Master’s thesis project in Operations Research (Spring 2021)
Briefly, how to apply for an OR Master-Thesis project

The starting dates for a master-thesis in the Spring are:

- 4/1 2021
- 25/1 2021

A thesis can be either 30 ECTS points, 32.5 ECTS points or 35 ECTS points and can last for 5 or 6 months, depending on the number of ECTS points.

If you want to write an OR master-thesis in the Spring of 2021, you should follow the following steps:

1. **READ THE PROJECT FOLDER** and spend some time thinking about what kind of OR Master’s thesis you want to write. You can find the folder at:

   https://www.ms.man.dtu.dk/english/education

2. Write an email, to the professor(s) you want to supervise your thesis writing. The email should clearly state:

   - Name, study number and study line.
   - When the project should start and end, and how many ECTS points.
   - Which project(s) are you interested in. This **may** be your own project, then it should be explained.
   - Which OR courses have you followed (and when)
   - What is your programming experience (specify programming languages and how experienced you are).
   - Attach a printout of your grade-sheet.

   The professor will probably call you in for a short interview before agreeing to become your supervisor.
Possible OR supervisors

• Associate Prof. Dario Pacino, Email: darpa@dtu.dk
  – Core: Container Terminal Optimization, Maritime Logistics, Heuristics, Modelling
  – Other: City Logistics, Smart City real-time optimization, Constraint Programming

• Prof. David Pisinger, Email: dapi@dtu.dk
  – Core: Maritime Logistics, Liner Shipping Network Design, Railway Optimization, Packing and Loading, Heuristics, Modelling, Network Optimization
  – Other: Health Care, Airport Optimization, Algorithms

• Assistant Prof. Evelien van der Hurk, Email: evdh@dtu.dk, Expertise area:
  – Core: (public) transport, network-flow problems, column generation, combinatorial optimization, data & statistics
  – Other: vehicle routing, health-care, supply chain management, simulation, forecasting

• Prof. Jesper Larsen, Email: jesla@dtu.dk
  – Core: public transport optimization, health care planning, integer programming
  – Other: vehicle routing, decomposition methods, matheuristics, airport optimization

• Part-time Lecturer Kourosh Rasmussen, Email: kmra@dtu.dk
  – Core: Using mathematical modelling in real life problem solving in finance, this includes but is not limited to: Household Finance, Asset Allocation, Risk management, Asset liability management

• Associate Prof. Richard Lusby, Email: rmlu@dtu.dk
  – Core: Decomposition Methods, Integer Programming, Passenger Railway Optimization, Robust Planning
  – Other: Matheuristics, Scheduling, Staff Rostering, Transportation

• Prof Stefan Røpke, Email: ropke@dtu.dk
  – Core: Vehicle routing, integer programming, decomposition methods, meta-heuristics, maritime transport, public transport
  – Other: Collaborative game theory, stochastic optimization, Artificial Intelligence

• Assistant Prof. Nina Lange, Email: nilan@dtu.dk, Expertise area:
  – Other: Portfolio Theory, Fixed Income Markets

• Associate Prof. Thomas Stidsen, Email: thst@dtu.dk, Expertise area:
  – Core: Educational timetabling, health-care planning, multi-objective optimization, manpower planning, integer programming
  – Other: financial optimization, energy modelling and optimization
Welcome

In this folder the Division of Management Science presents a wide range of interesting master’s thesis projects. Every year we offer many different projects and at the end of each semester we update this folder and publish it so that you may see what we offer.

As the contents of this folder will show you, we offer a wide variety of different projects. A wide network of industrial contacts enable us to offer you projects in cooperation with companies with many different facets, or you can choose a project with a strong theoretical background.

The typically requirement for starting a master’s project in Management Science is that you have followed an advanced OR/FE course (beyond an introductory course covering linear programming etc.).

At the Technical University of Denmark research in Management Science is done at the department of Management Engineering. Here the division of Management Science consists of almost 20 researchers, Ph.D. students and research assistants. Further information about the division of Management Science can be found on our homepage at [www.man.dtu.dk](http://www.man.dtu.dk). DTU Management Engineering is proud to be member of the Danish Operations Research Society – the largest OR network in Scandinavia.

Apart from the project proposals that are listed in this folder, you are always welcome to contact us if you have a project idea of your own. This folder may serve as a source of inspiration. Your main supervisor must be a permanent staff member, which at present means Dario Pacino, David Pisinger, Evelien van der Hurk, Jesper Larsen, Kourosh Rasmussen, Nina Lange, Richard Lusby, Stefan Røpke, and Thomas Stidsen. In addition our Ph.D. students and Post Docs often take part in the supervision with their fresh ideas and hands on knowledge.

A number of office spaces and computers are available for master students in Management Science. Requests can be made to your supervisor.

Some of the projects in this folder can also be used as the basis for bachelor projects. If you are interested, ask the designated supervisor of the project.
Projects with Dario Pacino as supervisor

Operations Research at Ørsted Operations

1. SUPERVISOR: Dario Pacino

2. PROJECT GROUP:

3. PROJECT BACKGROUND: Ørsted operates several offshore wind farms around the world. As part of a larger digitisation initiative, Ørsted is looking to expand digital capabilities in the field of planning and scheduling, which includes the adoption of products and methods relying on Operations Research. Ørsted continuously identifies new areas to explore and products to improve and therefore invites students to work with us on those during their master thesis

4. PROJECT ASSIGNMENT: Ørsted is interested in the following topics.

   Logistics Configuration:
   • Determine how to configure or re-configure logistics for new or existing wind farms or clusters of wind farms
   • How to procure logistics for a site or cluster (price, type, duration)

   Advanced Planning and Scheduling:
   • Yearly campaign planning of maintenance activities
   • Handling the exchange of major components
   • Medium-term alignment of the activity portfolio
   • Day-to-day activity scheduling and transfer planning

   Common to all our planning horizons is the impact of actual and expected weather conditions leading to stochastic programming being an interesting approach


6. GROUP SIZE: 1-2

7. CHARACTERISTICS OF THE ASSIGNMENT: Advanced planning & scheduling, Operations & Maintenance, offshore wind power

8. REMARKS: There will be no opportunity to publish any work directly related to the thesis and the student will have to sign an Ørsted/DTU student project agreement. For Ørsted to have any benefit from a master thesis project, the student(s) must be willing to work closely with the Ørsted supervisor(s) and according the their/his/her steer (e.g. weekly status meetings)
1. **SUPERVISOR:** Dario Pacino

2. **PROJECT GROUP:**

3. **PROJECT BACKGROUND:** PostNord (ex. Post Danmark) can trace its history as far back as 1624 when King Christian IV signed a decree concerning the establishment of a network of postmen in Denmark. Ever since then, we have provided reliable, fast and accessible transport of mail in Denmark and abroad. Today PostNord provides basic postal services to all customers in Denmark – senders and recipients alike. PostNord is working towards a much more data driven way of thinking using both operations research and operations management as means to obtain a higher service level while keeping prices low.

4. **PROJECT ASSIGNMENT:** Route optimization with varying weekday patterns of the collecting vehicles.

Today we plan our collecting vehicles mainly with a weekday pattern called Monday-Thursday and Friday which means that the routes are the same from Mondays to Thursdays and for Fridays respectively. But since we know that the number of parcels that have to me collected are decreasing during the week it could be interesting to examine the potential in other weekday patterns which could be a setup for each weekday or maybe the same for Monday-Tuesday, Wednesday-Thursday and Friday.

5. **PREREQUISITES:** Operations Research methods, including metaheuristics.

6. **GROUP SIZE:**

7. **CHARACTERISTICS OF THE ASSIGNMENT:**

8. **REMARKS:**
1. **SUPERVISOR:** Dario Pacino

2. **PROJECT GROUP:**

3. **PROJECT BACKGROUND:** PostNord (ex. Post Danmark) can trace its history as far back as 1624 when King Christian IV signed a decree concerning the establishment of a network of postmen in Denmark. Ever since then, we have provided reliable, fast and accessible transport of mail in Denmark and abroad. Today PostNord provides basic postal services to all customers in Denmark – senders and recipients alike. PostNord is working towards a much more data driven way of thinking using both operations research and operations management as means to obtain a higher service level while keeping prices low.

4. **PROJECT ASSIGNMENT:** Zone optimizing of our InNight business distribution net. Today Denmark is split into a fixed number of zones, where we have one distributing vehicle handling the goods in that area. Today the zones are made from knowledge of the geography and the customers in each area. It could be interesting to evaluate these zones using a mathematical approach to see it is possible to make the zone split better in terms of fewer zone, kilometer driven or something third. The desire is to find a zone split that are feasible for a whole year or at least 6 months.

5. **PREREQUISITES:** Operations Research methods, including metaheuristics.

6. **GROUP SIZE:**

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Clustering models.

8. **REMARKS:**
1. **SUPERVISOR:** Dario Pacino

2. **PROJECT GROUP:**

3. **PROJECT BACKGROUND:** Collecting and sharing data is the focus of nowadays maritime companies. As digitization become more and more a reality, the need to make use of the available data is increasing. This need has been recognised not only by the maritime industry, but also from data providers and data sharing platforms. PORTCHAIN is a Danish start-up that focuses on data sharing and data processing between container carriers and terminals. They are interested in identifying synergies between carriers and terminals in order to improve efficiency for both parties.

4. **PROJECT ASSIGNMENT:** The aim of this project is, in collaboration with PORTCHAIN, to identify important opportunities in the integrated planning between container carrier and terminal. The project will focus on seaside operations and in particular in the interplay between stowage planning and quay crane scheduling.

5. **PREREQUISITES:** Operations Research methods, both in terms of mathematical programming and heuristic implementation.

6. **GROUP SIZE:** 1-2

7. **CHARACTERISTICS OF THE ASSIGNMENT:**

8. **REMARKS:**
Stochastic RORO ship planning

1. SUPERVISOR: Dario Pacino

2. PROJECT GROUP:

3. PROJECT BACKGROUND: RORO stands for Roll-On Roll-Off, and it is used to describe the maritime shipping segment that transports wheeled cargo such as cars, and trailers. As cargo is loaded on the vessels, the balance of the ship changes. Currently cargo is allocated in the vessels disregarding stability restrictions. The ship is then allowed to sail by loading ballast water and reaching a stable state. Ballast water is, however, costly as it implies a bigger fuel consumption during sailing.

4. PROJECT ASSIGNMENT: This project aims at implementing a model/algorithm to solve the stowage planning problem of RORO vessels. Deterministic models are, however, not interesting as the exact arrival time of the cargo is not known. Stochastic optimization models are envision as a way to achieve better stowage plans that minimize the use of ballast water.

5. PREREQUISITES: Knowledge or interest in learning stochastic optimization. Some programming skills for scenario generation

6. GROUP SIZE: 1-2

7. CHARACTERISTICS OF THE ASSIGNMENT:

8. REMARKS: Possibility of research publication.

Stochastic bike re-balancing

1. SUPERVISOR: Dario Pacino

2. PROJECT GROUP:

3. PROJECT BACKGROUND: Shared bicycle systems are now popular everywhere. We have all seem the orange Donkey Republic bikes or the while Bycyklen in Copenhagen. At the end of the day, those bikes might not be placed in the ideal stations for the new morning routines. It is therefore that in the evening you might see large vans doing what is called “re-balancing”.

4. PROJECT ASSIGNMENT: In this project you will be working in close collaboration with one of our PhD students and his bike demand prediction systems. Your task will be to use the data from the prediction model to implement an optimized bike re-balancing model. We envision the use of stochastic optimization methods such as Sample Average Approximation (SAA), robust optimization or stochastic programming.

5. PREREQUISITES: Knowledge of operations research methods. Knowledge of stochastic optimization is not needed so long as you have an interest in learning about it.

6. GROUP SIZE: 1-2

7. CHARACTERISTICS OF THE ASSIGNMENT:

8. REMARKS:
Projects with David Pisinger as supervisor

Optimizing labor ordering and berth scheduling for liner vessels

1. SUPERVISOR:  David Pisinger, David F. Koza

2. PROJECT BACKGROUND:  When container vessels berth at a port to load or unload containers, the cargo carrier needs to book cranes and gangs (that operate the cranes) in advance. The more cranes/gangs are booked, the higher is the productivity (number of moved containers per hour) and the earlier the vessel can leave the port again. Gangs work in shifts that may have different costs depending on the time or weekday. Many other restrictions, as e.g. limited berth availability windows or tidal restrictions, may apply. The time a vessel spends at a port also affects the subsequent sailings and port calls; the faster a vessel finishes operations at a port, the more time is left to sail to the next port and to finish operations at the next port and vice versa. Due to these interdependencies, the planning problem becomes quite complex. The project is carried out together with Maersk Line planners that face these problems on a weekly basis.

3. PROJECT ASSIGNMENT:  Describe the resulting vessel berth scheduling and gang optimization problem and examine related literature. Formulate and implement mathematical models to solve the problem and possible extensions. Generate a set of good solutions that can be presented to planners. Analyse the results and derive decision rules to support planners.

Data for actual gang optimization problems will be provided by Maersk Line. Good results may therefore have an actual impact.

4. PREREQUISITES:  Motivation to work on and learn about a practical problem; experience with mathematical modelling and associated languages (e.g. CPLEX or Gurobi); fluency in English (as communication with Maersk planners will be in English); programming skills are of advantage.

5. GROUP SIZE:  1-2

6. CHARACTERISTICS OF THE ASSIGNMENT:  Liner shipping, scheduling, mathematical modeling, applied optimization
Efficient algorithms for cargo routing in liner shipping networks

1. SUPERVISOR: David Pisinger, David F. Koza

2. PROJECT BACKGROUND: The liner shipping network design problem is a very hard combinatorial optimization problem and subject of ongoing research. The challenge is to construct a network of liner services that operate on cyclic routes, and to route containers through this network such that revenues minus cost are maximized. The majority of solution approaches, including the most promising ones, require to solve a very large number of cargo routing problems as intermediate and reoccurring steps. More efficient algorithms for the cargo routing problem therefore have the potential to significantly improve the performance of network design algorithms as well.

The cargo routing problem consists of finding a path from an origin port to a destination port through a very large network, while respecting constraints as e.g. transit time limits. The cargo routing problem is a shortest path problem with resource constraints (SPPRC).

The goal of this thesis is to investigate how the existing algorithms can be improved, or to develop new approaches. Possible directions of research include the implementation and testing of alternative algorithms (e.g. the A*-algorithm, heuristics) or improved preprocessing techniques.

3. PROJECT ASSIGNMENT: Implement and test different exact or heuristic algorithms and/or preprocessing techniques for the cargo routing problem. Developed algorithms can be tested and evaluated within a solution framework for liner shipping network design, written in C++ and developed at the OR group.

4. PREREQUISITES: Interest in algorithms and their implementation; good programming skills, ideally C++ (as our framework and existing methods are coded in C++); Mandatory courses: 42115 Network Optimization

5. GROUP SIZE: 1-2

6. CHARACTERISTICS OF THE ASSIGNMENT: Cargo routing, resource constrained shortest path problem, liner shipping network design, graph based algorithms
1. **SUPervisor:** David Pisinger, David F. Koza

2. **PROJECT BACKGROUND:** The liner shipping network design problem is a very hard combinatorial optimization problem and subject of ongoing research. The challenge is to construct a network of liner services that operate on cyclic routes, and to route containers through this network such that revenues minus costs are maximized. The majority of solution approaches imposes only very few restrictions on the design of liner shipping services; in practice, however, network planners have to consider various factors and trade-offs when designing a liner service. Network planners would, for example, try to limit the duration of a service, as shorter services can be adjusted more easily and are easier to cope with in case of delays or disruptions. Another example is the rotation design: in practice, services that call a particular port more than twice are very rare.

Imposing additional restrictions on the service design makes the problem of generating liner services more difficult. Early in the project we will discuss practically relevant restrictions with Maersk planners. The goals are to investigate how these can be modeled, to develop tailored solution algorithms to solve the service design problem efficiently, and to analyze how those additional restrictions affect network design and cost.

3. **PROJECT ASSIGNMENT:** Construct a mathematical model for the liner service design problem with additional side constraints. Develop and implement heuristic or exact solution algorithms (e.g. dynamic programming based algorithms) to solve the problem. You will have access to a solution framework for liner shipping network design, written in C++ and developed at the OR group, and we would aim at embedding and testing your developed methods within this framework.

4. **PREREQUISITES:** Good programming skills, ideally C++ (as our framework and existing methods are coded in C++); Mandatory courses: ‘42115 Network Optimization’. Course ‘42885 Maritime Logistics’ and other OR courses are of advantage.

5. **GROUP SIZE:** 1-2

6. **CHARACTERISTICS OF THE ASSIGNMENT:** Liner shipping network design, graph based algorithms
Optimal Positioning of Vessels

1. **SUPERVISORS:** Nina Lange, David Pisinger

2. **PROJECT GROUP:** Ultrabulk

3. **PROJECT BACKGROUND:** Dry bulk commodities are moved worldwide in volumes of more than five billion tons per year performed by about 11000 ships. The trade routes can largely be divided into two groups originating respectively in the Atlantic and in the Pacific Basin. Sometimes ships and cargoes are matched too late keeping either waiting. Sometimes ships are sent to areas that turn out to be over-supplied (with ships) at the time of arrival. Sometimes an area can be under-supplied and fulfilling a contract to move cargo can become a tight issue. Sometimes ships of one company are concentrated in too few areas or spread too thin in too many areas. Vessel spot earnings is the indicator for tight vessel supply.

4. **PROJECT ASSIGNMENT:** Based on a time-series forecast of relative earnings, how should vessel voyage planning of next and next-next destinations be optimized across the Atlantic and the Pacific Basin.

5. **PREREQUISITES:** Various optimization courses is need to have, financial engineering courses are nice to have and a solid background in probability theory, statistics, time series and/or economics is a plus. The project contains programming in Julia, Python, R or Matlab.

6. **GROUP SIZE:** 2 persons (if you don’t have a thesis buddy and would like to work on this project, contact us anyways and we’ll see if we can find a solution).

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Shipping, Freight Rates, Multivariate Time Series, Optimization
Limiting COVID-19 outbreak by network decomposition

1. **SUPERVISOR:** David Pisinger, Niels-Christian Fink Bagger

2. **PROJECT BACKGROUND:** The COVID-19 pandemic caused many countries to lock down large parts of society by establishing different limitation policies as a mean to decrease the spread of the virus. People are working from home, cultural event are cancelled and people can only meet up in small gatherings, meaning that the contacts between individuals have significantly dropped. The limitation policies are evaluated based on population based simulations. As many limitation policies are limiting the contact between people it makes sense to look at the spread of the virus in social networks. Most research in the spread of a virus in networks are considering static networks, but as most social contacts are varying over time, dynamic networks are more interesting. Many limitation policies can be seen as decomposing the graph. When limitation policies are introduced, the decomposition is uncertain as we cannot know how the graph is decomposed, e.g., if there is a limit on social gatherings for 10 people, we cannot know which 10 people different individuals meet up with at social gatherings. Some places we can have impact on how the graph is decomposed, this could be schools, universities or work places, and these are the cases we are considering. The main objective of the project is to investigate the best way to decompose a given graph with a given set of restrictions.

3. **PROJECT ASSIGNMENT:** We have seen that decomposing graphs by minimizing distinct contacts between people, has a positive effect, but research show that there are other interesting measurements to look at when predicting the spread of a virus in a network. Such measurements include vitality and centrality, e.g., node vitality, closeness centrality and betweenness centrality. Common for these measurements is that the shortest paths between every pair of nodes need to be calculated. While the shortest path problem can be efficiently solved (even every pair of shortest paths), these problems need to be solved many times when using these measurements for decomposing social networks. The thesis could focus on how to efficiently use these measurements when decomposing social networks, and which of the measurements have the biggest impact on limiting the spread of COVID-19, either using exact methods or heuristics. The thesis could also investigate other measurements that are not mentioned here, or approximations of the before mentioned measurements.

4. **PREREQUISITES:** Operations research methods, combinatorics, graph theory, programming skills (Java, C++, C#, Julia).

5. **GROUP SIZE:** 1-2 students

6. **CHARACTERISTICS OF THE ASSIGNMENT:** Developing algorithms for clustering and/or community/betweenness/centrality detection in social networks.
LINE PLANNING FOR LINE CLOSURES AT DSB

1. SUPERVISOR: Evelien van der Hurk

2. PROJECT BACKGROUND: An alternative service needs to be provided during track closures that result e.g. from necessary maintenance. Generally, the train service will be replaced by busses. However, replacing the existing trainline directly with busses may be neither optimal for the passengers nor for the operator. Alternative services such as express lines and busses connecting to alternative train lines may together provide better service at lower costs than replacing the closed track service directly with busses.

3. PROJECT ASSIGNMENT: In this project you will optimize the bus replacement service for a closure. The project could focus on:
   - The optimization model for the selection of busses
   - The generation of alternative bus lines
   - The (detailed) assessment of the passenger service of a selected bus-plan

   This master thesis project is based on a real case study of a closure on the DSB S-tog; and good outcomes may result in interest of DSB to include the developed procedures, outcomes or (optimization) methods in practice.

4. PREREQUISITES:  
   - Programming skills (e.g. Julia lang, Python, Java, ...)
   - Introduction to Operations Research: as well as a second course (equivalent to) (42113) Networks or Integer Programming.
   - Knowledge about column generation and Optimization in Public Transport (42881) would be an advantage.

5. GROUP SIZE: 1-2


LINE PLANNING FOR DSB

1. SUPERVISOR: Evelien van der Hurk, Richard Lusby
2. PROJECT BACKGROUND: All passengers want high frequency direct train services to their destination. Furthermore, many passengers prefer their train service to arrive just in time for work: e.g. arriving at Københavns Hovedbanegård at 8:30 in the morning. Providing such a service to all passengers is infeasible due to limited available track capacity and limited available resources. Line planning can assist the operator in selecting which direct services (lines) to operate to best balance provided passenger service against operating cost, within the available capacity.

3. PROJECT ASSIGNMENT: The project focuses on developing decision support tools for lineplanning at DSB or Movia, and could involve some small case studies. The thesis could for instance focus on:

- including realistic passenger route choice (The passenger service depends on the routes the passengers choose in the offered lineset. As passengers can choose a route themselves, and their interest may conflict with the operators best interest in case of limited capacities, including realistic passenger route choice is a challenging task.)
- integration of lineplanning with timetabling (not only how often, but also when should the trains run? Does integration of lineplanning and timetabling lead to different outcomes than solving the problems sequentially?)
- generation of linepools (which candidate lines could one consider?)
- improving scalability of existing models (Line planning problems, especially including dynamic route choice of passengers, are challenging problems to solve. In this task you would work on algorithms and methods to increase the speed of solving these algorithms.)

4. PREREQUISITES: Programming skills (e.g. Julia lang, Python, Java, ...)
- Introduction to Operations Research: as well as a second course (equivalent to) (42113) Networks or Integer Programming.
- Knowledge about column generation and Optimization in Public Transport (42881) would be an advantage.

5. GROUP SIZE: 1-2


ON DEMAND PUBLIC TRANSPORT PLANNING

1. SUPERVISOR: Evelien van der Hurk

2. PROJECT GROUP: Konsentra, Norwegian on-demand public transport operator in the Oslo area

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3. PROJECT BACKGROUND: Konsentra coordinates, plans and provides public transport for schoolkids as well as anyone with special mobility needs. They operate around 200 minibusses and collaborate with several taxi companies to provide around 1.2 million journeys per year. This project is about creating better schedules for their transport.

At Konsentra they care about quality, timeliness, and greeting the customer with a smile! They create a new schedule every day to serve their many customers. Some of these are children that cannot use regular public transport to get to their schools, because they live in remote areas. Others are people with special needs (e.g. wheelchair transportation, autistic, ...), that therefore require special public transportation. The target of Konsentra is to provide high level service efficiently: therefore they aim to include as much ride sharing, using their mini-busses, as possible.

Due to the special nature of their clients, there are also special constraints on the travel demand of their customers. For example, some passengers may really need regularity in their schedule and need to always be picked up by the same driver. Others require a companion when traveling, who needs to be picked up before them, and dropped off after them. Some passengers have a specification from their doctor stating they need to travel alone. Also, the need for wheelchair transportation limits the type of vehicles that can be used. All passengers have a constraint on the maximum time between pick-up and required time of arrival at their destination, which depends on their age.

Currently, the making of a schedule is a combined automatic scheduler and manual effort.

4. PROJECT ASSIGNMENT: In this assignment you will develop a tool for generating a daily schedule for Konsentra. Their current automatic tool reaches an average of 2.6 passengers per trip – while mini busses can take up to 16 passengers! Your objective is to beat the 2.6 – and maybe even beat their manual solutions that reach between 3.2 and 3.4 passengers per trip!

In this project the student should develop a solution method for optimizing a the daily on demand public transport schedule. To beat the above target, you could focus on:

• Developing an advanced solution method
• Investigate the benefits of a different operation strategy, such as:
  – Re-assignment of the 4 operating zones
  – Re-defining the minimum travel time from a fixed time for all, to a budget in addition of the minimal travel time
  – Your own suggestion!

5. PREREQUISITES:  
• Programming skills (e.g. Julia lang, Python, Java, ...)
• Introduction to Operations Research: as well as a second course (equivalent to) (42113) Networks or Integer Programming.
• Knowledge about (meta/math) heuristics, decomposition methods, and/or column generation would be an advantage – as well as knowledge on vehicle routing.

6. GROUP SIZE: 1-2

7. CHARACTERISTICS OF THE ASSIGNMENT: optimization, public transport, vehicle routing

8. REMARKS:
1. **SUPERVISOR:** Evelien van der Hurk

2. **PROJECT GROUP:** Theoretical work based on the concept of on-demand minibusses, such as the Uber-bus

3. **PROJECT BACKGROUND:** You are probably familiar with the concept of shared transport options like Uber and Lyx. These are focussed on sharing private vehicles in a taxi-service kind of way. A different form of public transport is that of on-demand mini-busses: Uber is introducing this in Egypt, while there exists already many informal systems for this in other countries like South Africa.

   The research questions here are: first if all, if you have such an on-demand system, what is the best way to operate it? And secondly, given an idea about the demand over time, what would be the best lines to operate?

4. **PROJECT ASSIGNMENT:** You will employ simulation and/or optimization techniques to try to investigate at least one of the above research questions.

5. **PREREQUISITES:**
   - Programming skills (e.g. Julia lang, Python, Java, ...)
   - Introduction to Operations Research: as well as a second course (equivalent to) (42113) Networks or Integer Programming.
   - Knowledge about (meta/math) heuristics, decomposition methods, and/or column generation would be an advantage – as well as knowledge on vehicle routing.

6. **GROUP SIZE:** 1-2

7. **CHARACTERISTICS OF THE ASSIGNMENT:** optimization, public transport, vehicle routing, line planning

8. **REMARKS:**
Projects with Jesper Larsen as supervisor

ROUTING OF CARETAKES WITH JOINT VISITS

1. SUPERVISOR: Jesper Larsen

3. PROJECT BACKGROUND: In Denmark the principle of letting the elderly stay in their home for as long as possible is an important part of the social policy. Each municipality has a staff of caretakers that visits the elderly performing a number of different tasks.
   Each visit needs to be started within a given time window, and has a pre-specified service time. Each caretaker is available in a given time window defining the shift of the caretaker.
   The planning process consists of assigning visits to caretakers and subsequently build routes for the caretakers. Among the visits are some visits where more than one caretaker needs to be present to perform the task. Here the service that needs to be performed for the citizen cannot start before all caretakers are present.

4. PROJECT ASSIGNMENT: The aim of the project is to investigate the possibilities to come up with an integrated approach for solving the home care routing problem. Special attention should be put on solution time and the robustness of the plans in order to avoid re-planning as far as possible. The solution approach can be optimal or near-optimal.

5. PREREQUISITES: Introduction to Operations Research, courses equivalent to (42113) Networks and Integer Programming and (42132) Large Scale Optimization using decomposition. Good programming skills.


SCHEDULING TRAIN CLEANING

1. PROJECT SUPERVISOR: Jesper Larsen, Richard Lusby

2. PROJECT GROUP: NN (DSB)

3. PROJECT BACKGROUND: An important part of good passenger service is to maintain a nice and clean environment for the passengers. In the trains that is the responsibility of the operator, that is, DSB. Although the cleaning is done by an external contractor the schedules for the cleaning is made by DSB and then forwarded to the contractor. At DSB there are three different types of cleaning based on how much time is available and how thorough the cleaning should be. Cleaning can only be performed at designated stations on the route. The process of developing the schedules for the cleaning is currently being done manually with no or very little system support.

4. ASSIGNMENT: The aim of this thesis is to develop, implement and present a method for automatically determining the cleaning schedules. The schedules must comply with the rules and regulations of DSB and must be able to minimize cost and/or other appropriate measures. The project also allows to develop new ideas for producing the schedule and compare to real-life schedules from DSB.
5. QUALIFICATIONS: At least Introduction to Operations Research and Integer Programming. Programming experience is an advantage.

6. GROUP SIZE: 1-2 persons


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1. SUPERVISOR: Jesper Larsen

3. PROJECT BACKGROUND: Newly admitted patients need a free bed that satisfies both the personal preferences (single, twin room, or a ward) as well as the medical needs of the patient located in the department that is specialized in treating the clinical picture. The assignment of patients to beds is often carried out by a central admission office that individually contacts every appropriate department a few days before the effective admission of the patient. Other hospitals organize the admission of patients without a central admission office, leaving admission responsibility with the departments. In the latter case, a lack of overview of the departments may result in under occupancy. Patients may be refused in one department while free suitable beds are available in another department. Generally speaking patients can be divided in two groups: inpatients and outpatients. Inpatients spend several days or nights in a hospital, whereas the admission of outpatients is expressed in hours. This project will concentrate inpatients only. Inpatients can further be divided in three groups: emergency, elective and admitted patients. Emergency patients are hard to schedule, since by definition they have no appointment with the physician and arrive at random. Elective inpatients are waiting for an admission date. This means that an admission office can determine when to admit them. Such patients allow the hospital to improve its occupancy rate as they can be assigned to the most appropriate period. In this paper however, we simplify the problem by assuming that the patients’ admission dates are known before. The physician who advised the patient to be admitted to the hospital, diagnosed the patient’s disease which is associated with a default (average) length-of-stay.

4. PROJECT ASSIGNMENT: Present methods for solving the patient admission scheduling problem all rely on metaheuristics which often does not exploit problem structure very good. This project should devise and implement a solution approach based on mathematical programming. It is forseen that the initial parts of the project will consist in developing mathematical models and the second part of implementing and testing the most promissing model.

5. PREREQUISITES: (42101) Introduction to Operations Research, and a background at least equivalent to (42114) Integer Programming is necessary. Knowledge about column generation would be an advantage. Good programming skills.

6. GROUP SIZE: 1-2 students

1. **SUPERVISOR:** Jesper Larsen

2. **PROJECT GROUP:** Troels Range (Sydvestjysk Hospital)

3. **PROJECT BACKGROUND:** In the Region of Southern Denmark, specially educated staff visits citizens that cannot come to the hospital for taking blood samples in their own home. When a blood sample has been taken, it has to be back to the hospital within a certain time in order to ensure it can be used for diagnosis. As new visits appear in real-time, routes cannot be calculated statically. Instead, they can potentially change during the day.

4. **PROJECT ASSIGNMENT:** Given data from Sydvestjysk Hospital, the assignment of the project is to make a solution approach for the problem that can encompass the dynamic nature of the problem, thereby potentially recompute the solution every time new visits appear in the system.

5. **PREREQUISITES:** (42101) Introduction to Operations Research, and a background at least equivalent to (42114) Integer Programming is necessary. Knowledge about column generation would be an advantage. Good programming skills.

6. **GROUP SIZE:** 1-2 students.

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**CAN DO AND MUST DO ORDERS**

1. **SUPERVISOR:** Jesper Larsen

2. **PROJECT GROUP:** Kristian Hauge (AMCS)

3. **PROJECT BACKGROUND:** In this route planning problem, a number of fixed customers is serviced at regular intervals. Each customer has a stock of goods (e.g., petrol) that they gradually consume over time. It is necessary to refill the stock of the customers before they run out. However, the time at which the customers are refilled will determine both the size of the order that should be delivered as well as the expected interval before another delivery is needed.

   The biggest challenge in this type of planning scenario is not solving the route planning problems themselves, but determining the right day for visiting the customers.

4. **PROJECT ASSIGNMENT:** Given real customer data including known stock levels and consumption, the task is to design and test various strategies for when customers should be visited.

5. **PREREQUISITES:** (42101) Introduction to Operations Research, and a background at least equivalent to (42114) Integer Programming is necessary. Knowledge about column generation would be an advantage. Good programming skills.

6. **GROUP SIZE:** 1-2 students.
8. REMARKS: AMCS is a software company specialising in fleet management products. I have other similar optimisation problems in the area of routing and scheduling from AMCS. I can send you the other suggested projects if you contact me.

NETWORK OPTIMIZATION IN AIRLINE REVENUE MANAGEMENT WITH CUSTOMER CHOICE

1. SUPERVISOR: Jesper Larsen

2. PROJECT GROUP: Amadeus IT Group, an IT company developing software for the travel industry

3. PROJECT BACKGROUND: Commercial airlines operate complex hub-and-spoke networks, allowing customers to reach destinations around the world via millions of possible itineraries. The practice of revenue management aims to select the optimal prices for each itinerary to maximize revenue across the airline’s network. The science of airline revenue management has evolved over the last four decades, and now encompasses customer choice modeling, optimization through dynamic programming, and sophisticated demand forecasting models. The goal of this project is to assess, develop, and test methods for network optimization of airline itinerary prices that incorporate models of customer choice between different itineraries. While the problem can be represented as a linear program, the problem space is highly complex and requires intense computation as the number of variables increases exponentially with the number of flights in the airline’s network. The project will benchmark state-of-the-art approaches against current industry-standard heuristic methods for network optimization and use simulations to assess the business impact and revenue performance of correctly incorporating customer choice into network revenue management.

4. PROJECT ASSIGNMENT: Develop a framework to integrate customer choice modelling into the network optimization models used in airline revenue management. The project will begin with a review of current industry-standard approaches and new literature on network optimization. Then, using a simple airline network, the project will investigate how to jointly optimize the prices of multiple itineraries based on the demand and capacity for each flight and a model of customer itinerary choice. Solutions may involve the application of parallelization or cloud computing to reduce computation time, or simplification of the problem through heuristics or approximations. Approaches will be verified analytically and through the development of simulations.

5. PREREQUISITES: Strong background in mathematical optimization, linear programming, and column generation, including Introduction to Operations Research (42101) and Large Scale Optimization using Decomposition (42136). Strong technical skills with experience in Python. Experience in developing simulation models is a plus. Familiarity with reading academic papers in operations research.


7. CHARACTERISTICS OF THE ASSIGNMENT: Mathematical modelling; optimization; linear programming; dynamic programming; discrete choice modelling; simulations. Possibility for a paper or conference presentation.
Projects with Kourosh Rasmussen as supervisor

| Personalized Life Cycle Pension Products |

1. SUPERVISORS: Kourosh Marjani Rasmussen (DTU MAN)

3. PROJECT BACKGROUND: The decision of how much to save for future consumption and the risk taking structure of the asset allocation strategy should be tied to such personal decisions as to how much to work, how much to consume, when to retire, how to insure the household against unpredictable events, etc. These ideas are, per se, not new, but personalized pension products are nowhere to be found. Concrete implementations of this idea, together with life coaching type of advice will indeed be a much needed innovation in the pension industry.

4. PROJECT ASSIGNMENT: In this project we will experiment with life-cycle investment products where risk taking should not only consider the actual value of a person’s portfolio but also the yet un-earned expected life income. This will mean more risk taking when the person is young. As part of this project the students should develop new risk scoring techniques for the individual. They should also compare performance of the new products with most common pension products that are around today. The students should finally test for responsiveness of such strategies to shocks such as loss of income and unfavorable market developments.

5. PREREQUISITES: Core courses in Financial Engineering such as 42104 Introduction to Financial Engineering and 42123 Optimization in Finance.

6. GROUP SIZE: 1 or 2 persons.


| EXCHANGE TRADED FUNDS (ETF) |

1. SUPERVISORS: Kourosh Marjani Rasmussen (DTU MAN)

3. PROJECT BACKGROUND: There is a growing body of empirical evidence that active managed mutual funds are not able to beat the index (which is nothing else than the weighted return of the single stocks) systematically over a prolonged period of time. One possible explanation for this fact is that financial markets are highly efficient, i.e. that market prices reflect nearly all information available at a certain point in time. Another explanation might be asymmetric information, i.e. that mutual fund managers are exploited by “insiders”. Therefore, in the last years the demand from institutional and private investors for so-called index trackers is growing.

4. PROJECT ASSIGNMENT: There are different interesting topics to be addressed in this project. One core question is how to minimize the tracking error while taking transaction costs into consideration. How do products with different tracking techniques perform? What are
the pros and cons? Another related topic is the theoretical explanation why (independent of transaction costs) fund managers might perform worse than index trackers. Interested students can contact the supervisor to hear more about concrete project possibilities. The students are very welcome to come up with their own suggestions as to specific problem descriptions within the framework of the given project area.


6. GROUP SIZE: 1 or 2 persons.


FINANCIAL ADVICE FOR HOUSEHOLD

1. SUPERVISORS: Kourosh Marjani Rasmussen

3. PROJECT BACKGROUND: The complexity of the financial decisions a household has to take has grown considerably during recent years with the steady introduction of new financial products such as different types of loans and pension schemes.

On the one hand this introduces new financing and investment opportunities for the household. On the other hand it imposes financial risks on the household that need to be managed in an economically reasonable manner.

The individual households are in need of personal financial advice to make the right decision due to the course of their lives in order to meet their financial objectives in a sustainable manner.

The governments are interested that the households make informed financial decisions in order to minimize the financial risks that will eventually put a burden on the existing welfare systems.

Finally financial institutions should be interested in giving good advice to their clients for competition reasons (customer goodwill) and for satisfying regulatory requirements.

The cost of old fashioned face to face financial advice makes it unrealistic to provide thorough and holistic (including the households complete economy over a lifetime) advice for all clients. Innovative and affordable net-based solutions are needed to educate the household in their financial decision and help them monitor and manage the performance of these decisions. This should be done in a way that appeals to the household, encourages them to actually use the solutions.

4. PROJECT ASSIGNMENT: There are several topics to be addressed in this project. Interested students can contact the supervisor to hear more about concrete project possibilities. The students are very welcome to come up with their own suggestions as to specific problem descriptions within the framework of the given project area.

6. GROUP SIZE: 1 or 2 persons.


ROBUST INVESTMENTS IN THE FINANCIAL MARKETS

1. SUPERVISOR: Kourosh Marjani Rasmussen

3. PROJECT BACKGROUND: About 84 percent of U.S. stock funds that are actively managed, rather than passively tracking an index, underperformed, in 2011, when compared to the Standard & Poor’s indexes representing the market segment the funds invest in, according to S&P’s 10th annual fund performance scorecard. Over three years, from 2009 through 2011, about 56 percent of stock funds underperformed relative to S&P benchmarks. Over five years, 61 percent underperformed. Going back 10 years, the average percentage of funds underperforming has been about 57 percent. More often than not, a majority of funds underperform because returns are reduced by investment fees to cover fund operations, including costs to pay managers and analysts who support them. Those fees are difficult to offset, even if a manager is a strong stock-picker. At actively managed funds, expense ratios typically range from 0.5 percent to 2 percent. That’s the amount investors pay each year, expressed as a percentage of a fund’s assets. Nevertheless the majority of the average investors savings today end in such stock funds or more broad mutual funds. Index funds (such as ETFs) charge lower fees – as little as 0.06 percent at some funds – because they don’t rely on professionals to pick stocks. Index funds are designed to track an index, delivering investment returns that are slightly smaller than the benchmark to account for fees covering operations. The purpose of this project is to identify robust investment strategies for different categories of investors, ranging from people investing part of their salaries for their retirements to the private banking clients, high net worth individuals and finally corporate investors.

4. PROJECT ASSIGNMENT: There are several topics to be addressed in this project. Interested students can contact the supervisor to hear more about concrete project possibilities. The students are very welcome to come up with their own suggestions as to specific problem descriptions within the framework of the given project area.


6. GROUP SIZE: 1 or 2 persons.

Projects with Nina Lange as supervisor

Time Series Modelling of Bulk Freight Rates

1. SUPERVISORS: Nina Lange (jointly with DTU Compute)

2. PROJECT GROUP: Ultrabulk

3. PROJECT BACKGROUND: Dry bulk commodities are moved worldwide in volumes of more than five billion tons per year performed by about 11000 ships. The trade routes can largely be divided into two groups originating respectively in the Atlantic and in the Pacific Basin. Sometimes ships and cargoes are matched too late keeping either waiting. Sometimes ships are sent to areas that turn out to be over-supplied (with ships) at the time of arrival. Sometimes an area can be under-supplied and fulfilling a contract to move cargo can become a tight issue. Sometimes ships of one company are concentrated in too few areas or spread too thin in too many areas. Vessel spot earnings is the indicator for tight vessel supply. Many shipping companies are currently investing heavily in building models in order to forecast shipping rates as billions of dollars are made/lost due to the guessing of the direction of the markets.

4. PROJECT ASSIGNMENT: The purpose of the assignment is to find a good model for forecasting Panamax dry bulk route relative earnings for a period of four to 16 weeks ahead in order to position the vessels accordingly. The part regarding optimal positioning of vessels does not need to be included in the thesis.

5. PREREQUISITES: Core courses in Financial Engineering: 42104 Introduction to Financial Engineering and a solid background in probability theory, statistics and time series is also needed. The project contains programming in Python, R or Matlab.

6. GROUP SIZE: 1 or 2 persons.

7. CHARACTERISTICS OF THE ASSIGNMENT: Shipping, Time Series Analysis, Freight Rates, Multivariate Time Series, Forecasting,

Optimal Positioning of Vessels

1. SUPERVISORS: Nina Lange, David Pisinger

2. PROJECT GROUP: Ultrabulk

3. PROJECT BACKGROUND: Dry bulk commodities are moved worldwide in volumes of more than five billion tons per year performed by about 11000 ships. The trade routes can largely be divided into two groups originating respectively in the Atlantic and in the Pacific Basin. Vessels are performing two types of voyages – spot or contract. A contract voyage is typically one of a number of voyages known in advance and a spot voyage is a single voyage booked just before the start of the voyage. The shipping company needs to cover the contract voyages in the time frame agreed with the customer and at the same time is needs to make sure that the vessel can take advantage of a strong/weak spot market.
4. **PROJECT ASSIGNMENT:** Based on a time-series forecast of relative earnings, how should vessel voyage planning of next and next-next destinations be optimized across the Atlantic and the Pacific Basin.

5. **PREREQUISITES:** Various optimization courses is need to have, financial engineering courses are nice to have and a solid background in probability theory, statistics, time series and/or economics is a plus. The project contains programming in Julia, Python, R or Matlab.

6. **GROUP SIZE:** 2 persons (if you don’t have a thesis buddy and would like to work on this project, contact us anyways and we’ll see if we can find a solution).

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Shipping, Freight Rates, Multivariate Time Series, Optimization

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### Optimal operation of batteries in the electricity market

1. **SUPERVISORS:** Nina Lange, Stefan Røpke

2. **PROJECT GROUP:** Possible industry collaborator

3. **PROJECT BACKGROUND:** The decarbonisation of the energy industry is a main target of most nations. Fossil fuels are being phased out as the main primary energy sources and replaced by renewable energy from wind or solar power. The increasing share of energy from variable sources into the electricity production makes the balancing of large-scale electric systems more difficult and costly, but the decreasing costs of storage technologies have made battery energy storage systems an appealing solution for a number of applications, notably on the balancing markets. In the United Kingdom, the electricity market was recently reformed to authorise stand-alone batteries to participate in the balancing mechanism.

4. **PROJECT ASSIGNMENT:** The goal of the project is to make algorithms for optimal charging and discharging of a battery in the UK electricity market. The emphasis of the project is up to the student(s). More focus can be put on modelling of electricity prices as input to the optimization algorithm or focus can be put on designing optimal algorithms based on a simpler price forecast.

5. **PREREQUISITES:** Core courses in Financial Modelling is a plus, if the focus is on the modelling of the electricity markets. Core courses in optimization is a plus, if the focus is on the charge/discharge algorithm. The project contains programming in Julia, Python, R or Matlab.

6. **GROUP SIZE:** 1 or 2 persons.

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Optimization, batteries, electricity markets, balancing markets

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### Hedging of Wind Investments

1. **SUPERVISORS:** Nina Lange

2. **PROJECT GROUP:** Possible industry collaborator

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3. **PROJECT BACKGROUND:** A fund management company focusing on renewable investments would like to do an investigation of different risk management strategies for their portfolio of wind investments.

4. **PROJECT ASSIGNMENT:** To investigate if and how to hedge the wind investment and to make a flexible risk management framework that can take into account that markets are evolving.

5. **PREREQUISITES:** It requires good programming skills and a good background in finance, preferably a course in derivatives (like Financial Products) and a financial risk management course. The project contains programming in Julia, Python, R or Matlab.

6. **GROUP SIZE:** 1 or 2 persons.

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Hedging, electricity markets, derivatives
COST OPTIMIZATION OF INLAND TRANSPORTATION USING TRIANGULATION

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP: Stefan Guericke, Klaus Holst, Soren Vedel (Maersk)

3. PROJECT BACKGROUND: Maersk is primarily known for its ocean-based transportation services and handles around 20% of all containers in the world using its own vessels. However, most cargo needs to move beyond the destination port to an inland customer location (e.g. a warehouse, store door), and for this area Maersk does not own assets and instead relies on local trucking companies to execute the transportation. This project focuses on how to leverage triangulation during planning to reduce the expenses of inland trucking.

Vendor trucks spend a lot of the time on the road without containers: For a normal trucking order, a vendor is tasked with transporting a container between two sites (pick up full container at site A and drop it off at site B), as well as the empty return move to the site of the trucking company (going from drop off site B to vendor site without any container). In triangulation, one utilizes the otherwise empty return move to carry another container back, and this usually comes at a much lower rate since the truck had to take that route anyway.

Clearly, smart planning is the key to realize the benefits of triangulation: by automatically identifying which transportation orders can be combined to achieve a triangulation (those close enough in both time and geography) during planning, Maersk can consistently leverage triangulation whenever it offers opportunity for lowering cost.

4. PROJECT ASSIGNMENT: Build a basic model with triangulation, and solve it. This should include locations, delivery times, some finite number of vendors, one type of container, transportation rates and ignore empty repositioning. The model development will involve defining an appropriate objective function. Various types of triangulation must be considered, so too pickup and delivery time windows. As extensions, how to model empty repositioning and solution methods for larger regions (potentially cross-border transportation) are possible directions.

5. PREREQUISITES: Courses: Integer Programming (42114), Large Scale Optimization using Decomposition (42136), Good Programming Skills (Julia or C++)

6. GROUP SIZE: 1 student

7. CHARACTERISTICS OF THE ASSIGNMENT: Model development, Algorithm Design, Programming

8. REMARKS:
COMBINING BENDERS DECOMPOSITION AND A DICHOTOMIC SEARCH FOR 2-STAGE STOCHASTIC BI-OBJECTIVE PROGRAMS

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP:

3. PROJECT BACKGROUND: When formulating an optimization problem it is not uncommon to be able to identify multiple, often conflicting, objective functions. The focus of this project is on bi-objective programs (or problems with two objectives). For such problems the aim is to find a set of efficient solutions, as opposed to a single optimal solution (which is the case for optimization problems with a single objective function). A variety of techniques exists for finding the set of efficient solutions, and one such approach is known as a dichotomic search, which solves a sequence of weighted objective functions that is comprised of the two separate objective functions. Benders decomposition has been widely used to solve two-stage stochastic programs with success. This project will couple Benders decomposition and a dichotomic search to solve two-stage stochastic programs.

4. PROJECT ASSIGNMENT: Devise a Benders Decomposition approach that uses a dichotomic search to identify all extreme non-dominated solutions to a bi-objective two-stage stochastic program. One possible application to be considered is the hierarchical facility location problem under uncertainty. A comparison of the devised algorithm with existing approaches must be provided.

5. PREREQUISITES: Courses: Integer Programming (42114), Large Scale Optimization using Decomposition (42136), Good Programming Skills (Julia or C++)


7. REMARKS:

INTEGRATING TRAIN TIMETABLING, ROUTING, AND TRACK MAINTENANCE SCHEDULING AT THE CHINESE HIGH SPEED RAILWAY

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP: Qin Zhang

3. PROJECT BACKGROUND: The Chinese High Speed Railway is the largest high speed railway in the world. To operate this system efficiently it high quality scheduling is of paramount importance. Frequently, track circuits within the network must be removed from operation to undergo maintenance. Such requests are usually received after the timetable (specifying at what times train services will run) has been made. Trains that have been assigned to tracks reserved for maintenance must be rescheduled to allow the maintenance to be performed. The timing of a maintenance task is flexible; it just must be carried out within
a specified time window. Trains can be delayed at their origin or at stops along their route. This project will focus on developing an algorithm (exact or heuristic) to simultaneously optimize re-scheduling the timetable, re-routing the trains, and scheduling the maintenance so that undue delay and/or cancellations can be avoided.

4. PROJECT ASSIGNMENT: Design an algorithm (heuristic or exact) for simultaneously determining an adjusted timetable (together with conflict-free trains routes) and timings for a set of maintenance tasks in a subpart of the Chinese High Speed Railway network. Provide a comparison of the algorithm’s results with the current best known values.

5. PREREQUISITES: Courses: Integer Programming (42114), Large Scale Optimization using Decomposition (42136), Good Programming Skills (Julia or C++)

7. CHARACTERISTICS OF THE ASSIGNMENT: Model development, Algorithm design, Programming


8. REMARKS:

| ROLLING STOCK SCHEDULING WITH MAINTENANCE REQUIREMENTS AT THE CHINESE HIGH SPEED RAILWAY |

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP: Qingwei Zhong

3. PROJECT BACKGROUND: The Chinese High Speed Railway is the largest high speed railway in the world. Approximately 2,500 high speed trains are in operation on a daily basis. To ensure the safety of the system, the high speed trains must be regularly maintained (every 24 hours or 5,500 km). This project will focus on developing a column generation approach to find a high quality, maintenance feasible rolling stock schedule for a subpart of the Chinese High Speed Railway. Determining a rolling stock schedule entails finding a sequence of trips for each high speed train will perform (and its composition) that collectively cover all timetabled trips.

4. PROJECT ASSIGNMENT: Implement a column generation approach to solve the rolling stock scheduling problem with maintenance requirements at the Chinese High Speed Railway. Sequences of trips assigned to individual units must adhere to the maintenance restrictions specified. A comparison of the performance of the proposed method with existing methodologies must be included.

5. PREREQUISITES: Courses: Integer Programming (42114), Large Scale Optimization using Decomposition (42136), Good Programming Skills (Julia or C++)

7. CHARACTERISTICS OF THE ASSIGNMENT: Model development, Decomposition Algorithm Design, Programming


8. REMARKS: Data provided by the Chinese High Speed Railway
DETECTING GOOD DECOMPOSITIONS FOR THE CAPACITATED LOT SIZING PROBLEM WITH SETUP TIMES

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP: Stefan Røpke

3. PROJECT BACKGROUND: Dantzig-Wolfe reformulation is a technique that can be used to improve the relaxation bound for mixed integer programs. The approach relies on a specification of so-called blocks. Each block contains a set of variables and constraints that are local to that block. The polyhedra defined by the blocks can be restated in terms of convex combinations of their extreme points, and the resulting reformulation is solved using column generation to improve the model’s computational tractability. In ongoing work at DTU, we have developed a tool, known as AUTODEC, for automatically implementing Dantzig-Wolfe reformulation. That is, given a mixed integer program and a specification of blocks, AUTODEC will automatically implement Dantzig-Wolfe decomposition. For some problems, in particular, the so-called Capacitated Lot-Sizing Problem with Setup Times, the approach is highly sensitive to the number of blocks specified. In this project, the focus of the project is developing techniques for – automatically – determining the best number of blocks (and their respective sizes).

4. PROJECT ASSIGNMENT: The purpose of this project is to further automate AUTODEC by investigating techniques for automatically detecting good block structures for the Capacitated Lot-Sizing problem with setup times. Possible directions to explore include machine learning, community algorithms, and hypergraph partitioning.

5. PREREQUISITES: Courses: Integer Programming (42114), Large Scale Optimization using Decomposition (42136), Good Programming Skills (Julia)


8. REMARKS:

REMOVING REDUNDANT COLUMNS IN COLUMN GENERATION

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP:

3. PROJECT BACKGROUND: One known downside of using column generation to solve mixed integer programs is that often (many) columns that are not necessary to define any integer solution are generated. Detecting such redundant columns and preventing their generation can have a positive impact on the convergence of column generation, particularly for time dependent decompositions (see Lübbecke et al. (2019). The approach proposed by Lübbecke et al. (2019)) adds classical Benders cuts in the subproblems to ensure that redundant columns are not generated. The focus of this thesis is on investigating the performance of the Lübbecke et al. (2019) approach on the capacitated lot-sizing problem with setup times and the temporal knapsack problem.
4. PROJECT ASSIGNMENT: Implement the approach of Lübbecke et al (2019) within AUTO-DEC, a tool developed at DTU to automatically implement Dantzig Wolfe Decomposition, and investigate the impact of removing redundant columns problem classes like e.g., the temporal knapsack problem and the capacitated lot-sizing problem with setup times. Comparisons to existing state-of-the-art methodologies will be made. A summary of alternative approaches that attempt to generate only columns that define integer solutions is also mandatory.

5. PREREQUISITES: Courses: Integer Programming (42114), Large Scale Optimization using Decomposition (42136), Good Programming Skills (Julia)

7. CHARACTERISTICS OF THE ASSIGNMENT: Decomposition Algorithm Design, Programming


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SOLVING A HIERARCHICAL FACILITY LOCATION & VEHICLE ROUTING PROBLEM

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP:

3. PROJECT BACKGROUND: Hierarchical facility location problems are concerned with determining the location of facilities in a multi-level network. Typically, the objective is to serve the customers at the lowest level efficiently and effectively. One practical application of the HFLP is in the design of a reverse logistics network. Reverse logistics can be thought of as the opposite of the standard supply chain; products move from the end user back to the manufacturer where they can be properly re-purposed or recycled. Examples of two types of facilities in reverse logistic networks include collection centers and recycling centers. Where to place these different facilities to minimize, among other things, the transportation cost is of crucial importance. Fleets of specific, capacitated vehicles are available in each level of the hierarchy to transport the product moving in each level and require routing. In this thesis the focus is on designing a solution approach to simultaneously solve this hierarchical (facility) location routing problem. As the demand for a particular "customer" in each level can be satisfied by multiple vehicles, each routing problem is essentially a split delivery vehicle routing problem, which is coupled together by the facility placements.

4. PROJECT ASSIGNMENT: Design an implement a meta-heuristic and/or an exact approach to solve the hierarchical location routing problem. Test the methodology on randomly generated instances.

5. PREREQUISITES: Courses: Integer Programming (42114), Large Scale Optimization using Decomposition (42136), Good Programming Skills (Julia or C++)

7. CHARACTERISTICS OF THE ASSIGNMENT: Model development, Decomposition Algorithm Design, Programming

8. REMARKS:

**BENDERS DECOMPOSITION FOR THE SPLIT DELIVERY VEHICLE ROUTING**

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP:

3. PROJECT BACKGROUND: The so-called split delivery vehicle routing problem (SDVRP) is a variant of the well known vehicle routing problem in which a customer’s order can be split across multiple vehicles. State-of-the-art solution approaches for the SDVRP commonly use a relaxed two-index flow formulation. As it is a relaxation, integer solutions must be checked for feasibility and cut away if they are infeasible. Such a Branch-and-cut approach can be implemented as a benders decomposition procedure, where benders/feasibility cuts can be generated from an appropriate subproblem. Determining integer infeasibility of the subproblem can be particularly time consuming. Improvements in relation to this will result in significant improvements to the approach.

4. PROJECT ASSIGNMENT: This thesis will focus on implementing the benders decomposition procedure in Julia/JuMP with cut callbacks and in particular focus on detecting integer infeasibility of the subproblem. The developed methodology will be tested on well-known benchmark instances.

5. PREREQUISITES: Courses: Integer Programming (42114), Large Scale Optimization using Decomposition (42136), Good Programming Skills (Julia or C++)

7. CHARACTERISTICS OF THE ASSIGNMENT: Model development, Decomposition Algorithm Design, Programming


8. REMARKS:

**PRODUCTION & SUPPLY CHAIN OPTIMIZATION WITH COLUMN GENERATION**

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP: Bo Vaaben - OpsAnalytics

3. PROJECT BACKGROUND: A large production company has three factories in Europe and distributes approximately 60 different product types to customers all over the world. The company can distribute the products by various modes of transportation. The company would like to optimize their daily plans for which products should be produced at each factory and how the products should be distributed. The problem is consequently an integrated production and supply chain model. A model, which solves this daily, planning problem does already exist and is implemented in OPL.
4. PROJECT ASSIGNMENT: In collaboration with Ops-Analytics the student should reformulate and improve an existing optimization that can be formulated and solved using column generation. To prototype various possible decompositions, AUTODEC (a tool that automatically implements Dantzig-Wolfe Decomposition can be used). The student must identify and implement a decomposition algorithm to solve the problem. Solution quality provided by, not to mention the speed of, the designed algorithm will be compared to the existing model.

5. PREREQUISITES: Courses: Integer Programming (42114), Large Scale Optimization using Decomposition (42136), Good Programming Skills (Julia, C++)

7. CHARACTERISTICS OF THE ASSIGNMENT: Model development, Decomposition Algorithm Design, Programming


8. REMARKS: Data will be provided by Ops-Analytics, and the project will be confidential.

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THE CLASSIFICATION YARD BLOCK-TO-TRACK ASSIGNMENT PROBLEM

1. SUPERVISOR: Richard Lusby

3. PROJECT BACKGROUND: Classification yards act as large consolidation points in the freight rail industry. The handling of rail cars at such yards is of paramount importance to their efficiency. At a classification yard arriving (or so-called inbound) trains are disassembled and re-grouped/classified into groups of rail cars sharing the same destination. These groups of rail cars are then combined to form new outbound trains, which subsequently leave the yard. How best to sort the rail cars such that the average dwell time in the yard for all rail cars is minimized is an interesting research question and not trivial to answer. A classification yard consists of a number of parallel tracks (each with a certain length) on which cars can be sorted. Which track to assign each rail car is an important subproblem in the handling of rail cars and is the focus of this project.

4. PROJECT ASSIGNMENT: For this project the student(s) will be required to propose mathematical model(s) for the the block-to-track assignment problem, discussing any advantages and/or disadvantages. In addition, implementation of an exact algorithm or a metaheuristic will be required to validate the model.


7. CHARACTERISTICS OF THE ASSIGNMENT: Model analysis, meta-heuristic implementation. Good programming skills will be an advantage

8. REMARKS: Data will be provided by Ops-Analytics, and the project will be confidential.

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THE CARDINALITY CONSTRAINED SHIFT DESIGN PROBLEM WITH MEAL BREAKS
1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP:

3. PROJECT BACKGROUND: The Shift Design Problem is an important optimization problem which arises when scheduling personnel in industries that require continuous operation. Based on the forecast, required staffing levels for a set of time periods, a set of shift types that best covers the demand must be determined. In order to make sure a solution to this problem is easily managed in practice, the number of shift types one is allowed to use is bounded by some upper limit (hence *cardinality constrained*), and typically the chosen set must be the same on each day of the planning horizon. This is despite the fact that the demand scenarios for each day are not identical. Finally, it is important to identify when meal breaks should be provided to staff members within each of the shift types as this also impacts the quality of the final solution.

4. PROJECT ASSIGNMENT: For this project the student(s) will be required to formulate the cardinality constrained shift design problem with meal break selection as an optimization problem and implement a solution algorithm (exact and/or heuristic) to solve it.


6. GROUP SIZE: 1-2

7. CHARACTERISTICS OF THE ASSIGNMENT: Model analysis, meta-heuristic implementation. Good programming skills (C++, Java) will be an advantage

8. REMARKS:

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CYCLIC ROSTER CONSTRUCTION

1. SUPERVISOR: Jesper Larsen and Richard Lusby

3. PROJECT BACKGROUND: For large companies efficiently rostering the employees is an extremely important, yet highly challenging problem. The final rosters must usually obey a large set of union rules, consider employee satisfaction, be cyclic in nature, and distribute the workload as evenly as possible across the employees. Staff salaries often constitute the single most expensive resource companies face, and hence optimizing staff utilization can be of significant benefit.

4. PROJECT ASSIGNMENT: This project considers cyclic roster construction for airport security staff. The student must devise an optimization based algorithm for designing rosters (with a cyclicity of 4 weeks) that teams of security officers will work. It is anticipated that the student(s) will devise a column generation procedure to solve this.

5. PREREQUISITES: Courses: Integer Programming (42114), Large Scale Optimization using Decomposition (42136) or Optimization using meta-heuristics (42137), good programming skills

6. GROUP SIZE: 1-2 Students
7. CHARACTERISTICS OF THE ASSIGNMENT: Integer Programming, Column Generation, Staff Rostering, Cyclic Rostering

POWER PLANT PREVENTIVE MAINTENANCE SCHEDULING

1. SUPERVISOR: Richard Lusby

3. PROJECT BACKGROUND: Scheduling power plant preventive maintenance is an important problem for any power company. This problem entails determining when each power plant should be taken “offline” to perform the necessary safety inspections and/or running maintenance. Power plants are essential components of the electricity network and any failures have the potential to be very disruptive. Since power plants cannot produce when taken offline, it is essential that their respective maintenance periods are coordinated as efficiently as possible. Furthermore, the demand for power is stochastic in nature and one must minimize the cost associated with maintaining the power plants while satisfying the demand in a variety of scenarios.

4. PROJECT ASSIGNMENT: The aim of this project is to develop an optimization tool for determining this preventive maintenance scheduling problem. It is expected that the student will implement an exact decomposition based algorithm, or an advanced metaheuristic. Data for this problem is available and the solutions obtained with the developed methodology will be compared to the known benchmarks.

5. PREREQUISITES: Courses: Integer Programming(42114), Large Scale Optimization using Decomposition (42136) or Optimization using meta-heuristics (42137), good programming skills

6. GROUP SIZE: 1-2 Students

7. CHARACTERISTICS OF THE ASSIGNMENT: Integer Programming, Decomposition, Maintenance, Scheduling

PHARMACEUTICAL MANUFACTURING

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP: Jesper Larsen

3. PROJECT BACKGROUND: The production of a pharmaceutical product can be a complicated process. Typically, it is synthesized in batches from quantities of raw material in such a way that the greatest quantity of the final product, having a pre-specified potency, can be manufactured. Complicating issues include the deterioration of the quality of the raw material over time (which ultimately results in a final product with a lower potency), target batch sizes for the final product, and mixing restrictions on the input raw material. Decisions on which raw materials to mix, and when and where to produce the final products must be made. The unnecessary wastage of raw material should be avoided; however, supplementary production can be possible in some cases.
4. PROJECT ASSIGNMENT: Devise a mathematical programming model, along with a solution method, to optimize the manufacturing process of a pharmaceutical product. Typically, the objective of the problem is to maximize the quantity of the final product produced; however, here consideration will also be given to the sensitivity of the solution to changes in input parameters. In addition, an extensive review of Operations Research methods applied to similar problems must be completed. For the solution method, exact and/or heuristic methods may be developed.

5. PREREQUISITES: Integer Programming (42114), Optimization using meta-heuristics (42137), good programming skills

6. GROUP SIZE: 1-2 students

7. CHARACTERISTICS OF THE ASSIGNMENT: Modelling, algorithm design, literature study

8. REMARKS:

Routing in Blood Sample Retrieval

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP: Troels Martin Range

3. PROJECT BACKGROUND: Taking blood samples for analysis is typically conducted at the location of the hospital. However, some patients are too weak to travel from their homes to the hospital, and the hospital of South West Jutland is experimenting with taking the blood samples in the homes of the patients. As a consequence, a nurse or a bioanalyst has to visit the patient to take the sample. These visits (for non-emergency patients) have to be booked in the hospital’s appointment system called BookPlan which is developed by CapGemini. Hence the problem is to identify a sequence of visits to patients homes such that as many patients can be visited within as short a timeframe as possible. This constitutes a classical time constrained routing problem, and an investigation of possible solutions for this is the aim of this project.

4. PROJECT ASSIGNMENT: This constitutes a classical time constrained routing problem, and an investigation of possible solutions for this is the aim of this project.

Constrained Quadratic Assignment for Facility Layout Decision

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP: Jesper Larsen, Troels Martin Range
3. PROJECT BACKGROUND: A recurrent issue when making changes in a hospital is where different functions have to be positioned such that the total distance traveled is minimized. A number of positions are typically available and functions can be placed at these positions. The hospital of South West Jutland is focusing on minimizing the nonproductive travel distance of employees (which corresponds to walking between functions). A number of workshops is being held where (among other aspects) repositioning of functions is being discussed. In practice, a point observation (following one or more employees on a given day) of the number of trips between functions is conducted and the repositioning is based on this observation. The distance between positions can be measured in meters or number of steps. The problem under consideration corresponds to a quadratic assignment problem where potential side constraints may be added e.g., the distance between certain facilities should not be greater than a given amount or if one function is in a specific position then another cannot be close by.

4. PROJECT ASSIGNMENT: The focus of this project is to formulate and solve the above problem using Operations Research techniques, ultimately providing a tool that can possibly benchmark proposed solutions.

5. PREREQUISITES: Courses: Integer Programming (42114), Optimization using meta-heuristics (42137), good programming skills

6. GROUP SIZE: 1-2 students

7. CHARACTERISTICS OF THE ASSIGNMENT: Modelling, algorithm design

8. REMARKS: Courses: Integer Programming (42114), Optimization using meta-heuristics (42137), good programming skills

6. GROUP SIZE: 1-2 students

7. CHARACTERISTICS OF THE ASSIGNMENT: Modelling, algorithm design

8. REMARKS:
Projects with Stefan Røpke as supervisor

NETWORK OPTIMIZATION ALGORITHMS

1. SUPERVISOR: Stefan Røpke and Simon Spoorendonk (Flowty IVS)

3. PROJECT BACKGROUND: Network optimization problems can be challenging to solve with commercial MIP solvers like CPLEX or GUROBI because of the combinatorial complexity and underlying graph structure. Network optimization problems occur in a wide range of applications within routing, planning, and scheduling.

   The project is carried out in collaboration with Flowty IVS. Flowty offers a library of algorithms tailored for networks, this includes dynamic programming, cutting planes, decomposition methods and heuristics.

4. PROJECT ASSIGNMENT: The purpose of the project is to work on a subtopic within network optimization, e.g., implementing i) a heuristic for a general network optimization problem, ii) a machine learning algorithm to choose the “right” columns in a column generation algorithm, or iii) an algorithm to reuse computations when re-optimizing models with new input data.

5. PREREQUISITES: Programming skills (Julia, Python, C++), good knowledge of network optimization

6. GROUP SIZE: 1-2

7. CHARACTERISTICS OF THE ASSIGNMENT: exact methods, heuristics, framework

LINER SHIPPING NETWORK DESIGN

1. SUPERVISOR: Stefan Røpke

3. PROJECT BACKGROUND: Many of the goods that we buy in shops have been produced far from Denmark and are transported here using container ships. Container ships travel along fixed routes and several ships share the same routes such that the ports on the routes receive a weekly visit by a container ship. The routes combined constitute a transportation network that allow cargoes to be shipped between two ports that are not connected by any route. This is possible by transshipment cargoes between different routes one or more times during the voyage.

   The set of routes that a container liner company chooses to operate has a large impact on its business: The network decides the cost of operations; it decides which cargoes that can be transported as well as the level of service provided to the customers (shipping times).
4. **PROJECT ASSIGNMENT:** Design and implement a solution method for the liner shipping network design problem. Test the approach on instances from LinerLib data set.

5. **PREREQUISITES:** Some programming experience in e.g. C, C#, C++, Java or Julia. At least one of the courses 42114 Integer programming, 42137 Optimization using metaheuristics, 42115 Network Optimization, 42132 Large Scale Optimization using decomposition.

6. **GROUP SIZE:** 1-2

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Maritime optimization, integer programming, transportation

8. **REMARKS:** David Pisinger offers a similar project.
TIMETABLES FOR REGIONAL AND INTERCITY TRAINS

1. SUPERVISOR: Stefan Røpke

2. PROJECT BACKGROUND: Producing a timetable for the regional and intercity trains in Denmark is a difficult and time consuming task. Today the timetable is planned in a (mostly) manual way. For that reason it is promising to explore if operations research algorithms can be used to assist in the construction of time tables. The project is carried out in collaboration with DSB and should aim at developing a prototype that takes real-life constraints into account.

4. PROJECT ASSIGNMENT: The project can focus on the time tabling project alone or components of other train planning problems can be included, for example decisions related to stopping patterns for trains or scheduling of rolling stock. Data is already available and it is possible to build on existing models and algorithms or to start from scratch.

5. PREREQUISITES: Some programming experience, experience with either integer programming or experience with metaheuristics is highly recommended.

6. GROUP SIZE: 1-2 students

7. CHARACTERISTICS OF THE ASSIGNMENT: Trains, time tabling, integer programming

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Automatic Dantzig Wolfe Decomposition

1. SUPERVISOR: Stefan Røpke and Jens Vinther Clausen and/or Richard Lusby

2. PROJECT BACKGROUND: At DTU we are currently doing research on how to automatize Dantzig-Wolfe decomposition. A goal of the research project is to develop methods that solves mixed integer programming programs using Dantzig-Wolfe decomposition and column generation entirely without any user involvement. In the long run, such methods could be embedded into solvers like CPLEX or Gurobi and improve their performance on certain problem classes. We would like to invite MSc students to collaborate on this project. The research is on the forefront and a successful master’s thesis could potentially lead to a journal paper.

4. PROJECT ASSIGNMENT: Many projects can be envisioned within the Automatic Dantzig Wolfe Decomposition research project. Some examples are:

   - Test the developed methods on new problem classes. Is it possible to find new classes of problems where the approach has potential?
   - A very time consuming part of the algorithm is to solve the sub-problems during column generation. Is it possible to devise fast heuristic to speed up the sub-problem solve time?
   - At the moment the algorithm is very generic, but it is possible to specialize the algorithm to a specific problem classes. It could be interesting to work on a specialized version of the algorithm for solving important problem types.
Often it is possible to aggregate identical sub-problems when applying Dantzig-Wolfe decomposition. This is not currently supported by the algorithm and would be a valuable addition.

5. PREREQUISITES: Programming experience, experience with column generation and Dantzig-Wolfe decomposition, for example through the courses 42136 Large Scale Optimization using Decomposition.

6. GROUP SIZE: 1-2 students

7. CHARACTERISTICS OF THE ASSIGNMENT: Dantzig-Wolfe decomposition, column generation, integer programming

Machine learning and metaheuristics

1. SUPERVISOR: Stefan Røpke

2. PROJECT BACKGROUND: Machine learning is a subject that has become extremely popular in the last decade. It is interesting to examine if machine learning techniques can be used to improve the performance of metaheuristics. Any metaheuristic can be the focus of the study, but adaptive large neighborhood search is perhaps especially well-suited given DTU’s expertise on the metaheuristic.

4. PROJECT ASSIGNMENT: Investigate if one or more components of a particular metaheuristic can be improved using machine learning techniques. It could for example be interesting to investigate if the adaptive tuning of destroy/repair methods embedded in Adaptive large neighborhood search could be done more intelligently using machine learning techniques. It could also be interesting to investigate if the acceptance criterion that are part of many heuristic can be chosen in an online way, taking information about the features of the current data-set into account.

5. PREREQUISITES: Programming experience. The course 42137, Optimization using metaheuristics could be useful and so could courses on machine learning algorithms.

6. GROUP SIZE: 1-2 students

7. CHARACTERISTICS OF THE ASSIGNMENT: Metaheuristics, machine learning algorithms
HEURISTICS FOR MIXED INTEGER CONIC PROBLEMS

1. SUPERVISOR: Stefan Røpke

3. PROJECT BACKGROUND: Even though an mixed-integer optimization problem is solved with a branch & bound algorithm then a heuristic for finding good feasible solutions is useful. An interesting project is to generalize the heuristics from linear to conic case. In particular the efficient generalization of the feasibility pump heuristic would be interesting. The project is to be carried out in collaboration with MOSEK ApS.

4. PROJECT ASSIGNMENT: Get to know second-order cone programming and some of the standard heuristics for mixed integer linear programming. Develop and implement a heuristic for mixed integer conic problems.

5. PREREQUISITES: Programming skills. Some flair for mathematics.

6. GROUP SIZE: 1-2


8. REMARKS: Relevant literature

• Alizadeh, Goldfarb, Second-order cone programming, Mathematical programming 95 (2003) 3-51.
• Fischetti, Glover, Lodi, The feasibility pump, Mathematical programming 104 (2005), 91-104

SOLVING REAL LIFE VEHICLE ROUTING PROBLEMS

1. SUPERVISOR: Stefan Røpke

3. PROJECT BACKGROUND: Real life vehicle routing problems typically contains more complicated constraints or objective functions compared to the standard problems studied in the literature. In this project we will contact the company AMCS who specializes in vehicle routing software and the exact topic of the project will be decided by the problems the company currently are working on.

4. PROJECT ASSIGNMENT: Develop heuristics or exact methods for solving real life vehicle routing problems.

5. PREREQUISITES: Mandatory:

• Programming experience.

Nice to have, but not mandatory:

• Integer programming (42114).
• Optimization using metaheuristics (42137)
• Transport optimization (42117)

6. GROUP SIZE: 1-2

COMPONENTS OF A MIXED INTEGER LINEAR PROGRAMMING SOLVER

1. SUPERVISOR: Stefan Røpke

3. PROJECT BACKGROUND: Writing a mixed integer linear programming solver that can compete with state of the art solvers require many software components like separation routines for known cutting planes, heuristics for finding feasible solutions, presolvers for simplifying the problem and methods for selecting which variables to branch on, to name a few. Writing just one of these components can be an interesting challenge in itself.

4. PROJECT ASSIGNMENT: The purpose of this project is to work on a selected component and test the impact of that component. It could for example be implementing a new separation routine for cutting planes or a new heuristic for finding feasible solutions. The project is to be carried out in collaboration with MOSEK ApS.

5. PREREQUISITES: Programming skills (C or C++). Good knowledge of integer programming.

6. GROUP SIZE: 1-2


EVALUATING SIMPLE AND FAST HEURISTICS FOR THE CAPACITATED VEHICLE ROUTING PROBLEM.

1. SUPERVISOR: Stefan Røpke

3. PROJECT BACKGROUND: The capacitated vehicle routing problem (CVRP) has been studied for more than 50 years and many simple and fast heuristics for solving the problem have been proposed over the years. Researchers and practitioners have a good idea of the strengths and weaknesses of the main types of heuristics but surprisingly there is no comprehensive test of a wide range of the heuristics on a large sample of CVRP instances. A very good comparison could be published in an academic journal.

4. PROJECT ASSIGNMENT: Some of the simple and fast should be implemented. Focus should also be on designing/selecting test instances and performing a fair comparison of the heuristics.

5. PREREQUISITES: Mandatory:
   
   • Programming experience.

   Nice to have, but not mandatory:

   • Integer programming (42114).
   • Optimization using metaheuristics (42137)
   • Transport optimization (42117)
6. GROUP SIZE: 1-2


STOCHASTIC VEHICLE ROUTING PROBLEMS

1. SUPERVISOR: Stefan Røpke

3. PROJECT BACKGROUND: Classical vehicle routing problems like the capacitated vehicle routing problem (CVRP) or the vehicle routing problem with time windows (VRPTW) assume that all data are known in advance. This assumption is obviously not always satisfied in practice. It is therefore interesting to study variants of the vehicle routing problem where part of the input data is given as random variables with known distribution, commonly known as stochastic vehicle routing problems. Examples are the vehicle routing problem with stochastic demands or the vehicle routing problem with stochastic travel times.

4. PROJECT ASSIGNMENT: Select a stochastic vehicle routing problem and design/implement a solution method for it.

5. PREREQUISITES: Programming skills. Relevant courses (none of them are a strict requirement): 42114 Integer Programming. 42115 Network Optimization. 42137 Optimization using metaheuristics. 42117 Transport optimization

6. GROUP SIZE: 1-2


8. REMARKS: Relevant literature (one example):

Optimal operation of batteries in the electricity market

1. SUPERVISORS: Nina Lange, Stefan Røpke

2. PROJECT GROUP: Possible industry collaborator

3. PROJECT BACKGROUND: The decarbonisation of the energy industry is a main target of most nations. Fossil fuels are being phased out as the main primary energy sources and replaced by renewable energy from wind or solar power. The increasing share of energy from variable sources into the electricity production makes the balancing of large-scale electric systems more difficult and costly, but the decreasing costs of storage technologies have made battery energy storage systems an appealing solution for a number of applications, notably on the balancing markets. In the United Kingdom, the electricity market was recently reformed to authorise stand-alone batteries to participate in the balancing mechanism.

4. PROJECT ASSIGNMENT: The goal of the project is to make algorithms for optimal charging and discharging of a battery in the UK electricity market. The emphasis of the project is up to the student(s). More focus can be put on modelling of electricity prices as input to the optimization algorithm or focus can be put on designing optimal algorithms based on a simpler price forecast.
5. **PREREQUISITES:** Core courses in Financial Modelling is a plus, if the focus is on the modelling of the electricity markets. Core courses in optimization is a plus, if the focus is on the charge/discharge algorithm. The project contains programming in Julia, Python, R or Matlab.

6. **GROUP SIZE:** 1 or 2 persons.

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Optimization, batteries, electricity markets, balancing markets

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**Operations research and biodiversity preservation**

1. **SUPERVISORS:** Stefan Røpke

2. **PROJECT GROUP:** Professor, Niels Strange from Department of Food and Resource Economics (IFRO) at University of Copenhagen

3. **PROJECT BACKGROUND:** All over the world species are facing extinction due to human activities. One way to combat this extinction is to protect land areas that are rich in biological life in order to prevent destruction of the habitats of the endangered species. Unfortunately, it is not possible to protect all the areas that biologist would like to conserve (it is simply too costly compared to the money available for such activities). Operations research techniques can therefore be used to help select the most valuable areas to protect given the budget available for buying land. For more information, see, for example: Strange, Niels, Jette B. Jacobsen, Bo J. Thorsen, and Peter Tarp. "Value for money: protecting endangered species on Danish heathland." Environmental management 40, no. 5 (2007): 761-774

4. **PROJECT ASSIGNMENT:**
   - Read existing work on biodiversity preservation using OR techniques.
   - Select a case and gather data.
   - Develop a model that selects areas to protect based on a given budget. The model can take stochasticity into account.

5. **PREREQUISITES:** Modelling experience. Integer programming (42114). Experience with stochastic programming is a plus.

6. **GROUP SIZE:** 1 or 2 persons.

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Biodiversity, modelling, stochasticity.
CO₂ neutral container shipping

1. SUPERVISORS: Stefan Røpke

3. PROJECT BACKGROUND: The transport sector is facing huge changes in the next decades. Eventually it will have to change its energy source from fossil fuels to renewable energy. In this project we like to focus on how the container shipping industry could switch to renewable energy. One possibility is to switch to fuels such as hydrogen or ammonia. Hydrogen can be produced from water and ammonia can be produced from hydrogen and nitrogen with nitrogen being abundant in the atmosphere. In both cases electricity is needed in the production of the fuels and that electricity could for example come from wind turbines or other renewable sources.

4. PROJECT ASSIGNMENT: Assume that the hydrogen is chosen as the fuel of future container ships. The project could look into where the hydrogen should be produced and where container ships should be fueled in the most efficient way. A straightforward approach would be to produce the hydrogen next to the most busy harbors around the globe using wind turbines, but it may more beneficial to produce the hydrogen elsewhere (where wind conditions may be better or where other sources of renewable energy exists) and transport the hydrogen to the harbors where the fuel is needed. Therefore a mathematical model should be developed that chooses the production locations for hydrogen and plans transport to harbors where the fuel is needed, if necessary

5. PREREQUISITES: Some programming experience, modelling experience. Integer programming (42114)

6. GROUP SIZE: 1 or 2 persons.


CO₂ neutral truck transport

1. SUPERVISORS: Stefan Røpke

3. PROJECT BACKGROUND: Currently, it is not clear how heavy road based transport (trucks) should be fueled in a future where fossil fuels are no longer used in the transportation sector. For personal cars it seems like battery powered electric cars is a possible way forward. However, this solution does not seem suitable for heavy trucks given the current technology. The weight and volume of the needed batteries would simply be impractical. Instead two main directions are being investigated: 1) either trucks could be powered using fuels produced using electricity (electrofuels), an example could be hydrogen, 2) or the trucks could be supplied with electricity while driving, this could be using overhead wires, power rails in the roads or wireless charging built into roads. Electricity would (of course) need to be generated using renewable sources for all of these alternatives to be CO₂ neutral.

4. PROJECT ASSIGNMENT: In this project we will look at the operations research problems that arise with a system where trucks are supplied with electricity while driving. One of the two following assignments should can be addressed in the project:
1. Building up infrastructure for charging-while-driving is going to be extremely costly no matter what technology one chooses (overhead wires/power rails/wireless charging). On could imagine a system where trucks can be charged while driving on highways and need a (low capacity) battery for the trips outside the highway network. However, is this the smartest placement of charging infrastructure? Perhaps one would obtain a better coverage of Denmark by only providing charging-while-driving on some highway segments and then also provide charging-while-driving on some segments outside the highway network. In this assignment you should develop a model that selects the road-segments where charging-while-driving is installed. The segments should be selected to maximize the number of trips that can be carried out by electric trucks given a certain budget on how much infrastructure to install.

2. In the second assignment one should assume that charging-while-driving already has been installed on selected road segments and this is given as input. One should then model and solve a vehicle routing problem for electric trucks that can recharge while driving on the powered road segments. The vehicle routing problem addresses how to distribute goods from a central depot to a number of customers using a fleet of trucks. The output of the vehicle routing problem is a delivery route for each truck. Given that the trucks only have a limited range when driving outside the powered road segments this creates new constraints in the vehicle routing problem and means that solutions, potentially would look different from a solution using diesel based trucks.

5. PREREQUISITES: Programming experience, Some of the courses 42114 Integer programming, 42137 Optimization using metaheuristics and 42117 Transport optimization

6. GROUP SIZE: 1 or 2 persons.

7. CHARACTERISTICS OF THE ASSIGNMENT: Road based transportation, CO2 neutral fuels, Transport optimization.
Projects with Thomas Stidsen as supervisor

OPTIMAL DECISION TREES

1. SUPERVISOR: Thomas Stidsen

3. PROJECT BACKGROUND: Decision trees is a classical approach to clustering, which has been used for many practical problems for decades. Recently, Prof. Dimitris Bertsimas has suggested that this approach can be improved. In this project we will attempt to implement a new approach where decision trees are created using MIP models and optimal decision trees are created.

4. PROJECT ASSIGNMENT: Use MIP models to create optimal decision trees

5. PREREQUISITES: Introduction to Operations Research (42101), Mathematical Programming with Modelling Software (42112). Some knowledge of statistics is required.

1. **SUPERVISOR:** Thomas Stidsen

3. **PROJECT BACKGROUND:** Clustering algorithms has for decades been performed using various heuristic algorithms. In this project the job is to apply mathematical programming (Mixed Integer Programming), so to get exact solutions to the clustering problem.

4. **PROJECT ASSIGNMENT:** The project is to implement new clustering methods using mixed integer programming and compare the performance with the classical clustering algorithms.

5. **PREREQUISITES:** Introduction to Operations Research (42101), Mathematical Programming with Modelling Software (42112), programming experience in Julia/JUMP

6. **GROUP SIZE:** 1-2 persons.
1. **SUPERVISOR:** Thomas Stidsen, Line Reinhardt, Anders Andersen

3. **PROJECT BACKGROUND:** In the typical ER units, doctors will (naturally) prioritize critically wounded people. This makes sense, but it also means that people with less than lifethreatning problems, e.g. a broken leg, can wait for hours. Maybe it is possible to make a fast track treatment for simple cases, a little like fast track payment in supermarkets.

4. **PROJECT ASSIGNMENT:** The project should model the operation of an ER with real data from e.g. the hospital in Slagelse. Using simulation tools it should be possible to evaluate the possible benefits of fast track treatment.

5. **PREREQUISITES:** Introduction to Operations Research (42101), Simulation in Production og Services (42413)

6. **GROUP SIZE:** 1-2 persons.

7. **CHARACTERISTICS OF THE ASSIGNMENT:** If fast tracks can be demonstrated to be efficient, it may lead to better ER’s in Denmark.

8. **REMARKS:**
1. **SUPERVISOR**: Thomas Stidsen

3. **PROJECT BACKGROUND**: The classical approach to Linear Regression usually involves the Lasso algorithm. Recently, Prof. Dimitris Bertsimas has suggested that this approach can be improved. In this project we will attempt to implement his approach and compare it to the Lasso approach. This should lead to a quantification of the two approaches.

4. **PROJECT ASSIGNMENT**: Solve Linear Regression using Quadratic MIP.

5. **PREREQUISITES**: Introduction to Operations Research (42101), Mathematical Programming with Modelling Software (42112). Programming experience is a big plus and so is knowledge of the Lasso algorithm.

6. **GROUP SIZE**: 1-2 persons.
1. **SUPERVISOR:** Thomas Stidsen

3. **PROJECT BACKGROUND:** Mixed Integer Programming (MIP) models are very very important for solving Operations Research problems. They can however be hard to solve, both in theory and practice. But which features makes a MIP models hard?

4. **PROJECT ASSIGNMENT:** Given a set of MIP models, the idea is to generate a number of measures, which we think could be a measure of the hardness of the models. Afterwards, different statistical instruments can be used to find the best combination, to predict how hard the problem is to solve.

5. **PREREQUISITES:** Introduction to Operations Research (42101), Integer Programming (42114) Programming experience is a must.

6. **GROUP SIZE:** 1-2 persons.

7. **CHARACTERISTICS OF THE ASSIGNMENT:** The project is novel and a good project could be of large value to the OR society.

8. **REMARKS:**
1. **SUPERVISOR:** Thomas Stidsen

3. **PROJECT BACKGROUND:** Novo Nordisk has initiated a large collection of digitalization projects, to improve the performance of one of their production facilities. One of the projects involves the manufacturing process of plastic components for medical devices, mainly for diabetic and haemophilia patients. The facility that is considered contains more than 40 production lines and produces more than 100 different articles. Before the project was initiated, the planning of the facility has been done manually in Excel. A system has been built using Gurobi and Python to support the planner in the decision process, when planning the production eight weeks ahead in time. The goal is to be able to plan a full year ahead.

4. **PROJECT ASSIGNMENT:** Two potential directions are proposed:

   1. One direction is to investigate metaheuristics to improve the solution time, as the current model is not tractable for more than an 8-10 weeks planning horizon.
   2. Another direction is to investigate decompositions. The current idea for the one-year planning model is to decide on the activities on each line on a weekly basis. It could be interesting to consider a Dantzig-Wolfe decomposition, where the model is decomposed per line (or a group of lines) or per week.

   The student will have a lot of freedom to choose exactly what aspects of the problem to study.

5. **PREREQUISITES:** Introduction to Operations Research (42101), Integer Programming (42114), Mathematical Programming Modelling (42112), Optimization using Metaheuristics (42137) or Large Scale Optimization using Decomposition (42136). Programming experience is beneficial

6. **GROUP SIZE:** 1-2 persons.

8. **REMARKS:**