Master’s thesis project in Management Science (Spring 2018)
The 3 steps for applying for an OR Master-Thesis project

The starting dates for a master-thesis in the Spring 2018 are:

- 2/1 2018
- 22/1 2018

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

If you want to write an OR master-thesis in the Spring of 2018, you should follow the following 3 steps:

1. **READ THE PROJECT FOLDER** and spend some time thinking about what kind of OR master-thesis you want to write.

2. Write an email, **BEFORE Monday 27/11 2017**, to the professor(s) you want to supervise your thesis writing. The email should clearly state:
   - Name and study number.
   - When the project should start and end, and how many ECTS points.
   - Which project(s) are you interested in. This may be your own project, then it should be explained.
   - What OR courses have you followed (and when)
   - What is your programming experience (specify programming languages and how experienced you are).
   - Attach a printout of your grade-sheet.

   The professor will probably call you in for a short interview before agreeing to become your supervisor. When the professor expects a good match between you, the project, and their expertise area, they may invite you for an interview. You may request such a meeting in your email. If they do not see a match, they will let you know as soon as possible. To allow for time for interviews, we encourage you to send an email to the professor(s) of your interest as soon as possible.

   When you send an invitation to multiple professors, please express your preference for a specific project/professor no later than 27/11. You may choose, if preferred, to privately express this preference to the central thesis administrator Thomas Stidsen.

3. At the latest on Tuesday 4/12 2018 you will receive a proposal for a thesis topic and a supervisor for your master thesis. You may accept or reject this proposal. It is the departments aim to find the best match between student’s expressed capabilities & interests in step 2, the available projects and the supervisors expertise areas. If you decide to reject the proposal, you may contact the thesis coordinator, Thomas Stidsen, to discuss available solutions. You will have the best chance of ending up with your preferred project at your preferred professor when you follow step 1 and step 2.
Possible OR supervisors

• Assistant Prof. Charlotte Vilhelmsen, Email: chaaan@dtu.dk
  – Core: Health-care planning, tramp ship routing and scheduling, optimisation under uncertainty
  – Other: Vehicle routing, column generation

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

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

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

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

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

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

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

• Assistant Prof. Rune Larsen, Email: rular@dtu.dk

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

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

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

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

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

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

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

Some of the projects in this folder can also be used as the basis for bachelor projects. If you are interested, ask the designated supervisor of the project.
1. SUPERVISORS: Claus Madsen (DTU MAN), Kourosh Marjani Rasmussen (DTU MAN)

3. PROJECT BACKGROUND: The price of a derivative (or a whole portfolio of derivatives) might take positive or negative values over time. E.g., a plain-vanilla interest rate swap or a forward has a market value of zero at the beginning. Afterwards, dependent of the evolution of the interest rates, the market value becomes positive or negative.

In most cases the contracts are traded directly between financial institutions (OTC), i.e. no clearing house guarantees for the fulfillment of the payments. This means that for contracts with a positive market value a possible default risk of the counterparty has to be taken into account. CVA or credit value adjustment measures the expected loss of a specific counterparty over time. Of course, connected to his measure, there are also some capital requirements, which are relevant for a bank. The CVA is, among other factors, important also for the pricing of financial products.

4. PROJECT ASSIGNMENT: There are different ways to minimize the CVA risk in general: netting agreements, collaterals, counterparty diversification. Several topics are relevant in this project. Interested students can contact the supervisors to hear more about concrete project possibilities. The students are very welcome to come up with their own suggestions as to specific problem descriptions within the framework of the given project area.


6. GROUP SIZE: 1 or 2 persons.

1. **SUPERVISORS:** Kourosh Marjani Rasmussen (DTU MAN)

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

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


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

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Index Tracking, Optimization, Market Microstructure, Market Efficiency.
1. SUPERVISORS: Kourosh Marjani Rasmussen

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

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

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

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

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

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

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


6. GROUP SIZE: 1 or 2 persons.

THE IMPACT OF FORECAST QUALITY ON ELECTRICITY MARKET CLEARING

1. SUPERVISORS: Pierre Pinson (DTU Elektro), Kourosh Marjani Rasmussen (DTU MAN)

3. PROJECT BACKGROUND: As more wind energy is traded through electricity markets, the offering strategies of the participants, if not the market clearing procedures themselves, increasingly integrate forecast information as input. This was somehow already the case with forecasts for the demand side in the past, with the difference that such predictions were much more accurate.

4. PROJECT ASSIGNMENT: The scope of this project is to study and analyse the impact of forecast quality (mainly for wind power generation) on the outcome of electricity markets. Different types of market clearing procedures will be considered, consisting of simple deterministic optimization problems in some cases, or in complex stochastic optimization ones when forecast uncertainty is to be fully accounted for. The output of this work will be highly relevant to define the type of market clearing that may optimize social welfare, provide the more adequate price signals to market participants, but also to indicate necessary further research in the improvement of forecasting methodologies since uncovering the sub-optimality of market clearing induced by forecast quality (or the lack of).

This work is to be framed as part of DTU’s leading research in integration of renewable energy in power systems and electricity markets, also linked to a large Danish project on Future Electricity Markets (’5s’).

5. PREREQUISITES: Time series analysis, Optimization, Programming

6. GROUP SIZE: 1 or 2 persons.

1. **SUPERVISORS:** Pierre Pinson (DTU Elektro), Kourosh Marjani Rasmussen (DTU MAN)

3. **PROJECT BACKGROUND:** Investment models in new energy capacities rely on models for the dynamics of electricity markets. Current assumptions on such models are challenged by the further integration of renewable energy capacities and by the rapid and profound changes in the design of electricity markets.

4. **PROJECT ASSIGNMENT:** The aim of this project is to simulate and characterize the dynamics of electricity markets under different design options, with focus on market clearing procedures. It will be based on real data from the Nord Pool electricity market for Scandinavia. Emphasis will also be placed on the impact of uncertainties and changes in the dynamics induced by wind power generation.

   This work is to be framed as part of DTU’s leading research in integration of renewable energy in power systems and electricity markets, also linked to a large Danish project on Future Electricity Markets (‘5s’).

5. **PREREQUISITES:** Time series analysis, Optimization, Programming, Courses in Financial Engineering

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

1. SUPERVISOR: Kourosh Marjani Rasmussen

3. PROJECT BACKGROUND: About 84 percent of U.S. stock funds that are actively managed, rather than passively tracking an index, underperformed, in 2011, when compared to the Standard & Poor’s indexes representing the market segment the funds invest in, according to S&P’s 10th annual fund performance scorecard.

Over three years, from 2009 through 2011, about 56 percent of stock funds underperformed relative to S&P benchmarks. Over five years, 61 percent underperformed. Going back 10 years, the average percentage of funds underperforming has been about 57 percent.

More often than not, a majority of funds underperform because returns are reduced by investment fees to cover fund operations, including costs to pay managers and analysts who support them. Those fees are difficult to offset, even if a manager is a strong stock-picker. At actively managed funds, expense ratios typically range from 0.5 percent to 2 percent. That’s the amount investors pay each year, expressed as a percentage of a fund’s assets.

Nevertheless the majority of the average investors savings today end in such stock funds or more broad mutual funds.

Index funds (such as ETFs) charge lower fees – as little as 0.06 percent at some funds – because they don’t rely on professionals to pick stocks. Index funds are designed to track an index, delivering investment returns that are slightly smaller than the benchmark to account for fees covering operations.

The purpose of this project is to identify robust investment strategies for different categories of investors, ranging from people investing part of their salaries for their retirements to the private banking clients, high net worth individuals and finally corporate investors.

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


6. GROUP SIZE: 1 or 2 persons.

1. SUPERVISOR: Kourosh Marjani Rasmussen

3. PROJECT BACKGROUND: Volatile freight prices due to seasonality and strong business cycles, fluctuations in bunker prices, interest rates, foreign exchange rates and vessel values dominate the shipping market today. Adding an extreme competitive and thereby price effective environment to this makes risk management very important for ship owners and charterers.

Specialized financial derivatives are available today, via specialized clearing houses, for risk management against the aforementioned sources of risk. Most notably these include Forward Freight Agreements (FFA), Freight Future Contracts and FFA options (put and call).

Shipping finance is still to be considered an immature field of study. Shipping risk management using quantitative methods like mathematical optimization is to our best of knowledge an unexplored field.

This project deals with the financial risks ship owners are running regarding the freight price uncertainty. Decision tools for effective risk management in shipping should be developed as part of this project.

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


6. GROUP SIZE: 1 or 2 persons.

BUNKER FUELING PLANS IN SHIPPING
IN THE FACE OF UNCERTAINTY

1. SUPERVISOR: Kourosh Marjani Rasmussen

3. PROJECT BACKGROUND: When planning for bunker fueling in Liner Shipping lots of different practical and legal constraints should be respected.

   This project builds upon the master thesis of Plum and Jensen from 2007 - Minimization of Bunker Costs. In their fueling plan they include selection of bunkering ports as well as how much and what grade to bunker at any chosen port. The fixed bunker reserve requirements are respected by the plan.

   The existing model is deterministic, but there are uncertain elements such as bunker prices and bunker usage to be dealt with. The idea with this project is to extend the model of Plum and Jensen by scenario representations of the uncertain parameters.

   It is desirable to identify the value of adding this complexity to the model structure and suggesting means to realize the extra potential, if such potential indeed exists.

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


6. GROUP SIZE: 1 or 2 persons.

1. SUPERVISORS: Pierre Pinson (DTU Elektro), Kourosh Marjani Rasmussen (DTU MAN)

3. PROJECT BACKGROUND: The increasing penetration of wind energy, and more generally renewable power generation, is inducing new issues in power systems operations while challenging the conventional approach to market design and participation in electricity markets. Especially, the increased variability and limited predictability of stochastic power producers (wind, solar, etc.) calls for additional flexibility in power systems operations. This effect is magnified by the behavioral changes on the demand side, also expected to be more proactive in the future. Flexibility is therefore seen as some form of a service to be provided by the other market participants, for which no adequate price signal exist today. Consequently, some market operators are envisaging to readily define market products that rewards market participants for their flexibility, or more generally to revisit market design for adequate price signals to be sent to these producers able to provide this new type of service.

4. PROJECT ASSIGNMENT: The aim of this MSc project is to analyse various proposals for trading flexibility in electricity markets, with focus on the optimization problem defining the market clearing mechanisms, as well as the way market participants may place offers and be rewarded for such a service. This work is to be framed as part of DTU’s leading research in integration of renewable energy in power systems and electricity markets, also linked to a large Danish project on Future Electricity Markets (’5s’).

5. PREREQUISITES: Optimization, Programming, Courses in Financial Engineering

6. GROUP SIZE: 1 or 2 persons.

1. **SUPERVISOR:** Charlotte Vilhelmsen

3. **PROJECT BACKGROUND:** Tramp ships operate much like taxies following the available demand as opposed to liner ships that operate more like buses on a fixed route network according to a published timetable. Tramp operators can determine some of their demand in advance by entering into long-term contracts and then try to maximise profits from optional voyages found in the spot market. Routing and scheduling a tramp fleet to best utilise fleet capacity is therefore an ongoing and complicated problem comprising simultaneous decisions on which cargoes from the spot market to transport, which ship each cargo should be transported on, and which order and timing the given cargoes for a given ship must be transported in. Here we add further complexity to the routing and scheduling problem by incorporating voyage separation requirements that enforce a minimum time spread between some voyages. The incorporation of these separation requirements helps balance the conflicting objectives of maximising profit for the tramp operator and minimising inventory costs for the charterer, since these costs increase if similar voyages are not performed with some separation in time.

4. **PROJECT ASSIGNMENT:** Develop, implement and test a solution method that can route and schedule a fleet of tramp ships while adhering to given voyage separation requirements.

5. **PREREQUISITES:** Integer programming course and good programming skills are required.

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Tramp Shipping, Routing, Scheduling, Temporal dependencies.
OPTIMIZING RESOURCE UTILIZATION IN SHARED OUTPATIENT CLINICS

1. SUPERVISOR: Charlotte Vilhelmsen, Dario Pacino, Thomas Stidsen

3. PROJECT BACKGROUND: The Capital Region of Denmark, Rigshospitalet and Ole Kirk’s Foundation have joined forces in a partnership to build a first-rate hospital building that sets new standards for the treatment of children, adolescents, pregnant women and their families. The working title of the construction project is: Children’s Hospital Copenhagen. According to project director Bent Ottesen, who was in charge of a prior feasibility study, the new building provides an exceptional opportunity to integrate patient care, research and education and will provide faster diagnosis and more streamlined care. One major shift in paradigms is that rather than patients going to see the healthcare personnel, the later will come to the patient. Furthermore, future outpatient clinics will be shared between departments. Such changes will require careful planning of availability of human resources.

4. PROJECT ASSIGNMENT: Due to a shift from resource- to flowoptimization, careful scheduling of available resources is required for efficiency. A proposed research question may be “how can human resources (i.e. doctors, specialists, nurses etc.) be utilized efficiently in shared outpatient clinics?”

5. PREREQUISITES: Not mandatory but would be a great help: courses 42112 and 42413 (dependent on focus)


7. CHARACTERISTICS OF THE ASSIGNMENT:
DAILY PLANNING OF OPERATING ROOMS AT RIGSHOSPITALET

1. SUPERVISOR: Charlotte Vilhelmsen

3. PROJECT BACKGROUND: At any major hospital the scheduling of operating rooms is a critical activity. Not only is surgery a major cost driver but for staff it is important to be able to deliver the best possible care. There are several planning stages but the most important one is the daily planning. At Rigshospitalet the surgery plan for the next day is produced at 2pm. After this plan has been determined patients can prepared for the upcoming operations. Poor planning lead to staff doing overtime and surgery cancellations although the patient is ready for the operation.

4. PROJECT ASSIGNMENT: This project is concerned with investigating the possiblities of delivering high-quality decision support using integer programming, stochastic programming and mathematical optimization. The input to the planning process are the planned operations for the next day. They differ in complexity and duration. In addition, special equipment not available in every operating room may limit the possibilities. Finally, one also has to set aside resources for emergency operations and take into account the stochasticity of the duration of each surgery. The project should contain all important parameters and produce a surgery plan for the daily problem.

5. PREREQUISITES: Integer Programming, knowledge about stochastic programming and good programming skills

6. GROUP SIZE: 1-2 students

7. CHARACTERISTICS OF THE ASSIGNMENT: Implementation of solution method for stochastic programming model
IS A CONSOLIDATED REGIONAL SERVICE CENTER
A GOOD IDEA?

1. SUPERVISOR: Dario Pacino or Evelien van der Hurk

2. PROJECT GROUP:

3. PROJECT BACKGROUND: Today the Capital Region of Denmark has a centralized warehouse located in Glostrup. The warehouse supplies all hospitals in the region with most consumables - most of them stored at the warehouse and packed into trolleys for the wards, departments or functions (customers) at the 11 hospitals and other customers such as the psychiatric hospitals and general practices. In a supplementary flow goods are cross-docked at the warehouse - the supplier delivers one consolidated delivery for the whole region at the warehouse and the goods are then divided into smaller local deliveries together with goods from other suppliers and sometimes deliveries from the warehouse for each customer. At the same time all hospitals receives deliveries from a regional owned drug store, a private or a regional owned linen supplier, two central regional sterilization units, a wide range of different third party logistic companies and sometimes from an external kitchen just to mention some of the large incoming flows. Added to the incoming flow there is a large flow of waste and materials for refurbishment combined with return logistics in the outgoing flow. To minimize the number of deliveries for each hospital and each customer and at the same time to optimize the utilisation of the customer packed trolleys it is considered to establish a regional consolidated service centre where all the mentioned deliveries are cross-docked into a smaller number of mixed deliveries for each customer.

4. PROJECT ASSIGNMENT: How to assess the potential in a consolidated service centre including a list of pros and cons in terms of soft (customer experience) and hard (economy) facts.

5. PREREQUISITES:

6. GROUP SIZE: 1-2 students

7. CHARACTERISTICS OF THE ASSIGNMENT:

8. REMARKS:
1. **SUPERVISOR:** Dario Pacino or Evelien van der Hurk

3. **PROJECT BACKGROUND:** The Capital Region of Denmark has a centralized warehouse located in Glostrup. The warehouse supplies all hospitals in the region with most consumables - most of them stored at the warehouse and packed into trolleys for the wards, departments or functions (customers) at the 11 hospitals and other customers such as the psychiatric hospitals and general practices. In a supplementary flow goods are cross-docked at the warehouse - the supplier delivers one consolidated delivery for the whole region at the warehouse and the goods are then divided into smaller local deliveries together with goods from other suppliers and sometimes deliveries from the warehouse for each customer. In an optimal world the CD-items follows the warehouse deliveries but how should the CD-deliveries be handled when there is no warehouse deliveries?

4. **PROJECT ASSIGNMENT:** Help the logistic organisation in setting up a cost and customer optimised setup for handling CD-deliveries in terms of optimal flow and customer oriented solutions.

5. **PREREQUISITES:**

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:**

8. **REMARKS:**
OPTIMIZING TIME SCHEDULES
OF SHARED OUTPATIENT CLINICS

1. SUPERVISOR: Dario Pacino or Charlotte Vilhelmsen or Peter Jacobsen or Thomas Stidsen

2. PROJECT GROUP:

3. PROJECT BACKGROUND: The Capital Region of Denmark, Rigshospitalet and Ole Kirk’s Foundation have joined forces in a partnership to build a first-rate hospital building that sets new standards for the treatment of children, adolescents, pregnant women and their families. The working title of the construction project is: Children’s Hospital Copenhagen. According to project director Bent Ottesen, who was in charge of a prior feasibility study, the new building provides an exceptional opportunity to integrate patient care, research and education and will provide faster diagnosis and more streamlined care. One major shift in paradigms is that rather than patients going to see the healthcare personnel, the later will come to the patient. Furthermore, future outpatient clinics will be shared between departments. Such changes will require careful planning of when elective patients are to be seen.

4. PROJECT ASSIGNMENT: The major research question to be answered is “how to optimize utilized time for optimal flow of future treatment of elective patients”.

5. PREREQUISITES: The major research question to be answered is “how to optimize utilized time for optimal flow of future treatment of elective patients”.

6. GROUP SIZE: 1-2

7. CHARACTERISTICS OF THE ASSIGNMENT:

8. REMARKS:
CUSTOMER SEGMENTATION
AND OPTIMIZING DELIVERIES

1. SUPERVISOR: Dario Pacino or Evelien van der Hurk

2. PROJECT GROUP:

3. PROJECT BACKGROUND: The Capital Region of Denmark has a centralized warehouse located in Glostrup. The warehouse supplies all hospitals in the region with most consumables - most of them stored at the warehouse and packed into trolleys for the wards, departments or functions (customers) at the 11 hospitals and other customers such as the psychiatric hospitals and general practices. In a supplementary flow goods are cross-docked at the warehouse - the supplier delivers one consolidated delivery for the whole region at the warehouse and the goods are then divided into smaller local deliveries together with goods from other suppliers and sometimes deliveries from the warehouse for each customer. Today customers have 1, 2, 3, 4 or 5 delivery days per week based on an unstructured and history based setup. At the same time it is not possible for the central warehouse to differentiate the service for the customers e.g. in case of backorders and they are handled as first come first serve.

4. PROJECT ASSIGNMENT: Set up a model for differentiating the customers and optimising the delivery pattern with a strong focus on total cost of ownership in the supply chain from the warehouse to the point of use.

5. PREREQUISITES:

6. GROUP SIZE: 1-2 students

7. CHARACTERISTICS OF THE ASSIGNMENT:

8. REMARKS:
1. **SUPERVISOR:** Dario Pacino or Evelien van der Hurk

3. **PROJECT BACKGROUND:** Today the Capital Region of Denmark has a centralized warehouse located in Glostrup. The warehouse supplies all hospitals in the region with most consumables - most of them stored at the warehouse and packed into trolleys for the wards, departments or functions (customers) at the 11 hospitals and other customers such as the psychiatric hospitals and general practices. In a supplementary flow goods are cross-docked at the warehouse - the supplier delivers one consolidated delivery for the whole region at the warehouse and the goods are then divided into smaller local deliveries together with goods from other suppliers and sometimes deliveries from the warehouse for each customer. When ordering from the central warehouse the lead time depends on the number of delivery days per week for the specific customer but for customers with daily deliveries the lead time is under 24 hours. When ordering a CD-delivery the lead time varies from day to day and up to weeks. Added to this the customers often experiences the goods can only be bought in larger volumes than needed. Given that the space for storage at each customer is a scares resource the regional supply chain wants to optimize the usage of storage points in the entire supply chain.

4. **PROJECT ASSIGNMENT:** Set up a model for evaluating and optimizing the storage points in the entire supply chain from vendor to customer

5. **PREREQUISITES:**

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:**

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

2. **PROJECT GROUP:**

3. **PROJECT BACKGROUND:** Container vessels are known to be one of the most $CO_2$ efficient ways to transport goods. Even though the emissions per ton/mile are minimal the total amount of produced emissions is huge. Since the economic crisis of 2009, the carriers have adopted a sailing policy called "slow steaming". With this policy, vessels are meant to sail at slow speeds thus reducing emissions, bunker consumption and costs. Such a strategy can make economic sense only if the extra transport times do not affect the customers. This can be achieved by reducing the ship’s time at port.

4. **PROJECT ASSIGNMENT:** The aim of the project is to exploit the flexibility that type based stowage plans can offer when optimizing port operations. Your task will be to develop a solution method for the optimization of the ship loading operations. This will include the assignment of containers to the vessel and the scheduling of the cranes and terminal vehicles.

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

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:**

8. **REMARKS:** Little academic work available. Chance of publication.
1. **SUPERVISOR:** David Pisinger

3. **PROJECT BACKGROUND:** We consider the problem of loading some rectangular boxes into a container of given size. The problem has important applications in logistics, production planning, etc. and numerous exact and heuristic algorithms have been presented for its solution. However, few of these are able to handle all the additional constraints that appear in real-life applications.

4. **PROJECT ASSIGNMENT:** Based on existing algorithms for container loading, it is requested to investigate how these can be extended to handle a number of additional constraints. Such constraints can be: priorities of the loaded items, balance constraints, stackability of items, etc.

5. **PREREQUISITES:** Large Scale Optimization using decomposition (42132), Optimization using metaheuristics (42133). Some programming experience is required.

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:** The project involves analysis, design, implementation and testing.
1. SUPERVISOR:  David Pisinger

2. PROJECT GROUP:  Tommy Clausen, Morten Nielsen (WorkBridge)

3. PROJECT BACKGROUND:  The baggage scheduling problem concerns the routing of baggage through the airport for transferring passengers. When passengers have short transfers, their baggage is transported by a dedicated service to ensure that they can be delivered to the destination aircraft on time. All incoming bags for short transfers arrive at a central dispatching facility, from which vehicles are dispatched to deliver the bags. From the dispatch centre, bags can be delivered to the regular baggage site of the destination flight, or to the aircraft itself. The choice of destination depends on the delivery time available. After delivery, the vehicles return to the facility to be dispatched again. The arrival times of the relevant bags depend on the arrival time of the aircraft, but are subject to a number of uncertain factors. The factors include aircraft delays, transport time from the aircraft and processing time in the dispatch facility.

4. PROJECT ASSIGNMENT:  The aim of this project is to develop a scheduling algorithm for the dispatching facility that minimizes the number of undelivered bags for a day of operation. The number of vehicles and the arrival times of the bags are assumed to be fixed. The project should emphasize:
   • A good description of the problem’s underlying model
   • A well-described algorithm for solving the problem. The algorithm should be self-developed and not use solver software such as Integer Programming solvers
   • Fast computation times to allow re-scheduling as delays occur

5. PREREQUISITES:  Courses in Operations Research. Good programming skills is an advantage


7. CHARACTERISTICS OF THE ASSIGNMENT:  Analysis, modeling, and implementation of a real-life transportation problem
1. **SUPERVISOR:** David Pisinger

2. **PROJECT GROUP:** Line Blander Reinhardt

3. **PROJECT BACKGROUND:** The Liner Shipping companies such as Maersk has a network of different cyclic routes which are interconnected at some ports. Each of these routes are cyclic on a fixed weekly schedule. The routes are called strings. Optimizing the liner shipping network design is a very hard problem and often inconvenient for the company. However the company often is able to change a single route or to change the times for port visits.

4. **PROJECT ASSIGNMENT:** Several models for optimizing and constructing single strings. However looking at optimizing berth times on an entire network taking connections into account has not been looked into yet. The project consists of modeling the problem of finding optimal berthing times for the strings on the network given a set of origin destination demands and in some cases also some time limit for the transport duration of the demand. The cost of transhipment should include a time at port aspect to model a correct time at port. The problem may be solved using metaheuristics or exact methods.

5. **PREREQUISITES:** Integer Programming (42114), Network Optimization (42115)

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Liner Shipping, Modeling, Transhipment, network design
1. **SUPERVISOR:** David Pisinger

2. **PROJECT GROUP:** Tommy Clausen, Morten Nielsen (WorkBridge)

3. **PROJECT BACKGROUND:** The workload coverage problem specifies a set of shifts for workers and a workload profile detailing the amount of work that must be covered for all skills and time periods (e.g. 5 agents at 08:00, 7 agents at 08:15, etc). Each worker has a set of skills and availability times that determine which parts of the workload he or she is able to cover. The problem is then to determine the staffing levels for all time periods and skills. In the static version of the problem, the times of all tasks contributing to the workload profile are known in advance and it is certain how many workers of each skill will be required at any time. This makes the problem relatively easy to solve. In the aviation industry, the times of almost all tasks are linked to the arrivals and departures of specific aircraft. As aircraft are frequently delayed, the times of the resulting tasks are subject to a large degree of uncertainty, so the exact task times are not known at the time of calculation. This leads to the stochastic workload coverage problem, where the uncertain task times lead to probabilistic workload requirements.

4. **PROJECT ASSIGNMENT:** The project should consider the following
   - How is the uncertainty on tasks represented as a stochastic workload profile?
   - How can the coverage of a set of shifts be evaluated on a stochastic workload? In particular, how are two stochastic workloads compared?
   - What is the effect of flight delays on an existing set of shifts?

5. **PREREQUISITES:** Courses in Operations Research

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Modeling, analysis and implementation for a real-life problem

8. **REMARKS:** If desired, the project can be expanded by e.g. considering how to create more robust shifts. However, this should not be the main focus of the project.
1. **SUPERVISOR:** David Pisinger

2. **PROJECT GROUP:** Line Blander Reinhardt

3. **PROJECT BACKGROUND:** In liner shipping the vessels sail on a fixed schedule. However due to temporary port closures and weather conditions disruptions are not uncommon in liner shipping. These disruptions can result in containers on the vessel not making their connection on other vessels or reaching destination on time. There are many ways to get a vessel back on schedule. These methods involves speeding up the vessel at a higher fuel consumption cost, skipping a port transhipping containers with origin and destination at that port on other vessels, changing the order of the port visits or delaying the connecting vessels so that the transhipment can occur.

4. **PROJECT ASSIGNMENT:** A basic model for handling disruptions has been studied however it is quite limited and the project described here consists of extending the model to handle more situations. Such situations could be to consider letting another vessel on another schedule make the port visit or leaving part of cargo behind to reduce time a port. Another issue is that in the existing model the cargo missing connections and delayed are evaluated by a fixed cost. However it would be very relevant to consider and evaluate the possibility of rerouting of containers onto other vessels in the network.

5. **PREREQUISITES:** Integer Programming (42114), Network Optimization (42115)

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Disruption management, Liner Shipping, Modeling.
1. SUPERVISOR:  David Pisinger

2. PROJECT GROUP:  Torben Barth

3. PROJECT BACKGROUND:  Robustness is an important issue in the context of planning decisions at an airport. Many factors are not known until the realization of the events like the arrival of the aircraft at the parking position. For example before the final arrival of the aircraft at the parking position, it could happen that the planned position changes and that the estimation of arrival time changes many times. At Frankfurt Airport exist today several solutions to support the dispatchers of the baggage handling processes. For example one solution generates suggestions for assigning baggage carousels to flights at baggage claim. The existing solutions are based on MIP models and solve the problem with CPLEX. These solutions take the uncertainty in a basic way under consideration.

4. PROJECT ASSIGNMENT:  The goal for the project is to develop an improved model for one of the sub processes of baggage handling. The improved model should achieve more robust solutions. In a first step, it is necessary to determine and analyse the different factors of uncertainty. The identified factors should be described and modelled in a quantitative way before the existing models are extended. The data will be provided by Fraport the owner and operator of Frankfurt Airport.

5. PREREQUISITES:  Courses in Operations Research. Good programming skills is an advantage. German language skills could be of advantage.


7. CHARACTERISTICS OF THE ASSIGNMENT:  Analysis, modelling, and implementation of a real-life decision problem.

8. REMARKS:  External stay at Frankfurt Airport could be an option.
1. **SUPERVISOR:** David Pisinger

3. **PROJECT BACKGROUND:** ENERPLAN is a joint project between DTU Management, ITU and Maersk Line, which aims at reducing the energy consumption in Liner Shipping by use of advanced optimization techniques. One of sub-projects is to re-design the routes of the vessels, such that the global transportation needs are satisfied, delivery times are met, and least possible fuel is used.

4. **PROJECT ASSIGNMENT:** Based on existing literature for bus route planning, the task is to design a heuristic which can propose some sensible routes and calculate the cheapest flow through the network. As input is given a matrix of transportation demands between pairs of ports, travel distances between the ports, and a set of vessels with associated capacity.

5. **PREREQUISITES:** Introduction to Operations Research (42101), Large Scale Optimization using decomposition (42132), Optimization using metaheuristics (42133). Some programming experience is required.

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:** The project involves analysis, design, implementation and testing.

8. **REMARKS:** Not much has been published on this subject, but the supervisor has access to some preliminary reports.
1. SUPERVISOR: Evelien van der Hurk

2. PROJECT GROUP: OPS Analytics

3. PROJECT BACKGROUND: Aircraft rotation planning is about assigning individual aircrafts to flights in a scheduled timetable. In creating such a rotation one needs to take into account many different constraints. For example, one needs to ensure that the required capacity of the aircraft in terms of the number of passenger seats is sufficient. In addition, all aircrafts need regular maintenance and check ups which usually can only take place at a limited set of airports. Thus in creating the rotation one has to ensure that the aircraft visits an airport where maintenance can be performed regularly, and that there is time reserved in the schedule to perform all necessary maintenance.

The creating of such a schedule is complex, in part, due to the many possible feasible routings for a single aircraft. Therefore column generation, that aims to solve the optimization model using only a subset of all feasible routes, is generally considered a reasonable approach.

The project is in collaboration with Bo Vaaben at OPS Analytics, which is a consulting company focusing on improving operational efficiency for its customers through all stages of the operation from strategic planning to execution and post operational analysis. ops-analytics.com

4. PROJECT ASSIGNMENT: In this project the student should develop a solution method for optimizing a monthly aircraft rotation plan given a number of real-life practical constraints such as:
   - Passenger capacity
   - Maintenance requirements
   - Fuel efficiency
   - Preferred aircraft equipment for specific flights

   The initial proposal would be to use column generation. Therefore some programming experience is required, and familiarity with column generation is highly recommended.

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 column generation and Optimization in Public Transport (42881) would be an advantage.

6. GROUP SIZE: 1-2

7. CHARACTERISTICS OF THE ASSIGNMENT: optimization, airlines, column generation

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

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

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

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

4. **PREREQUISITES:** Introduction to Operations Research, and a background at least equivalent to (42113) Networks and Integer Programming is necessary. Knowledge about column generation and Optimization in Public Transport (42881) would be an advantage. Good programming skills (Julia Lang, Java, etc) are required.

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

1. **SUPERVISOR:** David Pisinger, Richard Lusby, Evelien van der Hurk

2. **PROJECT BACKGROUND:** Copenhagen Central is the main hub in the Øresund region, and the opening of the new high-speed track to Ringsted, establishment of the metro city ring, and possibly new connections via Fehmern will strengthen the position. Also the new signaling system will make it possible to increase frequency of trains at various legs adding pressure on the infrastructure. Copenhagen Central is located in central Copenhagen so expanding platforms or tracks is not a viable option. This makes it necessary to develop decision support tools that can provide a better capacity utilization, help identify bottlenecks and assist future investments.

3. **PROJECT ASSIGNMENT:** The aim of the project is to assess the capacity utilization of Copenhagen central station by integrating/coordinating three different optimization problems. In particular, the project will address the platform assignment problem, how to route timetabled train services through the station, and how to plan the necessary shunting movements for any required depot activities. All problems are highly interdependent and must be solved simultaneously in order to determine the capacity utilization of the station given an input timetable, [5, 6]. The focus will be on a microscopic level, where the exact location of the train units must be monitored at any given time. In determining the capacity utilization of the station consideration must be given to the objectives of the routing problems (i.e. what level of robustness should be included), see e.g. [1, 2],and some coordination with the timetabling is envisaged, [3]. A poor quality timetable might be inherently restrictive from a capacity utilization perspective. The project could address tactical or operational level variants of the problem. In an operational setting it may be worthwhile to dynamically reorder, reroute, or re-time trains to obtain a better utilization of the available capacity (see e.g. [4]).

4. **PREREQUISITES:** Introduction to Operations Research, and a background at least equivalent to (42113) Networks and Integer Programming is necessary. Knowledge about column generation and Optimization in Public Transport (42881) would be an advantage. Good programming skills are essential.

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

6. **REMARKS:**
   
   
   

1. **SUPERVISOR:** Evelien van der Hurk, Richard Lusby

2. **PROJECT BACKGROUND:** The crew costs form a major part of operational costs for a rail operator. Reducing crew costs by creating more efficient rosters could be a huge benefit for the operator. At the same time, it is crucial that the resulting rosters match the preferences of staff.

   Generally, the scheduling of crew is split in two separate, consecutive, phases: the creation of duties, and the assignment of duties to individual rosters of crew members. Your task would be to aim to improve the rosters, by either improving the rostering tool, or by looking at the integration between rostering and duty-generation.

   The project will be in collaboration with DSB, the largest passenger railway operator in Denmark.

3. **PROJECT ASSIGNMENT:** The difficulty of this problem is that for both the duty set and the set of rosters a huge amount of feasible options exist. Hence one would likely solve this problem using column generation and/or heuristics.

   There exist options to work with the DSB on real data for this problem. Strong programming skills are a requirement.

4. **PREREQUISITES:** Introduction to Operations Research, and a background at least equivalent to (42113) Networks and Integer Programming is necessary. Knowledge about column generation and Optimization in Public Transport (42881) would be an advantage. Good programming skills are essential.

5. **GROUP SIZE:** 1-2
LINE PLANNING FOR DSB

1. **SUPERVISOR:** Evelien van der Hurk, Richard Lusby

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

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

4. **PREREQUISITES:** Introduction to Operations Research, and a background at least equivalent to (42113) Networks and Integer Programming is necessary. Knowledge about column generation and Optimization in Public Transport (42881) would be an advantage. Good programming skills.

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

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

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

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

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

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

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

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

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

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

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

6. GROUP SIZE: 1-2

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

8. REMARKS:
1. **SUPERVISOR:** Richard Lusby, Evelien van der Hurk

2. **PROJECT BACKGROUND:** Timetabling is a critical problem for railway operators, arising at each of the strategic, tactical, and operational planning levels. It involves determining the departure and arrival time of each of the planned train services in the schedule (on a macroscopic level), and the exact claim and release times of atomic infrastructure components (i.e. switches) on a microscopic level. Its importance is further highlighted by the fact that it directly influences the quality of the rolling stock and crew schedules that can be obtained. Several competing objectives are typically considered (robustness, operational cost, and passenger travel time) and the problem usually comes in two forms, periodic and aperiodic.

3. **PROJECT ASSIGNMENT:** This project will focus on a multiobjective approach to timetabling (applicable at all planning levels) and assess the impact of integration with the subsequent planning levels of rolling stock and crew planning. In particular, to what extent does the timetable impact the quality of the rolling stock and crew schedules? Railway timetabling is an extremely well studied problem; however, not as much has been done with respect to integration with subsequent planning levels. Timetable and rolling stock integration is described in [2]. On a strategic and tactical level the focus is on generating a robust timetable from a passenger perspective (which is feasible on the microscopic level) minimizing operational cost. On an operational level the focus would be on re-timetabling (i.e. in the presence of disruptions), see e.g. [3], deciding which services should be cancelled and which services should be re-timed. Naturally, this would also have an integration angle. The final timetable must be able to be assigned rolling stock and crew. An approach that coordinates all three problems has been presented in [1]; however, this procedure appears to lack microscopic feasibility checking and mainly consists of simple feedback loops.

4. **PREREQUISITES:** Introduction to Operations Research, and a background at least equivalent to (42113) Networks and Integer Programming is necessary. Knowledge about column generation and Optimization in Public Transport (42881) would be an advantage. Good programming skills.

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

6. **REMARKS:**


1. SUPERVISOR: Jesper Larsen

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

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

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

1. **SUPERVISOR:** Jesper Larsen

2. **PROJECT GROUP:** Richard Lusby

3. **PROJECT BACKGROUND:** A number of real-life logistics problem can be solved by cluster-first route-second approach. The routing problems are then basically a traveling salesman problem with additional constraints. In a number of cases the problem to be solved is a clustered traveling salesman problem (CTSP). In the CTSP the customers are divided into non-disjoint set. When one customer in a set is visited all other customers of the same set have to be visited before proceeding to another customer.

4. **PROJECT ASSIGNMENT:** Work in the area is sparse. In this project one need to describe, implement and test an optimal method for the CTSP problem.

5. **PREREQUISITES:** Introduction to Operations Research, courses equivalent to (42113) Networks and Integer Programming. Good programming skills.

6. **GROUP SIZE:** 1-2 students.
1. **PROJECT SUPERVISOR:** Jesper Larsen, Martin Kidd

2. **PROJECT GROUP:** Anders Lassen (Kopenhagen Fur)

3. **PROJECT BACKGROUND:** Kopenhagen Fur solely sell furs through auctions. 5 times during the year approx. 30 million skins are sold on auction at Kopenhagen Fur, making KF by far the biggest fur auction house in the work. The mink farmers turnover come from these auctions. The selling method is based on very high tasit knowledge among our auctioneers.

4. **ASSIGNMENT:** Come up with methods to improve the average selling bid. Through video analysis, auction room behaviour, data analysis etc. Develop operational theories that can help KF auctioneers to improve the selling bid.

5. **QUALIFICATIONS:** Operations Research, statistics. Game theory would be an advantage.
1. **PROJECT SUPERVISOR:** Martin Kidd, Jesper Larsen

2. **PROJECT GROUP:** NN (Kopenhagen Fur)

3. **PROJECT BACKGROUND:** Kopenhagen fur sort their mink skins by quality manually using a mostly visual process. The project will look into ways to better subdivide the quality and speed up the process for a limited subset of the incoming mink skins. The quality can be subdivided into several manually detectable features.

4. **ASSIGNMENT:** Setting up a machine learning strategy to improve the classification success rate for one or more manually detectable features. The assignment will consist of:
   
   - Selecting filters and features on images of mink skins
   - Analyzing, selecting and implementing an adaptable machine learning strategy like neural network, nearest neighbor, SVM etc.
   - Finetuning the image acquisition process to optimize the results

5. **QUALIFICATIONS:** Operations Research, basic knowledge on machine learning. Programming ability is an advantage.
1. **SUPERVISOR:** Jesper Larsen

2. **PROJECT GROUP:** Jakob Birkedal

3. **PROJECT BACKGROUND:** Moving a container over long distances from one point to another is often done as a sequence of moves using some intermediate points. The first truck is picking up the container at its origin and moving it to the first intermediate point where it is dropped off. Later an empty second truck arrives to pick it up and drive it to the next drop off point. The last truck finally delivers the container at its destination. For a container there might be several possible routes and intermediate points. This is an excellent example of collaborative logistics.

4. **PROJECT ASSIGNMENT:** Given a set of containers, their origins and destinations, potential intermediate points and a fleet of trucks the aim is to determine truck routes minimizing transportation cost and delivery of the last container. Develop an optimal approach to solve the problem.

5. **PREREQUISITES:** Course work corresponding to Network and Integer Programming. Good programming skills are necessary.

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Practical problem solving, prototype implementation.
1. **PROJECT SUPERVISOR:** Jesper Larsen, Richard Lusby

2. **PROJECT GROUP:** NN (DSB)

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

4. **ASSIGNMENT:** The aim of this thesis is to develop, implement and present a method for automatically determining the cleaning schedules. The schedules must comply with the rules and regulations of DSB and must be able to minimize cost and/or other appropriate measures. The project also allows to develop new ideas for producing the schedule and compare to real-life schedules from DSB.

5. **QUALIFICATIONS:** At least Introduction to Operations Research and Integer Programming. Programming experience is an advantage.

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

1. SUPERVISOR: Jesper Larsen

2. PROJECT GROUP: Emil Krapper

3. PROJECT BACKGROUND: Route planning with visit patterns is a well known problem in the garbage collection industry. A set of customers needs to be serviced during a week. Each customer has different visit frequency requirements. For instance a customer must be visited once every week or twice every week. Certain customers may also need to be visited on specific days. When solving this problem, the resulting routes often end up overlapping each other. For instance customers on the same road get treated by different drivers on different days, where they might as well be treated by the same driver on the same day. Although these overlapping routes have good objective values, they are essentially bad for the drivers, for whom treating every customer on the same road at the same time is easier.

4. PROJECT ASSIGNMENT: Given data for real life route planning problems with visit patterns, the student should come up with a method to measure the “goodness” of routes with respect to overlaps. This measurement should be implemented in an algorithm for solving the problem.

5. PREREQUISITES: Courses in Operations Research. Good programming skills is an advantage.

6. GROUP SIZE: 1-2 persons

7. CHARACTERISTICS OF THE ASSIGNMENT: Transport optimization, mathematical modeling and prototype implementation.
1. SUPERVISOR: Jesper Larsen

2. PROJECT GROUP: Emil Krapper

3. PROJECT BACKGROUND: The problem is a classical route planning problem with time windows. The problem is complicated by a demand uncertainty, a well known issue for companies delivering services or goods within predefined time windows. When a customer calls in to order a service or a product, a time window for the delivery will have to be agreed on. As soon as the time windows are decided upon they cannot be changed again. The choice of time windows for deliveries can be done by the planning system. However, due to the possibility of more orders arriving later, the best plan now may not be the best plan later. Hence the planner should not only ensure that the plan has a low cost, it should also ensure that the plan is robust, leaving as much room for future changes as possible.

4. PROJECT ASSIGNMENT: Given real data the weight of the robustness of a plan should be analyzed. An algorithm that creates robust routes based on order data should be created.

5. PREREQUISITES: Courses in Operations Research. Good programming skills is an advantage.

6. GROUP SIZE: 1 - 2 persons

7. CHARACTERISTICS OF THE ASSIGNMENT: Transport optimization, mathematical modeling and prototype implementation.
1. SUPERVISOR: Richard Lusby

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

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


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

8. REMARKS:
THE CARDINALITY CONSTRAINED SHIFT DESIGN PROBLEM
WITH MEAL BREAKS

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP:

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

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


6. GROUP SIZE: 1-2

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

8. REMARKS:
HEURISTIC APPROACHES TO THE CREW PAIRING PROBLEM

1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP:

3. PROJECT BACKGROUND: The crew pairing problem is one of the most widely studied problems in the field of Operations Research. Arising in the airline industry, it involves determining a set of cost minimal sequences of flights, or so-called pairings, which cover the planned flight schedule and which can be sequential assigned to flight crew. Nowadays, solutions to this problem are found by large-scale integer programming formulations, which are solved using sophisticated decomposition techniques. In this project we would like to investigate the application of metaheuristics to this problem. Ideally, such approaches would provide solutions of similar quality, much faster. This could be attractive for small/mid sized airline companies who do not have a business case for expensive state-of-the-art commercial solvers. Robustness aspects that preserve feasibility of the solution in the presence of disruptions will also be considered.

4. PROJECT ASSIGNMENT: Develop a metaheuristic approach for solving the crew pairing problem for a medium sized airline company. Emphasis should be given to the quality of the solution, the run time required, and its robustness.

5. PREREQUISITES: 42401, 42113/42114, 42112/42116, Good programming skills

6. GROUP SIZE: 1-2 students

7. CHARACTERISTICS OF THE ASSIGNMENT: Algorithm design, airline application, literature study

8. REMARKS:
1. SUPERVISOR: Jesper Larsen and Richard Lusby

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

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

5. PREREQUISITES: 42114, 42136 or 42137, good programming skills

6. GROUP SIZE: 1-2 Students

7. CHARACTERISTICS OF THE ASSIGNMENT: Integer Programming, Column Generation, Staff Rostering, Cyclic Rostering
1. SUPERVISOR: Richard Lusby

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

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

5. PREREQUISITES: 42114, 42136 or 42137, good programming skills

6. GROUP SIZE: 1-2 Students

7. CHARACTERISTICS OF THE ASSIGNMENT: Integer Programming, Decomposition, Maintenance, Scheduling
1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP:

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 prespecified 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 material 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: 42114/42115, 42112/42116/421374, good programming skills

6. GROUP SIZE: 1-2 students

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

8. REMARKS:
1. **SUPERVISOR:** Jesper Larsen and Richard Lusby

2. **PROJECT GROUP:** Shyam Sundar

3. **PROJECT BACKGROUND:** The Driver Scheduling Problem involves finding an optimal set of driver duties to cover a timetabled set of trips of vehicle blocks. A vehicle block is an itinerary of a bus between its departure from the depot and its return to the depot. Due to various labor regulations in the public bus transportation industry, a driver may cover only a few consecutive trips of a block before the driver must take a break or be relieved of duty. A duty typically consists of trips from multiple blocks with breaks between them. Optimizing the Driver Scheduling Problems for large cities can take considerable amount of computation time due to the numerous possible combinations of trips from multiple blocks. The optimal solution, however, is only likely to contain certain combinations of the blocks. The structure of the vehicle blocks and the city network could be exploited to predict which blocks are most likely to be combined in the final solution. By predetermining some of the block combinations, the performance of the optimization algorithm in terms of computation time, the convergence to good solutions, and the scalability to large problems, is expected to improve significantly.

4. **PROJECT ASSIGNMENT:** The aim of the project is to find patterns or rules to identify the combination of blocks in the optimal solution, potentially, using machine learning techniques. It is expected that the identified rule-set and/or patterns will be applied to all real life large scale instances from various Scandinavian bus transit companies. A developed optimization algorithm that solves the Driver Scheduling Problem will be provided for benchmarking purposes.

5. **PREREQUISITES:** 42114/42115, 42112/42116/42137, good programming skills

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

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

8. **REMARKS:**
1. **SUPERVISOR:** Richard Lusby

2. **PROJECT GROUP:** Jesper Larsen, Troels Martin Range

3. **PROJECT BACKGROUND:** The rooms at the Fælles akutmodtagelse (FAM), or emergency ward, at the Hospital of South West Jutland are standardized such that they are (in practice) identical. When a patient enters the FAM they are triaged and then assigned to a room in which they can be treated. Each room has a cabinet containing most of the necessary equipment and materials. These cabinets are also standardized. The cabinet has a number of roll-out shelves which are subdivided into compartments. A number of materials (or a piece of equipment) can be placed in the compartments, but each compartment can only hold one type of material. The compartments are made up of horizontal (left to right) and vertical (front to back) splitters. Consequently all compartments between two horizontal splitters have the same “depth” and all compartments between two vertical splitters have the same “width”. The materials – both number and type – which can be placed in a compartment depend on the size of the compartment. To minimize the time used by the staff to collect the necessary materials for treatments it is desirable to have materials used frequently in conjunction on the same shelf. Furthermore, it is desirable if the replenishment of the materials in the cabinets can be synchronized such that several types of material can be replenished at the same time. The problem is then to determine the number and layout of shelves in the cabinets.

4. **PROJECT ASSIGNMENT:** The aim of this project is to devise a mathematical model and applicable solution approach to determine the optimal dimensioning of the cabinets. Exact and/or heuristic methods are possible. It is anticipated that real-life data will be used to validate the performance of the developed methodology.

5. **PREREQUISITES:** 42114/42115, 42112/42116/421374, good programming skills

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Modelling, algorithm design

8. **REMARKS:**
1. **SUPERVISOR:** Richard Lusby

2. **PROJECT GROUP:** Troels Martin Range

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

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

5. **PREREQUISITES:** 42114/42115, 42112/42116/421374, good programming skills

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Modelling, algorithm design

8. **REMARKS:**
1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP: Jesper Larsen, Troels Martin Range

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

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

5. PREREQUISITES: 42114/42115, 42112/42116/421374, good programming skills

6. GROUP SIZE: 1-2 students

7. CHARACTERISTICS OF THE ASSIGNMENT: Modelling, algorithm design

8. REMARKS:
1. SUPERVISOR: Richard Lusby

2. PROJECT GROUP: Bo Vaaben

3. PROJECT BACKGROUND: Given a set of flights to be flown and a fleet of aircraft (possibly of different types), the aircraft rotation problem involves determining a specific route (i.e., sequence of flights) to be flown by each aircraft in the fleet. Several practical constraints must be respected when doing this. These include, but are not limited to:

   1. Passenger capacity
   2. Fuel efficiency
   3. Preferred aircraft equipment for specific flights

In addition to these, maintenance requirements constitute an important set of restrictions that influence the routes that will be ultimately flown. Aircraft undergoing maintenance cannot be used, and all aircraft must periodically (or once a certain number of e.g., take-offs and landings has been reached) receive maintenance. Consideration on how best to include these restrictions to generate maintenance feasible routes is the focus of this project.

4. PROJECT ASSIGNMENT: The aim of this project is develop a column generation based approach to produce maintenance feasible aircraft rotations.

5. PREREQUISITES: 42114/42115, 42112/42116/421374, good programming skills

6. GROUP SIZE: 1-2 students

7. CHARACTERISTICS OF THE ASSIGNMENT: Modelling, algorithm design

8. REMARKS:
1. **SUPERVISOR:** Richard Lusby

2. **PROJECT GROUP:** Bo Vaaben

3. **PROJECT BACKGROUND:** Determining an optimal flight trajectory from one airport to another must take into account a number of different aspects, one of which is congested airspace. This project will focus on how congested airspace influences the optimal flight trajectory.

4. **PROJECT ASSIGNMENT:** The project will look into the two main aspects:

   1. Research methods for applying congested areas to a trajectory optimization model.
   2. Given a specific combination of airspace congestion zones and expected delays through these zones, the student should provide a model or a method which can find the optimal set of flight trajectories for a set of airline flights.

5. **PREREQUISITES:** 42114/42115, 42112/42116/421374, good programming skills

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Modelling, algorithm design

8. **REMARKS:**
1. **SUPERVISOR:** Richard Lusby

3. **PROJECT BACKGROUND:** Disruptions occur on a daily basis in the railway industry. If handled poorly, these can have a rippling effect through planned rolling stock and crew schedules, potentially destroying the optimized planned schedules. It is essential that any railway company has efficient tools for recovering as quickly as possible when a disruption occurs. This project focuses on railway rolling stock units and how best to reschedule them once a disruption occurs. Many factors need to be considered and the time available to find a feasible solution is limited.

4. **PROJECT ASSIGNMENT:** For this project the student(s) will be required to design and implement an advanced metaheuristic for rescheduling rolling stock units in the case of a disruption. A number of important practical constraints must be adhered to in order to produce a feasible solution. The algorithm will be benchmarked on data from an industrial partner.

5. **PREREQUISITES:** Introduction to Operations Research (42101), Mathematical Programming with Modelling Software (42112), Optimization using meta-heuristics (42137)

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

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

8. **REMARKS:**
1. **SUPERVISOR:** Richard Lusby

2. **PROJECT GROUP:**

3. **PROJECT BACKGROUND:** This project focuses on scheduling the shunting movements of train units at large stations. Over the course of a day train units are regularly taken in and out of service. Primarily this occurs when starting or ending certain timetabled trips or when modifying the length of trains in service to better match the forecast passenger demand. Shunting a train unit involves driving it to or from the depot (a parking area for idle train units), and identifying when to do this is typically done manually. Scheduling a shunting movement requires allocating a route from/to the platform to/from the depot and as such utilizes track capacity at the station. When train units have a choice of depots the complexity of not only when to schedule the movement, but where to park the unit increases. By simultaneously coordinating the scheduling of shunting movements with timetabled train services, potentially the capacity utilization of the station can be improved. This is particularly important for stations where track utilization is high.

4. **PROJECT ASSIGNMENT:** Devise a solution method to efficiently coordinate the required shunting movements with the timetabled railway services through a large station. The solution must be robust in the sense that any minor disturbances will not hinder the execution of the found schedule. It should also not impact the preferred routes of the timetabled services. Exact and/or heuristic methods may be developed.

5. **PREREQUISITES:** 42401, 42113/42114, 42112/42116, Good programming skills

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Algorithm design, railway application, literature study

8. **REMARKS:**
1. **SUPERVISOR:** Richard Lusby

2. **PROJECT GROUP:** Martin Sandqvist Hendriksen

3. **PROJECT BACKGROUND:** Designing high quality utility networks, e.g. electricity grids or telecommunication networks, is extremely challenging. Such problems are typically characterized by a large number of customers (or demand points), which need to be efficiently connected to a set of sources, directly or indirectly. This project focuses on the design of telecommunication networks, the aim being to minimize the cost incurred of laying fiber optic cable in connecting a set of customers to a set of serving structures. A serving structure has limited capacity and can only service a certain number of customers. In addition to the routing, focus should also be placed on how to cluster customers together. Ideally customers should be grouped according to certain demographics (whether or not they are residential or industrial, income level, etc).

4. **PROJECT ASSIGNMENT:** Devise an algorithm for solving this utility network design problem. Exact and/or heuristic approaches may be considered. The algorithm should produce high quality solutions, indicating what clusters the demand points are partitioned into as well as how the customers within a cluster are connected. Extensions of the work will include identifying the best server location as opposed to assuming a fixed location.

5. **PREREQUISITES:** 42401, 42113/42114, 42112/42116, Good programming skills

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Algorithm design, utility network design, literature study

8. **REMARKS:**
1. **SUPERVISOR:** Rune Larsen

2. **PROJECT GROUP:** The topic is of potential interest to Banedanmark.

3. **PROJECT BACKGROUND:** Everybody complains about trains not being on time, but nobody fixes it. Be the one to do something about it.

   Congestion at stations is a prime source of delays and delay propagation. Macro and micro simulation methods have been employed to address the problem, but the macro simulation methods becomes too imprecise, and the micro simulation methods too slow. In between these two methods are the mesoscopic simulation methods. Some aspects are modelled in detail, while compromises are made with respect to the representation of other aspects of the system.

   An framework exists for simulating the problem using an event graph based methods, but extensions is needed to accommodate recourse options.

4. **PROJECT ASSIGNMENT:** Apply the framework to a medium sized Danish railway station using sampled input delays, and expand the model to include simple recourse options. If time permits, apply the framework to Copenhagen central station.

5. **PREREQUISITES:** Programming is a must. Simulation is **not**. Knowledge of simple graph theory is an advantage.

6. **GROUP SIZE:** Groups of 1-2 students is recommended

8. **REMARKS:** The problem can be adapted to accommodate the skills, interests and ambitions of the students.
1. **SUPERVISOR:** Rune Larsen

3. **PROJECT BACKGROUND:** Solving a static vehicle routing problem for a real life company is often just the first step towards having a commercially viable product. During the execution of a solution, disruptions and delays will happen. Incorporating these into the solution is a hard problem that needs to be solved in a very short time frame. Furthermore any re-optimisation is subject to constraints on what can be re-optimised based on what events have already occurred.

   By using simulation, some of these problems can be detected ahead of time while more remedial measures are available.

4. **PROJECT ASSIGNMENT:** Implement, develop/extend and test the above methods on a sample problem chosen in collaboration with the supervisor and potentially an external collaborator.

5. **PREREQUISITES:** Programming is strictly required. Knowledge on heuristics or mathematical modelling is advantageous.

6. **GROUP SIZE:** Groups of 1-2 students is recommended

8. **REMARKS:** The problem can be adapted to accommodate the skills, interests, and ambitions of the students.
1. **SUPERVISOR**: Stefan Røpke

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

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

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

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

7. **CHARACTERISTICS OF THE ASSIGNMENT**: Integer programming, exact methods, heuristics, cutting planes.
1. SUPERVISOR: Stefan Røpke

3. PROJECT BACKGROUND: Normally a specialized version of primal simplex algorithm is considered the best algorithm for network flow problems. However, as the result of Mittelman documents¹ a generic dual simplex algorithm does very well on network flow problems. Therefore, an interesting project is to present a specialized version of the dual simplex algorithm for network flow problems. The project is to be carried out in collaboration with MOSEK ApS.

4. PROJECT ASSIGNMENT: Develop a specialized version of dual simplex algorithm for network flow problems. Implement the ideas in a suitable programming language such as C or C++.

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


7. CHARACTERISTICS OF THE ASSIGNMENT: Simplex, Linear Programming

¹See http://plato.asu.edu/ftp/network.html
1. **SUPERVISOR:** Stefan Røpke

3. **PROJECT BACKGROUND:** In an edge matching puzzle one is given a number of quadratic puzzle pieces (tiles) that has to fit into one larger rectangle. Each of the four sides of the puzzle piece has a certain color and/or pattern and two pieces can only be placed next to each other if the adjacent sides have exactly the same color/pattern. The borders of the large rectangle may also have patterns that need to match up with the puzzle pieces. An example of a solution to an edge matching puzzle with $6 \times 6$ pieces is shown in the figure below (Reproduced from Ansotegui et al. (2013)).

The most well known edge matching puzzle is probably the Eternity II puzzle. It was a puzzle that could be bought in toy and game stores. Solving the puzzle is extremely difficult. The first to find a solution before noon on December 31st 2010 would have been
awarded with a prize of 2 million dollars! The puzzle has never been solved and nobody won the prize. The solution is still unknown but there is no prize associated with finding the solution anymore. More information can be found on the puzzle's Wikipedia page (http://en.wikipedia.org/wiki/Eternity_II_puzzle).

Edge matching puzzles have been studied in the academic literature, for example determining the computational complexity involved in solving the puzzle (see e.g. Demaine and Demaine (2007)). Some papers have also been published that examine ways to solve the problem (see for example Ansotegui et al. (2013)).

4. PROJECT ASSIGNMENT: Develop an integer programming model that solves edge matching puzzles. Implement exact and/or heuristic methods for solving the game.

5. PREREQUISITES: Mandatory:

   • Programming experience.
   • 42114 Integer programming or 42112 Mathematical Programming with Modeling Software.

   Nice to have, but not mandatory:

   • Optimization using metaheuristics (42137).

6. GROUP SIZE: 1-2


8. REMARKS: Relevant literature:

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

1. SUPERVISOR: Stefan Røpke

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

4. PROJECT ASSIGNMENT: Implementations of some of the simple and fast heuristics can be found on the internet while others must be implemented from scratch. Focus should also be on designing/selecting test instances and performing a fair comparison of the heuristics.

5. PREREQUISITES: Mandatory:
   • Programming experience.
   Nice to have, but not mandatory:
   • Integer programming (42114).
   • Optimization using metaheuristics (42137)
   • Vehicle Routing and Distribution Planning (13442)

6. GROUP SIZE: 1-2

1. SUPERVISOR: Stefan Røpke

3. PROJECT BACKGROUND: Graph partitioning is a problem that comes in several variants and have many applications. Typically graph partitioning calls for determining $k$ (with $k$ being a parameter) components of the graph such that the total weight of edges between components is minimized. Another variant is to find a set of nodes such that removing these nodes from the graph splits it into a number of non-connected components.

In this project we study the problem due to its applications in continuous and discrete optimization. Graph partitioning methods can be used to rearrange the constraint matrix such that it gets into a form that is applicable for Dantzig Wolfe decomposition methods (see Bergner et al. in the references below for examples).

Graph partitioning is also used when solving large, sparse systems of linear equations in interior point methods for linear programming. Improvements in the graph partitioning in MOSEKs solvers can result in (much) faster solution of some large-scale linear programs. Graph partitioning can also be used for more efficient parallelization.

4. PROJECT ASSIGNMENT: Develop heuristics for graph partitioning with applications to mathematical programming in mind. The project is to be carried out in collaboration with MOSEK ApS.

5. PREREQUISITES: Programming skills. Knowledge of metaheuristics could be an advantage

6. GROUP SIZE: 1-2

7. CHARACTERISTICS OF THE ASSIGNMENT:

8. REMARKS: Relevant literature:

HEURISTICS FOR MIXED INTEGER CONIC PROBLEMS

1. SUPERVISOR: Stefan Røpke

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

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

5. PREREQUISITES: Programming skills. Mathematical maturity.

6. GROUP SIZE: 1-2


8. REMARKS: Relevant literature

- Fischetti, Glover, Lodi, The feasibility pump, Mathematical programming 104 (2005), 91-104
1. **SUPERVISOR:** Stefan Røpke

3. **PROJECT BACKGROUND:** Real life vehicle routing problems typically contain 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)
   - Vehicle Routing and Distribution Planning (13442)

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

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

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

5. PREREQUISITES: Programming skills. Relevant courses (none of them are a strict requirement): 42114 Integer Programming. 42115 Network Optimization. 42137 Optimization using metaheuristics. 13442 Vehicle Routing and Distribution Planning

6. GROUP SIZE: 1-2


8. REMARKS: Relevant literature (one example):

1. **SUPERVISOR**: Stefan Røpke

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

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

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

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

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

8. **REMARKS**: David Pisinger offers a similar project.
1. **SUPERVISOR:** Stefan Røpke

2. **PROJECT GROUP:** Anders Reenberg Andersen & Region Sælland

3. **PROJECT BACKGROUND:** The queueing network is important to the understanding and optimization of flow within many different industries such as manufacturing, data transmission and health care. When the network contains more advanced features, such as time-dependency, a popular approach is to simulate and conduct optimization based on a meta-heuristic. On the other hand, this approach often leads to a very case-dependent heuristic and cannot guarantee nor determine the solution quality. As an alternative, queueing networks can in some cases be modelled analytically, yielding a mathematical structure that can be utilized to form more useful solution methods.

4. **PROJECT ASSIGNMENT:** The aim of this project is to optimize analytically modelled time-dependent queueing networks, and investigate methods for which the solution quality can either be guaranteed or determined.

5. **PREREQUISITES:** 42101 Introduction to Operations Research, 42137 Optimization using Metaheuristics and programming experience (C#, Java, C/C++ or similar). Preferred experience with modelling of statistical and/or stochastic processes.

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Stochastic optimization, queueing theory, heuristics
1. **SUPERVISOR:** Stefan Røpke, Federico Farina

2. **PROJECT BACKGROUND:** Producing a timetable for the regional and intercity trains in Denmark is a difficult and time consuming task. Today the timetable is planned in a (mostly) manual way. For that reason it is promising to explore if operations research algorithms can be used to assist in the construction of time tables.

4. **PROJECT ASSIGNMENT:** Examine the literature on train timetabling. Select a method for solving the timetabling problem and apply it on data from a Danish case.

5. **PREREQUISITES:** Some programming experience, experience with integer programming and relevant modeling languages (e.g. GAMS or OPL studio)

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:** Trains, time tabling, integer programming
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.
1. **SUPERVISOR:** Thomas Stidsen, Line Reinhardt, Anders Andersen

3. **PROJECT BACKGROUND:** In the region of Sealand, Lean-coaches have sessions in many different locations at different times. Given the preferences of the Lean-coaches, regarding time, place, transport form and type of blackboard, create the best possible plan for the coaches.

4. **PROJECT ASSIGNMENT:** This is a classical OR project, where a number of tasks are scheduled to maximize value. MIP models or metaheuristics should be used.

5. **PREREQUISITES:** Introduction to Operations Research (42101), Mathematical Programming with Modelling Software (42112), Optimization using metaheuristics (42137)

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:** The problem will be of direct benefit for the Lean-coaches today.

8. **REMARKS:**
**SEPARATE TRACKS IN THE ER**

1. **SUPERVISOR:** Thomas Stidsen, Line Reinhardt, Anders Andersen

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

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

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

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

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

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

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

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

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

MEASURING HARDNESS OF MIP MODELS

1. SUPERVISOR: Thomas Stidsen

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

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

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


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

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

3. **PROJECT BACKGROUND:** The Danish company PlanDay (www.planday.com) sells software for manpower planning at restaurants and cafe’s. The company supports a large number of restaurants and cafe’s domestically and abroad, selling as a Software As A Service (SAAS).

4. **PROJECT ASSIGNMENT:** In this project, the job is to create models (probably Mixed Integer Programming) and algorithms, decomposition or meta-heuristic to automate the planning process. The focus will be to design models which can help real customers and hopefully be parameterized such that the model can suite a large group of restaurants.

5. **PREREQUISITES:** Introduction to Operations Research (42101), Mathematical Programming with Modelling Software (42112) and either Optimization using Meta-heuristics (42137) or Large Scale Optimization using Decomposition (42136)

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

7. **CHARACTERISTICS OF THE ASSIGNMENT:** The project involves both design and implementation of model and algorithms.

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

2. PROJECT GROUP: Line Reinhardt, Anders Reenberg Andersen & Region Sjælland

3. PROJECT BACKGROUND: Assigning nurses to rosters is an everyday challenge to the hospital planner. The task often encompasses a large number of nurses featuring many different skills and preferences. At the same time, nurses take up a substantial fraction of hospital staff spendings, making nurse rostering one of the most important planning problems for the hospital to consider. Even so, planning is often conducted manually with only little support from computer software. Still, using mathematical programming, studies have shown a potential of about 40% savings in supplementary salaries alone, corresponding to several millions in savings for the hospital.

4. PROJECT ASSIGNMENT: The aim with this project is to assess the potential savings using mathematically supported rostering, taking the operational aspect in scheduling and rescheduling of nurses into account. Some of these aspects could be: Sick days, holidays, staff preferences etc. Data will be provided for a real hospital case, as well as results from this project will be used to improve the planning of staff for the specific hospital.

5. PREREQUISITES: 42114 Integer Programming and 42136 Large Scale Optimization using Decomposition or 42137 Optimization using Metaheuristics. Programming experience (C#, Java, C/C++ or similar).

6. GROUP SIZE: 1-2 persons

7. CHARACTERISTICS OF THE ASSIGNMENT: Integer programming, Large scale optimization, Staff rostering, Applied OR

8. REMARKS: An overview of the nurse rostering problem:
