Master's thesis project in Management Science

Section for Operations Research

Section for Operations & Supply Chain Management

Fall 2024

Last update: 5. april 2024

DTU

How to apply for a Master's thesis project within Management Science

The starting dates for a Master's thesis in the Fall semester 2024 are:

- Tuesday 5/8 2024
- Monday 26/8 2024

A thesis can be either 30 ECTS points, 32.5 ECTS points or 35 ECTS points and can last for five or six months, depending on the size of the project and/or if you have coursework in parallel to the thesis.

If you want to write a Bachelor's thesis or a Master's thesis in the Fall of 2024, you **MUST** fill in the **Management Science - MSc/BSc thesis request form**, before 1 May 2024 at the link below:

`https://forms.office.com/e/D3eCVFYuFx`

As stated in the form, the Management Science division does not guarantee that you will find a supervisor and a suitable topic. We will get back to all applicants on 16 May 2024.

To answer questions on exam projects, we have an on-line zoom meeting, 12.00-12.45, Friday 19/4. The zoom link is:

`https://dtudk.zoom.us/j/62060087998`

Both this project folder pdf document and a link to the Zoom presentation (after 19/5), will be available on the DTU-Management web-site:

`https://www.man.dtu.dk/english/education/exam-projects`

Welcome

In this folder, the Division of Management Science presents a wide range of exciting topics for Master's theses. Every year, we offer many different projects, and we update this folder at the end of each semester. The primary aim of the folder is to serve as a source of inspiration. Your main supervisor must be a faculty member; please refer to the list of faculty members mentioned in the following pages. In addition to our faculty, our PhD students and PostDocs often participate in the supervision with their fresh ideas and hands-on knowledge.

As this folder will show you, we offer a wide variety of projects. An extensive network of industrial contacts enables us to offer you projects in cooperation with many different companies. You can also choose a project which requires you to possess a strong theoretical background.

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

Operations Research

The typical requirement for starting a Master's project in Operations Research is that you have followed an advanced OR course (beyond our introductory course number 42101).

The Section for Operations Research consists of more than 15 people working on different aspects of Operations Research. The department is proud to be a member of the Danish Operations Research Society – the largest OR network in Scandinavia.

Operations & Supply Chain Management

We expect you to have taken at least two courses within O & SCM to qualify for your thesis with us. In most cases, the student projects within O & SCM are carried out in close collaboration with a company or public institution. This often implies the resulting thesis to be kept confidential when this is deemed necessary by the external host.

The Section for Operations & Supply Chain Management employs 12-15 researchers, including professors, senior researchers and PhD students and PostDocs.

Further information

A number of desks in a shared office space are available for Master's thesis students in Management Science. Requests can be made to your supervisor.

Further information about the division of Management Science can be found on our homepage at `www.man.dtu.dk`.

Best regards,

The faculty of Management Science

Potential supervisors - Operations Research

- Professor Bissan Ghaddar, Email: bisgh@dtu.dk
  - Core: Non-linear optimization, network optimization applied to energy and transport, electric vehicle routing, machine learning for optimization, last-mile optimization
  - Other: robust optimization, telecommunication operations optimization
- Associate Professor Dario Pacino, Email: darpa@dtu.dk
  - Core: Container Terminal Optimization, Maritime Logistics, Heuristics, Modelling
  - Other: City Logistics, Smart City real-time optimization, Constraint Programming
- Professor David Pisinger, Email: dapi@dtu.dk
  - Core: Maritime Logistics, Liner Shipping Network Design, Wind Farms, Packing and Loading, Heuristics, Modelling, Airport Optimization
  - Other: Transportation problems, Network Optimization, Algorithms, (Meta)heuristics, Stochastic Optimization
- Associate Professor Evelien van der Hurk, Email: evdh@dtu.dk, Expertise area:
  - Core: (public) transport, network-flow problems, column generation, combinatorial opimization, data & statistics
  - Other: vehicle routing, health care, simulation, forecasting
- Professor Jesper Larsen, Email: jesla@dtu.dk
  - Core: transport optimization, integer programming
  - Other: scheduling, health care, production planning
- Associate Professor Richard Lusby, Email: rmlu@dtu.dk
  - Core: Decomposition Methods, Integer Programming, Passenger Railway Optimization, Robust Planning
  - Other: Matheuristics, Scheduling, Staff Rostering, Transportation
- Professor 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, machine learning, financial engineering, sustainability
- Associate Professor Thomas Stidsen, Email: thst@dtu.dk
  - Core: Educational timetabling, health-care planning, multi-objective optimization, manpower planning, integer programming
  - Other: financial optimization, energy modelling and optimization

Potential supervisors - Operations & Supply Chain Management

- Associate Professor Michael Bruhn Barfod, Email: mbba@dtu.dk
  - Core: Impact assessment, multi-criteria decision analysis (MCDA), costomized decision support systems, maritime transport
  - Other: Problem structuring, stakeholder involvement, transport system assessment
- Professor Jens Otto Brunner, Email: jotbr@dtu.dk
  - Core: Healthcare Operations Management, Health Analytics
  - Other: Mathematical Programming, Optimization, Simulation, Artificial Intelligence (Machine Learning)
- Professor Jasmine Lam, Email: slela@dtu.dk
  - Core: Maritime transport, maritime logistics, port planning and management, sustainable logistics
  - Other: Data analytics
- Professor Allan Larsen, Email: alar@dtu.dk
  - Core: Optimisation and simulation of supply chains, transport optimisation, freight transport and logistics and supply chains and logistics in healthcare
  - Other: Healthcare operations management
- Associate Professor Joe Naoum-Sawaya, Email: joenao@dtu.dk
  - Core: Column generation, Benders decomposition, machine learning, supply chain, logistics, transportation
  - Other: telecommunication networks, water networks, sharing economy
- Senior Researcher George Panagakos, Email: geopan@dtu.dk
  - Core: Maritime operations, maritime freight logistics, environmental performance of shipping
  - Other: Sustainable transport, impact assessment of policy issues

Projects with Michael Barfod as supervisor

MSc Project
Decision support using multi-criteria decision analysis

1. SUPERVISOR: Michael Barfod

2. PROJECT GROUP: Depends on the specific thesis project and the potential collaboration with an external company. In case of company collaboration an external advisor from the company is associated with the thesis project.

3. PROJECT BACKGROUND: Recent research has shown that conventional assessment methods such as cost-benefit analysis is inadequate as a decision support tool when addressing decision problems involving criteria of a more strategic and qualitative character. Multi-criteria decision analysis (MCDA) can be applied to the assessment scheme to deal with this issue

4. PROJECT ASSIGNMENT: Current research deals with the difficult task of identifying the most suitable decision aids for supplementing or replacing the cost-benefit analysis. Several MCDA techniques have been suggested as suitable for decision-making when dealing with selections among a limited number of alternatives. However, these techniques become inappropriate when dealing with a large number of alternatives and criteria. This project aims to look into the possibilities of using outranking methods, such as ELECTRE and PROMETHEE, belonging to the so-called constructive MCDA approach. These methods can handle a large number of alternatives and criteria simultaneously utilizing a voting mechanism. The different methods can be applied to a suitable case study, and the results can be benchmarked against the outcome of a conventional analysis.

5. PREREQUISITES: Decision Support and Strategic Assessment (42879)

5. GROUP SIZE: 2-3 persons

MSc Project
Reducing emissions in the maritime sector

1. SUPERVISOR: Michael Barfod

2. PROJECT GROUP: Depends on the specific thesis project and the potential collaboration with an external company. In case of company collaboration an external advisor from the company is associated with the thesis project.

3. PROJECT BACKGROUND: In April 2018, IMO adopted its initial strategy (revised in 2023) to reduce ship GHG emissions. Aiming at phasing out GHG emissions as soon as possible in this century, IMO set the targets of: 1) Carbon intensity of the ship to decline through further improvement of the energy efficiency for new ships to review to strengthen the energy efficiency design requirements for ships, 2) Carbon intensity of international shipping to decline to reduce CO2 emissions per transport work, as an average across international shipping, by at least 40% by 2030, compared to 2008, 3) Uptake of zero or near-zero GHG emission technologies, fuels, and/or energy sources to represent at least 5%, striving for 10% of the energy used by international shipping by 2030, and 4) GHG emissions from international shipping to reach net zero GHG emissions by or around 2050, whilst pursuing efforts towards phasing them out as called for in the Vision consistent with the long-term temperature goal set out in Article 2 of the Paris Agreement.

Measures suggested in IMO's strategy include providing power supply from renewable sources to ships and ports and developing the necessary infrastructure to support the supply of alternative low - and zero -carbon fuels. Short-term candidate measures include initiating research and development activities addressing marine propulsion, alternative low- and zero-carbon fuels, and innovative technologies to enhance ship energy efficiency further.

4. PROJECT ASSIGNMENT: Students will be working with different approaches to meet the overall goal of reducing emissions in the maritime sector. This can e.g. include:

– Examine the carbon emission reduction potential of various technical and operational energy efficiency measures for specific types of ships

– Examine the carbon emission reduction potential of alternative fuels as both short- and long-term measures

– Design decision support systems to assist the maritime industry in meeting the reduction targets in the most cost-effective way

5. PREREQUISITES: Good knowledge of statistics, Decision support and strategic assessment (42879)

5. GROUP SIZE: 2-3 persons

BSc/MSc Project
Green Maritime Corridors

1. SUPERVISOR: Michael Barfod, Sadaf Farboodi

2. PROJECT GROUP: Depends on the specific thesis project and the potential collaboration with an external company. In case of company collaboration an external advisor from the company is associated with the thesis project.

3. PROJECT BACKGROUND: Although the 4th Greenhouse Gas Study of IMO highlighted that the shipping industry has continued its trend of decoupling emissions from the global growth of seaborne trade, emissions are projected to increase from about 90% of 2008 emissions in 2018 to 90-130% of 2008 emissions by 2050. Alternative marine fuels are seen as a necessary means to reach net-zero GHG emissions by or around 2050, as the IMO revised strategy for GHG emission reduction stipulates.

Green maritime corridors is a concept addressing the uncertainties associated with the substantial investments in ships, fuels, and fueling infrastructure required for kick-starting green transition in the sector through testing and demonstrating new solutions at scale. Cargo owners, vessel operators, port operators, marine fuel producers, bunkering service providers are only few of the stakeholders involved in turning a green maritime corridor into reality.

4. PROJECT ASSIGNMENT: Students will be working with different approaches to assess the feasibility of a potential green maritime corridor. This can e.g. include:

– Examine the technical feasibility of a potential corridor and the related pre-conditions

– Examine the economic and regulatory feasibility of a potential corridor and the related pre-conditions

5. PREREQUISITES: Good knowledge of statistics, Decision support and strategic assessment (42879)

5. GROUP SIZE: 2-3 persons

BSc/MSc Project
Alternative fuels for maritime propulsion

1. SUPERVISOR: Michael Barfod

2. PROJECT GROUP: Depends on the specific thesis project and the potential collaboration with an external company. In case of company collaboration an external advisor from the company is associated with the thesis project.

3. PROJECT BACKGROUND: The shipping industry is responsible for 2.8% of the global GHG emissions, and had a 20% increase in GHG emissions over the past decade. A significant reason for this situation is that the industry depends on ships that operate primarily with fossil fuels. To make things more challenging, the demand for shipping has grown faster than energy efficiency improvements. In 2023, only 1.8% of the ships, representing 6.5% of total shipping tonnage, operated on alternative fuels. However, more than 25% of the newly ordered ships under construction will run using alternative fuels.
Several alternative fuels are proposed for the future of shipping, including both bio-fuels and e-fuels such as methanol, ammonia, hydrogen, and LNG. However, the shipping sector will compete with other sectors due to the scarcity of these fuels, and moreover, there will not be a single fuel that fits all purposes. Thus, a comprehensive assessment is needed.

4. PROJECT ASSIGNMENT: Students will be working with the strategic decision of a case company to identify the most attractive alternative fuels for the future.
The study will include an economic analysis for the investment in new ships as well as retrofitting existing ones. The analysis will moreover include a strategic assessment of environmental, technical, and social criteria that reflect the company's focus areas.
The strategic analysis will be performed using the concept of multi-criteria decision analysis (MCDA) and include a formal structuring of the decision problem, identification of criteria to include, and a thorough analysis of the assessment scales used under the criteria. For the latter significant desk research will be necessary to set up global scales for each criterion and assign scores for the alternative options.
The study will conclude with a set of recommendations for the way forward.

5. PREREQUISITES: Good knowledge of economics, Decision support and strategic assessment (42879)

5. GROUP SIZE: 2-3 persons

Projects with Jens O. Brunner as supervisor

BSc/MSc Project
OPERATING ROOM PLANNING AND SCHEDULING

HCOM
Health Care Operations Management

1. SUPERVISOR: Jens O. Brunner

2. PROJECT GROUP: PhD students and/or external supervisors might support the students if needed.

3. PROJECT BACKGROUND: At just under 40% of total expenditure, a hospital's operating rooms are the most significant cost generator and one of the largest sources of revenue. This requires efficient planning of the ORs to be performed on the strategic (case mix planning), tactical (master surgery scheduling), and operational (replanning, sequencing) levels. However, the operating rooms' capacities and those of down- and upstream or other related departments (e.g., intensive care unit, sterilization department) must be considered. In case of capacity bottlenecks in these departments, efficient patient flow might need to be improved.

4. PROJECT ASSIGNMENT: The students select a specific planning problem and appropriate solution methodology (mathematical programming, simulation, machine learning) and conduct the following tasks:

- Searching and classifying relevant (scientific) literature
- Searching and analyzing real-world data (might be provided)
- Formulating a (precise) problem description and a (generic) mathematical model
- Implementing the model in standard software and/or developing a solution algorithm
- Designing an experimental study
- Drawing managerial insights and critically discussing the results

5. PREREQUISITES: Mandatory:

- Knowledge of Operations Research and Management Science
- Knowledge of mathematical modeling, simulation, or machine learning
- Knowledge of relevant software packages (Julia, Gurobi, Cplex, AnyLogic, etc.)

Optional:

- (Basic) Programming skills (C++, Java, Python, etc.)
- Knowledge in Healthcare Operations Management

5. GROUP SIZE: 2-4 students

BSc/MSc Project
PERSONNEL PLANNING AND SCHEDULING IN HEALTHCARE

HCOM
Health Care Operations Management

1. SUPERVISOR: Jens O. Brunner

2. PROJECT GROUP: PhD students and/or external supervisors might support the students if needed.

3. PROJECT BACKGROUND: The healthcare system's biggest challenge is the acute staff shortage (physicians, nurses, therapists). According to a recent study, there are only 62 applicants for every 100 unfilled jobs. The effects of demographic change will exacerbate this problem in the future. Therefore, large healthcare companies and hospitals need efficient workforce planning and scheduling. In addition, attractive and individualized roster models offer a competitive advantage over other employers. Current research on rostering and workforce planning seeks to achieve adequate staffing and appropriate workloads while allowing employees to have a as fair and appealing as possible roster. Part-time and personal preferences - such as regular days off, specific shift sequences, or individual limits on the number of night shifts - are also considered. Personnel planning can be performed on the strategic (staffing), tactical (rostering), and operational (replanning) levels.

4. PROJECT ASSIGNMENT: The students select a specific planning problem and appropriate solution methodology (mathematical programming, simulation, machine learning) and conduct the following tasks:

- Searching and classifying relevant (scientific) literature
- Searching and analyzing real-world data (might be provided)
- Formulating a (precise) problem description and a (generic) mathematical model
- Implementing the model in standard software and/or developing a solution algorithm
- Designing an experimental study
- Drawing managerial insights and critically discussing the results

5. PREREQUISITES: Mandatory:

- Knowledge of Operations Research and Management Science
- Knowledge of mathematical modeling, simulation, or machine learning
- Knowledge of relevant software packages (Julia, Gurobi, Cplex, AnyLogic, etc.)

Optional:

- (Basic) Programming skills (C++, Java, Python, etc.)
- Knowledge in Healthcare Operations Management

5. GROUP SIZE: 2-4 students

BSc/MSc Project
EFFICIENCY ANALYSIS IN HEALTHCARE

HCOM
Health Care Operations Management

1. SUPERVISOR: Jens O. Brunner

2. PROJECT GROUP: PhD students and/or external supervisors might support the students if needed.

3. PROJECT BACKGROUND: Because of rising costs in the healthcare system, attempts have been made for several years to make it more efficient. The most significant step in this context was undoubtedly introducing the DRG system in many countries. DRG stands for diagnosis-related group and is a system that groups patients with similar diseases and expenses. Therefore, it provides insights into hospital activities and thus enables managing the funding in the healthcare system at a hospital level. However, measuring hospitals' or departments' efficiency still isn't answered. In the scientific literature, several methods can help answer this question. The most common is the Data Development Analysis (DEA), which has undergone numerous exciting developments since the introduction of the basic model.

4. PROJECT ASSIGNMENT: The students select a specific model for efficiency analysis and conduct the following tasks:

- Searching and classifying relevant (scientific) literature
- Searching and analyzing real-world data (might be provided)
- Formulating a (precise) problem description and a (generic) mathematical model
- Implementing the model in standard software
- Drawing managerial insights and critically discussing the results

5. PREREQUISITES: Mandatory:

- Knowledge of Operations Research and Management Science
- Knowledge of mathematical modeling, simulation, or machine learning
- Knowledge of relevant software packages (Julia, Gurobi, Cplex, AnyLogic, etc.)

Optional:

- (Basic) Programming skills (C++, Java, Python, etc.)
- Knowledge in Healthcare Operations Management

5. GROUP SIZE: 2-4 students

BSc/MSc Project
ANALYSIS OF EMERGENCY DEPARTMENTS

HCOM
Health Care Operations Management

1. SUPERVISOR: Jens O. Brunner

2. PROJECT GROUP: PhD students and/or external supervisors might support the students if needed.

3. PROJECT BACKGROUND: The emergency department (ED) is one of the most critical departments of a hospital. For some years, the medical profession has agreed that this form of initial medical care for emergency patients will prevail over discipline-specific emergency rooms. The ED combines the expertise of all medical disciplines and is the central point of contact for all types of emergencies. This also includes intensive care patients, who reach hospitals primarily through the ED. Therefore, facility design, staffing, and scheduling are complex and vital. The emergency patients' stochastic arrival and treatment times add to this complexity. Numerous approaches exist to analyze and study EDs under several conditions and assumptions.

4. PROJECT ASSIGNMENT: The students select a specific planning problem and appropriate solution methodology (mathematical programming, simulation, machine learning) and conduct the following tasks:

- Searching and classifying relevant (scientific) literature
- Searching and analyzing real-world data (might be provided)
- Formulating a (precise) problem description and a (generic) mathematical model
- Implementing the model in standard software and/or developing a solution algorithm
- Designing an experimental study
- Drawing managerial insights and critically discussing the results

5. PREREQUISITES: Mandatory:

- Knowledge of Operations Research and Management Science
- Knowledge of mathematical modeling, simulation, or machine learning
- Knowledge of relevant software packages (Julia, Gurobi, Cplex, AnyLogic, etc.)

Optional:

- (Basic) Programming skills (C++, Java, Python, etc.)
- Knowledge in Healthcare Operations Management

5. GROUP SIZE: 2-4 students

Projects with Joe Naoum-Sawaya as supervisor

BSc/MSc Project
OPTIMIZATION MODELS FOR EMERGENCY EVACUATION

1. SUPERVISOR: Joe Naoum-Sawaya

3. PROJECT BACKGROUND: In several emergency situations, evacuation is a necessary response to move people from danger zones to safer places, in order to reduce the threat on their lives. Many situations, such as wildfires, hurricanes, floods, as well as human-induced events, may require fast evacuation. Since evacuation is sensitive to time and the availability of limited resources (cars, roads, fuel), it is critical to optimize the evacuation process.

4. PROJECT ASSIGNMENT: The aim of this project is to develop optimization models to preplan the evacuation process in designated areas. The objective is to distribute a set of limited resources (e.g. evacuation vehicles, fuel, medical resources, etc.) to an area that may need future evacuation. The main challenge that needs to be addressed in this research is the modeling of the stochastic nature of the problem due to the underlying uncertainty of emergency situations. Specifically, there can be uncertainties in the availability of (volunteers') vehicles at the time of evacuation, in the number and locations of individuals that need to be evacuated, the status of the roads, and in the locations of the safe zones. This challenge is aggravated by the fact that there may be very limited past data mainly because emergency evacuation events are relatively rare. Thus special data-driven techniques for rare events need to be developed in this project.

5. PREREQUISITES: Introduction to Operations Research, Markov decision process, and coding skills in Python, C, C++, or Java.

5. GROUP SIZE: 1 or 2 students

BSc/MSc Project
CONTAINER PACKING OPTIMIZATION

1. SUPERVISOR: Joe Naoum-Sawaya

3. PROJECT BACKGROUND: Container packing deals with stacking a set of boxes of different shapes, weights, and characteristics in a shipping container to be transported by a truck or by ship. Efficiently packing the container is an important part of logistics operations that impacts costs, safety, and the overall efficiency of operations. Several practical constraints may impact the packing of the container, including the order of the arriving items, the shape of each item, the weight that each item can support, and the desired order of item removal from the container once the container arrives at the destination (or in some cases at multiple destinations).

4. PROJECT ASSIGNMENT: The aim of this project is to develop an optimization model to find the optimal packing of a container given a set of items that need to be packed. The project requires the development and evaluation of different heuristic methods. Furthermore, it includes the development of a visualization platform that can easily be used to visualize the packed container and guide the operations team in following the recommended packing plan.

5. PREREQUISITES: Introduction to Operations Research and strong coding skills in Python, C, C++, or Java.

5. GROUP SIZE: 1 or 2 students

MSc Project
DISTRIBUTED OPTIMIZATION SOLVER

1. SUPERVISOR: Joe Naoum-Sawaya

3. PROJECT BACKGROUND: Despite the very rapid development of optimization solvers, the common architecture is to have a solver that runs on a single computer or a centralized computing resource using parallel processes. With that being said, it is well known that many computers are underutilized and highly valuable computing power is wasted without any benefit (in fact wasted computing is responsible for a significant proportion of energy and water usage).

4. PROJECT ASSIGNMENT: Inspired by Distributed Ledger Technology, the aim of this project is to design a distributed optimization platform. This will necessitate the development of the underlying framework, the protocols, as well as the economics of the solution. It is not expected that the team will develop a complete solution, but to develop a proof-of-concept that validates the solution and makes the case for future developments.

5. PREREQUISITES: Introduction to Operations Research and strong coding skills in Python, C, C++, or Java with ideally some experience in distributed computing.

5. GROUP SIZE: 2 or 3 students

Projects with Jasmine Lam as supervisor

MSc Project
RENEWABLE ENERGY FOR SEAPORTS

1. SUPERVISOR: Jasmine Lam

2. PROJECT GROUP: Depends on the specific thesis project and the potential collaboration with an external company.

3. PROJECT BACKGROUND: The maritime industry is increasingly pursuing sustainable development due to concerns on environmental pollution and resource preservation. The demand for addressing global warming has triggered the wave of energy transition to use more sustainable types of energy to lower the reliance on fossil fuels. Renewable energy sources, such as wind and solar, are promising options to substantially reduce greenhouse gas emissions and pollutants. However, there are many parameters to be considered for the adoption of renewable energy. In the port industry, there is a strong demand for developing new and effective solutions to achieve eco-friendly operations and enhance productivity/growth simultaneously. The project will analyse renewable energy options applicable for seaports and contribute to the development of sustainable solutions in a selected focus area.

4. PROJECT ASSIGNMENT: This thesis topic will be scoped after discussions with the student(s) to match the methodological background and interest of the student(s). However, the thesis project will likely either be based on a multi-criteria decision making approach or simulation modelling (discrete-event, agent-based or system dynamics).

5. PREREQUISITES: At least two, preferably more, MSc courses relevant to sustainable operations or logistics or transport and methodologies, e.g.: 42402 Sustainable Operations and Supply Chain Management, 42417 Simulation in Operations Management, 42380 Supply Chain Analytics.

5. GROUP SIZE: 2 to 3 students

MSc Project
RENEWABLE ENERGY FOR SHIPPING

1. SUPERVISOR: Jasmine Lam

2. PROJECT GROUP: Depends on the specific thesis project and the potential collaboration with an external company.

3. PROJECT BACKGROUND: The maritime industry is increasingly pursuing sustainable development due to concerns on environmental pollution and resource preservation. The demand for addressing global warming has triggered the wave of energy transition to use more sustainable types of energy to lower the reliance on fossil fuels. Green alternative fuels from renewable energy sources, such as green methanol and green hydrogen, are promising options to substantially reduce greenhouse gas emissions and pollutants. However, there are many parameters to be considered for the adoption of renewable energy. There is a strong demand for developing new and effective solutions to achieve eco-friendly operations and enhance productivity/growth simultaneously. The project will analyse renewable energy options applicable for shipping and contribute to the development of sustainable solutions in a selected focus area.

4. PROJECT ASSIGNMENT: This thesis topic will be scoped after discussions with the student(s) to match the methodological background and interest of the student(s). However, the thesis projects will likely either be based on a multi-criteria decision making approach or simulation modelling (discrete-event, agent-based or system dynamics).

5. PREREQUISITES: At least two, preferably more, MSc courses relevant to sustainable operations or logistics or transport and methodologies, e.g.: 42402 Sustainable Operations and Supply Chain Management, 42417 Simulation in Operations Management, 42380 Supply Chain Analytics.

5. GROUP SIZE: 2-3 students.

MSc Project
SHIP-SHORE COMMUNICATION FRAMEWORK IN THE PRESENCE OF AUTONOMOUS SHIPS

1. SUPERVISOR: Jasmine Lam and Seyed Parsa Parvasi

2. PROJECT GROUP: Depends on the specific thesis project and the potential collaboration with an external company.

3. PROJECT BACKGROUND: Maritime transportation is undergoing a transformative shift with the introduction of Maritime Autonomous Surface Ships (MASS). MASS, as a disruptive technology, has the potential to revolutionize global shipping, emphasizing the need to analyze changes to ship-shore systems for sustainability. However, MASS faces challenges in accurately predicting obstacles' movements and intentions, necessitating advanced navigation technologies and better communication strategies, including MASS-to-MASS and MASS-to-SCC (shore control centers). The shift to a new framework for communication can be capable by using the advent of Industry 4.0, Internet of Things (IoT), and smart logistics. The overall goal of the project is to develop a safe, secure and smart autonomous ship-shore communication conceptual framework to analyze and compare communication types in ship-shore interfaces.

4. PROJECT ASSIGNMENT: This thesis topic will be scoped after discussions with the student(s) to match the methodological background and interest of the student(s). The focus is autonomous ship-shore communication conceptual framework.

5. PREREQUISITES: At least two, preferably more, MSc courses relevant to communication technology, operations management or logistics or transport and methodologies, e.g.: 42417 Simulation in Operations Management, 42380 Supply Chain Analytics.

5. GROUP SIZE: 2-3 students.

Projects with Allan Larsen as supervisor

BSc/MSc Project
SUPPLY CHAINS AND LOGISTICS

1. SUPERVISOR: Allan Larsen

2. PROJECT GROUP: Depends on the specific thesis project and the potential collaboration with an external company. In most cases, at least one external advisor is associated with the thesis project.

3. PROJECT BACKGROUND: Supply chains are omnipresent in the world today. Efficient and sustainable planning and management of private companies and public institutions' supply chains have become critical functions in almost all companies. Supply chains are becoming increasingly complex as the world witnesses major disruptive events such as pandemics, geo-political instability and climate change. Simulation and/or optimisation modelling allow companies to assess potential impacts of changes in e.g. demand and supply and allow more efficient use of resources, implying more sustainable operations regarding economic, climate, and environmental effects.

4. PROJECT ASSIGNMENT: As an MSc thesis student with this topic, you will typically work with a company and get to solve a (close to) real-life problem using the tools and methodologies from your studies. These types of theses are typically based upon one of the following methodologies: Simulation modelling and/or optimisation (mathematical optimisation or metaheuristics). These all require some element of modelling and implementation. Thus, it is essential that you are interested in working with tools such as AnyLogic, AnyLogistix, or similar and/or feel comfortable with programming languages such as Julia, Python, and Java (or equivalent).

NB! It is important to note that the methodology used in this topic should align with the above description and be based on quantitative methods. Broader and more qualitative studies, such as lean management, may be relevant but impossible under this topic.

NB2! Students already in contact with a company potentially interested in hosting a thesis are encouraged to inquire about the relevance of the thesis topics with the advisor. Furthermore, in cases where one of the students is already employed by the company, please enquire about the company's willingness to host the other student(s) in the thesis group. This is often easy to set up as the non-employed students typically sign an unpaid student contract with the company allowing access to data etc.

5. PREREQUISITES: At least two, preferably more, MSc courses within O & SCM; e.g.: 42402 Sustainable Operations and Supply Chain Management, 42417 Simulation in Operations Management, 42380 Supply Chain Analytics and 42382 Industry 4.0 in Operations Management. Furthermore, advanced operations research courses are strongly encouraged if the project involves optimisation models.

5. GROUP SIZE: 2-4 students.

BSc/MSc Project
CITY LOGISTICS AND URBAN FREIGHT TRANSPORT

1. SUPERVISOR: Allan Larsen

2. PROJECT GROUP: Depends on the specific thesis project and the potential collaboration with an external company.

3. PROJECT BACKGROUND: Freight transport in large cities is becoming an increasingly challenging task as cities are growing (higher demand), the citizens expect low response time (higher intensity) and traffic congestion is rising (lower travel speed).

4. PROJECT ASSIGNMENT: This thesis topic will be scoped after discussions with the student(s) to match the methodological background and interest of the student(s). However, the projects should depart in the area of last-mile logistics, which can be described as the last steps in the transport chain bringing the freight/goods to the final destination, such as the inner part of a big city or a suburban mall.

The theses within this topic will typically involve modelling, implementing, and experimenting with various types of vehicle routing problems subject to constraints characterising the city logistics context of the problem. Current examples within this thesis topic include modelling multi-echelon distribution planning problems while taking the design of the network of distribution hubs/centres, satellites and alternative fuelled vehicles into consideration.

5. PREREQUISITES: At least two, preferably more, MSc courses within O & SCM; e.g.: 42402 Sustainable Operations and Supply Chain Management, 42417 Simulation in Operations Management and 42380 Supply Chain Analytics. Furthermore, it is strongly encouraged to have taken advanced operations research courses such as 42136 Optimisation using metaheuristics.

5. GROUP SIZE: 2-4 students.

BSc/MSc Project
CIRCULAR SUPPLY CHAINS IN THE FISHERIES

1. SUPERVISOR: Allan Larsen

2. PROJECT GROUP: PostDoc Ali Ghavamifar will most likely join the project group. Furthermore, an external company may join (or host) the thesis group depending on the specific thesis project.

3. PROJECT BACKGROUND: Supply chains in the food sector pose unique challenges in terms of management and control, mainly due to factors such as perishability and the growing demand for sustainable solutions. This complexity equally applies to the fisheries sector, which, like the broader food industry, plays a vital role in modern societies.

The fisheries supply chain commences at sea with the capture of fish, or in some cases, at aquafarms. From there, it proceeds through land-based processing, extends to distribution to consumer markets, and ultimately culminates in the delivery of products to retailers and end customers. At each stage of this supply chain, there is a looming risk of wasting valuable resources, spanning from primary products, such as processed fish for consumption, to what is referred to as rest raw materials (RRM). While RRM may carry less value than primary products, it still holds significant value for businesses within the fisheries sector and society as a whole, as it serves as a crucial component in producing collagen and vitamins. Consequently, optimizing the management of RRM helps reduce the waste of this valuable resource.

The thesis will be connected to the ongoing research project SMARTCHAIN, which is developing approaches and tools for sustainable utilisation, production planning, logistics optimisation, and traceability to facilitate the transfer of bio-resources from catch/production throughout the value chain of fisheries and aquaculture products.

4. PROJECT ASSIGNMENT: This thesis topic will be scoped after discussions with the student(s) to match the methodological background and interest of the student(s). However, the thesis projects will either be based on an optimisation approach (meta-heuristic or mathematical optimisation) or simulation modelling (discrete-event, agent-based or system dynamics). Via the SMARTCHAIN project, the supervisor and co-advisor have contacts with companies and institutions within the fisheries. This means the thesis project may be carried out in collaboration with one of these companies.

5. PREREQUISITES: Preferably, students have taken courses within O & SCM; e.g., 42402 Sustainable Operations and Supply Chain Management and 42380 Supply Chain Analytics. Furthermore, depending on the methodological approach, either competencies in simulation acquired through, e.g. 42417 Simulation in Operations Management AND/OR competences within advanced operations research courses such as 42136 Optimisation using meta-heuristics is strongly encouraged.

5. GROUP SIZE: 2-4 students.

Projects with Evelien van der Hurk as supervisor

MSC and BSC Strategies to limit the spread of infectious diseases

1. SUPERVISOR: Evelien van der Hurk, Rowan Hoogervorst

2. PROJECT BACKGROUND: What are the best policies to limit the spread of an infectious disease? Many will remember the periods with lock downs to limit the spread of Covid-19, as well as the requests to also limit the personal contacts one has. The most popular models to inform these policies are based on homogeneous mixing of population, where simply a reduction in the number of contacts a person makes leads to a reduction in disease spread. However, research has shown that people are more likely to interact with a smaller number of contacts consisting of e.g. friends, relatives, and colleagues. Therefore these standard models tend to overestimate the risks of contacts between people – especially in settings where the same group of people meet over time. If we would have better models, could we allow more contacts between people to actually reach the same effect of limiting an infectious disease?

In this project you will focus on modelling the spread of an infectious disease like COVID-19 in a social network. 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. You will investigate how a (set of) contact limitation policies could curb the spread of the disease. Ideally, one would want few(er) limitations. The modeling of such limitations can be seen as decomposing a 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.

The main objective of the project is to investigate the policies specifically aimed at limiting contacts in people's private social network, acknowledging the uncertainty of the way these measures will decompose a given graph.

3. PROJECT ASSIGNMENT: We have seen that decomposing graphs by minimizing distinct contacts between people has a positive effect when we can organize these decompositions perfectly. However, in social settings we do not have this full control.

What are the impacts of recommending a limit on the total number of contacts a day, versus the creation of "bubbles"of different types? How does this interact with how "open"the society is in general? What is the effecitiveness of these measures given that they do not provide a precise control over the decomposition of the graph?

There have been several standard graph-types developed to describe social networks in general, e.g.: Erdos-Renyi Model, the Watts-Strogatz Model, and the Barabasi-Albert Model. The thesis could focus on how different ways of recommended contact limitations would influence the spread of the disease in these different types of graphs. One could for example use classification of nodes in terms of e.g. vitality and centrality, e.g., node vitality, closeness centrality and betweenness centrality to formulate "worst case"and "best case"outcomes of the recommendations.

The thesis could also investigate other measurements that are not mentioned here, or approximations of the before mentioned measurements.

Finally, an alternative direction is focusing on how to limit spread of covid in transportation, when one would be allowed to assign passengers a specific boarding location for the vehicle.

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

5. GROUP SIZE: 2–3 students

MSC and BSC SEAMLESS SUSTAINABLE EVERYDAY URBAN MOBILITY

1. SUPERVISOR: Evelien van der Hurk

2. PROJECT BACKGROUND: Even if everyone would be driving electric cars tomorrow, we would not reach the CO2 targets to limit global warming to $1.5 - -2$ degrees. Therefore we need to increase the share of other forms of sustainable transportation: walking, biking, and public transportation. Often, these modes are connected in a door-to-door journey, and therefore providing a smooth integration between these different modes could increase their share.

Typically, there would be a limited budget available to upgrade parts of the system. The question is then which parts of the system should be upgraded to attract the majority of passengers. This question can be investigated on many different levels:

- Network level: which lines should be upgraded to BRT/light rail to provide a faster more reliable service?
- Station level: which stations should be upgraded to provide more attractive entrance and exit points to the system? Which stations could profit most from being connected to other modes of shared transportation like shared cars or bikes?
- Street level: which streets could best be upgraded (for walking or biking) to increase their share in general and increase the catchment areas of public transport stations?

3. PROJECT ASSIGNMENT: All the above listed problems are closely related to well-known optimization models in OR, such as (quadratic) knapsack problems, set covering problems, or problems related to network optimization and multi-commodity flow problems. Your thesis could either focus on a) investigating solution methods for special cases of these problems, or b) investigating these problems based on real-life data and a case from the Copenhagen Region. Either way, your thesis would contribute to the international EASIER project where together with Norwegian, Swedish and German partners we aim to increase the share of sustainable transportation modes.

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.

6. GROUP SIZE: 2–3

7. CHARACTERISTICS OF THE ASSIGNMENT: optimization, public transport

MSc ON DEMAND LINE PLANNING (FOR AN UBER BUS)

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: 2–3

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

MSc IMPROVING BUS TRANSFERS

1. SUPERVISOR: Evelien van der Hurk

3. PROJECT BACKGROUND: One of our previous studies showed that we can improve transfer times of busses without increasing vehicle costs. However, this has never been implemented at Movia. The question you will investigate is: could we actually create something that reduces transfer times at Movia?

4. PROJECT ASSIGNMENT: There are two main issues with the approach in the previous paper:

- The approach used an (expensive) solver in a matheuristic
- The approach ignored any uncertainty in the driving times of the busses

In your project you will investigate at least one of the two above questions. Real data from Movia could be obtained, or we could work with the data from the previous study. The first task would be aimed at testing simpler heuristics in order to see if they could still obtain a benefit in transfer times. The second would be focused on somehow taking uncertainty into account, either in an evaluation setting (by programming a simulation), through data analysis (of operational data, to signal problems in delays), or from a pro-active optimization perspective to (re)distribute slack.

You can read more about our previous study here:
`https://www.sciencedirect.com/science/article/pii/S0191261517304915`

5. PREREQUISITES: There are a number of prerequisites for this project:

- 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: 2–3

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

Projects with Bissan Ghaddar as supervisor

BSc/MSc Project
DYNAMIC ROUTE PLANNING FOR LAST-MILE DELIVERY

1. SUPERVISOR: Bissan Ghaddar

3. PROJECT BACKGROUND: There has never been a time with more demand than now for e-retailing and as a consequence last-mile services. The growth in demand is also bringing significant challenges. With the abundance of options, customers are ever more demanding and expecting more control. With the existing strategies, matching customers' foregoing expectations causes significant economic burdens and ecological disturbances. As a result, e-retailers need to define efficient routing strategies for their last-mile services. Outsourcing is one option to address the challenges in same-day delivery services and to satisfy the increasing demand, enhance scalability, and improve the customer experience.

4. PROJECT ASSIGNMENT: The aim of this project is to evaluate the impact of outsourcing and postponing strategy for a dynamic multi-period vehicle routing problems with probabilistic demand information. The objective is to identify a last-mile delivery plan with a minimum total cost of service, which includes the setup and operational costs of the company's fleet of vehicles and the cost of outsourcing. The project will consist of formulating a multi-stage stochastic programming model to represent the dynamic decisions considered in the problem and developing a solution approach to solve the resulting model. Given the relevance of the problem in practice, the project will analyze different planning strategies to evaluate the impact of postponement and outsourcing decisions.

5. PREREQUISITES: Introduction to Operations Research, Markov decision process, and coding skills in C, C++, or Java.

5. GROUP SIZE: 2 students

BSc/MSc Project
OPTIMAL DESIGN OF E-COMMERCE NETWORKS USING AUTONOMOUS AIRPLANES

1. SUPERVISOR: Bissan Ghaddar

3. PROJECT BACKGROUND: Pilotless airplanes are expected to play a crucial role in the resilient and sustainable supply chains of the future. Autonomous autopilot technology can perform the equivalent functions of a commercial pilot: taxi, take-offs, en-route flying, landing, and collision avoidance. By replacing the cockpit with more cargo volume, removing flight time duty limits, and reducing pilot labor costs, preliminary analysis anticipates reducing per-pound-kilometer operating costs by up to 40%. To realize the full potential of this autonomy, it is essential to design from the ground up a fast, flexible, and cost-efficient network that will operate a fleet of self-flying airplanes.

4. PROJECT ASSIGNMENT: The aim of this project is to model the network design problem for autonomous airplanes used for e-commerce delivery. Another component is to collect relevant real-world data and experiment with different heuristics to efficiently solve large-scale real networks.

5. PREREQUISITES: Strong programming skills (python and/or Julia). Good knowledge of mathematical programming.

5. GROUP SIZE: 2 students

MSc Project
LEARNING-BASED METHODS FOR POWER NETWORKS

1. SUPERVISOR: Bissan Ghaddar

3. PROJECT BACKGROUND: The optimal power flow (OPF) problem is modeled as a non-linear quadratic optimization problem that is difficult to solve due to the power flow constraints. Additionally, mixed integer problems such as security-constrained OPF problems are even more difficult due to the additional binary variables. Due to the computational challenges of solving such nonconvex problems, many efforts have focused on linearizing or approximating the problem in order to solve the problem faster. However, many of these approximations can be fairly poor representations of the actual system state and still require solving an optimization problem, which can be time-consuming for large networks.

4. PROJECT ASSIGNMENT: The aim of this project is to learn feasible solutions of the the valve setting problem wherein machine learning and optimization work hand-in-hand to find high quality solutions. The first step is understanding the features that need to be collected for the learning phase and then designing a learning model that can exploit the problem constraints and generate high quality feasible solutions. The resulting models will be tested on several power network instances of varying sizes and evaluated in terms of prediction accuracy, operational feasibility, and solution quality.

5. PREREQUISITES: Strong programming skills (python). Good knowledge of mathematical programming and machine learning.

5. GROUP SIZE: 2 students

MSc Project
SOLVING SVM WITH FEATURE SELECTION USING SEMIDEFINITE PROGRAMMING

1. SUPERVISOR: Bissan Ghaddar

3. PROJECT BACKGROUND: Data driven decision support systems are nowadays an integral part of many businesses. Support vector machines (SVMs) is a class of data-driven machine learning approach that deals with predictive binary classification, i.e. the assignment of class labels to unlabeled data. SVM finds a maximum margin function that separates the observations into two classes where each observation is a point in a multidimensional space of feature measurements. New unlabeled data are then assigned a class based on their geometric position relative to the classifier function. Given the vast amount of complex features that modern systems use, finding the classifier function often requires the simplification of the features space by identifying the dimensions that have the most distinguishing power. It is therefore essential to jointly optimize the feature selection and the classification in order to ensure the best performance of the decision support system.

4. PROJECT ASSIGNMENT: The aim of this project is to use semidefinite programming to solve SVM problems with feature selection. The problem is a quadratic problem with binary variables and is difficult to solve for practical applications. Cuts based on optimization-based bound tightening techniques will be investigated to see the impact on the solution.

5. PREREQUISITES: Strong programming skills (python). Good knowledge of mathematical programming and machine learning.

5. GROUP SIZE: 2 students

MSc Project
A BRANCH AND BOUND ALGORITHM FOR MIXED INTEGER SEMIDEFINITE PROGRAMMING

1. SUPERVISOR: Bissan Ghaddar

3. PROJECT BACKGROUND: Mixed integer semidefinite programs (SDP) arise in many applications including finance, energy, and water networks. In this research, the focus is on mixed integer optimal power flow problems and in particular transmission expansion planning problems that arise in power networks. The goal is to determine which transmission power lines to expand on while adhering to the forecasted demand and non-linear power flow constraints. The problem can be modeled as a nonconvex quadratic optimization problem with binary variables. Semidefinite programming provides strong relaxations for these problems and having a branch-and-bound SDP solver can provide high quality bounds in these cases.

4. PROJECT ASSIGNMENT: The aim of this project is to develop a mixed integer SDP algorithm targeting large-scale transmission expansion instances. The branch and bound will decide on the binary variables to branch on and at each node a SDP relaxation is solved. Additional cuts can be added to improve the quality of the relaxation.

5. PREREQUISITES: Strong programming skills (C or python or Julia). Good knowledge of mathematical programming.

5. GROUP SIZE: 2 students

MSc Project
POLYNOMIAL OPTIMISATION SOLVER

1. SUPERVISOR: Bissan Ghaddar

3. PROJECT BACKGROUND: Polynomial optimization is used for solving optimization problems where the objective function and constraints can be represented as polynomial equations or inequalities. These types of optimization problems are common in various fields, including energy applications, telecom systems, economics and finance, quantum computing, and other complex real-world problems. There are very few software tools and libraries available for solving polynomial optimization problems and most of them are targeted for small instances.

4. PROJECT ASSIGNMENT: The aim of this project is to develop a general polynomial optimization solver targeting large-scale instances. One aspect is to experiment with different relaxations and methodologies that can be integrated into the solver. The other task is to exploit problem structure and mainly sparsity to lower the computational time of solving such problems.

5. PREREQUISITES: Strong programming skills (C or C++ or Julia). Good knowledge of mathematical programming.

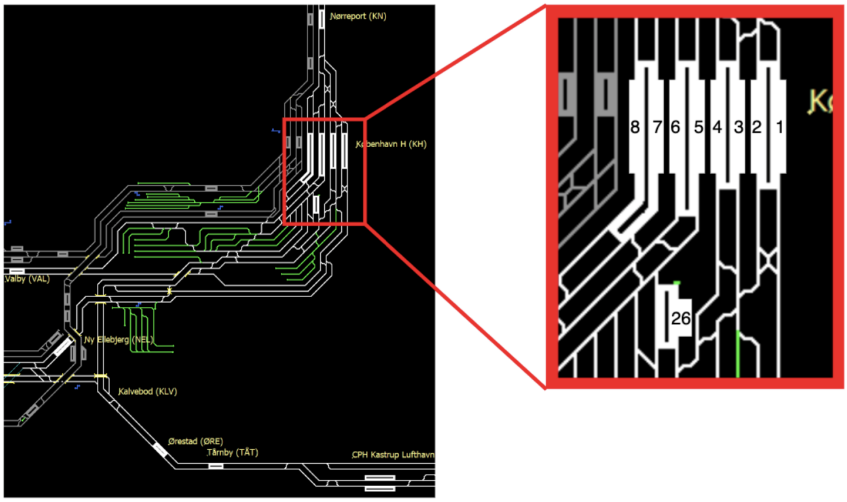
5. GROUP SIZE: 2 students

Projects with Jesper Larsen as supervisor

BSc/MSc Project
OPTIMISED PLANNING OF TRAIN ROUTING
AT COPENHAGEN CENTRAL STATION

1. SUPERVISOR: Jesper Larsen

3. PROJECT BACKGROUND: Copenhagen Central Station is the largest station in Denmark. The station is being used by more than 100,000 passengers every day. In order to ensure a smooth and efficient operation the planners that are assigning trains to platforms have a hard time to determine a schedule that works well in practice and delivers a good service to the community.



4. PROJECT ASSIGNMENT: The aim of this project is to establish an optimisation model (exact or heuristic) to generate a schedule for the rush hour at Copenhagen Central Station. all trains in the plan must be specifically routed through the Copenhagen Central station to avoid unwanted complications. The problem consists of routing regional and long distance trains (F&R) at the Copenhagen central station given a specific timetable.

If time permits additional constraints are: optimise buffers between trains on the same platform, ensure north- and south-bound trains on their preferred platforms etc.

5. PREREQUISITES: Introduction to Operations Research and it would be good with integer programming but that can be integrated in the project. Good programming skills.

6. GROUP SIZE: At least two persons.

BSc/MSc Project
SCHEDULING TRAIN CLEANING

1. PROJECT SUPERVISOR: Jesper Larsen

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

7. CHARACTERISTICS OF THE ASSIGNMENT: Real-life problem solving, modelling and solving. Heuristics.

8. REMARKS: The student will have to sign a cooperation agreement. Publishing must be agreed with supervisor.

BSc/MSc Project
PATIENT ADMISSION SCHEDULING

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 foreseen that the initial parts of the project will consist in developing mathematical models and the second part of implementing and testing the most promising 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: At least two students

8. REMARKS: For more details and test problems go to `http://allserv.kahosl.be/~peter/pas/`.

MSc Project
VRPs WITH INTERDEPENDENT ORDERS

1. SUPERVISOR: Jesper Larsen

2. PROJECT GROUP: Kristian Hauge (AMCS)

3. PROJECT BACKGROUND: In the world of waste collection, it is not always only about collection and waste. Specifically for bulk waste in skip containers, the container itself is often part of the optimisation. This includes delivering, emptying, and sometimes returning the containers to their owners. A container that is not owned by the customer can be delivered to another customer who has requested the same type of container, instead of simply being returned to a depot. This can save a lot of driving to and from depots. However, because of this, and because a vehicle can only carry a handful of full containers at a time, a route often consists of stops that are tightly connected to each other and even depend on each other. Scheduling of terminal stops and choice of terminals can also depend on and/or affect the orders on a route.

When there is a lot of interdependence between stops, an algorithm that is well suited for optimising other types of VRPs may not be well suited for this problem.

4. PROJECT ASSIGNMENT: Given real-life data, the task is to design and implement an algorithm for solving the described VRP.

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

6. GROUP SIZE: At least two students.

8. REMARKS: AMCS is a software company specialising in fleet management products. Transport optimisation, mathematical modelling and prototype implementation.

MSc Project
SEQUENCE BUILDING WITH NARROW TIME WINDOWS

1. SUPERVISOR: Jesper Larsen

2. PROJECT GROUP: Kristian Hauge (AMCS)

3. PROJECT BACKGROUND: Given a set of orders, a route/sequence needs to be built with the following constraints:

- A small portion of the orders (< 10%) will have time windows. Time windows can be as narrow as 30 minutes.
- A feasible solution is not guaranteed due to time windows and order locations, so soft time windows are allowed – there will be an increasing cost the larger a time window violation.
- A good solution must be produced as fast as possible.

A route consists of around 100-200 orders.

4. PROJECT ASSIGNMENT: Given real life data, implement an algorithm that can build an order sequence give the listed constraints.

5. PREREQUISITES: Courses in Operations Research and knowledge of metaheuristics. Good programming skills are an advantage.

6. GROUP SIZE: At least two students.

8. REMARKS: AMCS is a software company specialising in fleet management products. Transport optimisation, mathematical modelling and prototype implementation.

MSc Project
LARGE SCALE RESIDENTIAL VRP

1. SUPERVISOR: Jesper Larsen

2. PROJECT GROUP: Kristian Hauge (AMCS)

3. PROJECT BACKGROUND: Residential VRPs involve most addresses in a town or city. The number of orders can therefore be very high, think 10000 to 100000. Even though these problems have few or no restrictions, they are still challenging to solve due to their size.

4. PROJECT ASSIGNMENT: Given real life data, implement an algorithm for solving large VRPs. Ideas for extensions/focus areas:

- With no restrictions, routes are expected to not overlap. Seek to reduce/avoid this.
- Routes that are neighbours are often expected to be separated along the most logical lines. These lines are usually easy to identify or compare for the human eye and are often related to features such as highways, rivers, or "gaps" between orders such as parks or industrial areas.
- Having a distance matrix available is useful, but for very large VRPs, memory is precious. How many distances do we need to calculate and cache?

5. PREREQUISITES: Courses in Operations Research and knowledge of metaheuristics. Good programming skills are an advantage.

6. GROUP SIZE: At least two students.

8. REMARKS: AMCS is a software company specialising in fleet management products. Transport optimisation, mathematical modelling and prototype implementation.

MSc Project
USING COLUMN GENERARION FOR THE ELECTRIC BUS SCHEDULING PROBLEM

1. SUPERVISOR: Jesper Larsen

2. PROJECT GROUP: NN (Qampo)

3. PROJECT BACKGROUND: Given a set of timetabled trips and recharging stations, the electric vehicle scheduling problem (E-VSP) is concerned with finding a vehicle schedule that covers the trips and satisfies the driving range and recharging requirements of electric buses while minimizing operational cost. Currently, a column generation algorithm in combination with variable fixing strategies is used to find feasible solutions. For some of the real-life instances, we have observed the following behaviours of column generation: 1) the linear programming objective does not change for several iterations, 2) dual fluctuations seem to be quite large. Overall, we see that the convergence of the column generation algorithm has been quite slow for some cases.

4. PROJECT ASSIGNMENT: One would have to implement column generation for the E-VSP and the aim of the project could be to explore acceleration techniques such as dual stabilization or other techniques to speed up the column generation progress. We can provide some real-life instances for the project. An instance would contain a set of trips, set of deadheads, set of vehicle types, set of nodes (including where recharging stations are present).

5. PREREQUISITES: Courses in Operations Research and knowledge of column generation and Dantzig-Wolfe decomposition. Knowledge of other decomposition approaches would be an advantage. Strong programming skills are an advantage.

6. GROUP SIZE: At least two students.

BSc/MSc Project
SOLUTION APPROACHES TO THE SOLAR FARM CABLE LAYOUT PROBLEM

1. SUPERVISOR: Jesper Larsen

3. PROJECT BACKGROUND: Solar energy is a renewable and sustainable energy, which gets more and more important in times where humanity aims to reduce the usage of fossil fuels. Photovoltaic modules are used to convert sun light into electricity. Often this is done in large solar farms. We model a solar farm as layered graph, where the power generated by the strings (several connected photovoltaic modules) needs to be conducted throughthe layers of the graph. For the connection of two vertices there are different typesof cables with different capacities and costs. The problem is now to find a cable layout with minimal costs, which does not violate cable or vertex capacities.

4. PROJECT ASSIGNMENT: Current methods still have problems solving large solar farm cases. Here MILPs are not able to solve the problems in 24 hours. Therefore this project has a focus on developing new matheuristics or new optimal methods based on alternative decomposition techniques.

5. PREREQUISITES: Courses in Operations Research and potentially knowledge of metaheuristics. Good programming skills are an advantage.

6. GROUP SIZE: At least two students.

8. REMARKS: The project is based on the MSc thesis of Dominik Stampa entitled "Theory and Algorithms of the SolarFarm Cable Layout Problem". With the thesis also follows instances and data.

BSc/MSc Project
PHARMACEUTICAL MANUFACTURING

1. SUPERVISOR: 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: At least two students

Projects with Richard Lusby as supervisor

MSc Project
INVENTORY OPTIMIZATION UNDER UNCERTAINTY

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP: Thea Rønn (Visma)

3. PROJECT BACKGROUND: Visma Resolve works with inventory optimization in ERP services. Based on historical data, they use AI and optimization to propose suggestions for a user's inventory management strategies.

In the simplest version of the inventory optimization problem, a retailer orders products from a set of suppliers in order to meet customer demand over a given planning period. Each product has a price, a cost, and a lead time. The products are placed in storage before they are eventually sold to customers. The simplest version is deterministic, meaning that the demand for each product in a given period is known in advance. In other words, expected sales quantities and dates for each product on each discrete time point in the planning period are provided as input to the problem. The most essential decisions to be made concern how much and when to order each product. The definition of the objective is open for discussion, but could for example be to maximize profits, minimize out-of-stock events, and/or minimize unnecessary products in stock.

Many extensions of this basic problem can be considered, the most pressing being the requirement to better solve real-world problem by taking more inventory management aspects into consideration. Examples include multiple suppliers of one product, assembly of raw materials or goods into one or more products, and operating with a cap on how long products can stay in storage before they cannot be sold anymore ("shelf life"). Another interesting extension is to treat the demand as stochastic instead of deterministic. Then, a stochastic optimization model can be implemented. To take this further, the demand can be forecast using predictive models, such as time series and/or machine learning models. The predicted demands can be treated as either deterministic and stochastic. In the deterministic case, the predicted demand is taken as is. In the stochastic case, a confidence interval for the forecast demand can be used to identify the low, medium, and high demand scenarios used by a stochastic optimization model.

4. PROJECT ASSIGNMENT: Formulate an appropriate stochastic optimization model and solution approach for solving inventory management problems arising in practice. The project should consider how machine learning techniques can contribute to this. A thorough literature review should be performed to find interesting aspects that can/should be considered, Visma will schedule interviews with users of inventory management systems to identify functionality that would have a positive impact on the outcome of the project.

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

6. GROUP SIZE: 2-3 students

MSc Project
DYNAMIC DIAL-A-RIDE PROBLEMS WITH FIXED ROUTES

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP: Siv Marie Cartland Hansen

3. PROJECT BACKGROUND: Movia's Flextrafik provides transportation services tailored to elderly individuals and those with disabilities who cannot utilize standard public transportation options. Flextrafik offers door-to-door service, facilitating transportation from a passenger's residence to destinations such as hospitals for medical appointments. This service operates on a demand-responsive basis, without fixed timetables or predefined routes. This means that vehicle schedules adapt to transportation requests, which may be booked in advance or arise dynamically in real-time. Flextrafik aims to optimize vehicle schedules for cost efficiency while minimizing inconvenience to passengers. This project focuses on designing optimization tools to assist with the vehicle scheduling process.

4. PROJECT ASSIGNMENT: This project deals with a variant of the so-called *Dial-a-ride* problem (DARP) from the Operations Research literature. The DARP seeks to find a set of minimum cost vehicle routes while satisfying a given number of transportation requests (where each request is defined by a pickup location and a delivery location). This project considers a dynamic variant in which a given percentage of the requests are received in real-time and focuses on developing an on-line optimization algorithm to optimize the vehicle routes in real-time. Furthermore, the impact of combining the pure dial-a-ride aspect of the problem with a set of fixed routes (the location, frequency, and timings to be decided) must be assessed. It is expected that data from Movia will be provided.

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

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

6. GROUP SIZE: 2 students

MSc Project
ON-DEMAND BUS PLANNING WITHIN PUBLIC TRANSPORTATION NETWORKS

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP: Siv Marie Cartland Hansen

3. PROJECT BACKGROUND: Traditional public transportation networks typically operate according to fixed lines, frequencies, and timetables. The rigidity of such a system, with respect to routes offered and their associated timings, means that it may not adequately cater for the diverse needs of all travellers. As an example, to avoid cost inefficiencies, public transportation operators (bus, train, or metro companies) typically offer low frequency services when connecting sparsely populated suburban areas to high density urban centers. Longer waiting times as a result of decreases in operating frequency are also common during times of the day when passenger demand drops. In recent years, there has been a growing interest, particularly within bus transportation, in the use of demand responsive (i.e., on demand) services. On demand buses do not operate according to fixed routes or schedules but rather adapt/respond to the demand to provide not only more cost-effective schedules for the operator but also reduced travel times for the passengers. This project will therefore consider how on-demand buses can complement an existing public transportation network.

4. PROJECT ASSIGNMENT: Given an existing public transportation network (the scope of which is to be decided), investigate the impact of replacing a set of low frequency lines with a set of on-demand buses that can be more flexibly operated. This will entail developing a mathematical model and an appropriate optimization algorithm to determine the vehicle schedules given static (and possibly dynamic) demand. Through a quantitative comparison of the network with and without on-demand buses, it is expected that the project will provide valuable insight into when/where it makes sense to operate either fixed or flexible services. Initially, the focus will be on a single bus line with the ambition to move to a more complicated network setting. We anticipate using data from Movia and/or open source data.

5. PREREQUISITES: Courses: Integer Programming (42114), Large Scale Optimization using Decomposition (42136) or Optimization using Metaheuristics (42137), Good Programming Skills (Julia or C++)

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

6. GROUP SIZE: 2 students

MSc Project
FINDING STRUCTURALLY DIFFERENT LINER SHIPPING NETWORKS VIA MULTI-OBJECTIVE OPTIMIZATION

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP: Natalia Rezanova (Maersk)

3. PROJECT BACKGROUND: The liner shipping network design problem is an extremely difficult optimization problem that involves determining the set of most profitable vessel services to operate based on the forecast demand between pairs of origin and destination ports. For each service, which typically comprises a sequence of a ports that will be visited with a weekly frequency, the vessel capacity must be decided and consideration must be given to how the cargo will flow through the network (as an example, there could be time restrictions on certain cargoes). This project focuses on developing an approach to find structurally different liner shipping networks with the aim of quantifying the "distance"between two networks. With an appropriate distance measure defined, the problem of finding structurally different networks can be formulated as multi-objective optimization under the assumption that two networks that are significantly dissimilar have a different profit.

4. PROJECT ASSIGNMENT: Currently, Maersk uses the Levenshtein distance to quantify the difference between two vessel services. This can be used as a starting point to develop a measure for liner shipping network similarity. Other measures should also be considered and developed. With an appropriate distance measure determined, the aim would then be to formulate the liner shipping network design problem as a bi-objective problem (i.e., only two objectives), the first being profit, the second being distance, and implement a heuristic approach to solve this problem. For the implementation a simple Large Neighbourhood Search can be considered (as in the paper below) and tested on the open-source linerlib data.

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

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

6. GROUP SIZE: 2 students

8. REMARKS: Relevant Literature:

Krogsgaard, A., Pisinger, D., & Thorsen, J. (2018). A flow-first route-next heuristic for liner shipping network design. Networks, 72(3), 358-381.

MSc Project
MATHEURISTICS FOR LINER SHIPPING NETWORK DESIGN

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP: Natalia Rezanova (Maersk)

3. PROJECT BACKGROUND: The liner shipping network design problem is an extremely difficult optimization problem that involves determining the set of most profitable vessel services to operate based on the forecast demand between pairs of origin and destination ports. For each service, which typically comprises a sequence of a ports that will be visited with a weekly frequency, the vessel capacity must be decided and consideration must be given to how the cargo will flow through the network (as an example, there could be time restrictions on certain cargoes). This project focuses on developing effective matheuristics for the liner shipping network design problem.

4. PROJECT ASSIGNMENT: The students are first required to develop a Mixed Integer Programming (MIP) formulation of the problem and test its performance on the publicly available instances in linerlib. One (or more) matheuristics (of the students' choice) must then be implemented. The performance of the matheuristics must then be compared to that of the (MIP) formulation

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

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

6. GROUP SIZE: 2 students

MSc Project
USING MACHINE LEARNING TO IMPROVE COLUMN GENERATION FOR LARGE CARGO-FLOW PROBLEMS

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP: Natalia Rezanova (Maersk)

3. PROJECT BACKGROUND: The liner shipping network design problem is an extremely difficult optimization problem that involves determining the set of most profitable vessel services to operate based on the forecast demand between pairs of origin and destination ports. For each service, which typically comprises a sequence of a ports that will be visited with a weekly frequency, the vessel capacity must be decided and consideration must be given to how the cargo will flow through the network (as an example, there could be time restrictions on certain cargoes). For a fixed set of vessel services, how to best move (or flow) the demand can be modelled as a large-scale multicommodity flow problem that can be solved using column generation. This project focuses on this large-scale flow problem and aims to improve the performance of column generation by using machine learning techniques.

4. PROJECT ASSIGNMENT: The use of machine learning techniques to improve the performance of column generation is gaining interest in the academic literature. In routing problems, one idea is to try and reduce the size of the network considered in the pricing problem by "learning"which arcs are likely to be part of the optimal solution to the linear relaxation of the problem, as is suggested in Morabit et al. (2023). The students are required to implement a column generation approach to solve the large-scale flow problem (for training and testing purposes) and then implement (and enhance) the ideas of Morabit et al. (2023) to see whether the machine learning based approach can provide significant improvements to the column generation approach.

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

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

6. GROUP SIZE: 2 students

8. REMARKS: Relevant Literature:

Morabit, M., Desaulniers, G., & Lodi, A. (2023). Machine-learning–based arc selection for constrained shortest path problems in column generation. INFORMS Journal on Optimization, 5(2), 191-210.

MSc Project
DECOMPOSITION METHODS FOR MAKESPAN MINIMIZATION OF UNRELATED PARALLEL MACHINES

1. SUPERVISOR: Richard Lusby

3. PROJECT BACKGROUND: This project focuses on the problem of minimizing the makespan of a set of unrelated parallel machines, generally denoted as $R||C_{max}$. Commonly found in manufacturing, the problem requires one to assign a set of tasks to a set of machines in such a way that the makespan, i.e., the time taken to complete all tasks, is minimized. The problem is difficult for a commercial Mixed Integer Linear Programming Solver as the makespan objective induces weak linear programming bounds. In this project, the focus is therefore on solving this problem with decomposition methods and/or heuristics.

4. PROJECT ASSIGNMENT: Investigate the applicability of exact decomposition methods (e.g., Dantzig-Wolfe Decomposition or Lagrangian Relaxation) and/or metaheuristics and compare their performance to existing approaches from the literature using a publicly available benchmark suite of instances.

5. PREREQUISITES: Courses: Integer Programming (42114), Large Scale Optimization using Decomposition (42136) or Optimization using Metaheuristics (42137), Good Programming Skills

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

6. GROUP SIZE: 2-3 students.

8. REMARKS:

MSc Project
COMBINING BENDERS DECOMPOSITION AND A DICHOTOMIC SEARCH FOR 2-STAGE STOCHASTIC BI-OBJECTIVE PROGRAMS

1. SUPERVISOR: Richard Lusby

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 consists 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

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

6. GROUP SIZE: 2-3 students.

MSc Project
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 techniqes 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

7. CHARACTERISTICS OF THE ASSIGNMENT: Algorithm Design, Programming, Machine Learning

6. GROUP SIZE: 2-3 students.

MSc Project
REMOVING REDUNDANT COLUMNS IN COLUMN GENERATION

1. SUPERVISOR: Richard Lusby

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 AUTODEC, 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

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

6. GROUP SIZE: 2-3 students.

8. REMARKS: Lübbecke, M. E., Maher, S. J., and Witt, J., Avoiding redundant columns by adding classical Benders cuts to column generation subproblems (2019).

MSc Project
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 the 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

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

6. GROUP SIZE: 2-3 students.

MSc Project
PRODUCTION & SUPPLY CHAIN OPTIMIZATION USING DECOMPOSITION

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, already exists.

4. PROJECT ASSIGNMENT: In collaboration with Ops-Analytics the student should reformulate and improve an existing optimization model and explore the potential of decomposition approaches. As a minimum, the student must identify and implement a decomposition algorithm to solve the problem. The solution quality provided and the time needed by 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

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

6. GROUP SIZE: 2-3 students.

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

Projects with Dario Pacino as supervisor

BSc/MSc Project - RORO STOWAGE PLANNING

1. SUPERVISOR: Dario Pacino

3. PROJECT BACKGROUND: Under the ROROGREEN research project, DTU, SDU, RUC, and DFDS are working to reduce the emissions of short-sea shipping. At the core of that effort we find the stowage planning problem. In stowage planning we aim at finding the position that each cargo should have on a vessel. The more efficient a stowage planning problem we have, the more emission we are able to reduce.

4. PROJECT ASSIGNMENT: There are several tasks (or project topics) that can be tackled while studying the stowage planning problem. The projects will require the implementation of a mathematical model or the development of metaheuristic method. A project within RORO stowage planning can focus one or more of the following challenges:

- Ensuring vessel stability
- Real-time decision-making (online optimization, reinforcement learning, ...)
- Handling cargo sequencing
- Handling of stochastic cargo arrivals
- Handling of stochastic cargo weights

5. PREREQUISITES: A solid understanding of mathematical modelling and metaheuristics, and a good programming skills.

6. GROUP SIZE: 2-4

BSc/MSc Project - CONTAINER STOWAGE PLANNING

1. SUPERVISOR: Dario Pacino

3. PROJECT BACKGROUND: Most consumer items that you have at home have likely been transported on a container ship. In nowadays ever growing globalization and the ever present focus on sustainable transport, it is important that we ensure that ocean sailing vessels are efficiently utilized. This means that cargo is arranged such that we best utilize vessel capacity and minimize cargo handling time. This is not an easy task with today's container vessels carrying up to 24.000 containers. Research in this area is still ongoing and no efficient and effective algorithms have yet been identified.

4. PROJECT ASSIGNMENT: In this project you will work on implementing a solution method for the Container Stowage Problem, which is the problem. The project envisions the use of either matheuristic or metaheuristic techniques. A project within container stowage planning can focus one or more of the following challenges:

- Ensuring vessel stability
- Handling of stochastic data from forecasts

5. PREREQUISITES: Knowledge of operations research methods and programming skills.

6. GROUP SIZE: 2-4

MSc Project - GENERIC HEURISTIC SOLVER FOR 0/1 IPs

1. SUPERVISOR: Dario Pacino

2. PROJECT GROUP:

3. PROJECT BACKGROUND: Heuristics and metaheuristics are notoriously hard to implement and maintain, and as a consequence most optimization experts revert to mathematical programming. Unfortunately, mathematical programming is not able to solve all problems. Research on metaheuristics is often limited to either specific application areas or classical problems, and little knowledge is available on model-based approaches.

4. PROJECT ASSIGNMENT: In this project we aim at taking the first steps into the implementation of a general purpose heuristic solver for 0/1 Integer Programming (IP) models. Your task will be to implement and test one or more heuristic procedures for the general class of binary 0/1 integer programs.

5. PREREQUISITES: Knowledge of operations research methods, metaheuristics and programming skills.

6. GROUP SIZE: 2-4

Projects with David Pisinger as supervisor

MSc Project - EFFICIENT ALGORITHMS FOR CARGO ROUTING

1. SUPERVISOR: David Pisinger

2. PROJECT GROUP: David Pisinger

3. 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.

4. 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.

5. 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

6. GROUP SIZE: 2-3

7. CHARACTERISTICS OF THE ASSIGNMENT: Cargo routing, resource constrained shortest path problem, liner shipping network design, graph based algorithms

MSc Project - ENERGY PRODUCTION PLANNING

1. SUPERVISOR: David Pisinger

2. PROJECT GROUP: Mette Gamst (Energinet)

3. PROJECT BACKGROUND: The Unit Commitment problem (UC) is to select which units to produce energy over the coming time horizon in order to minimize operational costs. The problem is important both on a daily scheduling basis, but also when planning future investments in new power plants, wind farms, or solar plants. In Denmark, Energinet is the main infrastructure owner, responsible for ensuring that sufficient energy is available for the industry and households.

To improve efficiency, and hence meet our targets for more sustainable energy, the energy systems are becoming more coupled. This means for instance, that electricity can be used in the direct form, or transformed to heat through heat pumps. Furthermore, we may have heat storage, that save energy to future time slots.

The Unit Commitment problem is difficult to solve (it is an NP-hard problem) and in order to support strategic decisions we often need to solve the problem for 10-20 years on an hourly basis. Therefore, it would be very interesting to implement fast heuristics that provide near-optimal solutions in very short time.

4. PROJECT ASSIGNMENT: Describe the general mathematical formulation (a full model of the UC considered by Energinet will be available). Design and implement various metaheuristics to solve the problem. These can be based on greedy principles, local search, matheuristics. Analyse the results and compare to existing solutions. Realistic data will be provided by Energinet.

5. PREREQUISITES: Motivation to work on and learn about a practical problem; Good programming skills; Experience with implmentation of metaheuristics.

6. GROUP SIZE: 2-3

7. CHARACTERISTICS OF THE ASSIGNMENT: Mathematical modeling, applied optimization, metaheuristics, energy models.

MSc Project - OPTIMIZING BAGGAGE HANDLING

1. SUPERVISOR: David Pisinger

2. PROJECT GROUP: David Pisinger

3. PROJECT BACKGROUND: Copenhagen airport is one of the largest airports in Scandinavia, handling more than 20 millions of passengers per year. An important part of the airport operation is to handle checked-in baggage, such that it effortlessly (for the passenger) arrives at the end destination. The baggage handling consists of several phases: Baggage drop-off, security scanning, early baggage storage, sorting, loading, unloading, baggage reclaim. Each of the phases demand some resources that can be optimized. The goal of the project is to use the existing resources in the best possible way such that more passengers can be handled without investment in new infrastructure.

Past projects have included: Check-in counter assignment, algorithms for early baggage storage, assignment of boxes in the sorting facility, optimization of belts in baggage reclaim area. The concrete project will be discussed and scoped with Copenhagen Airport.

4. PROJECT ASSIGNMENT: Describe the problem both in words and as a mathematical model. Develop solution methods based on either heuristics or MIP-models. If relevant, construct a simulation algorithm to study the baggage flow. Solve real-life and synthetic problems. Compare results to historic data. Experiment with possible extensions, and provide advice for future.

Data will be provided by Copenhagen Airport.

5. PREREQUISITES: Motivation to work on and learn about a practical problem; experience with mathematical modelling and/or heuristics. Good programming skills.

6. GROUP SIZE: 2-3

7. CHARACTERISTICS OF THE ASSIGNMENT: Mathematical modeling, applied optimization, metaheuristics, simulation.

MSc Project - WORK PLANNING IN A PHARMACY

1. SUPERVISOR: David Pisinger

2. PROJECT GROUP: David Pisinger, a hospital pharmacy

3. PROJECT BACKGROUND: A hospital pharmacy is responsible for handling medication to one of the major region hospitals. The pharmacy has 45 pharmacologist and 7 pharmacist employed. The daily tasks consist of both medication management (MM) and medication service (MS). The MS tasks include: Handling requests, ordering new products, put products in place in the warehouse. The clinical sections have different load: black (4 point, very high load), red (3 point, high load), yellow (2 point, medium load), green (1 point, low load). The objective is to schedule work such that all tasks are covered, and such that the work load is fair (with respect to points). Furthermore, the employees may have scheduled holidays, be sick, on leave, etc.

4. PROJECT ASSIGNMENT: Formulate the problem as an optimization problem. Describe all constraints in words and also in mathematics. Implement a heuristic for solving the assignment problem. Solve real-life and synthetic problems. Compare results to historic data. Experiment with possible extensions.

Data will be provided by Herlev Hospital.

5. PREREQUISITES: Motivation to work on and learn about a practical problem; experience with mathematical modelling and/or heuristics. Good programming skills.

6. GROUP SIZE: 2-3

7. CHARACTERISTICS OF THE ASSIGNMENT: Mathematical modeling, applied optimization, metaheuristics, crew scheduling.

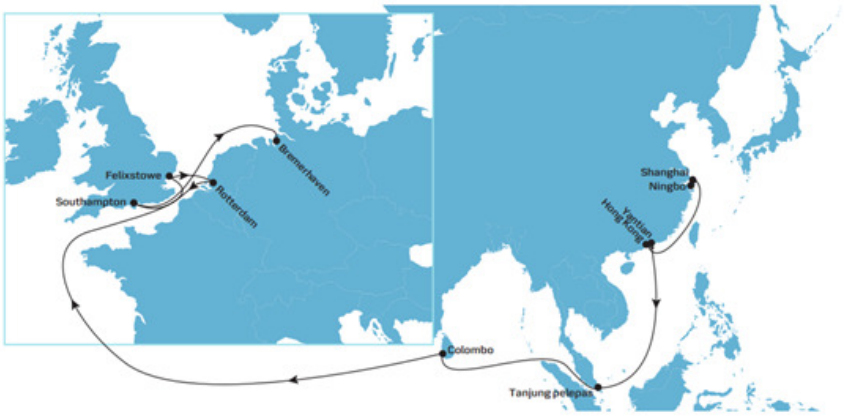
Projects with Stefan Røpke as supervisor

MSc Project - LINER SHIPPING NETWORK DESIGN

1. SUPERVISOR: Stefan Røpke

2. 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 recieve 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 transshipping 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).



3. PROJECT ASSIGNMENT: Design and implement a solution method for the liner shipping network design problem. Test the approach on instances from LinerLib data set.

4. 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.

5. GROUP SIZE: 2-3

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

7. REMARKS: David Pisinger offers a similar project.

BSc/MSc Project
Portfolio optimization using (mixed integer) linear programming

1. SUPERVISOR: Stefan Røpke

2. PROJECT BACKGROUND: Portfolio optimization is a quantitative investment strategy that aims to construct an investment portfolio with the highest possible expected return for a given level of risk or the lowest possible risk for a given level of expected return. It's a crucial concept in finance and asset management, helping investors make informed decisions about how to allocate their assets to achieve their financial goals.

Classical portfolio optimization models were based on quadratic programming but a number of portfolio optimization models based on mixed integer linear programming have been proposed over the last 20 to 30 years. The book: Mansini, Renata, Wlodzimierz Ogryczak, M. Grazia Speranza. Linear and mixed integer programming for portfolio optimization. Springer, 2015 gives a good introduction to the subject. The book can be downloaded from `https://link.springer.com/content/pdf/10.1007/978-3-319-18482-1.pdf`.

3. PROJECT ASSIGNMENT: Study the main models and implement a selection of the models. Test the models on data from the stock market (for example the Danish or US stock market). Analyze how useful the models are.

4. PREREQUISITES: Mandatory:

- 42101 Introduction to Operations Research
- 42112 Mathematical Programming Modelling
- Ability to work with data in Python or Julia.

Nice to have:

- Other Operations Research courses

5. GROUP SIZE: 2-3 students

MSc Project - AUTOMATIC DANTZIG WOLFE DECOMPOSITION

1. SUPERVISOR: Stefan Røpke and 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.

3. 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.

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

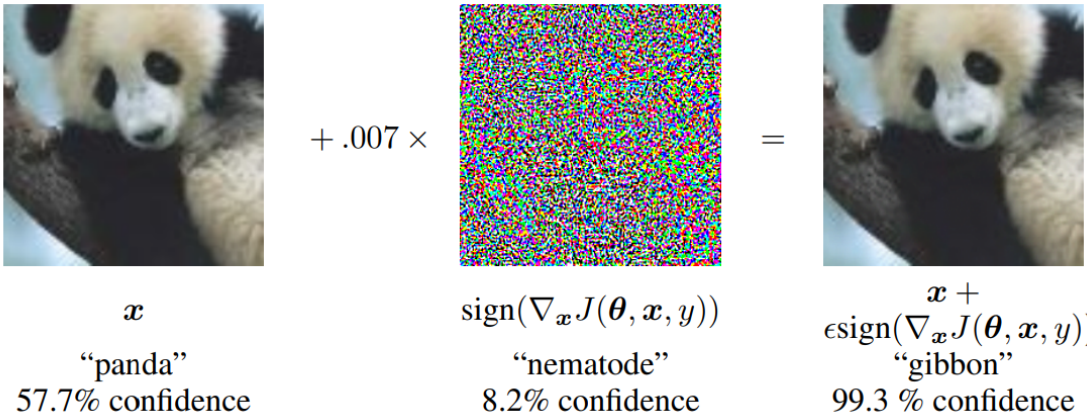
5. GROUP SIZE: 2-3 students

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

MSc project - VERIFICATION OF NEURAL NETWORKS

1. SUPERVISOR: Stefan Røpke and Richard Lusby

2. PROJECT BACKGROUND: In the past decade we have seen neural networks being used with great success in a number of applications. However, there are some concerns about using neural networks when it comes to decisions that potentially could mean life and death to a person. An example of such an application is the use of neural networks in self-driving cars. Part of the concern is fueled by the presence of "adversarial examples" for neural networks. Adversarial examples are inputs to the neural network that are blatantly being mis-classified by the neural network. Figure 1 shows an example of an adversarial example. On the left we have a picture of a panda which also is being classified as an image of a panda with good confidence by an image recognition neural network. We then apply a small modification of the picture which is shown in the center of the figure (notice that the change is exaggerated in the center image, the real change is just 0.7% of what is shown) and the result is the picture on the right which to the human eye looks almost identical to the left image. The neural network however now thinks that the image shows a gibbon and it is even extremely confident in this classification.



Figur 1: Example of an adversarial example. The figure is from *Goodfellow, Ian J., Jonathon Shlens, and Christian Szegedy. "Explaining and harnessing adversarial examples."arXiv preprint arXiv:1412.6572 (2014).*

One way to verify that a trained neural network is robust to adversarial attacks involves solving optimization problems like linear programming problems or mixed integer programming problems. The basic idea is that we would like to verify with certainty that there are no adversarial examples in a "neighborhood" around a certain input example. The "neighborhood" defines how large modifications we allow to make to the input example and we detect an adversarial example if the output changes dramatically inside this neighborhood. Verifying that there are no adversarial examples amounts to maximizing an objective function that measures output change and checking that the value of the objective function is limited for all inputs within the neighborhood of the input example.

3. PROJECT ASSIGNMENT:

- Develop a mathematical optimization model that verifies that a simple neural network is robust against adversarial attacks

After that one could

- Develop faster methods for solving the optimization problem (faster than just solving it with a standard generic MIP or LP solver)
- Experiment with the definition of neighborhood or the definition of the objective function in the optimization problem
- Conclude if the implemented model/method is useful for verifying that a neural network is robust against adversarial attacks.

4. PREREQUISITES:

- Introduction to operations research
- Introduction to Machine Learning and Data Mining

5. GROUP SIZE: 2-3 students

6. CHARACTERISTICS OF THE ASSIGNMENT: Neural networks, Linear programming, Integer Programming.

MSc project
LINER SHIPPING NETWORK DESIGN

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: 2-3

7. CHARACTERISTICS OF THE ASSIGNMENT: non-linear programming, integer programming, heuristics.

8. REMARKS: Relevant literature

- Lobo, Vandeberghe, Boyd, Lebret, Applications of second-Order cone programming, Linear algebra and its applications 284 (1998) 193-228
- Alizadeh, Goldfarb, Second-order cone programming, Mathematical programming 95 (2003) 3-51.
- Fischetti, Glover, Lodi, The feasibility pump, Mathematical programming 104 (2005), 91-104

MSc Project
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: 2-3

7. CHARACTERISTICS OF THE ASSIGNMENT: Vehicle routing, heuristics, exact methods.

MSc project - 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: 2-3

7. CHARACTERISTICS OF THE ASSIGNMENT: Integer programming, exact methods, heuristics, cutting planes.

MSc project - 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: 2 to 3 students

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

BSc/MSc project
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 to 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: 2 to 3 students

7. CHARACTERISTICS OF THE ASSIGNMENT: Biodiveristy, modelling, stochasticity.

MSc project - CO_2 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: 2 to 3 students

7. CHARACTERISTICS OF THE ASSIGNMENT: Liner shipping, CO_2 neutral fuels, Transport optimization.

BSc/MSc project - CO_2 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 CO_2 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 one 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: 2 to 3 students

7. CHARACTERISTICS OF THE ASSIGNMENT: Road based transportation, CO_2 neutral fuels, Transport optimization.

BSc project - WAREHOUSE LOCATION

1. SUPERVISORS: Stefan Røpke

3. PROJECT BACKGROUND: If a company has to distribute goods to a wider geographic area it may be beneficial to locate a number of warehouses within the area. Transport between the source of the goods and the warehouses can be done cost efficiently with large trucks while the final delivery from warehouses may be done using smaller trucks or vans, that could have a low carbon-emission impact (for example, if electric vehicles are used). The placement of the warehouses will have a large impact on the performance of the overall transport system.

4. PROJECT ASSIGNMENT: Study and implement one or more operations research methods for placement of the warehouses. Design ways to evaluate the performance of the solutions found by the implemented methods. The performance could consider both the expected cost and expected CO2 emissions from the solution.

5. PREREQUISITES: 42101 Introduction to operations research

6. GROUP SIZE: 2 to 3 students

7. CHARACTERISTICS OF THE ASSIGNMENT: Transport, CO2 emissions.

BSc/MSc project - NETWORK DESIGN WITH STOCHASTIC DEMANDS

1. SUPERVISORS: Stefan Røpke

3. PROJECT BACKGROUND: Network design problems are a class of problems with many applications, for example: Cable routing in wind farms, planning of bus lines, planning of communication networks, and planning of routes for container ships. Often the network design has to be done without fully knowing all the inputs to the problem. For example, we won't know the exact passenger demand in the future when designing bus lines or how much energy each wind turbine will need to send through the cables when doing cable routing in wind farms.

4. PROJECT ASSIGNMENT: The project can focus on a specific application or on a generic network design problem. Likewise, the project can focus on solution methods, or it can focus on how optimal solutions take stochasticity into account (attempting to understand the solutions produced by a MIP solver). Different objective functions can be considered, such as optimizing the expected cost or focusing on the worst-case scenarios.

5. PREREQUISITES: 42101 Introduction to Operations Research and ideally, 42586 Decisions under uncertainty. For a master's thesis, it is expected that the students have followed one of the advanced Operations Research courses: 43136 Large Scale Optimization using Decomposition, 42137 Optimization using metaheuristics or 42117 Transport optimization

6. GROUP SIZE: 2 to 3 students

7. CHARACTERISTICS OF THE ASSIGNMENT: Decisions under uncertainty, network design.

Projects with Thomas Stidsen as supervisor

MSc project
OPTIMIZED CONFERENCE SCHEDULING

1. SUPERVISOR: Thomas Stidsen & Dario Pacino

3. PROJECT BACKGROUND: In 2024, one of the largest OR conferences in the world EURO takes place at DTU, 30/6-3/7 2024, see `https://euro2024cph.dk`. To plan a conference such a large conference is a challenging task, but over the years, since 2015, Thomas Stidsen has been the scheduler of the EURO and IFORS conferences. Dario Pacino is the local chair of EURO 2024, in charge of the planning at DTU. To schedule the conferences since 2015, a MIP model has been used. This model is however rather hard to solve, and typically a gap of 30 % is achieved.

4. PROJECT ASSIGNMENT: The project is to first carefully describe the model. Then to develope advanced optimization approaches to get better solutions faster. The solutions can be metaheuristics, decomposition algorithms or math heuristics.

5. PREREQUISITES: Mathematical Programming with Modelling Software (42112) and either Optimization using Metaheuristics (42137) or Large Scale Optimization using Decomposition (42136) or both.

5. GROUP SIZE: 2-3 persons

BSc/MSc DSB, SCHEDULING TRAIN CLEANING

1. SUPERVISOR: Thomas Stidsen

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 schedule for the cleaning is made by DSB and then forwarded to the contractor. At DSB there are two different types of cleaning based on how much time is available and how thorough the cleaning should be. These cleanings can only be performed at designated stations on the route. There is a third kind of cleaning, which is performed while the train is moving with passengers on board. The process of developing the schedules for the cleaning is currently being done manually with no or very little system support.

4. PROJECT ASSIGNMENT: The aim of this thesis is to analyze, develop, implement, and present a method for automatically determining the cleaning schedules. First, an analysis on how often the cleanings need to be made, should be done based on past timetables. With his information and the fact that the schedules must comply with the rules and regulations of DSB, the student 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. PREREQUISITES: Mathematical Programming with Modelling Software (42112) and at least two other Operations Research course

5. GROUP SIZE: 2-3 persons

MSc DSB, INTEGRATED TRAIN DRIVER AND STATION DRIVER DUTY PLANNING AT DSB

1. SUPERVISOR: Thomas Stidsen

3. PROJECT BACKGROUND: DSB has two types of drivers. There are the classic train drivers who drive the commercial departures on the main tracks and there are the station drivers who only drive within the station on local tracks. The train drivers are allowed to drive on some tracks within a station but not necessarily all and the station drivers are not allowed to drive on any main tracks out side a station. The station drivers are normally attached to a specific station whereas the train drivers vary w.r.t. what part of the rail network they are allowed to drive. The duties of any driver are composed by task derived from the rolling stock schedule. The Rolling stock schedule is the plan for the train sets defining what train types are covering which departures and how many sets must cover each departure. The train sets have various needs of refueling, emptying of toilets, cleaning inside and out etc. that is carried out in the stations. Between having these needs handled and covering specific departures the train sets may be parked in the station.

4. PROJECT ASSIGNMENT: Today duties of drivers are planned completely separately and the decision of what type of driver covers a task is made in advanced. Formulate and implement an integrated model of making duties for respectively train drivers and station drivers based on the tasks in the rolling stock schedule. The objective is to answer the question of how many drivers of each type must be located on each crew depot.

5. PREREQUISITES: Mathematical Programming with Modelling Software (42112) and at least two other Operations Research course

5. GROUP SIZE: At least two students

BSc/MSc DSB, WORKSHOP TRAINS ON THE DAY OF OPERATION

1. SUPERVISOR: Thomas Stidsen

3. PROJECT BACKGROUND: A frequent challenge for DSB is that at the day of operation it is decided that some trains need to go to the workshop at the end of the day, e.g. because of technical problems. Today, dispatchers use a tool that optimizes the route of one single vehicle at the time.

4. PROJECT ASSIGNMENT: The scope of this problem is to find the best route for these vehicles such that the affected trains reach their destination at the right time. The aim is to utilize this vehicle for passenger transportation as much as possible instead of just sending it to the workshop empty, which is expensive for the operator. We want to create the cheapest solution by avoiding deadhead trips but also not messing with the plan too much. The solution method needs to create fast solutions. In this case, as we are helping the dispatchers on the day of operation, it is more important to be able to find fast solutions, rather than the optimal solution.

5. PREREQUISITES: Mathematical Programming with Modelling Software (42112) and at least two other Operations Research course

5. GROUP SIZE: 2-3 persons

MSc DSB, RESCHEDULING OF THE TIMETABLE AFTER A PLANNED DISRUPTION

1. SUPERVISOR: Thomas Stidsen

3. PROJECT BACKGROUND: When creating the timetable, Banedanmark plans different rail closures that affect the planned timetable. These closures influence the capacity of the tracks and therefore a new timetable needs to be planned. A lot of times the tracks are unavailable, which means that instead of driving in a stretch with 2 tracks, now the trains need to share one track even though they drive in opposite directions.

4. PROJECT ASSIGNMENT: At DSB, nowadays, this adjustment is performed manually. The planners have different tools that support them, but no optimization solution is yet in use. The topic of this project is to reschedule the timetable of the affected trains in such a scenario to adhere to the limitations of the network and replan as many trains as possible. The main goal is to create a schedule as similar as possible to the original. It is also possible to cancel trains partially or completely, but this is the least desired solution. Data, a mathematical model, and a greedy algorithm are already available. We are interested in metaheuristics solutions.

5. PREREQUISITES: Optimization using metaheuristics (42112) and at least two other Operations Research course

5. GROUP SIZE: 2-3 persons

MSc DSB, OPTIMIZATION OF THE ROLLING STOCK PLAN

1. SUPERVISOR: Thomas Stidsen

3. PROJECT BACKGROUND: Optimizing the distribution of rolling stock plays a pivotal role in enhancing both the passenger experience and operational costs within the railway system. By strategically planning train length and type in accordance with specific timetables and passenger demand, an efficient and seamless travel experience can be provided. Simultaneously, this optimization endeavour aims to minimize operational costs by reducing deadhead trips and maximizing the utilization of resources. This delicate balance between enhancing passenger satisfaction and optimizing operational efficiency underscores the crucial importance of meticulously planning and allocating rolling stock within the railway network.

4. PROJECT ASSIGNMENT: Given a timetable, passenger demand data, a rolling stock pool with associated passenger capacities and operating costs and a network of tracks and stations, the primary goal is to distribute the rolling stock to ensure optimal space utilization while minimizing operational costs. Constraints may arise from the properties of the train types, as well as the track and station network. The project involves developing a mathematical model to address these complexities and optimize the rolling stock distribution process.

5. PREREQUISITES: Mathematical Programming with Modelling Software (42112) and at least two other Operations Research course

5. GROUP SIZE: 2-3 persons

MSc DSB, RE-PLANNING OF ROLLING STOCK PLAN DUE TO TRACK WORKS

1. SUPERVISOR: Thomas Stidsen

3. PROJECT BACKGROUND: As a part of the ongoing improvement of the railway infrastructure, large and complex track works must be carried out for large periods of time during the year. As a railway operator, DSB must adapt the timetable, rolling stock, station, and duty schedules according to the prerequisites the track work implies. Together with the infrastructure manager, DSB agrees on a timetable that respects the limitations of a track work. As a subsequent task, DSB must adapt the rolling stock and station schedule to the new timetable, while taking passenger flow, maintenance reservations and station capacity into account. Today, this is a manual task, with only very basic system support in terms of shortcuts, validation of lists etc.

4. PROJECT ASSIGNMENT: The aim of this thesis is to analyze, develop and implement a method for automatically replanning of the rolling stock schedule, while taking station capacity and guidelines into account. An approach should take the following into account:

- A new timetable with adjusted times and/or cancelled trains
- A partly planned rolling stock plan, containing conflicts based on the new timetable (starting point)
- Rolling stock balances on stations (boundary conditions)
- Other relevant restrictions, for instance guidelines for turnaround times, coupling and decoupling etc.

The approach should support the following goals:

- A feasible rolling stock plan w.r.t. constraints
- Optimized seating capacity w.r.t. the passenger demand
- Feasible station plan w.r.t. capacity and servicing tasks (fueling)

Priority: fast solution > optimal solution (heuristics).

5. PREREQUISITES: Mathematical Programming with Modelling Software (42112) and at least two other Operations Research course

5. GROUP SIZE: 2-3 persons

MSc DSB, INTEGRATED TRAIN GUARD DUTY PLANNING

1. SUPERVISOR: Thomas Stidsen

3. PROJECT BACKGROUND: Traditionally, train guard services at DSB have been divided into two separate employee groups, one for the long-distance F&R passenger train services across the country and one for the Copenhagen suburban S-tog passenger train services. To improve employee satisfaction and efficiency an idea is to merge the two employee groups. One step in this direction has been completed enabling the same employee to work in both areas but on different days, hence one whole day on the S-tog services and the next whole day on the F&R services. This step on its own improves employee satisfaction as more work variance has been ensured. The next step is to combine the two services into the same working day, to see if efficiency can be improved. As a secondary goal work variance is intensified even more. While F&R tasks are defined on specific train tasks with departure station and time and arrival time and station, tasks on the S-tog service are defined by the expected presence on one of the 6 S-tog train lines for a certain time interval. During a service day, each of the 6 lines must be covered by two train guards. On each day there are 3 shifts for each line starting respectively at 4, 11 and 17 o'clock and each shift ending 7:56 hours later. Friday and Saturday there is an additional shift starting at 21:30 for each of the 6 lines. The idea is to allow duties that contain tasks on both services during the same day, an example being that the first 3 hours in a duty cover an S-tog line while the remaining duty covers tasks on the F&R service. As a constraint, tasks covering one of the S-tog lines always start and end on the Copenhagen main station (KH).

4. PROJECT ASSIGNMENT: The aim of this project is to analyze, develop and implement a method to construct an efficient duty set that allows the two services to be combined during a working day. All tasks on the two services must be covered.

5. PREREQUISITES: Mathematical Programming with Modelling Software (42112) and at least two other Operations Research course

5. GROUP SIZE: 2-3 persons

BSc/MSc RHEUMATISM TREATMENT PLANNING

1. SUPERVISOR: Thomas Stidsen

3. PROJECT BACKGROUND: The Danish organisation Gigtforeningen, is an organisation which treats patients for rheumatism. Given a specialized hospital which offers different treatments to patients, the planning problem is to select which treatment of the patient to perform when, given the different resources.

4. PROJECT ASSIGNMENT: The project assignment is first to analyze the planning problem, then to model the problem with one or more MIP models and finally to solve the problem.

5. PREREQUISITES: Mathematical Programming with Modelling Software (42112) and at least two other Operations Research course

5. GROUP SIZE: At least two students

BSc/MSc PRIMARY SCHOOL TIMETABLING

1. SUPERVISOR: Thomas Stidsen

3. PROJECT BACKGROUND: Timetabling in Danish primary schools is a complex task, which today becomes increasingly time consuming, since the timetable today is changed a number of times each school year. The most used software in Denmark today, actually comes from a master thesis from DTU, from 1992. The idea with this project is to try to use modern optimization techniques and better models to improve the timetabling tools. This project is performed together with the Danish software company Subit (subit.dk).

4. PROJECT ASSIGNMENT: The project assignment is to first analyze the problem, formulate a MIP model and finally create a solution approach, either (meta)heuristic, decomposition algorithm or mathheuristic. The programming requirements in this project are substantial.

5. PREREQUISITES: Mathematical Programming with Modelling Software (42112) and at least two other Operations Research course

5. GROUP SIZE: 2-3 persons

BSc/MSc TOOL CONSTRAINED SCHEDULING

1. SUPERVISOR: Thomas Stidsen

3. PROJECT BACKGROUND: The Danish company NetHire, supports all kind of tools used by companies running projects on many sites. Companies can rent tools from one of many NetHire storages, they can store their own tools there and possibly let others rent their tools.

4. PROJECT ASSIGNMENT: Assume a company, e.g. in pluming, has number of plummers working on a number of different projects. Each project has a number of required operations and for each operation a number of different tools are necessary. Since some of the tools are rather expensive, they have to be shared. This project is done in collaboration between DTU and NetHire, a Danish company specialized in supplying tools to Danish companies. The idea is to optimize the schedule of the projects to evaluate how many tools should be bought and how much project time could be saved by buying more tools. When buying, new tools, it also becomes possible to rent out the tools to other plummers.

5. PREREQUISITES: Mathematical Programming with Modelling Software (42112) and at least two other Operations Research course

6. GROUP SIZE: At least two students

BSc/MSc EXAM ROOM ALLOCATION AT DTU

1. SUPERVISOR: Thomas Stidsen

3. PROJECT BACKGROUND: Every semester DTU plans the written exams in a large number of rooms. Help the DTU planners to do it optimally.

4. PROJECT ASSIGNMENT: Given a set of written exams, a set of students, select the rooms and timeslots for the exams. Notice, the dates for the exams are given, but the time of day and room needs to be decided.

5. PREREQUISITES: Mathematical Programming with Modelling Software (42112) and at least two other Operations Research course

6. GROUP SIZE: 1-2 persons.

MSc TIMETABLING AT DTU

1. SUPERVISOR: Thomas Stidsen

2. PROJECT GROUP: Jette Kolby Laub Kristiansen

3. PROJECT BACKGROUND: Currently, the DTU timetable is static, i.e. courses are given in the timeslot every semester. Hence, currently, DTU only has to assign rooms to the lectures and exercises. If it was allowed to actually move some of the courses to new timeslots, better room utilization could be achieved.

4. PROJECT ASSIGNMENT: Given the data for the courses for a semester, create an optimized timetable. First fix the timeslots, but then investigate what could be achieved regarding better timetabling. Could evening teaching be avoided ? Can use of flipped classroom for certain courses be utilized in the timetable.

5. PREREQUISITES: Mathematical Programming with Modelling Software (42112) and at least two other Operations Research course

6. GROUP SIZE: 1-2 persons, preferable 2.

MSc MAINTENANCE PLANNING AT TOTAL

1. SUPERVISOR: Thomas Stidsen

2. PROJECT GROUP: Christian Brunbjerg Jespersen (DTU Construct)

3. PROJECT BACKGROUND: Total currently operates all oil and gas production in the Danish part of the North Sea. Running these oil-platforms is a complex and costly operation. In particular, maintenance of the platforms is costly, being responsible for app. 40 % of the operating costs. Planning when and what to maintain is complex, because it involves both planned repairs, urgent repairs, limitations on the crew which is needed for the repairs etc. All in all, this creates a very hard planning (optimization) problem.

4. PROJECT ASSIGNMENT: Currently a PhD project at DTU has created a MIP model, in Julia, for the maintenance planning problem. This basis can be extended into both improved MIP models and improved solution models. The project is open to whether to focus on model improvements or optimization improvements with e.g. math-heuristics.

5. PREREQUISITES: Introduction to Operations Research (42101), Mathematical Programming with Modelling Software (42112) and at least one other Operations Research course, e.g. Large Scale Optimization using Decomposition (42136) or Optimization using metaheuristics (42137)

6. GROUP SIZE: 1-2 persons, preferable 2.

MSc MANY-OBJECTIVE PROBLEMS INVOLVING STAKEHOLDERS

1. SUPERVISOR: Thomas Stidsen & Michael Barfod

3. PROJECT BACKGROUND: Decision-making is often faced with complex problems with many possible solutions involving many objectives (criteria) and where different stakeholders are trying to influence the result. This calls for methodologies such as multi-criteria decision analysis (MCDA) and multi-objective optimization (MOO). Despite many years of research, such planning problems combining many objectives (more than 3) and several stakeholders, are not adequately addressed.

4. PROJECT ASSIGNMENT: This is a joint MSc project, where methods from both the O&SCM and OR sections are utilized. The students will work with MCDA as well as MOO, and the focus will be on theory development and implementation. We expect implemented methods, so a certain amount of programming skills are necessary. As data the project will utilize relatively simple test problems.

5. PREREQUISITES: Introduction to Operations Research (42101), Mathematical Programming with Modelling Software (42112), Decision support and strategic assessment (42879). It will also be very beneficial if the student has had Optimization using Metaheuristics (42137).

6. GROUP SIZE: 2-3 persons

MSc 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.

6. GROUP SIZE: 1-2 persons.

MSc MATHEMATICAL PROGRAMMING CLUSTERING

1. SUPERVISOR: Thomas Stidsen

3. PROJECT BACKGROUND: Clustering algorithms have 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 algorihtms.

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

6. GROUP SIZE: At least two students

MSc Project
LINEAR REGRESSION DONE RIGHT

1. SUPERVISOR: Thomas Stidsen

3. PROJECT BACKGROUND: The classical approach to Linear Regression usually involves the Lasso algorithm. Recently, Professor 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 Quadradic 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: At least two students