séparable de coût minimal, in: LIMOS, UMR 6158 – CNRS, ROADEF’05, 2005]
we present a new two-index formulation for the problem, and solve both formulations through branch-and-price. The three-index algorithm by Truffot et al. is improved by introducing a simple heuristic method to reach a feasible solution by eliminating some symmetry. A novel branching strategy for the two-index formulation is presented, forbidding subpaths in the branching children. Though the proposed heuristic for the three-index algorithm improves its performance, the three-index algorithm is still outperformed by the two-index algorithm, both with respect to running time and to the number of solved test instances.
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 basic bounds for the problem, and illustrations of problem solutions are given to provide an impression of how solutions of 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 neighbourhood search obtains 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. With the purpose of solving the DTSPMS to optimality, several 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.
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 conv tribute 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 scheduling, rolling stock re-scheduling, railway crew re-scheduling, and airline crew recovery. In addition, the project has resulted in the three scientific publications listed below. 1. Rezanova NJ, Ryan DM. The train driver recovery problem–A set partitioning based model and solution method. Computers and Operations Research, in press, 2009. doi: 10.1016/j.cor.2009.03.023. 2. Clausen J, Larsen A, Larsen J, Rezanova NJ. Disruption management in the airline industry–Concepts, models and methods. Computers and Operations Research, in press, 2009. doi: 10.1016/j.cor.2009.03.027. 3. Rezanova NJ, Ryan DM. The train driver recovery problem–A set partitioning based model and solution method. IMM-Technical Report-2006-24. Informatics and Mathematical Modelling, Technical University of Denmark, 2006. Available at http://www2.imm.dtu.dk/pubdb/p.php?5157.
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 intrinsic 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.

**General information**
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Organisations: Department of Informatics and Mathematical Modeling, Operations Research, Department of Management Engineering
Authors: Wanscher, J. (Intern), Clausen, J. (Intern), Larsen, J. (Intern)
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**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.

**General information**
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Groth, J. J. (Intern), Larsen, J. (Intern), Clausen, J. (Intern)
Publication date: Apr 2009

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A branch-and-cut-and-price framework for vehicle routing problems

General information
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Organisations: Operations Research, Department of Management Engineering
Authors: Jepsen, M. K. (Intern), Petersen, B. (Intern), Spoorendonk, S. (Intern)
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Main Research Area: Technical/natural sciences

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A general framework for branch-and-cut-and-price

General information
State: Published
Organisations: Department of Management Engineering, Operations Research, HEC Montreal, Ecole Polytechnique de Montreal
Authors: Desrosiers, J. (Ekstern), Desaulniers, G. (Ekstern), Spoorendonk, S. (Intern)
Publication date: 2009
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A general framework for branch-and-cut-and-price

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Organisations: Operations Research, Department of Management Engineering, HEC Montreal, Ecole Polytechnique de Montreal
Authors: Desrosiers, J. (Ekstern), Desaulniers, G. (Ekstern), Spoorendonk, S. (Intern)
Publication date: 2009
Main Research Area: Technical/natural sciences
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Source-ID: 251473
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2009

A multi-level variable neighborhood search heuristic for a practical vehicle routing and driver scheduling problem
This paper addresses an integrated vehicle routing and driver scheduling problem arising at the largest fresh meat producer in Denmark. The problem consists of a one-week planning horizon, heterogeneous vehicles, and drivers with predefined work regulations. These regulations include, among other things, predefined workdays, fixed starting time, maximum weekly working duration, break rule. The objective is to minimize the total delivery cost. The real-life case study is first introduced and modelled as a mixed integer linear program. A multilevel variable neighborhood search heuristic is then proposed for the problem. At the first level, the problem size is reduced through an aggregation procedure. At the second level, the aggregated weekly planning problem is decomposed into daily planning problems, each of which is solved by a variable neighborhood search. At the last level, the solution of the aggregated problem is expanded to that of the original problem. The method is implemented and tested on real-life data consisting of up to 2000 orders per week. Computational results show that the aggregation procedure and the decomposition strategy are very effective in solving this large scale problem, and our solutions are superior to the industrial solutions given the constraints considered in this
An Adaptive Large Neighborhood Search Algorithm for the Resource-constrained Project Scheduling Problem

We present an application of an Adaptive Large Neighborhood Search (ALNS) algorithm to the Resource-constrained Project Scheduling Problem (RCPSP). The ALNS framework was first proposed by Pisinger and Røpke [19] and can be described as a large neighborhood search algorithm with an adaptive layer, where a set of destroy/repair neighborhoods compete to modify the current solution in each iteration of the algorithm. Experiments are performed on the well-known J30, J60 and J120 benchmark instances, which show that the proposed algorithm is competitive and confirms the strength of the ALNS framework previously reported for different variants of the Vehicle Routing Problem.

Analysis of internal network requirements for the distributed Nordic Tier-1

General information
State: Published
Organisations: Operations Research, Department of Management Engineering, Nordic DataGrid Facility, NORDUnet A/S
Authors: Kleist, J. (Ekstern), Behrmann, G. (Ekstern), Fischer, L. (Ekstern), Gamst, M. (Intern), Grønager, M. (Ekstern)
Publication date: 2009
Event: Abstract from Computing in High Energy and Nuclear Physics, Prague, Czech Republic, .
Main Research Area: Technical/natural sciences
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An Exact Method for the Double TSP with Multiple Stacks

The double travelling salesman problem with multiple stacks (DTSPMS) is a pickup and delivery problem in which all pickups must be completed before any deliveries can be made. The problem originates from a real-life application where a 40 foot container (configured as 3 columns of 11 rows) is used to transport up to 33 pallets from a set of pickup customers to a set of delivery customers. The pickups and deliveries are performed in two separate trips, where each trip starts and ends at a depot and visits a number of customers. The aim of the problem is to produce a stacking plan for the pallets that minimizes the total transportation cost (ignoring the cost of transporting the container between the depots of the two trips) given that the container cannot be repacked at any stage. In this paper we present an exact solution method based on matching k-best TSP solutions for each of the separate pickup and delivery TSP problems and show that previously unsolved instances can be solved within seconds using this approach.

General information
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Organisations: Operations Research, Department of Management Engineering, University of Auckland
Authors: Larsen, J. (Intern), Lusby, R. M. (Intern), Ehrgott, M. (Ekstern), Ryan, D. (Ekstern)
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TSP, Exact method, Packing, Routing, k-best solution
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Publication: Research - peer-review › Report – Annual report year: 2009

An Exact Solution Approach for the Maximum Multicommodity K-splittable Flow Problem

This talk concerns the NP-hard Maximum Multicommodity k-splittable Flow Problem (MMCKFP) in which each commodity may use at most k paths between its origin and its destination. A new branch-and-cut-and-price algorithm is presented. The master problem is a two-index formulation of the MMCKFP and the pricing problem is the shortest path problem with forbidden paths. A new branching strategy forcing and forbidding the use of certain paths is developed. The new branch-and-cut-and-price algorithm is computationally evaluated and compared to results from the literature. The new algorithm shows very promising performance by outperforming existing algorithms for several instances.

General information
State: Published
Organisations: Department of Management Engineering, Operations Research
Authors: Gamst, M. (Intern), Petersen, B. (Intern)
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A Practical Branch and Price Approach to the Crew Scheduling Problem with Time Windows

General information
State: Published
Organisations: Operations Research, Department of Management Engineering, Department of Informatics and Mathematical Modeling
Authors: Hansen, A. D. (Intern), Kolind, E. (Intern)
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Publication date: 2009
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Publication: Communication › Journal article – Annual report year: 2009

A Set Packing Inspired Method for Real-Time Junction Train Routing

Efficiently coordinating the often large number of interdependent, timetabled train movements on a railway junction, while satisfying a number of operational requirements, is one of the most important problems faced by a railway company. The most critical variant of the problem arises on a daily basis at major railway junctions where disruptions to rail traffic make the planned schedule/routing infeasible and rolling stock planners are forced to reschedule/re-route trains in order to recover feasibility. The dynamic nature of the problem means that good solutions must be obtained quickly. In this paper we describe a set packing inspired formulation of this problem and develop a branch-and-price based solution approach. A real life test instance arising in Germany and supplied by the major German railway company, Deutsche Bahn, indicates the efficiency of the proposed approach by confirming that practical problems can be solved to within a few percent of optimality in reasonable time.

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Organisations: Operations Research, Department of Management Engineering, University of Auckland
Authors: Lusby, R. M. (Intern), Larsen, J. (Intern), Ehrgott, M. (Ekstern), Ryan, D. (Ekstern)
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disruption management, train routing, optimization, duality
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Publication: Research › Report – Annual report year: 2009

A Survey of the Routing and Wavelength Assignment Problem

When transmitting data in an all-optical network, data connections must be established in such a way that two or more connections never share a wavelength on the same fiber. The NP-hard Routing and Wavelength Assignment (RWA) problem consists of finding paths and wavelengths for a set of data connections. This survey introduces the RWA and gives an overview of heuristic, metaheuristic and exact solution methods from the literature. Running times for the
heuristic methods are presented and computational results are discussed.

**A Unified Modeling and Solution Framework for Pre-Planned Protection in Survivable WDM Networks**

**General information**
State: Submitted
Organisations: Department of Management Engineering, Operations Research, Concordia University
Authors: Jaumard, B. (Ekstern), Sebbah, S. (Ekstern), Stidsen, T. K. (Intern)
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- Web of Science (2017): Indexed Yes
- BFI (2016): BFI-level 2
- Scopus rating (2016): CiteScore 1.86 SJR 1.579 SNIP 1.533
- BFI (2015): BFI-level 2
- Scopus rating (2015): SJR 1.553 SNIP 1.376 CiteScore 1.66
- BFI (2014): BFI-level 2
- Scopus rating (2014): SJR 1.57 SNIP 1.758 CiteScore 1.64
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- Scopus rating (2013): SJR 1.635 SNIP 1.559 CiteScore 1.73
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- Web of Science (2013): Indexed yes
- BFI (2012): BFI-level 2
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- Web of Science (2012): Indexed yes
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- Scopus rating (2011): SJR 1.731 SNIP 1.622 CiteScore 1.66
Clique inequalities applied to the vehicle routing problem with time windows

General information
State: Published
Organisations: Operations Research, Department of Management Engineering, Ecole Polytechnique de Montreal
Authors: Spoorendonk, S. (Intern), Desaulniers, G. (Ekstern)
Pages: 1-7
Publication date: 2009

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Customised Column Generation for Rostering Problems: Using Compile-time Customisation to create a Flexible C++ Engine for Staff Rostering

This paper describes a new approach for easily creating customised staff rostering column generation programs. In previous work, we have built a large very flexible software system which is tailored at run time to meet the particular needs of a client. This system has proven to be very capable, but is difficult to maintain, and incurs the time penalties of run-time customisation. Our new approach is to customise the software at compile time, allowing compiler optimisations to be fully exploited to give faster code. The code has also proven to be easier to read and debug.

General information
State: Published
Organisations: Department of Management Engineering, Operations Research, University of Auckland
Authors: Mason, A. J. (Ekstern), Ryan, D. (Intern), Hansen, A. D. (Intern)
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Electronic versions:
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.
General minisum circle location
In our paper we approximate a set of given points by a general circle. More precisely, we consider the problem of locating and scaling the unit ball of some given norm $k_1$ with respect to fixed points on the plane such that the sum of weighted distances between the circle and the fixed points is minimized, where the distance is measured by a norm $k_2$. We present results for the general case. In the case that $k_1$ and $k_2$ are both block norms, we are able to identify a finite dominating set in $\mathbb{R}^3$ for the problem, which can be obtained as the intersection of cones.
Locating a circle on the plane using the minimax criterion
We consider the problem of locating a circle with respect to existing facilities on the plane, such that the largest weighted distance between the circumference of the circle and the facilities is minimized. The problem properties are analyzed, and a solution procedure proposed.

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State: Published
Organisations: Operations Research, Department of Management Engineering, Royal Military College of Canada, Georg-August-Universität Göttingen
Authors: Brimberg, J. (Ekstern), Juel, H. (Intern), Schöbel, A. (Ekstern)
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Locating a minisum circle in the plane
We consider the problem of locating a circle with respect to existing facilities in the plane such that the sum of weighted distances between the circle and the facilities is minimized, i.e., we approximate a set of given points by a circle regarding the sum of weighted distances. If the radius of the circle is a variable we show that there always exists an optimal circle passing through two of the existing facilities. For the case of a fixed radius we provide characterizations of optimal circles in special cases. Solution procedures are suggested.

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State: Published
Organisations: Operations Research, Department of Management Engineering, Georg-August-Universität Göttingen
Authors: Brimberg, J. (Ekstern), Juel, H. (Intern), Schöbel, A. (Ekstern)
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Main Research Area: Technical/natural sciences

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Marginal revenue transformation in airline seat inventory control with two fare families and two markets

This paper considers the single-leg airline seat inventory control problem with fare classes divided into two fare families and demand for the fare classes segmented into two markets. The main contribution of this paper is that the seat inventory control problem is solved using the marginal revenue (MR) transformation of Fiig et al. (T. Fiig, K. Isler, C. Hopperstad, and P. Belobaba. Optimization of Mixed Fare Structures. Submitted to Journal of Revenue and Pricing Management, 2009), which enables the implementation of the more complex policy in traditional class-based revenue management systems. The reason for considering a two-market and two-family seat inventory control problem is the objective of airlines
such as SAS and Air Canada to serve both the business and leisure market while at the same time controlling sell-up behavior in the undifferentiated fare. A fare family is defined by a set of fare classes that are fully undifferentiated except for their price levels and customers will therefore always buy the lowest fare available within a family. We assume that the families are separated in terms of restrictions on service and flexibility and that there exists buy-up from the lowest to the highest fare class. We also assume that the markets are perfectly separable. Suppose that family 1 consists of the highest fare classes. Then the control problem is to decide which fare class from family 1 and 2 to offer at each point in time in each market. We can also decide not to offer any fare class from family 2. The set of classes that the airline chooses to open is called a policy. Let \( S \) denote a set of two fare classes \([i,j]\), where \( i \) is a fare class from family 1 and \( j \) is a fare class from family 2. We allow the fare class from family 2 to be the empty element, which corresponds to not offering any lower classes for sale. Furthermore, let \( Q(S) \) denote the total probability of purchase of set \( S \) and \( R(S) \) the total expected revenue from offering set \( S \). The application of the MR transformation to the scenario with two fare families and two markets can be described in three overall principles. 1) MR transformation from fare families to fare classes The first principle is that given a specific market the adjusted fare defined by the MR transformation is calculated for the subsets of fare classes on the efficient frontier of the set of points \([Q(S), R(S)]\), for all \( S \). In the case of two fare families the sets on the efficient frontier does not necessarily represent nested policies. 2) Nesting of fare family policies The second principle is that given a specific market the subsets on the efficient frontier are forced to be nested. The primary purpose of this principle is that it enables the continued use of the existing control mechanism in class-based RM systems. The result of enforcing the nesting property is that the adjusted fare for an individual fare class is found as the marginal revenue when the class is initially offered, i.e. nesting ensures that there is a unique marginal revenue value that can be assigned to the fare classes. The result of the elimination of non-nested sets is that potentially optimal sets are discarded but on the other hand it allows a very elegant way of implementation in existing class-based RM systems. The result of the first two principles is a set of independent fare classes in a given market. 3) MR transformation in perfectly separable markets The third principle is that the MR transformation is carried out for each market separately and because of our assumption of perfectly separable markets this results in independent fare classes across both fare families and markets. Based on the three principles above we can then optimize the control problem with adjusted fare classes using dynamic programming models that assume independent demand for each fare class. We present numerical results to illustrate the model and the performance of the dynamic programming algorithm. The results demonstrate that the computational complexity of the dynamic programming models is tolerable, which is a result of the undifferentiated fare structures for which only a single decision variable exists for each fare family.

Models for the Discrete Berth Allocation Problem: A Computational Comparison

In this paper we consider the problem of allocating arriving ships to discrete berth locations at container terminals. This problem is recognized as one of the most important processes for any container terminal. We review and describe the three main models of the discrete dynamic berth allocation problem, improve the performance of one model, and, through extensive numerical tests, compare all models from a computational perspective. The results indicate that a generalized setpartioning model outperforms all other existing models.

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Authors: Kallehauge, B. (Intern)
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Organisations: Logistics & ITS, Department of Transport, Operations Research, Department of Management Engineering, Technical University of Denmark
Authors: Buhrkal, K. (Ekstern), Zugliana, S. (Ekstern), Repke, S. (Intern), Larsen, J. (Intern), Lusby, R. M. (Intern)
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Multi-Objective and Multi-Constrained Non-Additive Shortest Path Problems

Shortest path problems appear as subproblems in numerous optimization problems. In most papers concerning multiple objective shortest path problems, additivity of the objective is a de-facto assumption, but in many real-life situations objectives and criteria, can be non-additive. The purpose of this paper is to give a general framework for dominance tests for problems involving a number of non-additive criteria. These dominance tests can help eliminate paths in a dynamic programming framework when using multiple objectives. Results on real-life multi-objective problems containing non-additive criteria are reported. We show that in many cases the framework can be used to efficiently reduce the number of generated paths.

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State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Reinhardt, L. B. (Intern), Pisinger, D. (Intern)
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Partial Path Column Generation for the ESPPRC

This paper presents a column generation algorithm for the Capacitated Vehicle Routing Problem (CVRP) and the Vehicle Routing Problem with Time Windows (VRPTW). Traditionally, column generation models of the CVRP and VRPTW have consisted of a Set Partitioning master problem with each column representing a route. Elementary routes (no customer visited more than once) have shown superior results for both CVRP and VRPTW. However, the pricing problems do not scale well when the number of feasible routes increases. We suggest to relax that ‘each column is a route’ into ‘each column is a part of the giant tour’; a so-called partial path, i.e., not necessarily starting and ending in the depot. This way, the length of the partial path can be bounded and a better control of the size of the solution space for the pricing problem can be obtained.

Partial Path Column Generation for the Vehicle Routing Problem

This paper presents a column generation algorithm for the Capacitated Vehicle Routing Problem (CVRP) and the Vehicle Routing Problem with Time Windows (VRPTW). Traditionally, column generation models of the CVRP and VRPTW have consisted of a Set Partitioning master problem with each column representing a route. Elementary routes (no customer visited more than once) have shown superior results for both CVRP and VRPTW. However, the pricing problems do not scale well when the number of feasible routes increases. We suggest to relax that ‘each column is a route’ into ‘each column is a part of the giant tour’; a so-called partial path, i.e., not necessarily starting and ending in the depot. This way, the length of the partial path can be bounded and a better control of the size of the solution space for the pricing problem can be obtained.

Partial Path Column Generation for the ESPPRC

This paper presents a column generation algorithm for the Capacitated Vehicle Routing Problem (CVRP) and the Vehicle Routing Problem with Time Windows (VRPTW). Traditionally, column generation models of the CVRP and VRPTW have consisted of a Set Partitioning master problem with each column representing a route. Elementary routes (no customer visited more than once) have shown superior results for both CVRP and VRPTW. However, the pricing problems do not scale well when the number of feasible routes increases. We suggest to relax that ‘each column is a route’ into ‘each column is a part of the giant tour’; a so-called partial path, i.e., not necessarily starting and ending in the depot. This way, the length of the partial path can be bounded and a better control of the size of the solution space for the pricing problem can be obtained.

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column generation, elementary shortest path problem, vehicle routing problem
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http://www.man.dtu.dk/upload/institutter/ipl/publ/publikationer%202009/rapport%202012.pdf
Partial path column generation for the vehicle routing problem with time windows

This paper presents a column generation algorithm for the Vehicle Routing Problem with Time Windows (VRPTW). Traditionally, column generation models of the VRPTW have consisted of a Set Partitioning master problem with each column representing a route, i.e., a resource feasible path starting and ending at the depot. Elementary routes (no customer visited more than once) have shown superior results on difficult instances (less restrictive capacity and time windows). However, the pricing problems do not scale well when the number of feasible routes increases, i.e., when a route may contain a large number of customers. We suggest to relax that 'each column is a route' into 'each column is a part of the giant tour'; a so-called partial path, i.e., not necessarily starting and ending in the depot. This way, the length of the partial path can be bounded and a better control of the size of the solution space for the pricing problem can be obtained.

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State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Petersen, B. (Intern), Jepsen, M. K. (Intern)
Pages: 1-6
Publication date: 2009

Railway Track Allocation: Models and Methods

Eciently coordinating the movement of trains on a railway network is a central part of the planning process for a railway company. This paper reviews models and methods that have been proposed in the literature to assist planners in nding train routes. Since the problem of routing trains on a railway network entails allocating the track capacity of the network (or part thereof) over time in a conict-free manner, all studies that model railway track allocation in some capacity are considered relevant. We hence survey work on the train timetabling, train dispatching, train platforming, and train routing problems, group them by railway network type, and discuss track allocation from a strategic, tactical, and operational level.

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Organisations: Operations Research, Department of Management Engineering, University of Auckland
Authors: Lusby, R. M. (Intern), Larsen, J. (Intern), Ehrgott, M. (Ekstern), Ryan, D. (Intern)
Number of pages: 29
Publication date: 2009
Solving the Airline Crew Pairing Problem using Subsequence Generation

Good and fast solutions to the airline crew pairing problem are highly interesting for the airline industry, as crew costs are the biggest expenditure after fuel for an airline. The crew pairing problem is typically modelled as a set partitioning problem and solved by column generation. However, the extremely large number of possible columns naturally has an impact on the solution time. In this work in progress we severely limit the number of allowed subsequent flights, i.e. the subsequences, thereby significantly decreasing the number of possible columns. Set partitioning problems with limited subsequence counts are known to be easier to solve, resulting in a decrease in solution time. The problem though, is that a small number of deep subsequences might be needed for an optimal or near-optimal solution and these might not have been included by the subsequence limitation. Therefore, we try to identify or generate such subsequences that potentially can improve the solution value.

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.
Sporbarhed kan give værdivækst

General information
State: Published
Organisations: Division of Food Production Engineering, National Food Institute, Operations Research, Department of Management Engineering
Authors: Jørgensen, S. B. (ed.) (Intern), Jensen, T. K. (Intern)
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Main Research Area: Technical/natural sciences

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The Danish fishing industry - towards supply chain modelling

General information
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Organisations: Operations Research, Department of Management Engineering, National Food Institute, National Institute of Aquatic Resources
Authors: Jensen, T. K. (Intern), Nielsen, J. (Intern), Larsen, E. (Intern), Clausen, J. (Intern)
Publication date: 2009

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Publication: Research › Conference abstract in proceedings – Annual report year: 2009

The Dynamic Multi-Period Vehicle Routing Problem
This paper considers the Dynamic Multi-Period Vehicle Routing Problem which deals with the distribution of orders from a depot to a set of customers over a multi-period time horizon. Customer orders and their feasible service periods are dynamically revealed over time. The objectives are to minimize total travel costs and customer waiting, and to balance the daily workload over the planning horizon. This problem originates from a large distributor operating in Sweden. It is modeled as a mixed integer linear program, and solved by means of a three-phase heuristic that works over a rolling planning horizon. The multi-objective aspect of the problem is handled through a scalar technique approach. Computational results show that our solutions improve upon those of the Swedish distributor.

General information
State: Published
Organisations: Logistics & ITS, Department of Transport, Operations Research, Department of Management Engineering, HEC Montreal
Authors: Wen, M. (Intern), Cordeau, J. (Ekstern), Laporte, G. (Ekstern), Larsen, J. (Intern)
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Main Research Area: Technical/natural sciences
dynamic, multi-objective, vehicle routing, multi-period, variable neighborhood search
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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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State: Published
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)
Number of pages: 15
Publication date: 2009

The Home Care Crew Scheduling Problem
In the Home Care Crew Scheduling Problem (HCCSP) a staff of caretakers has to be assigned a number of visits, such that the total number of assigned visits is maximised. The visits have different locations and positions in time, and travelling time and time windows must be respected. The challenge when assigning visits to caretakers lies in the existence of soft constraints and indeed also in temporal dependencies between the starting times of visits. Most former approaches to solving the HCCSP involve the use of heuristic methods. Here we develop an exact branch-and-price algorithm that uses clustering of the visits based on the problem structure. The algorithm is tested on real-life problem instances and we obtain solutions that are better than current practice in all cases.

General information
State: Published
Organisations: Operations Research, Department of Management Engineering, SAS
Authors: Rasmussen, M. S. (Intern), Justesen, T. (Ekstern)
Publication date: 2009
Main Research Area: Technical/natural sciences
Source-ID: 271677
Publication: Research › Conference abstract for conference – Annual report year: 2009

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.
The Vehicle Routing Problem with Time Windows and Temporal Dependencies

The vehicle routing problem with time windows and temporal dependencies (VRPTWTD) is an extension of the vehicle routing problem with time windows (VRPTW). Given is a fixed set of customers with individual demands and with time windows specifying when each customer accepts service. The objective is to find routes for a number of vehicles, all starting and ending at a central depot in such a way that the total distance is minimized. The extension that we present here is concerned with temporal dependencies between customers. A temporal dependency which is often encountered in practical instances and that has received the most attention in the literature, is the rather strict requirement of synchronization between two visits. Synchronization on visits is also used to model rendezvous between vehicles. Other, less restrictive, dependencies are constraints on minimum overlap between visits and limits on minimum or maximum gaps between visits. There is a vast amount of literature on VRPTW and its variants. VRPTW is known to be NP-hard, nevertheless exact solution of the problem has received a lot of attention. The most successful approach is based on a Dantzig-Wolfe decomposition of the mathematical model using column generation in a branch-and-cut-and-price framework. The motivation behind this work on the VRPTWTD is its many practical applications. With the inclusion of temporal dependencies in the model, we are able to describe numerous concrete problems. Practical applications include the fleet assignment and routing problem with synchronization constraints. The problem has been solved by column generation. The synchronized vehicle dispatching problem (SVPD), which is a dynamic vehicle routing problem with synchronization between vehicles. Constraint programming and local search are applied to arrive at high-quality feasible solutions. A problem from the Port of Singapore, where technicians are allocated to service jobs has previously been
Two- and Three-index formulations of the Minimum Cost Multicommodity k-splittable Flow Problem

**General information**
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Gamst, M. (Intern), Jensen, P. N. (Ekstern), Pisinger, D. (Intern), Plum, C. E. M. (Intern)
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Main Research Area: Technical/natural sciences
Source: orbit
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Publication: Research › Conference abstract for conference – Annual report year: 2009

The two formulations of the Minimum Cost Multicommodity k-splittable Flow Problem are compared. The first formulation is the time-indexed model, which models the problem by using time-indexed variables. The second formulation is the relaxed model, which is a relaxation of the time-indexed model. The performance of the time-indexed model was clearly better than the relaxed model for the instances where the optimal solution was obtained in the root node. The relaxation of the time-indexed model has some nice properties, it also retains its major drawback, namely the number of constraints. As a consequence, a hybrid method is implemented, where only a limited number of the violated cuts are added. This approach keeps most of the nice features of the time-indexed model, while at the same time lowering the solution time to the same level as the solution time of the relaxed model. In fact the hybrid method is only slower than the relaxed model in a small number of instances. The model presented in this paper is general and is therefore applicable to various practical problems. Future work could be adaption to real world problems. Another very interesting direction for future research could be to include additional cuts. Using the time-indexed formulation, we were able to solve many instances already in the root node of the branch-and-price tree, and this number could be increased by introducing additional cuts. The performance of the time-indexed model was clearly better than the relaxed model for the instances where the optimal solution was obtained in the root node.
Vehicle routing in newspaper distribution

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Kallehauge, B. (Intern)
Publication date: 2009

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 253268
Publication: Research - peer-review › Article in proceedings – Annual report year: 2009

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.

General information
State: Published
Organisations: Logistics & ITS, Department of Transport, Operations Research, Department of Management Engineering, HEC Montreal
Authors: Wen, M. (Intern), Larsen, J. (Intern), Clausen, J. (Intern), Cordeau, J. (Ekstern), Laporte, G. (Ekstern)
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Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 1.56 SJR 1.002 SNIP 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): SJR 0.996 SNIP 1.079 CiteScore 1.59
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 0.905 SNIP 0.903 CiteScore 1.43
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.019 SNIP 1.09 CiteScore 1.34
Web of Science (2014): Indexed yes
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)
Publication date: Sep 2008

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PhD thesis published by DTU Management
Source: orbit
Source-ID: 220436
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'être 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 proves 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.

General information
State: Published
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Authors: Kallehaugue, L. S. (Intern), Clausen, J. (Intern), Madsen, O. B. (Intern)
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The mortgage choice problem

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Rasmussen, K. M. (Intern), Clausen, J. (Intern)
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A Data Set for the Simultaneous Vehicle Scheduling and Passenger Service Problem

General information
State: Published
Organisations: Operations Research, Department of Management Engineering, Logistics & ITS, Department of Transport
Authors: Petersen, H. L. (Intern), Larsen, A. (Intern), Madsen, O. B. (Intern), Repke, S. (Intern)
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Edition: 1
Original language: English
Series: DTU Transport Technical Reports
Label Space Reduction in MPLS Networks: How Much Can A Single Stacked Label Do?
Most network operators have considered reducing LSR label spaces (number of labels used) as a way of simplifying management of underlaying virtual private networks (VPNs) and therefore reducing operational expenditure (OPEX). The IETF outlined the label merging feature in MPLS-allowing the configuration of multipoint-to-point connections (MP2P)-as a means of reducing label space in LSRs. We found two main drawbacks in this label space reduction scheme: a) it should be separately applied to a set of LSPs with the same egress LSR-which decreases the options for better reductions, and b) LSRs close to the edge of the network experience a greater label space reduction than those close to the core. The later implies that MP2P connections reduce the number of labels asymmetrically.
Limitations in Production and Stocks and their Effect on the Profitability of the Slaughterhouses

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Kjærgaard, N. C. (Intern)
Publication date: 2008

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Original language: English

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Optimizing Manpower Allocation for Ground Handling Tasks in Airports using Column Generation

The Manpower Allocation Problem with Time Windows, Job-Teaming Constraints and a limited number of teams (m-MAPTWTC) is the problem of assigning m teams to a number of tasks, where both teams and tasks are restricted by time windows outside which operation is not possible. Tasks may require several individual teams to cooperate. Cooperating teams have to be synchronized with each other. Due to the limited number of teams, some tasks may have to be left unassigned. The objective is to maximize the number of assigned tasks. The problem arises in various crew scheduling contexts where cooperation between teams/workers, possibly with different skills, is required. This study focuses on the scheduling of ground handling tasks in some of Europe's major airports. Any daily schedule must comply with the time windows and skill requirements of tasks, transportation time between locations, the working hours of the staff, synchronization requirements between teams, and union regulations. The problem is solved using column generation in a Branch-and-Price framework. Synchronization between teams is enforced by branching on time windows. The resource constrained shortest path subproblem is solved by a label setting algorithm. 12 authentic data sets from two of Europe's major airports are used for testing. Optimal solutions are found for 11 of the test instances. Keywords: Manpower allocation, crew scheduling, vehicle routing with time windows, synchronization, column generation, Branch-and-Price, time window branching, set partitioning, set covering, integer programming.

General information
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Organisations: Operations Research, Department of Management Engineering
Authors: Hansen, A. D. (Intern), Kolind, E. (Ekstern)
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General information
State: Published
Organisations: Embedded Systems Engineering, Department of Informatics and Mathematical Modeling, Operations Research, Department of Management Engineering
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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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The Home Care Crew Scheduling Problem

General information
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Organisations: Operations Research, Department of Management Engineering, Technical University of Denmark
Authors: Hansen, A. D. (Intern), Rasmussen, M. S. (Intern), Justesen, T. (Ekstern), Larsen, J. (Intern)
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TheHomeCareCrewSchedulingProblem.pdf
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The Simultaneous Vehicle Scheduling and Passenger Service Problem

General information
State: Published
Organisations: Department of Management Engineering, Operations Research, SAS
Authors: Dohn, A. H. (Intern), Rasmussen, M. S. (Intern), Justesen, T. (Ekstern), Larsen, J. (Intern)
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The Value of a General Increase in Slaughter Weight for Pigs

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Authors: Kjærsgaard, N. C. (Intern)
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The Value of Improved Measurements in a Pig Slaughterhouse

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Publication: Research › Report – Annual report year: 2008
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
State: Published
Organisations: Operations Research, Department of Informatics and Mathematical Modeling, Operations Research, Department of Management Engineering
Authors: Randleff, L. R. (Intern), Clausen, J. (Intern)
Publication date: Sep 2007

Publication Information
Original language: English
Series: IMM-PHD-2007-172
Main Research Area: Technical/natural sciences
Electronic versions:
phd172_lrr.pdf
Source: orbit
Source-ID: 200847
Publication: Research › Ph.D. thesis – Annual report year: 2007

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.

General information
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.

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

The Seventeenth International Conference on Automated Planning and Scheduling
Publisher: AAAI Press
ISBN (Print): 978-1-57735-344-7

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
State: Published
Organisations: Operations Research, Department of Management Engineering, Department of Informatics and Mathematical Modeling
Authors: Hansen, A. D. (Intern), Kolind, E. (Intern), Clausen, J. (Intern)
Publication date: 2007

Publication information
Publisher: Informatics and Mathematical Modelling, Technical University of Denmark, DTU
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
imm5192.pdf
Source: orbit
Source-ID: 220627
Publication: Research - peer-review › Article in proceedings – Annual report year: 2007

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
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 signifi cant. 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 responsible 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 e ciency 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 eld of electricity economics, due to the signifi cant 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 specifi 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 fi ve 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 focusses 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
The p/q-ACTIVE facility location problem: Investigation of the solution space and an LP-fitting heuristic - Technical Report

General information
State: Published
Organisations: Operations Research, Department of Management Engineering
Authors: Hansen, A. D. (Intern), Christensen, S. G. (Ekstern), Rousøe, D. M. (Ekstern)
Publication date: 2005

Projects:

Electric Urban Freight And Logistics
Department of Management Engineering
Management Science
Transport DTU
Operations Research
Operations Management
MT Højgaard A/S
Region Hovedstaden
Period: 01/01/2018 → …
Number of participants: 5
Acronym: EUFAL
Project ID: 7064-00007B
Project participant:
Pacino, Dario (Intern)
Christensen, Jonas Mark (Intern)
Larsen, Allan (Intern)
Malladi, Satya Sarvani (Intern)
Barfod, Michael Bruhn (Intern)
Project

Beam-ME
The project aims at speeding up GAMS-based energy system models. The System Analysis group takes part in the project with the open source energy system model Balmorel.
FutureGas
An effective and economically efficient integration of gas, renewable based gas as well as natural gas, requires three issues to be fulfilled: 1) In an overall system context, gas should be integrated where the system benefits are highest; 2) Gas should be used optimally, that is where the economic net gains are largest taking into account the cost of possible conditioning; and 3) If needed then conditioning of gas should be carried out in the most cost-efficient way. Conditioning here refers to cleaning, upgrading, mixing and/or pressurising to achieve a desired gas quality. Of course, this reflects that the high value areas for gas utilization depend on how gas enters into the energy system. Thus, to find the most efficient and cost-competitive solutions it is crucial in an energy system perspective to address the need, possibilities and cost-effectiveness for conditioning gas to be injected into the gas grids and how different gases most economically and efficiently can be utilized. A central part of this project is therefore to model both renewables injected to the gas grid as well as alternative uses of gas in an overall system context.

The aim of the FutureGas project is twofold:
1) In an energy system context to facilitate the integration of the gas system with the power system, the district heating system and the transportation sector taking into account possible synergies. Despite the huge amounts of energy being transported through the gas grid, it is currently only loosely coupled to the rest of the energy system mainly through use of gas in CHP plants.
2) To facilitate a cost-efficient uptake of renewable gases, hereby in the longer term substituting natural gas and fossil fuels. A number of renewable gases exist, differing in their possible application in the energy system and in their costs and requirements for conditioning. The best and most cost-effective solutions for utilising and conditioning a variety of renewable gases depend on the development of the entire energy system.

In FutureGas these two issues will be looked into with regard to energy system integration, gas conditioning and, finally, economic/policy perspectives. To enable this, a novel modelling framework will be developed comprising the total energy system with an international market dimension and handling risk and uncertainty. Moreover, this new framework will facilitate combined modelling of the physical energy systems with markets and policy instruments. Thus this project has a truly interdisciplinary nature. The major part of the research will be concentrated on addressing the gas supply side on conditioning of RE gases and operation of the gas grid in combination with the demand side (CHP, industry and transport) all in a system context, on developing the gas dimension in advanced system modelling and, finally, on identifying the required policy and market structures for a successful implementation.

Thus the overall vision of FutureGas is to pave the way for an effective and cost-efficient transition to an energy system independent of fossil fuels, ensuring a strong integration of gas with the entire energy system, an economically optimal conversion to renewable gases substituting natural gas in the long run and good access to gas markets for a wide range
of gas producing technologies.

Department of Management Engineering
Systems Analysis
Energy Systems Analysis
Management Science
Operations Research
Energy Economics and Regulation
Novo Nordisk Foundation Center for Biosustainability
Aarhus University
Chalmers University of Technology
University of Exeter
Florence School of Regulation - European University Institute
Delft University of Technology
Danish Gas Technology Centre A/S
HMN Naturgas
Danish Energy Association
Dansk Gas Distribution
NGF Nature Energy
RAM-lose
EA Energy Analysis A/S
Hydrogen Denmark
PlanEnergi
Energinet.dk

Danish Energy Agency
Period: 01/02/2016 → 31/01/2020
Number of participants: 10
Project ID: 82524
Number of related Ph.D. students: 4
Project participant:
Pisinger, David (Intern)
Wiese, Frauke (Intern)
Sadegh, Negar (Intern)
Aryal, Nabin (Intern)
Phd Student:
Nielsen, Lise Skovsgaard (Intern)
Pedersen, Rasmus Bo Bramstoft (Intern)
Amirkhizi, Tara Sabbaghi (Intern)
Buchholz, Stefanie (Intern)
Project Manager, academic:
Morthorst, Poul Erik (Intern)
Münster, Marie (Intern)

Financing sources
Source: Other public support (public)
Name of research programme: Innovation Fund Denmark

Relations
Activities:
Rammebetingelser - biogas og andre VE-gasser

Project

**Mobilitetspotentiale for Aarhus Letbane**

Department of Management Engineering
Management Science
Transport DTU
Operations Management
Operations Research
Office for Finance and Accounting
Period: 01/01/2016 → 01/01/2017
Number of participants: 5
Project participant:
Barfod, Michael Bruhn (Intern)
Kronbak, Jacob (Intern)
Larsen, Rune (Intern)
Pedersen, Thomas Ross (Intern)
Olsen, Allan (Intern)

**Optimizing Transportation, Planning, and Scheduling Problems using Decomposition Algorithms**

Operations Research
Department of Management Engineering
Period: 01/01/2009 → 31/12/2010
Number of participants: 1
Project ID: 80951
Contact person:
Spoorendonk, Simon (Intern)

**Financing sources**
Source: Forskningsrådene - Andre
Name of research programme: Forskningsrådene - Andre
Amount: 1,500,000.00 Danish Kroner

Project

**Activities:**

9th International Conference on Computational Logistics - 2018 (Event)

Period: 2018
Dario Pacino (Member)
Department of Management Engineering
Management Science
Transport DTU
Operations Research

Description
PC Member
Degree of recognition: International

Related event

9th International Conference on Computational Logistics - 2018
**Preference scheduling for nurses under Danish legislation**

**Period:** 2018

Elin Björk Bödvarsdottir (Guest lecturer)

Department of Management Engineering

Management Science

Operations Research

**Related event**

**EURO 2018 conference on Operational Research**

09/07/2018 → 11/07/2018

Valencia, Spain

Activity: Talks and presentations › Conference presentations

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**A Hybrid Heuristic for the Flexible Ship Loading Problem**

**Period:** 19 Jun 2018

Dario Pacino (Guest lecturer)

Department of Management Engineering

Management Science

Transport DTU

Operations Research

**Description**

Improving container terminal productivity is a shared goal between carriers and terminal operators. The Flexible Ship Loading Problem investigates a collaboration between the carrier, which provides a class-based stowage plan, and the terminal. The latter now has the flexibility of determining the position of specific containers, while planning the handing operations. In this work, we present how such a problem can be modelled, and how a hybrid heuristic approach can be used to find high-quality solutions in short computational time.

Degree of recognition: International

**Related event**

**INFORMS International Conference2018: A BETTER WORLD THROUGH O.R., ANALYTICS, AND AI**

17/06/2018 → 20/06/2018

Taipei, Taiwan, Province of China

Activity: Talks and presentations › Conference presentations

---

**Integrated Planning in Railway Station Capacity Analysis**

**Period:** 31 May 2018

Richard Martin Lusby (Guest lecturer)

Department of Management Engineering

Management Science

Transport DTU

Operations Research

**Description**

Presented at the DTU Transport Summit 2018

Degree of recognition: International

Documents:

rlusby-ts2018

**Related organisation**
Integrated Planning in Railway Station Capacity Analysis
Lusby, R. M. (Guest lecturer)
31 May 2018
Activity: Talks and presentations › Conference presentations

Tramp ship routing and scheduling with voyage separation requirements
Period: 27 May 2018 → 30 May 2018
Jesper Larsen (Guest lecturer)
Charlotte Vilhelmsen (Guest lecturer)
Richard Martin Lusby (Guest lecturer)
Department of Management Engineering
Management Science
Transport DTU
Operations Research
Degree of recognition: International
Documents:
Abstract-Book-ALL-v2-0

Related event
ROUTE 2018: International Workshop on Vehicle Routing, Intermodal Transportation and Related Areas
27/05/2018 → 30/05/2018
Snekkersten, Denmark
Activity: Talks and presentations › Conference presentations

Danish Operations Research Society (DORS) (External organisation)
Period: 16 Mar 2018
Dario Pacino (Chairman)
Department of Management Engineering
Management Science
Transport DTU
Operations Research

Description
President
Degree of recognition: International

Related external organisation
Danish Operations Research Society (DORS)
Activity: Membership › Membership of committees, commissions, boards, councils, associations, organisations, or similar

Applied nurse rostering at Danish hospitals in Region Zealand
Period: 15 Dec 2017
Niels-Christian Fink Bagger (Guest lecturer)
Department of Management Engineering
Management Science
Operations Research

Related event
Healthcare logistics: balancing between practice and theory*
13/12/2017 → 15/12/2017
Activity: Talks and presentations › Conference presentations
A Simulation-based Markov Decision Process for the Scheduling of Operating Theatres
Period: 20 Sep 2017 → 22 Sep 2017
Anders Reenberg Andersen (Guest lecturer)
Department of Management Engineering
Management Science
Operations Research
Degree of recognition: International
Documents:
Abstract

Related event

European Conference on Stochastic Optimization 2017
20/09/2017 → 22/09/2017
Rom, Italy
Activity: Talks and presentations › Conference presentations

Investigation of consumer's behavior towards investments in household energy efficient appliances
Period: 13 Sep 2017 → 15 Sep 2017
Mattia Baldini (Speaker)
Alessio Trivella (Other)
Jordan William Halverson Wente (Other)
Department of Management Engineering
Systems Analysis
Management Science
Operations Research

Description

The previous EEDAL conferences have been very successful in attracting an international audience. EEDAL has established itself as an influential and recognised international event to discuss the progress achieved and latest developments in technologies, behavioural aspects and policies. EEDAL is the venue to establish new collaborations and synergies and build international partnerships among stakeholders.

Degree of recognition: International
Documents:
SAVEE
Links:
http://eedal2017.uci.edu/schedule/

Related event

9th International Conference on Energy Efficiency in Domestic Appliances and Lighting
13/09/2017 → 15/09/2017
Irvine, United States
Activity: Talks and presentations › Conference presentations

Using OR + AI to predict the optimal production of offshore wind parks: a preliminary study
Period: 6 Sep 2017
Martina Fischetti (Guest lecturer)
Department of Management Engineering
Description
In this paper we propose a new use of Machine Learning together with Mathematical Optimization. We investigate the question of whether a machine, trained on a large number of optimized solutions, can accurately estimate the value of the optimized solution for new instances. We focus on instances of a specific problem, namely, the offshore wind farm layout optimization problem. In this problem an offshore site is given, together with the wind statistics and the characteristics of the turbines that need to be built. The optimization wants to determine the optimal allocation of turbines to maximize the park power production, taking the mutual interference between turbines into account. Mixed Integer Programming models and other state-of-the-art optimization techniques, have been developed to solve this problem. Starting with a dataset of 2000+ optimized layouts found by the optimizer, we used supervised learning to estimate the production of new wind parks. Our results show that Machine Learning is able to well estimate the optimal value of offshore wind farm layout problems.

Related event
International Conference on Optimization and Decision Science
04/09/2017 → 07/09/2017
Activity: Talks and presentations › Conference presentations

INFORMS Healthcare 2017
Period: 26 Jul 2017 → 28 Jul 2017
Anders Reenberg Andersen (Guest lecturer)
Department of Management Engineering
Management Science
Operations Research
Degree of recognition: International

Related event
INFORMS Healthcare 2017: Optimizing Operations & Outcomes
26/07/2017 → 28/07/2017
Rotterdam, Netherlands
Activity: Talks and presentations › Conference presentations

Tramp ship routing and scheduling with voyage separation requirements
Period: 17 Jul 2017
Jesper Larsen (Guest lecturer)
Charlotte Vilhelmsen (Other)
Richard Martin Lusby (Other)
Department of Management Engineering
Management Science
Transport DTU
Operations Research

Description
This presentation addresses a tramp routing and scheduling problem. Tramp ships operate like taxies by following the available demand, as opposed to liner ships that operate like busses on a fixed route network according to a published timetable. Tramp operators determine some of the demand in advance by ensuring long-term contracts. The rest of the demand comes from optional voyages found in the spot market. Routing and scheduling a tramp feet to best utilize feet capacity according to the current demand is therefore an ongoing and complicated problem. We add further complexity by incorporating voyage separation requirements that enforce a minimum time spread between some voyages. We
developed a new and exact Branch-and-Price procedure for this problem. A dynamic programming algorithm generates columns, while a novel time window branching scheme is used to enforce the voyage separation requirements. Computational results show that the algorithm finds optimal solutions very quickly for the vast majority of test instances. We compare the results with two earlier published methods and show that our Branch-and-Price approach outperforms both an a priori path generation method and an Adaptive Large Neighbourhood Search heuristic.

Degree of recognition: International

Related event

IFORS 2017: 21st Conference of the International Federation of Operations and Research
17/07/2017 → 21/07/2017
Québec City, Canada
Activity: Talks and presentations › Conference presentations

Consumer’s Attitude Towards Investments in Residential Energy Efficient Appliances: how End-user Choices Contribute to Change Future Energy Systems
Period: 21 Jun 2017
Mattia Baldini (Speaker)
Alessio Trivella (Other)
Jordan William Halverson Wente (Other)
Department of Management Engineering
Systems Analysis
Management Science
Operations Research
Degree of recognition: International
Documents:
Mattia Baldini
Links:

Related event

The 40th IAEE International Conference: Meeting the Energy Demands of Emerging Economies - Implications for Energy and Environmental Markets
18/06/2017 → 21/06/2017
Singapore, Singapore
Activity: Talks and presentations › Conference presentations

A matheuristic approach for Integrated Timetabling and Vehicle Scheduling Problem
Period: 17 May 2017
Joao Filipe Paiva Fonseca (Speaker)
Roberto Roberti (Other)
Evelien van der Hurk (Other)
Allan Larsen (Guest lecturer)
Department of Management Engineering
Management Science
Operations Management
Operations Research
Degree of recognition: International
Documents:
Abstract_JoaoFonseca

Related event

Mini-Workshop on Integrated Timetabling
15/05/2017 → 17/05/2017
Goettingen, Germany
Daily Pattern Formulation and Valid Inequalities for the Curriculum-based Course Timetabling Problem  
Period: 2016  
Niels-Christian Fink Bagger (Guest lecturer)  
Guy Desaulniers (Guest lecturer)  
Jacques Desrosiers (Guest lecturer)  
Department of Management Engineering  
Management Science  
Operations Research  

Related event  
11th International Conference on the Practice and Theory of Automated Timetabling  
23/08/2016 → 26/08/2016  
Italy  

Planning of Midwives  
Period: 4 Jul 2016  
Charlotte Vilhelmsen (Speaker)  
Jesper Larsen (Other)  
Department of Management Engineering  
Management Science  
Operations Research  

Description  
At a hospital in Denmark around 40 midwives support the pregnancy of approx. 6000 pregnant women every year. Their role is to monitor the pregnancies and prepare the women for labour. Based on the due date of a woman, authority guidelines prescribe specific and mostly rather narrow time windows within which the pregnant woman should have consultations with a midwife. Therefore, once a pregnant woman enters the system, here sequence of consultations for the time period until labour is fairly fixed. There is a clear goal that, as far as possible, each pregnant woman should see the same midwife at every consultation. Every week the newly arrived pregnant women are assigned an arbitrary free time slot belonging to a specific midwife. In turn this midwife is expected to have consultations with this woman in specific weeks according to the authority guidelines. This random assignment of pregnant woman to specific midwives, without any concern to the midwives’ future schedules, means that each midwife has a very unbalanced workload over the year. Furthermore, it means that there is an imbalance between the workloads of the different midwives. The aim of this project is therefore to devise a method that can make a fair distribution of pregnant women among the midwives. The distribution should result in a balanced work load for each midwife and a balanced work load among the midwives while at the same time making sure that the time windows for consultations are not violated.  
Degree of recognition: International  

Related event  
28th European Conference on Operational Research  
03/07/2016 → 07/07/2016  
Poznan, Poland  

Optimization of Medical Bed Resources using Queueing Theory and Hill Climbing  
Period: 3 Jul 2016 → 6 Jul 2016  
Anders Reenberg Andersen (Guest lecturer)  
Department of Management Engineering  
Management Science  
Operations Research
Optimization of Medical Bed Resources using Queueing Theory and Hill Climbing
Period: 24 May 2016 – 25 May 2016
Anders Reenberg Andersen (Guest lecturer)
Department of Management Engineering
Management Science
Operations Research
Degree of recognition: National

Flow Formulation-based Model for the Curriculum-based Course Timetabling Problem
Period: 2015
Niels-Christian Fink Bagger (Guest lecturer)
Thomas Jacob Riis Stidsen (Guest lecturer)
Matias Sørensen (Guest lecturer)
Simon Kristiansen (Guest lecturer)
Department of Management Engineering
Management Science
Operations Research

A heuristic and hybrid method for the tank allocation problem in maritime bulk shipping
Period: 6 Mar 2014
Charlotte Vilhelmsen (Speaker)
Jesper Larsen (Other)
Richard Martin Lusby (Other)
Department of Management Engineering
Management Science
Operations Research
Transport DTU
Degree of recognition: International
Documents:
Tank_Allocation_Abstract
3rd International Symposium on Combinatorial Optimization
04/03/2014 → 07/03/2014
Lisbon, Portugal
Activity: Talks and presentations › Conference presentations

The Tank Allocation Problem in Bulk Shipping
Period: 27 Sep 2013
Charlotte Vilhelmsen (Speaker)
Jesper Larsen (Other)
Richard Martin Lusby (Other)
Department of Management Engineering
Management Science
Operations Research
Transport DTU
Degree of recognition: International
Documents:
The_Tank_Allocation_Problem

Related event

4th International Conference on Computational Logistics
25/09/2013 → 27/09/2013
Copenhagen, Denmark
Activity: Talks and presentations › Conference presentations

Routing and Scheduling in Tramp Shipping - Integrating Bunker Optimization
Period: 4 Sep 2013
Charlotte Vilhelmsen (Speaker)
Jesper Larsen (Other)
Richard Martin Lusby (Other)
Department of Management Engineering
Management Science
Operations Research
Degree of recognition: International

Related event

OR 2013 - International Conference on Operations Research
03/09/2013 → 06/09/2013
Rotterdam, Netherlands
Activity: Talks and presentations › Conference presentations

Discrete optimization support system for the collection grid in large offshore wind parks
Period: 2012
Niels-Christian Fink Bagger (Guest lecturer)
Michael Lindahl (Guest lecturer)
Department of Management Engineering
Management Science
Operations Research

Related event

5th Nordic Optimization Symposium
07/06/2012 → 09/12/2012
Trondheim, Norway
**Matematik i planlægning**
Period: 23 Apr 2010
Simon Spoorendonk (Speaker)
Department of Management Engineering
Operations Research

**Description**
Place: Forskningens Døgn, Øster Borgerdyd Gymnasium

**Unknown external organisation**

**Prizes:**

**Best Student Thesis 2013**
Niels-Christian Fink Bagger (Recipient)
Department of Management Engineering, Management Science, Operations Research

**Details**
Awarded date: 2013
Degree of recognition: National
Granting Organisations: DONG Energy A/S
Prize: Prizes, scholarships, distinctions

**Best Thesis in Operations Research 2013**
Niels-Christian Fink Bagger (Recipient)
Department of Management Engineering, Management Science, Operations Research

**Details**
Awarded date: 29 Apr 2013
Degree of recognition: National
Granting Organisations: Danish Operations Research Society (DORS)
event: DORS - General Assembly
Prize: Prizes, scholarships, distinctions

**Teacher of the Year 2018 at DTU Management Engineering**
Charlotte Vilhelmsen (Recipient)
Department of Management Engineering, Management Science, Operations Research

**Details**
Awarded date: 3 May 2018
Degree of recognition: Local
Granting Organisations: Study board at DTU Management Engineering
event: DTU Management Engineering mini-conference
Prize: Prizes, scholarships, distinctions

**Press clippings:**

**Problemknuser i verdensklasse**
Simon Spoorendonk
09/12/2009
Department of Management Engineering, Operations Research

**Media contribution (1)**
Problemknuser i verdensklasse
09/12/2009
Print
EXT-OA
Simon Spoorendonk
Department of Management Engineering, Operations Research
Press / Media

Sporbarhed skal give værditilvækst
Toke Koldborg Jensen
11/02/2009
Department of Management Engineering, Operations Research

Media contribution (1)

Sporbarhed skal give værditilvækst
11/02/2009
DTU, Lyngby, Print
http://www.dtu.dk/centre/FoodDTU/FoodDTU_-_Midt_i_ugen/Midt_76_090211.aspx
DOC-OA
Toke Koldborg Jensen
Department of Management Engineering, Operations Research
Press / Media