A comparative study of time aggregation techniques in relation to power capacity expansion modeling

In this paper, we studied the aggregation techniques for power capacity expansion problems. Combining a growing demand for green energy with a hard constraint on demand satisfaction causes system flexibility to be a major challenge in designing a stable energy system. To determine both the need for flexibility and which technologies that could satisfy these needs at minimum cost, the system should be analyzed on an hour-by-hour scale for a long period of time. This often leads to computationally intractable problems. One way of getting more tractable models is to aggregate the time domain. Many different aggregation techniques have been developed, all with a common goal of selecting representative time slices to be used instead of the full time scale, gaining a problem size reduction in the number of variables and/or constraints. The art of aggregation is to balance the computational difficulty against the solution quality, making validation of the techniques crucial. We propose new aggregation techniques and compare these to each other and to a selection of aggregation techniques from the literature. We validate the aggregated problems against the non-aggregated problems and look into the sensitivity of the performance of the aggregation techniques to different data sets and to the selection of different element types. Our analysis shows that aggregation techniques can be used to achieve very good solutions in a short amount of time, and that simple aggregation techniques achieve good performance similar to that of techniques with higher complexity. Even though the aggregation techniques in this paper are applied to power capacity expansion models, the methodology can be used for other problems with similar time dependence, and we believe that results in agreement with the results seen here, would be achieved.
An adaptive large neighborhood search metaheuristic for the vehicle routing problem with drones
Unmanned Aerial Vehicles, commonly known as drones, have attained considerable interest in recent years due to the potential of revolutionizing transport and logistics. Amazon were among the first to introduce the idea of using drones to deliver goods, followed by several other distribution companies working on similar services. The Traveling Salesman Problem, frequently used for planning last-mile delivery operations, can easily be modified to incorporate drones, resulting in a routing problem involving both the truck and aircraft. Introduced by Murray and Chu (2015), the Flying Sidekick Traveling Salesman Problem considers a drone and truck collaborating. The drone can be launched and recovered at certain visits on the truck route, making it possible for both vehicles to deliver goods to customers in parallel. This generalization considerably decreases the operational cost of the routes, by reducing the total fuel consumption for the truck, as customers on the routes can be serviced by drones without covering additional miles for the trucks, and hence increase productivity. In this paper a mathematical model is formulated, defining a problem similar to the Flying Sidekick Traveling Salesman Problem, but for the capacitated multiple-truck case with time limit constraints and minimizing cost as objective function. The corresponding problem is denoted the Vehicle Routing Problem with Drones. Due to the difficulty of solving large instances to optimality, an Adaptive Large Neighborhood Search metaheuristic is proposed. Finally, extensive computational experiments are carried out. The tests investigate, among other things, how beneficial the inclusion of the drone-delivery option is compared to delivering all items using exclusively trucks. Moreover, a detailed sensitivity analysis is performed on several drone-parameters of interest.
**Green Liner Shipping Network Design**

Green Liner Shipping Network Design refers to the problems in green logistics related to the design of maritime services in liner shipping with a focus on reducing the environmental impact. This chapter discusses how to more efficiently plan the vessel services with the use of mathematical optimization models. A brief introduction to the main characteristics of Liner Shipping Network Design is given, as well as the different variants and assumptions that can be considered when defining this problem. The chapter also includes an overview of the algorithms and approaches that have been presented in the literature to design such networks.

**Mathematical Optimization and Algorithms for Offshore Wind Farm Design: An Overview**

Wind energy is a fast evolving field that has attracted a lot of attention and investments in the last decades. Being an increasingly competitive market, it is very important to minimize establishment costs and increase production profits already at the design phase of new wind parks. This paper is based on many years of collaboration with Vattenfall, a leading wind energy developer and wind power operator, and aims at giving an overview of the experience of using Mathematical Optimization in the field. The paper illustrates some of the practical needs defined by energy companies, showing how optimization can help the designers to increase production and reduce costs in the design of offshore parks. In particular, the study gives an overview of the individual phases of designing an offshore wind farm, and some of the optimization problems involved. Finally it goes in depth with three of the most important optimization tasks: turbine location, electrical cable routing and foundation optimization. The paper is concluded with a discussion of future challenges.
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.
Decomposition algorithms for the multi-modal ridesharing routing problem

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Large Neighborhood Search
In the last 15 years, heuristics based on large neighborhood search (LNS) and the variant adaptive large neighborhood search (ALNS) have become some of the most successful paradigms for solving various transportation and scheduling problems. Large neighborhood search methods explore a complex neighborhood through the use of heuristics. Using large neighborhoods makes it possible to find better candidate solutions in each iteration and hence follow a more promising search path. Starting from the general framework of large neighborhood search, we study in depth adaptive large neighborhood search, discussing design ideas and properties of the framework. Application of large neighborhood search methods in routing and scheduling are discussed. We end the chapter by presenting the related framework of very large-scale neighborhood search (VLSN) and discuss parallels to LNS, before drawing some conclusions about algorithms exploiting large neighborhoods.

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.

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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.

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 illustrate 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.
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.
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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Optimizing wind farm cable routing considering power losses
Wind energy is the fastest growing source of renewable energy, but as wind farms are getting larger and more remotely located, installation and infrastructure costs are rising. It is estimated that the expenses for electrical infrastructure account for 15-30% of the overall initial costs, hence it is important to optimize land inter-array cable routing. The routing should connect all turbines to one (or more) o shore sub-station(s) while respecting cable capacities, no-cross restrictions, connection-limits at the substation, and obstacles at the site. The objective is to minimize both the capital that must be spent immediately in cable and installation costs, and the future reduced revenues due to power losses. The latter goal has not been addressed in previous work. We present a Mixed-Integer Linear Programming approach to optimize the routing using both exact and math-heuristic methods. In the power losses computation, wind scenarios are handled eciently as part of the preprocessing, resulting in a MIP model of only slightly larger size. A library of real-life instances is introduced and made publicly available for benchmarking. Computational results on this testbed show the viability of our methods, proving that savings in the order of millions of Euro can be achieved.

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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.

The project was partly funded by the EU-project EWTC-II.
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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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.

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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.

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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.

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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.

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**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.

**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.
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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Optimizing the supply chain of biomass and biogas for a single plant considering mass and energy losses

The share of renewable energy in the Danish energy sector is increasing and the goal is that biogas production should reach a production level of 17 petajoules (PJ) in 2020 according to the Danish Energy Agency. However, this goal is currently not reachable due to lack of investments in biogas plants. In this paper, a mixed integer programming (MIP) model for finding the optimal production and investment plan for a biogas supply chain is presented to ensure better economy for the full chain hopefully stimulating future investments in biogas. The model makes use of step-wise linear functions to represent capital and operational expenditures at the biogas plant; considers the chain from the farmer to the end market; and includes changes of mass and energy content along the chain by modeling the losses and gains for all processes in the chain. Biomass inputs are scheduled on a weekly basis whereas energy outputs are scheduled on an hourly basis to better capture the changes of energy prices and potentially take advantage of these changes. The model is tested on a case study with co-digestion of straw, sugar beet and manure, considering natural gas, heat, and electricity as end products. The model finds a production and investment plan for a predefined location of the plant within half an hour of central processing unit (CPU) time. The resulting project turns out to be profitable and gives a production plan for each process, which underlines the possibilities of optimizing the processes in a biogas project.

General information
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.

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Integrating load-balancing into multi-dimensional bin-packing problems

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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.
Optimization of the drayage problem using exact methods

Major liner shipping companies offer pre- and end-haulage as part of a door-to-door service, but unfortunately pre- and end-haulage is frequently one of the major bottlenecks in efficient liner shipping due to the lack of coordination between customers. In this paper, we apply techniques from vehicle routing problems to schedule pre- and end-haulage of containers, and perform tests on data from a major liner shipping company. The paper considers several versions of the scheduling problem such as having multiple empty container depots, and having to balance the empty container depot levels. The influence of the side constraints on the overall cost is analysed. By exploring the fact that the number of possible routes in the considered case is quite limited, we show that the model can be solved within a minute by use of column enumeration. Alternative constraints and problem formulations, such as balancing empty container storage level at depots, are considered. Computational results are reported on real-life data from a major liner shipping company.

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Optimizing wind farm cable routing considering power losses

Wind energy is the fastest growing source of renewable energy, but as wind farms are getting larger and more remotely located, installation and infrastructure costs are rising. It is estimated that the expenses for electrical infrastructure account for 15-30% of the overall initial costs, hence it is important to optimize o shore inter-array cable routing. The routing should connect all turbines to one (or more) o shore sub-station(s) while respecting cable capacities, no-cross restrictions, connection-limits at the substation, and obstacles at the site. The objective is to minimize both the capital that must be spent immediately in cable and installation costs, and the future reduced revenues due to power losses. The latter goal has not been addressed in previous work. We present a Mixed-Integer Linear Programming approach to optimize the routing using both exact and math-heuristic methods. In the power losses computation, wind scenarios are handled eciently as part of the preprocessing, resulting in a MIP model of only slightly larger size. A library of real-life instances is introduced and made publicly available for benchmarking. Computational results on this testbed show the viability of our methods, proving that savings in the order of millions of Euro can be achieved.
The Edge Set Cost of the Vehicle Routing Problem with Time Windows

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 investments impose a cost for the company while they also give unlimited usage of a set of roads to all vehicles belonging to the company. This violates the traditional assumption that the path between two destinations is well defined and independent of other choices. Different versions for defining the edge sets are discussed and formulated. Both the multigraph case and the direct path case are described, and mixed-integer-programming formulations of the problem are presented for both cases. A solution method based on branch-price-and-cut is applied to the direct path case. The computational results show that instances with up to 40 customers can be solved in a reasonable time, and that the branch-cut-and-price algorithm generally outperforms CPLEX.

The liner shipping berth scheduling problem with transit times

In this paper speed optimization of an existing liner shipping network is solved by adjusting the port berth times. The objective is to minimize fuel consumption while retaining the customer transit times including the transhipment times. To avoid too many changes to the time table, changes of port berth times are only accepted if they lead to savings above a threshold value. Since the fuel consumption of a vessel is a non-linear convex function of the speed, it is approximated by a piecewise linear function. The developed model is solved using exact methods in less than two minutes for large instances. Computational experiments on real-size liner shipping networks are presented showing that fuels savings in the magnitude 2–10% can be obtained. The work has been carried out in collaboration with Maersk Line and the tests...
instances are confirmed to be representative of real-life networks.

The load-balanced multi-dimensional bin-packing problem

The bin-packing problem is one of the most investigated and applicable combinatorial optimization problems. In this paper we consider its multi-dimensional version with the practical extension of load balancing, i.e. to find the packing requiring the minimum number of bins while ensuring that the average center of mass of the loaded bins falls as close as possible to an ideal point, for instance, the center of the bin. We formally describe the problem using mixed-integer linear programming models, from the simple case where we want to optimally balance a set of items already assigned to a single bin, to the general balanced bin-packing problem. Given the difficulty for standard solvers to deal even with small size instances, a multi-level local search heuristic is presented. The algorithm takes advantage of the Fekete-Schepers representation of feasible packings in terms of particular classes of interval graphs, and iteratively improves the load balancing of a bin-packing solution using different search levels. The first level explores the space of transitive orientations of the complement graphs associated with the packing, the second modifies the structure itself of the interval graphs, the third exchanges items between bins repacking proper n-tuples of weakly balanced bins. Computational experiments show very promising results on a set of 3D bin-packing instances from the literature.
A combined stochastic programming and optimal control approach to personal finance and pensions

The paper presents a model that combines a dynamic programming (stochastic optimal control) approach and a multi-stage stochastic linear programming approach (SLP), integrated into one SLP formulation. Stochastic optimal control produces an optimal policy that is easy to understand and implement. However, explicit solution may not exist, especially when we want to deal with constraints, such as the limits on the portfolio composition, the limits on the insured sum, an inclusion of transaction costs or taxes on capital gains, which are important issues regularly mentioned in the scientific literature. Two applications are considered: (A) optimal investment, consumption and insured sum for an individual maximizing the expected utility of consumption and bequest, and (B) optimal investment for a pension saver who wishes to maximize the expected utility of retirement benefits. Numerical results show that among the considered practical constraints, the presence of taxes affects the optimal controls the most. Furthermore, the individual's preferences, such as impatience level and risk aversion, have even a higher impact on the controlled processes than the taxes on capital gains.

A Matheuristic for the Liner Shipping Network Design Problem with Transit Time Restrictions

We present a mathematical model for the liner shipping network design problem with transit time restrictions on the cargo flow. We extend an existing matheuristic for the liner shipping network design problem to consider transit time restrictions. The matheuristic is an improvement heuristic, where an integer program is solved iteratively as a move operator in a large-scale neighborhood search. To assess the effects of insertions/removals of port calls, flow and revenue changes are estimated for relevant commodities along with an estimation of the change in the vessel cost. Computational results on the benchmark suite LINER-LIB are reported, showing profitable networks for most instances. We provide insights on causes for rejecting demand and the average speed per vessel class in the solutions obtained.
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 sailings 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.

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**Optimal annuity portfolio under inflation risk**

The paper investigates the importance of inflation-linked annuities to individuals facing inflation risk. Given the investment opportunities in nominal, real, and variable annuities, as well as cash and stocks, we investigate the consumption and investment decisions under two different objective functions:
1) maximization of the expected CRRA utility function, and 2) minimization of squared deviations from an inflation-adjusted target. To find the optimal decisions we apply a multi-stage stochastic programming approach. Our findings indicate that independently of the considered objective function and risk aversion, real annuities are a crucial asset in every portfolio. In addition, without investing in real annuities, the retiree has to rebalance the portfolio more frequently, and still obtains the lower and more volatile real consumption.

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**Simultaneously Recovering Rolling Stock Schedules and Depot Plans Under Disruption**

In this paper we consider two important railway optimization problems. In particular, we focus on the Rolling Stock Rescheduling problem and the Depot Replanning problem, respectively. We present an integrated framework for solving these two problems simultaneously, and show that it is fast enough to be applied in a disruption recovery setting. Furthermore, we provide a comparison of several solution strategies to the Train Unit Parking Problem, and, by way of an
example prove the heuristic nature of a previously proposed optimal approach. We analyse the performance of the proposed methodology on a number of artificial data sets as well as several real-life case studies provided by DSB Stog, a suburban train operator in the greater Copenhagen area.

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. As a novelty 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 transshipments 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.

Solving the Liner Shipping Fleet Repositioning Problem with Cargo Flows
We solve a central problem in the liner shipping industry called the liner shipping fleet repositioning problem (LSFRP). The LSFRP poses a large financial burden on liner shipping firms. During repositioning, vessels are moved between routes in a liner shipping network. Liner carriers wish to reposition vessels as cheaply as possible without disrupting cargo flows. The LSFRP is characterized by chains of interacting activities with a multicommodity flow over paths defined by the activities chosen. Despite its industrial importance, the LSFRP has received little attention in the literature. We introduce a novel mathematical model and a simulated annealing algorithm for the LSFRP with cargo flows that makes use of a carefully constructed graph; we evaluate these approaches using real-world data from our industrial collaborator. Additionally, we compare the performance of our approach against an actual repositioning scenario, one of many undertaken by our industrial collaborator in 2011. Our simulated annealing algorithm is able to increase the profit from $18.1 to $31.8 million using only a few minutes of CPU time. This shows that our algorithm could be used in a decision support system to solve the LSFRP.
Speed Optimization in Liner Shipping Network Design

In the Liner Shipping Network Design Problem (LSNDP) services sail at a given speed throughout a round trip. In reality most services operate with a speed differentiated head- and back-haul, or even individual speeds on every sailing between two ports. The speed of a service is decisive for the bunker consumption in the network as well as the transit time of cargo. Speed optimization has been considered for tramp shipping showing significant reductions in fuel consumption. However, variable speeds has not been considered for post optimization of the LSNDP, where speed optimization could result in changes to the cargo flow due to transit time restrictions as well as significant savings in fuel consumption and required vessel deployment due to a weekly frequency requirement. We present a heuristic method to calculate variable speed on a service and present computational results for improving a solution of the LSNDP with average speeds to a solution with variable speed. We analyze the results according to transit time, fuel consumption and vessel deployment.

The time constrained multi-commodity network flow problem and its application to liner shipping network design

The multi-commodity network flow problem is an important sub-problem in several heuristics and exact methods for designing route networks for container ships. The sub-problem decides how cargoes should be transported through the network provided by shipping routes. This paper studies the multi-commodity network flow problem with transit time constraints which puts limits on the duration of the transit of the commodities through the network. It is shown that for the particular application it does not increase the solution time to include the transit time constraints and that including the transit time is essential to offer customers a competitive product. © 2015 Elsevier Ltd. All rights reserved.
The liner-shipping network design problem is to create a set of nonsimple cyclic sailing routes for a designated fleet of container vessels that jointly transports multiple commodities. The objective is to maximize the revenue of cargo transport while minimizing the costs of operation. The potential for making cost-effective and energy-efficient liner-shipping networks using operations research (OR) is huge and neglected. The implementation of logistic planning tools based upon OR has enhanced performance of airlines, railways, and general transportation companies, but within the field of liner shipping, applications of OR are scarce. We believe that access to domain knowledge and data is a barrier for researchers to approach the important liner-shipping network design problem. The purpose of the benchmark suite and the paper at hand is to provide easy access to the domain and the data sources of liner shipping for OR researchers in general. We describe and analyze the liner-shipping domain applied to network design and present a rich integer programming model based on services that constitute the fixed schedule of a liner shipping company. We prove the liner-shipping network design problem to be strongly NP-hard. A benchmark suite of data instances to reflect the business structure of a global liner shipping network is presented. The design of the benchmark suite is discussed in relation to industry standards, business rules, and mathematical programming. The data are based on real-life data from the largest global liner-shipping company, Maersk Line, and supplemented by data from several industry and public stakeholders. Computational results yielding the first best known solutions for six of the seven benchmark instances is provided using a heuristic combining tabu search and heuristic column generation.
A branch-and-cut algorithm for the capacitated profitable tour problem

This paper considers the Capacitated Profitable Tour Problem (CPTP) which is a special case of the Elementary Shortest Path Problem with Resource Constraints (ESPPRC). The CPTP belongs to the group of problems known as traveling salesman problems with profits. In CPTP each customer is associated with a profit and a demand and the objective is to find a capacitated tour (rooted in a depot node) that minimizes the total travel distance minus the profit of the visited customers. The CPTP can be recognized as the sub-problem in many column generation applications, where it is traditionally solved through dynamic programming. In this paper we present an alternative framework based on a formulation for the undirected CPTP and solved through branch-and-cut. Valid inequalities are presented among which we introduce a new family of inequalities for the CPTP denoted rounded multistar inequalities and we prove their validity. Computational experiments are performed on a set of instances known from the literature and a set of newly generated instances. The results indicate that the presented algorithm is highly competitive with the dynamic programming algorithms. In particular, we are able to solve instances with 800 nodes to optimality where the dynamic programming algorithms cannot solve instances with more than 200 nodes. Moreover dynamic programming and branch-and-cut complement each other well, giving us hope for solving more general problems through hybrid approaches. The paper is intended to serve as a platform for further development of branch-and-cut algorithms for CPTP hence also acting as a survey/tutorial.

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A Branch-and-Price Framework for Railway Rolling Stock Rescheduling During Disruptions

Rescheduling rolling stock during a disruption is a passenger railway optimization problem. In current practice this is typically optimized manually despite the high complexity and high runtime requirements of the task. In this paper we propose a path-based mathematical formulation that is solved using column generation in a complete Branch-and-Price framework. In contrast to flow-based approaches our formulation is more easily extended to handle certain families of constraints, such as train unit maintenance restrictions. We benchmark the framework against real-life instances provided by the suburban railway operator in Copenhagen (DSB S-tog). In combination with a lower bound method we show that near-optimal solutions can be found within a few seconds during a disruption. In addition we show that framework is also able to find solution within a few minutes for non-disturbed timetables.

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A matheuristic for the liner shipping network design problem

We present a matheuristic, an integer programming based heuristic, for the liner shipping network design problem. This problem consists of finding a set of container shipping routes defining a capacitated network for cargo transport. The objective is to maximize the revenue of cargo transport, while minimizing the cost of operating the network. Liner shipping companies publish a set of routes with a time schedule, and it is an industry standard to have a weekly departure at each port call on a route. A weekly frequency is achieved by deploying several vessels to a single route, respecting the available fleet of container vessels. The cargo transports make extensive use of transshipments between routes and the number of transshipments of the cargo flow is decisive for network profitability. Computational results are reported for the benchmark suite LINER-LIB 2012 following the industry standard of weekly departures on every schedule. The heuristic shows overall good performance and is able to find high quality solutions within competitive execution times. The matheuristic can also be applied as a decision support tool to improve an existing network by optimizing on a designated subset of the routes. A case study is presented for this approach with very promising results.

A matheuristic for the liner shipping network design problem

We present a matheuristic, an integer programming based heuristic, for the liner shipping network design problem. This problem consists of finding a set of container shipping routes defining a capacitated network for cargo transport. The objective is to maximize the revenue of cargo transport, while minimizing the cost of operating the network. Liner shipping companies publish a set of routes with a time schedule, and it is an industry standard to have a weekly departure at each port call on a route. A weekly frequency is achieved by deploying several vessels to a single route, respecting the available fleet of container vessels. The matheuristic is composed of four main algorithmic components: a construction heuristic, an improvement heuristic, a reininsertion heuristic, and a perturbation heuristic. The improvement heuristic uses an integer program to select a set of improving port insertions and removals on each service. Computational results are reported for the benchmark suite LINER-LIB 2012 following the industry standard of weekly departures on every schedule. The matheuristic can also be applied as a decision support tool to improve an existing network by optimizing on a designated subset of the routes. A case study is presented for this approach with very promising results.
A matheuristic for the liner shipping network design problem considering transit time restrictions

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Global liner shipping is a competitive industry, requiring liner carriers to carefully deploy their vessels efficiently to construct a cost competitive network. This paper presents a novel compact formulation of the liner shipping network design problem (LSNDP) based on service flows. The formulation alleviates issues faced by arc flow formulations with regards to handling multiple calls to the same port. A problem which has not been fully dealt with earlier by LSNDP formulations. Multiple calls are handled by introducing service nodes, together with port nodes in a graph representation of the problem, and by introducing numbered arcs between a port and a novel service node. An arc from a port node to a service node indicate whether a service is calling the port or not. This representation allows recurrent calls of a service to a port, which previously could not be handled by LSNDP models. The model ensures strictly weekly frequencies of services, ensures that port-vessel draft capabilities are not violated, respects vessel capacities and the number of vessels available. The profit of the generated network is maximized, i.e. the revenue of flowed cargo subtracted operational costs of the network and a penalty for not flowed cargo. The model can be used to design liner shipping networks to utilize a container carrier’s assets efficiently and to investigate possible scenarios of changed market conditions. The model is solved as a Mixed Integer Program. Results are presented for the two smallest instances of the benchmark suite LINER-LIB-2012 presented in Brouer, Alvarez, Plum, Pisinger, and Sigurd (2013).

A service flow model for the liner shipping network design problem

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Global liner shipping is a competitive industry, requiring liner carriers to carefully deploy their vessels efficiently to construct a cost competitive network. This paper presents a novel compact formulation of the liner shipping network design problem (LSNDP) based on service flows. The formulation alleviates issues faced by arc flow formulations with regards to handling multiple calls to the same port. A problem which has not been fully dealt with earlier by LSNDP formulations. Multiple calls are handled by introducing service nodes, together with port nodes in a graph representation of the problem, and by introducing numbered arcs between a port and a novel service node. An arc from a port node to a service node indicate whether a service is calling the port or not. This representation allows recurrent calls of a service to a port, which previously could not be handled by LSNDP models. The model ensures strictly weekly frequencies of services, ensures that port-vessel draft capabilities are not violated, respects vessel capacities and the number of vessels available. The profit of the generated network is maximized, i.e. the revenue of flowed cargo subtracted operational costs of the network and a penalty for not flowed cargo. The model can be used to design liner shipping networks to utilize a container carrier’s assets efficiently and to investigate possible scenarios of changed market conditions. The model is solved as a Mixed Integer Program. Results are presented for the two smallest instances of the benchmark suite LINER-LIB-2012 presented in Brouer, Alvarez, Plum, Pisinger, and Sigurd (2013).
**Bunker purchasing with contracts**

The cost for bunker fuel represents a major part of the daily running costs of liner shipping vessels. The vessels, sailing on a fixed roundtrip of ports, can lift bunker at these ports, having differing and fluctuating prices. The stock of bunker on a vessel is subject to a number of operational constraints such as capacity limits, reserve requirements and sulphur content. Contracts are often used for bunker purchasing, ensuring supply and often giving a discounted price. A contract can supply any vessel in a period and port, and is thus a shared resource between vessels, which must be distributed optimally to reduce overall costs. The Bunker Purchasing with Contracts Problem has been formulated as a mixed integer programme, which has been Dantzig-Wolfe decomposed. To solve it, a novel column generation algorithm has been developed. The algorithm has been run on a series of real-world instances with up to 500+ vessels and 500+ contracts, and provide near optimal solutions. This makes it possible for a major liner shipping company to plan bunker purchasing on a global level, and provides an efficient tool for assessing new contracts.

**Optimal retirement planning with a focus on single and multilife annuities**

We optimize the asset allocation, consumption and bequest decisions of an investor with uncertain lifetime and under time-varying investment opportunities. The asset menu is given by stocks, zero coupon bonds and pure endowments with different maturities. The latter are contingent on either a single or a joint life, and pay fixed or variable benefits. We further include transaction costs on stocks and bonds, and surrender charges on pure endowments. We show that despite high surrender charges, annuities are the primary asset class in a portfolio, and that annuity income is never fully consumed, but used for rebalancing purposes. We argue that the optimal retirement product for a household is much more complex than any of those available in the market. Every household should be offered an annuity tailored to its needs, using a unique combination of assets and mortality protection levels.
Single liner shipping service design
The design of container shipping networks is an important logistics problem, involving assets and operational costs measured in billions of dollars. To guide the optimal deployment of the ships, a single vessel round trip is considered by minimizing operational costs and flowing the best paying demand under commercially driven constraints. This paper introduces the Single Liner Shipping Service Design Problem. Arc-flow and path-flow models are presented using state-of-the-art elements from the wide literature on pickup and delivery problems. A Branch-and-Cut-and-Price algorithm is proposed, and implementation details are discussed. The algorithm can solve instances with up to 25 ports to optimality, a very promising result as real-world vessel roundtrips seldom involve more than 20 ports. © 2013 Elsevier Ltd.
An algorithm for solving the time-constrained multicommodity flow problem with applications in liner shipping network design

The liner shipping network design problem has proven to be hard to solve. However, well-designed route nets are paramount to liner shipping companies both in terms of competitiveness and environmental impact. Fast evaluations of the multicommodity flow subproblem is one of the bottlenecks when determining the optimal routing and fleet deployment in the network design problem. Additionally, most existing models do not consider the level of service. To accommodate that, we present an algorithm for solving the multicommodity flow subproblem with limits on commodity travel time.

Competitive Liner Shipping Network Design

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Integrated Job Scheduling and Network Routing

We consider an integrated job scheduling and network routing problem which appears in Grid Computing and production planning. The problem is to schedule a number of jobs at a finite set of machines, such that the overall profit of the executed jobs is maximized. Each job demands a number of resources which must be sent to the executing machine through a network with limited capacity. A job cannot start before all of its resources have arrived at the machine. The scheduling problem is formulated as a Mixed Integer Program (MIP) and proved to be NP-hard. An exact solution approach using Dantzig-Wolfe decomposition is presented. The pricing problem is the linear multicommodity flow problem defined on a time-space network. Branching strategies are presented for the branch-and-price algorithm and three heuristics and an exact solution method are implemented for finding a feasible start solution. Finally, interior point stabilization is used to decrease the number of columns generated in the branch-and-price algorithm. The algorithm is experimentally evaluated on job scheduling instances for a Grid network. The Dantzig-Wolfe algorithm with stabilization is clearly superior, being able to solve large instances with 1,000 jobs and 1,000 machines covering 24 hours of scheduling activity on a Grid network. The algorithm is also compared to simulations of a real-life Grid, and results show that the solution quality significantly increases when solving the problem to optimality. The promising results indicate that the algorithm can be used as an actual scheduling algorithm in the Grid or as a tool for analyzing Grid performance when adding extra machines or jobs. © 2012 Wiley Periodicals, Inc.
Separation and Extension of Cover Inequalities for Conic Quadratic Knapsack Constraints with Generalized Upper Bounds

Motivated by addressing probabilistic 0-1 programs we study the conic quadratic knapsack polytope with generalized upper bound (GUB) constraints. In particular, we investigate separating and extending GUB cover inequalities. We show that, unlike in the linear case, determining whether a cover can be extended with a single variable is NP-hard. We describe and compare a number of exact and heuristic separation and extension algorithms which make use of the structure of the constraints. Computational experiments are performed for comparing the proposed separation and extension algorithms. These experiments show that a judicious application of the extended GUB cover cuts can reduce the solution time of conic quadratic 0-1 programs with GUB constraints substantially. © 2013 INFORMS.

Single string planning problem arising in liner shipping industries: A heuristic approach

We propose an efficient heuristic approach for solving instances of the Single String Planning Problem (SSPP) arising in the liner shipping industry. In the SSPP a Liner Service Provider (LSP) only revises one of its many operational strings, and it is assumed that the other strings are unchangeable. A string is a service route composed of a sequence of port calls—a call is a visit to a port followed by loading/unloading operations made by a vessel. In a string the vessel's round trip terminates at the same port that it started from, and the port calls follow a published itinerary. The SSPP is regularly encountered by all LSPs, and a major part of their seasonal network planning process is devoted to repeatedly solving SSPP for different regions using experts' knowledge. Despite the practical importance of the problem, very little has been written about it in the literature. A revision is carried out in the form of a controlled re-sequencing, insertion and elimination of ports from along the current string, given a set of ports limited to those that exist on the string and a set of potential ones. The outcome determines the required capacity, service level (frequency), call sequence, etc., corresponding to the LSP's seasonal strategy. Exact decomposition methods are limited and can solve only very small size instances—small in
terms of the number of ports, vessel classes, vessel number and commodities. In contrast, the proposed heuristic method is an efficient approach for obtaining high quality and practical solutions to real-size instances in significantly less computational time.

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Organisations: Department of Management Engineering, Management Science, Artois University, Universite Blaise Pascal, Université Blaise Pascal, Clermont-Ferrand II, Universidade Federal do Rio de Janeiro
Contributors: Gelareh, S., Neamatian Monemi, R., Mahey, P., Maculan, N., Pisinger, D.
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Web of Science (2013): Impact factor 1.718
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Original language: English
Keywords: Liner shipping, Maritime, Network design, Metaheuristic
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Source ID: n::oai:DTIC-ART:elsevier/387815656::29104
Research output: Contribution to journal › Journal article – Annual report year: 2013 › Research › peer-review

Synchronized dial-a-ride transportation of disabled passengers at airports

The largest airports have a daily average throughput of more than 500 passengers with reduced mobility. The problem of transporting these passengers is in some cases a multi-modal transportation problem with synchronization constraints. A description of the problem together with a mathematical model is presented. The objective is to schedule 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 show 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 10 minutes.

General information
Publication status: Published
Organisations: Management Science, Department of Management Engineering
Contributors: Reinhardt, L. B., Clausen, T., Pisinger, D.
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Publication date: 2013
Peer-reviewed: Yes

Publication information
Journal: European Journal of Operational Research
Volume: 225
Issue number: 1
ISSN (Print): 0377-2217
Ratings:
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Scopus rating (2013): CiteScore 3.25 SJR 2.238 SNIP 2.67
Web of Science (2013): Impact factor 1.843
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Original language: English
The Rolling Stock and Depot Recovery Problem

**General information**

Publication status: Published

Organisations: Department of Management Engineering, Management Science

Contributors: Haahr, J. T., Lusby, R. M., Larsen, J., Pisinger, D.

Number of pages: 5

Publication date: 2013

Peer-reviewed: Yes

Event: Paper presented at Eighth Triennial Symposium on Transportation Analysis, San Pedro de Atacama, Chile.

Electronic versions:

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Research output: Contribution to conference › Paper – Annual report year: 2013 › Research › peer-review

The Vessel Schedule Recovery Problem (VSRP) – A MIP model for handling disruptions in liner shipping

Containerized transport by liner shipping companies is a multi billion dollar industry carrying a major part of the world trade between suppliers and customers. The liner shipping industry has come under stress in the last few years due to the economic crisis, increasing fuel costs, and capacity outgrowing demand. The push to reduce CO2 emissions and costs have increasingly committed liner shipping to slow-steaming policies. This increased focus on fuel consumption, has illuminated the huge impacts of operational disruptions in liner shipping on both costs and delayed cargo. Disruptions can occur due to adverse weather conditions, port contingencies, and many other issues. A common scenario for recovering a schedule is to either increase the speed at the cost of a significant increase in the fuel consumption or delaying cargo. Advanced recovery options might exist by swapping two port calls or even omitting one. We present the Vessel Schedule Recovery Problem (VSRP) to evaluate a given disruption scenario and to select a recovery action balancing the trade off between increased bunker consumption and the impact on cargo in the remaining network and the customer service level.

It is proven that the VSRP is NP-hard. The model is applied to four real life cases from Maersk Line and results are achieved in less than 5seconds with solutions comparable or superior to those chosen by operations managers in real life. Cost savings of up to 58% may be achieved by the suggested solutions compared to realized recoveries of the real life cases.

**General information**

Publication status: Published

Organisations: Department of Management Engineering, Management Science

Contributors: Brouer, B. D., Dirksen, J., Pisinger, D., Plum, C. E. M., Vaaben, B.

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Publication date: 2013

Peer-reviewed: Yes

**Publication information**

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Issue number: 2

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BFI (2013): BFI-level 1

Scopus rating (2013): CiteScore 3.25 SJR 2.238 SNIP 2.67

Web of Science (2013): Impact factor 1.843

ISI indexed (2013): ISI indexed yes

Web of Science (2013): Indexed yes

Original language: English

Keywords: Disruption management, Liner shipping, Mathematical programming, Recovery

DOIs:

10.1016/j.ejor.2012.08.016
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
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Contributors: Reinhardt, L. B., Pisinger, D.
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Peer-reviewed: Yes

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Journal: Flexible Services and Manufacturing Journal
Volume: 24
Issue number: 3
ISSN (Print): 1936-6582
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Scopus rating (2012): CiteScore 0.79 SJR 0.807 SNIP 0.521
Web of Science (2012): Impact factor 0.857
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
Original language: English
Keywords: containers, transhipment, liner shipping, branch and cut
DOIs:
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Source: orbit
Source ID: 278729
Research output: Contribution to journal › Journal article – Annual report year: 2011 › Research › peer-review

A hybrid adaptive large neighborhood search heuristic for lot-sizing with setup times
This paper presents a hybrid of a general heuristic framework and a general purpose mixed-integer programming (MIP) solver. The framework is based on local search and an adaptive procedure which chooses 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 suitable repair neighborhoods. The hybrid heuristic framework is applied to the multi-item capacitated lot sizing problem with setup times, where experiments have been conducted on a series of instances from the literature and a newly generated extension of these. On average the presented heuristic outperforms the best heuristics from the literature, and the upper bounds found by the commercial MIP solver ILOG CPLEX using state-of-the-art MIP formulations. Furthermore, we improve the best known solutions on 60 out of 100 and improve the lower bound on all 100 instances from the literature

General information
Publication status: Published
Organisations: Department of Management Engineering, Management Science
Contributors: Muller, L. F., Spoorendonk, S., Pisinger, D.
Pages: 614-623
Publication date: 2012
Peer-reviewed: Yes

Publication information
Journal: European Journal of Operational Research
Volume: 218
A Path Based Model for a Green Liner Shipping Network Design

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. An algorithm has been implemented for this model, unfortunately with discouraging results due to the structure of the subproblem and the lack of proper dominance criteria in the labeling algorithm.

General information
Publication status: Published
Organisations: Department of Management Engineering, Management Science, GERAD, Maersk Group
Contributors: Brouer, B. D., Jepsen, M. K., Plum, C. E. M., Desaulniers, G. ., Pisinger, D., Sigurd, M. M.
Number of pages: 22
Publication date: 2012

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Publisher: Department of Management Engineering, Technical University of Denmark
Original language: English
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Bunker Purchasing with Contracts

General information
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Organisations: Department of Transport, Transport optimisation and technique, Management Science, Department of Management Engineering, Maersk Group
Contributors: Farina, F., Neergaard Jensen, P., Plum, C. E. M., Pisinger, D.
Number of pages: 2
Publication date: 2012
Peer-reviewed: Yes
Event: Abstract from 3rd International Conference on Computational Logistics, Shanghai, China.
Scheduling of outbound luggage handling at airports

This article considers the outbound luggage handling problem at airports. The problem is to assign handling facilities to outbound flights and decide about the handling start time. This dynamic, near real-time assignment problem is part of the daily airport operations. Quality, efficiency and robustness issues are combined in a multi-criteria objective function. We present important requirements for the real world usage of the model and compare different solution techniques. One solution method is a heuristic approach oriented on the logic of GRASP (Greedy randomized adaptive search procedure). Another solution method is a decomposition approach. The problem is divided into different subproblems and solved in iterative steps. The different solution approaches are tested on real world data from Frankfurt Airport.

General information
Publication status: Published
Organisations: Department of Management Engineering, Management Science
Contributors: Barth, T. C., Pisinger, D.
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Editors: Klatte, D., Schmedders, K., Lüthi, H.
ISBN (Print): 978-3-642-29210-1
DOIs: 10.1007/978-3-642-29210-1_40
Solving Vehicle Routing with Full Container Load and Time Windows
A service provided by the liner shipping companies is the transport of containers by truck between the terminal and customers. These transports consist of import orders and export orders. Even though these transports concern containers and, therefore, each order is a full load, an import and an export order can be combined in one trip where the container is emptied at an import customer and taken to an export customer to be filled. Finding a set of optimal vehicle routes allowing these combinations is NP-hard. However, exploring the fact that the number of possible routes is small in the problem presented, we in this report show a model which can within seconds solve the problem to optimality. The model is tested on real-life data sets and additional constraints to the problem are considered.

The Multi-commodity One-to-one Pickup-and-delivery Traveling Salesman Problem with Path Duration Limits
The design of container shipping networks is an important real world problem, with assets and operational costs in billions of dollars. To guide the optimal deployment of the ships, a single vessel roundtrip is considered by minimizing operational costs and flowing the best paying cargo under commercial constraints. Inspiration for formulation and solution method is taken from the rich research done within pickup and delivery problems. The problem, the multicommodity one-to-one pickup and delivery traveling salesman problem with path duration limits is, to the best of our knowledge, considered for the first time. An arc flow and a path flow model are presented. A Branch and Cut and Price solution method is proposed and implemented.
The Vessel Schedule Recovery Problem: Disruption management in liner shipping
Maritime transportation is the backbone of world trade and is accountable for around 3% of the world’s CO2 emissions. We present the Vessel Schedule Recovery Problem (VSRP) to evaluate a given disruption scenario and to select a recovery action balancing the trade-off between increased bunker consumption and the impact on the remaining network and the customer service level. The model is applied to 4 real cases from Maersk Line. Solutions are comparable or superior to those chosen by operations managers. Cost savings of up to 58% may be achieved.

General information
Publication status: Published
Organisations: Department of Management Engineering, Management Science, Technical University of Denmark
Contributors: Brouer, B. D., Plum, C. E. M., Vaaben, B., Pisinger, D., Dirksen, J.
Publication date: 2012
Peer-reviewed: Yes
Electronic versions:
program-euro25.pdf
Source: dtu
Source ID: u:4583
Research output: Contribution to conference › Conference abstract for conference – Annual report year: 2012 › Research › peer-review

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-dependent. 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
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Organisations: Operations Research, Department of Management Engineering, Logistics & ITS, Department of Transport
Contributors: Reinhardt, L. B., Pisinger, D., Madsen, O. B., Kallehauge, B.
Number of pages: 124
Publication date: Sep 2011

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Publisher: DTU Management
Original language: English
(PhD thesis; No. 15.2011).
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Source: orbit
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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.

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.
Liner Shipping Cargo Allocation with Repositioning of Empty Containers

General information
Publication status: Published
Organisations: Operations Research, Department of Management Engineering
Contributors: Brouer, B. D., Pisinger, D., Spoorendonk, S.
Pages: 109-124
Publication date: 2011
Peer-reviewed: Yes

Publication information
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Issue number: 2
ISSN (Print): 0315-5986
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Web of Science (2011): Impact factor 0.295
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
Original language: English
Keywords: empty repositioning, Liner shipping, column generation, multicommodity flow

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
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Organisations: Operations Research, Department of Management Engineering
Contributors: Reinhardt, L. B., Pisinger, D.
Pages: 605-616
Publication date: 2011
Peer-reviewed: Yes

Publication information
Journal: Computers & Operations Research
Volume: 38
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.

General information
Publication status: Published
Organisations: Operations Research, Department of Management Engineering, Intel, University of Copenhagen
Contributors: Nisted, L., Pisinger, D., Altman, A.
Pages: 202-216
Publication date: 2011
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Journal: Journal of Combinatorial Optimization
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Scopus rating (2011): CiteScore 0.92 SJR 0.565 SNIP 1.05
Web of Science (2011): Impact factor 0.664
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
Original language: English
Keywords: Cutting problem, Semiconductor layout problem, Vertex-weighted clique problem, Column generation
DOIs:
10.1007/s10878-009-9284-z
Source: orbit
Source ID: 255242

Research output: Contribution to journal » Journal article – Annual report year: 2010 » Research » peer-review
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.

General information
Publication status: Published
Organisations: Operations Research, Department of Management Engineering
Contributors: Atamtürk, A., Muller, L. F., Pisinger, D.
Number of pages: 20
Publication date: 2011

Solving a Vehicle Routing Problem with a non-linear load dependent cost function
General information
Publication status: Published
Organisations: Department of Management Engineering, Operations Research, Department of Transport, Logistics & ITS
Contributors: Spoorendonk, S., Larsen, A., Pisinger, D., Røpke, S.
Publication date: 2011
Peer-reviewed: No
Event: Abstract from ROUTE 2011: International Workshop on Vehicle Routing, Intermodal Transport and Related Areas,
Sitges, Spain.
URLs:
http://www.uv.es/route2011/
Source: orbit
Source ID: 284890
Research output: Contribution to conference – Conference abstract for conference – Annual report year: 2011 – Research

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.

General information
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Organisations: Operations Research, Department of Management Engineering
Contributors: Reinhardt, L. B., Jepsen, M. K., Pisinger, D.
Number of pages: 15
Publication date: 2011
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.

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.
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.

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 a 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.
Heuristics for container loading of furniture

We consider a container loading problem that occurs at a typical furniture manufacturer. Each furniture item has an associated profit. Given container dimensions and a set of furniture items, the problem is to determine a subset of items with maximal profit sum that is loadable in the container. In the studied company, the problem arises hundreds of times daily during transport planning. Instances may contain more than one hundred different items with irregular shapes. To solve this complex problem we apply a set of heuristics successively that each solve one part of the problem. Large items are combined in specific structures to ensure proper protection of the items during transportation and to simplify the problem. The solutions generated by the heuristic has an average loading utilization of 91.3% for the most general instances with average running times around 100 seconds. (C) 2009 Elsevier B.V. All rights reserved.

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 primal heuristic obtains promising bounds. Our computational experiments on real instances of practical size indicate superiority of our approach.

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Contributors: Gelareh, S., Nickel, S., Pisinger, D.
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Issue number: 6
ISSN (Print): 1366-5545
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Web of Science (2010): Impact factor 1.954
Web of Science (2010): Indexed yes
Original language: English
Keywords: Mixed integer programming, Liner shipping, Hub-and-spoke network design, Enumeration, Lagrangian relaxation, Competition
DOI: 10.1016/j.tre.2010.05.005
URLs:
http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VHF-506HPNY-1&_user=10&_coverDate=11%2F30%2F2010&_rdoc=14&_fmt=high&_orig=browse&_origin=browse&_zone=rslt_list_item&_sec=doc-info(%23toc%236065%232010%23999539993%23232198763%23FLA%23display%23Volume)&_cdi=6065&_sort=d&_docanchor=&_ct=27&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=a498fc3f8e41ff32950bc1b7d7bec353&searchtype=a
Source: orbit
Source ID: 271290
Research output: Contribution to journal › Journal article – Annual report year: 2010 › Research › peer-review

Liner Shipping Hub Network Design in a Competitive Environment
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.

General information
Publication status: Published
Organisations: Operations Research, Department of Management Engineering, Karlsruher Institut für Technologie
Contributors: Gelareh, S., Nickel, S., Pisinger, D.
Number of pages: 16
Publication date: 2010

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Place of publication: Kgs. Lyngby
Publisher: DTU Management
ISBN (Print): 87-90-85573-6
Original language: English
Keywords: liner shipping, lagrangian decomposition, enumeration, mixed integer programming, hub-and-spoke network design, competition
Electronic versions:
2010_6.pdf
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.
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.
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 provider 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.

General information
Publication status: Published
Organisations: Operations Research, Department of Management Engineering
Contributors: Gelareh, S., Pisinger, D.
Number of pages: 21
Publication date: 2010

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Place of publication: Kgs. Lyngby
Publisher: DTU Management
ISBN (Print): 978-87-90855-91-8
Original language: English
(DTU Management 2010; No. 14).
Keywords: liner shipping, Benders decomposition, mixed integer programming, hub-and-spoke network design, fleet deployment, elastic demand
Electronic versions:
2010_14.pdf
URLs:

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.

General information
Publication status: Published
Organisations: Operations Research, Department of Management Engineering, University of Copenhagen
Contributors: Clausen, T., Hjorth, A. N., Nielsen, M., Pisinger, D.
Pages: 1244-1253
Publication date: 2010
Peer-reviewed: Yes

Publication information
Journal: European Journal of Operational Research
Volume: 207
Issue number: 3
ISSN (Print): 0377-2217
Ratings:
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 2.383 SNIP 2.445
Web of Science (2010): Impact factor 2.159
Web of Science (2010): Indexed yes
Original language: English
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.

General information
Publication status: Published
Organisations: Operations Research, Department of Management Engineering, University of Copenhagen
Contributors: Gamst, M., Jensen, P. N., Pisinger, D., Plum, C. E. M.
Pages: 82-89
Publication date: 2010
Peer-reviewed: Yes

Publication information
Journal: European Journal of Operational Research
Volume: 202
Issue number: 1
ISSN (Print): 0377-2217
Ratings:
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 2.383 SNIP 2.445
Web of Science (2010): Impact factor 2.159
Web of Science (2010): Indexed yes
Original language: English
Keywords: network flows, multicommodity flow, decomposition, transportation
DOI:
10.1016/j.ejor.2009.05.014
Source: orbit
Source ID: 250280
Research output: Contribution to journal › Journal article – Annual report year: 2010 › Research › peer-review

ENERPLAN - Green Logistics Solutions

General information
Publication status: Published
Organisations: Operations Research, Department of Management Engineering
Contributors: Pisinger, D.
Pages: 30-31
Publication date: 2009
Peer-reviewed: No

Publication information
Journal: ORbit : medlemsblad for Dansk Selskab for Operationsanalyse
Heuristic approaches for the two- and three-dimensional knapsack packing problem

The maximum profit two- or three-dimensional knapsack packing problem packs a maximum profit subset of some given rectangles or boxes into a larger rectangle or box of fixed dimensions. Items must be orthogonally packed, but no other restriction is imposed to the problem. We present anew iterative heuristic for the two-dimensional knapsack problem based on the sequence pair representation proposed by Murata et al. [VLSI module packing based on rectangle-packing by the sequence pair. IEEE Transaction on Computer Aided Design of Integrated Circuits and Systems 1996; 15:1518-24] using a semi-normalized packing algorithm by Pisinger [Denser packings obtained in $O(n \log \log n)$ time. INFORMS Journal on Computing 2007 19:395-405]. Solutions are represented as a pair of sequences. In each iteration, the sequence pair is modified and transformed to a packing in order to evaluate the objective value. Simulated annealing is used to control the heuristic. A novel abstract representation of box placements, called sequence triple, is used with a similar technique for the three-dimensional knapsack problem. The heuristic is able to handle problem instances where rotation is allowed. Comprehensive computational experiments which compare the developed heuristics with previous approaches indicate very promising results for both two- and three-dimensional problems. (C) 2007 Elsevier Ltd. All rights reserved.

Keyword: SEARCH, ALGORITHM, CONTAINER-LOADING PROBLEM, CUTTING STOCK PROBLEM

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.
Two- and Three-index formulations of the Minimum Cost Multicommodity k-splittable Flow Problem

General information
Publication status: Published
Organisations: Operations Research, Department of Management Engineering, University of Copenhagen
Contributors: Gamst, M., Jensen, P. N., Pisinger, D., Plum, C. E. M.
Publication date: 2009

Host publication information
Title of host publication: International Network Optimization Conference : INOC
Volume: TB1
Place of publication: Pisa, Italy
Electronic versions:
TB1-4.pdf
Source: orbit
Source ID: 253268

Chvátal-Gomory Rank-1 Cuts used in a Dantzig-Wolfe Decomposition of the Vehicle Routing Problem with Time Windows

General information
Publication status: Published
Organisations: University of Copenhagen
Contributors: Petersen, B., Pisinger, D., Spoorendonk, S.
Publication date: 2008

Host publication information
Title of host publication: The Vehicle Routing Problem: Latest Advances and New Challenges
Publisher: Springer
Editors: Golden, B., Raghavan, R., Wasił, E.
DOIs:
10.1007/978-0-387-77778-8_18
Source: orbit
Source ID: 240288

Liner Shipping Revenue Management with Respositioning of Empty Containers

General information
Publication status: Published
Organisations: University of Copenhagen
Contributors: Løfstedt, B., Pisinger, D., Spoorendonk, S.
Publication date: 2008

Publication information
Publisher: DIKU, University of Copenhagen, Denmark
Original language: English

Projects:

Dynamic Route Planning and Decision Support in Feeicer Lines
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Samfinansieret - Andet
01/10/2017 → 30/09/2020
Award relations: Dynamic Route Planning and Decision Support in Feeicer Lines
Project: PhD

Future Feeder Line Operations - Intermodal Transportation and Network Design under Uncertainty
Sacramento Lechado, D., PhD Student, Department of Management Engineering
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Award relations: Future Feeder Line Operations - Intermodal Transportation and Network Design under Uncertainty
Project: PhD

Flexible operations research methods for health care
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Stidsen, T. J. R., Main Supervisor
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Award relations: Flexible operations research methods for health care
Project: PhD

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.

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Project ID: 82524
External Project ID: 5160-00006B
Innovation Fund Denmark
01/02/2016 → 31/01/2020
Keywords: Gas, Renewable Gas, Energy System Analysis, Integrated Energy Systems, Energy System Modelling, Sector Coupling, Gas Quality, Sustainable Energy
Award relations: FutureGas
Project: Research

Analyse og modellering af distribuerede elsystemer med høj andel vedvarende energi
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01/05/2007 → 01/06/2011
Award relations: Analyse og modellering af distribuerede elsystemer med høj andel vedvarende energi
Project: PhD

Udvikling af optimeringsmodeller og løsningsmetoder til ruteplanlægning inden for trampfart
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Award relations: Udvikling af optimeringsmodeller og løsningsmetoder til ruteplanlægning inden for trampfart
Project: PhD

**Udvikling af optimeringsmodeller og løsningsmetoder til ruteplanlægning inden for trampfart**
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Award relations: Ikke-robust dekomponering og løsning af hårde korteste-vej problemer
Project: PhD

**Ikke-robust dekomponering og løsning af hårde korteste-vej problemer**
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Award relations: Ikke-robust dekomponering og løsning af hårde korteste-vej problemer
Project: PhD

**Beslutningsproblemer for energitransmissionsnetværk i et samfundsekonomisk perspektiv**
Villumsen, J. C., PhD Student, Department of Management Engineering
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Award relations: Beslutningsproblemer for energitransmissionsnetværk i et samfundsekonomisk perspektiv
Project: PhD

**Advanced mathematical modeling related to comprehensive energy system models**
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Gamst, M., Supervisor
Eksternt finansieret virksomhed
15/09/2016 → 18/02/2020
Award relations: Advanced mathematical modeling related to comprehensive energy system models
Project: PhD

**Optimization of operations in public transportation**
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Groth, J. J., Examiner
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01/10/2015 → 02/05/2019
Award relations: Optimization of operations in public transportation
Project: PhD

**Investment behaviour and uncertainty in energy saving**
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Juul, N., Supervisor
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Boomsma (fhv. Kristoffersen), T. K., Examiner
Tomasgard, A., Examiner
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01/04/2015 → 08/11/2018
Award relations: Investment behaviour and uncertainty in energy saving
Project: PhD
Integrated optimization of wind-farm layout and cable routing
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Vranceanu, I., Supervisor
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Vigo, D., Examiner
Industrial PhD
01/01/2015 → 16/04/2018
Award relations: Integrated optimization of wind-farm layout and cable routing
Project: PhD

Modelling use of biomass and waste in future energy systems
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Ravn, H. V., Supervisor
01/12/2014 → 01/06/2018
Project: PhD

Liner shipping network design based on local optimization
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01/09/2014 → 16/04/2018
Award relations: Liner shipping network design based on local optimization
Project: PhD

Mathematical Programming Approaches for Optimal University Timetabling
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Industrial PhD
01/02/2014 → 18/05/2017
Award relations: Mathematical Programming Approaches for Optimal University Timetabling
Project: PhD

Optimization of container line networks with flexible demands
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Award relations: Optimization of container line networks with flexible demands
Project: PhD

Airport Ground Staff Scheduling
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Gustafsson, T., Examiner
Scheduling of network traffic for Grid purposes
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Award relations: Scheduling of network traffic for Grid purposes
Project: PhD

Topics in Financial Engineering
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Award relations: Topics in Financial Engineering
Project: PhD

Next generation of life-cycle pension products
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Award relations: Next generation of life-cycle pension products
Project: PhD

PhD Scholarship in Liner Service Network Design
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Award relations: PhD Scholarship in Liner Service Network Design
Project: PhD

The dynamic vehicle routing problem
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Optimization of baggage handling at airports
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Project: PhD

Ikke-differentiabel optimering i heltalsprogrammering
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Award relations: Ikke-differentiabel optimering i heltalsprogrammering
Project: PhD

Solution methods for solving routing and scheduling problems
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01/08/2007 → 28/09/2011
Award relations: Solution methods for solving routing and scheduling problems
Project: PhD

Value Chain Optimisation in Biogas Production
Jensen, I. G., PhD Student, Department of Management Engineering
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Pisinger, D., Supervisor
Repke, S., Examiner
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15/08/2013 → 11/01/2018
Award relations: Value Chain Optimisation in Biogas Production
Project: PhD

Integreret disponering/genopretning af togdrift
Haahr, J. T., PhD Student, Department of Management Engineering
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Repke, S., Examiner
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SAVE-E: SAVE-E Energy Savings: Closing the Energy Efficiency Gap

Plans to reduce consumption of fossil fuels and hence emissions of CO2 include substitution to renewable energy sources, increased use of electricity and considerable efficiency improvements. Numerous studies have analysed and shown the feasibility of substitution to - and integration of - renewable energy sources. However, further studies have proven the existence of the energy-efficiency gap (EEG) and experience from various support and promotion policies have revealed that the EEG is hard to overcome. On the basis of these findings the aim of this project is to identify relevant factors influencing the EEG and to derive recommendations on how to surmount the EEG. An economic engineering approach is used to identify potentials of efficiency improvements. Based on this, we conduct a comprehensive micro-economic analysis of energy-saving investment behaviour of industries and households, i.e. identifying barriers for adoption and incentive schemes to resolve them. Combining potentials, barriers and incentives, strategies for implementing targeted improvements are developed and the trade-off between efficiency improvements and supply from renewable energy sources analysed. To evaluate macro-economic effects of the investments in savings a small macroeconomic model with detailed energy specifications is developed. Using this model, effects on growth, employment and public finances from using various incentive schemes are quantified.
The objectives of the project are to:
• Identify and quantify technical, economic and social barriers for potential energy savings.
• Analyse implementation strategies, evaluate incentives schemes, and find optimal trade-offs between efficiency improvements and additional renewable energy supply.
• Evaluate macro-economic effects of efficiency improvements and alternative incentive schemes.
• Contribute to development of methods and theory in the intersection of energy systems, behavioural economics, energy economics and stochastic programming areas.

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Project ID: 42-82508
01/01/2015 → 01/10/2019
Keywords: Energy economics savings optimisation

Collaborators: Gate 21, Rockwool International, Simon Fraser University, University of Copenhagen, Danish Building Research Institute, Dansk Energi, Danish Energy Agency, Roskilde University, Norwegian University of Science and Technology

Documents:
Project description
Project: Research

BioChain: Optimization of value chains for biogas production in Denmark
DSF
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01/03/2013 → 31/12/2016

Collaborators: Knowledge Centre for Agriculture, Aarhus University, University of Southern Denmark, University of Copenhagen

Project: Research

Activities:

Green liner shipping with optimization
Period: 26 Jul 2018
David Pisinger (Keynote speaker)

Transport DTU
Operations Research
Management Science
Department of Management Engineering

Documents:
abstract
Links:
https://events.unibo.it/euroalio2018/plenary-speakers

Related event
**Decomposition algorithms for the multi-modal ride-sharing routing problem**

*Period:* 9 Jul 2018  
*David Pisinger (Guest lecturer)*  
*Department of Management Engineering*  
*Management Science*  
*Transport DTU*  
*Operations Research*  
*Degree of recognition: International*  

*Documents:*  
abstract  
Links:  
https://www.euro-online.org/conf/admin/tmp/program-euro29.pdf (Complete program og conference)

**Related event**

**EURO 2018 conference on Operational Research**  
*09/07/2018 → 11/07/2018*  
*Valencia, Spain*  
*Keywords: Ride sharing, car sharing, decomposition*  
*Activity: Talks and presentations › Conference presentations*

**Disruption management in liner shipping - getting the containers delivered on time**  
*Period: 2 May 2018*  
*David Pisinger (Guest lecturer)*  
*Department of Management Engineering*  
*Management Science*  
*Transport DTU*  
*Operations Research*  

*Description*  
David Pisinger and Karina Kjeldsen  
*Degree of recognition: International*  

*Documents:*  
DMD 2018 DTU FINAL

**Related event**

**Danish Maritime Days 2018: A Major Event for the Global Maritime Industry**  
*01/05/2018 → 04/05/2018*  
*Copenhagen, Denmark*  
*Activity: Talks and presentations › Conference presentations*

**Network Design in Liner Shipping**  
*Period: 10 Jul 2017*  
*David Pisinger (Keynote speaker)*  
*Operations Research*  
*Management Science*  
*Department of Management Engineering*
Related event

VeRoLog 2017: Annual Workshop of the EURO Working Group on Vehicle Routing and Logistics optimization
10/07/2017 → 12/07/2017
Amsterdam, Netherlands
Activity: Talks and presentations › Conference presentations

Prizes:

Finalist - EURO Excellence in Practice Award (EEPA 2018)
David Pisinger (Recipient) & Martina Fischetti (Recipient)
Department of Management Engineering, Management Science, Transport DTU, Operations Research

Details
Awarded date: 11 Jul 2018
Degree of recognition: International
Granting Organisations: EURO - The association of European operational research societies
Prize: Prizes, scholarships, distinctions