Thesis Proposals
Autumn 2019
Operations Management

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Management Science - DTU Management Engineering
Writing your thesis within Operations Management

Welcome to the presentation of thesis proposals offered within the Operations Management group at the department of Management Engineering! With this booklet we hope to inspire you to select an intriguing topic for your coming thesis work.

Although the booklet is primarily directed towards MSc students, a large part of the topics presented will also be able to be scoped to match the academic level and aims of a BSc or BEng thesis project. The booklet could therefore also serve as inspiration to BSc and BEng students.

Some thesis projects are carried out internally here at DTU whereas others are performed in close collaboration with external organisations. In addition to the proposals listed in this booklet, you are welcome to suggest your own ideas for a project topic. If you do so, you need to consult a supervisor in order to scope the project so that it is academically sound, relevant and ambitious but also realistic to achieve within the project period. You should check with the potential supervisor whether you have the relevant prerequisites for carrying the specific thesis topic.

We look forward to meeting you as a thesis student in Operations Management!

The following list of faculty members are potential supervisors:

- Michael Bruhn Barfod, Associate Professor (mbba@dtu.dk)
- Steven Harrod, Associate Professor (stehar@dtu.dk)
- Lars Hvam, Professor (lahv@dtu.dk)
- Peter Jacobsen, Associate Professor (peja@dtu.dk)
- Martin Kidd, Assistant Professor (mpki@dtu.dk)
- Allan Larsen, Professor (alar@dtu.dk)
- Harilaos Psaraftis, Professor (hnpsar@dtu.dk)

Please note that it is indeed also possible to write your thesis in collaboration with other research groups within the Management Science division as well as across the department.

We wish you good luck in pursuing an interesting and ambitious thesis project!

Best regards,

The OM group
Michael Bruhn Barfod

Position:
Associate Professor, Operations Management

Research Area:
Assessment methodologies used in transport planning. Specific areas of interest:

- Applied decision analysis, sustainability assessments and customized decision support systems
- Problem structuring and stakeholder involvement in decision support processes
- Model building from initiation to implementation of various methodological approaches and data treatment

The research in particular applies theory in practice, and has often been carried out using real case data in various projects. These projects have besides articles (national as well as international) lead to the research results being applied both in industry and in the education provided at DTU.

Teaching:

I am teaching the following courses:

- 42879 Decision Support and Strategic Assessment (MSc, Autumn)
- 42997 Sustainable Transport (BEng, Autumn)
Steven Harrod

Position:
Associate Professor, Operations Management

Research Area:
I have specific career experience in road transport, railways, software development and marketing, and database development. I have published research on simulation, job shop systems, and railway timetables and capacity.

- Simulation: model building, statistical analysis of output, and applications
- Process analysis: modeling of manufacturing and service processes, control of work in progress (inventory) and flowtime.
- Freight transport: railway transport service design and competition with road transport.
- Railway management: service and operations design, economics of railway transport.
- Railway timetabling: optimization of train paths, calculation of capacity, and pricing of services

Teaching:
I teach the following courses:

- 42880 Railway Operations and Management (MSc, Autumn)
- 42976 Rail Traffic Engineering (BEng, Spring)
Lars Hvam

**Position:**

Professor, Operations Management

**Research Area:**

- Mass customization
- Complexity Management
- Configuration Management
- Production systems

**Teaching:**

I am teaching the following courses:

- 42406 Introduction to Production (5 ECTS) (BSc, Autumn)
- 42451 Mass customization – application of product configuration (10 ECTS) (MSc, Autumn)
- 42452 Complexity Management (5 ECTS) (MSc, January)
Peter Jacobsen

Position:
Associate Professor, Operations Management

Research Area:
Develop and apply methods within:

- Production systems - design, planning and optimization
- Logistics - planning and optimization of networks and supply chains
- Optimization of the complexity in production and logistics/SC systems
- Simulation - validation, verification and optimization
- Performance measurement/management
- Digitalization, big data and industry 4.0
- Industrial/healthcare area

Teaching:
I am teaching the following courses:

- 42371 Design of Lean Production and Service Systems (10 ECTS) (MSc, Spring)
- 42376 Operations Management in Health Care and Service Systems (5 ECTS) (MSc, Autumn)
Martin Kidd

**Position:**

Assistant Professor, Supply Chain Management and Logistics

**Research Area:**

Application of analytics (optimization, machine learning, data mining etc.) to strategic, tactical and operational planning and decision making problems in supply chain management and logistics, such as:

- Design and optimization of distribution networks
- Supplier and/or customer coordination/collaboration (e.g. VMI, contract design)
- Large-scale optimization for integrated planning problems (e.g. inventory-routing)

From a methodological point of view, my expertise and interests lie in the application of integer programming, matheuristics, and decomposition techniques.

**Teaching:**

I am teaching the following courses:

- 42380 Supply Chain Analytics (5 ECTS) (MSc, Spring – from 2020)
- 42401 Introduction to Management Science (5 ECTS) (MSc, Autumn)
Allan Larsen

**Position:**
Professor MSO, Operations Management

**Research Area:**
Digitalization and automation of the transport and logistics domains within the context of Industry 4.0. Applications of operations research based methodologies such as mathematical optimisation, metaheuristics and discrete event-based simulation to planning and management problems within freight transport and logistics.

Specific interests include:
- Urban freight transport (city logistics)
- Electro-mobility for freight transport
- Demand-responsive transport systems (autonomous vehicles and fleet management)
- Transport terminal management and optimisation
- Cold chain logistics
- The digital supply chain
- Improvements of efficiency in logistics, supply chains, warehousing, manufacturing through the use of simulation methodology

**Teaching:**
My teaching activities are centered on the following courses:
- 42587 Introduction to Operations and Supply Chain Management (BSc, Autumn) (previously 42582 Production and Planning)
- 42875/42992 Transport logistics and transport optimization (BSc+BEng, Spring)
- 42417 Simulation in Operations Management (MSc, June)
Harilaos N. Psaraftis

Position:

Professor, Transport optimisation

Research Area:

- Transport Logistics
- Specific areas of interest
- Maritime transport
- Green transport
- Vehicle routing & distribution
- Transport policy

Use of quantitative methods in planning and management of transport systems.

Selected projects:

- SuperGreen, EU FP7 project- overall consortium manager, DG-MOVE (2010-2013).
- TENTAcle, INTERREG VI project, Region Blekinge (Sweden) leader (2016-2019).
- Scandria2Act, INTERREG VI project, Region Berlin-Brandenburg (Germany) leader (2016-2019).
- BlueSiros, funded by the European Space Agency, DTU Space leader (2016-2017).
- SMART MARITIME, DTU scientific advisor, Marintek (Norway) leader, Norwegian Research Council (2016-2019).

Teaching:

- 42884 Green Transport Logistics
- 42885 Maritime Logistics (parts of)
Bed logistics at a hospital (MSc)

PROJECT SUPERVISOR: Associate professor Peter Jacobsen (peja@dtu.dk)

BACKGROUND: For many hospitals it is a problem to identify where, the beds are at a certain time. It is essential for the hospital to have beds available at the emergency department and not be in a situation where they are running out of clean beads. In addition, the planning of bed cleaning will be easier if the location and identification of the beds are available.

PROJECT DESCRIPTION: The project will look at the status for the hospitals and a literature research both domestic and international. The whole logistics from a patient is hospitalized and requires a bed, moved in the bed to different examinations at different departments, released from the hospital. The bed is then transported to the bed cleaning department and returned to the emergency department ready for a new patient.

PROJECT PURPOSE: The purpose of this project is to identify different technological solutions. Design of different scenarios measuring sensitivity if more beds are necessary or if newer patient treatments require other types of patient transportation. Make a cost benefit analysis and an implementation plan.

PREREQUISITES:

NUMBER OF STUDENTS: 1-2 MSc students (2 projects of 30-35 ECTS Credits).
Distribution of pharmaceuticals at a hospital (MSc)

PROJECT SUPERVISOR: Associate professor Peter Jacobsen (peja@dtu.dk)

BACKGROUND: Hospitalized patients require both customized/individual together with general pharmaceuticals products. The individual products needs to be available when needed. It is time consuming for the employees to keep track of the different types of products at the medicine room, ordering new and return old pharmaceuticals. Besides, they are forced to keep track of the products and an account as soon as the products enter the hospital.

PROJECT DESCRIPTION: The project will look at the status for the hospitals and a literature research both domestic and international and suggest solutions that are more efficient

PROJECT PURPOSE: The purpose of this project is to identify different supply chain possibilities for supplying pharmaceuticals from a supplier to the individual patients at a hospital.

PREREQUISITES:

NUMBER OF STUDENTS: 1-2 MSc students (2 projects of 30-35 ECTS Credits).
Performance of a supply chain (MSc)

PROJECT SUPERVISOR: Associate professor Peter Jacobsen (peja@dtu.dk)

BACKGROUND: Industry 4.0 is a new production philosophy. In some areas, they are also talking about a supply chain 4.0. Industry 4.0 contains new technological possibilities for companies to produce their products. In order to gain the full benefits the complete logistic chain needs to be considered.

PROJECT DESCRIPTION: The project will look at the status for Industry 4.0, possibilities for automation and how the performance of the logistic chain can be enhanced by applying industry 4.0 tools.

PROJECT PURPOSE: The purpose of this project is to identify possibilities for enhancing the performance of the logistics by using the industry 4.0 tools.

PREREQUISITES:

NUMBER OF STUDENTS: 1-2 MSc students (2 projects of 30-35 ECTS Credits).
The use of a Wave-Analogy algorithm to explore Cyber-resilience in a supply chain (MSc)

PROJECT SUPERVISORS: Associate professor Michael Bruhn Barfod, Postdoc Daniel Sepulveda, PhD and external supervisor Pablo Guerra, MSc, from Deloitte, Belgium.

BACKGROUND: Supply chains are dependent on Information Technology (IT) and cyberspace processes. Yet, despite the advantages of its increased connectivity and systems integration with suppliers and customers, this also has opened the door to new risks from and to supply chain partners. It has become increasingly clear that a supply chain not only needs to prevent cyber-attacks, but also prepare to have a reaction that minimizes consequences and maintains operational levels.

A novel wave-analogy framework has been proposed by Guerra & Sepulveda., (2019) which can serve to both describe the resilience of a system, and to guide the design of the organization for resilience. The use of this framework is dependent on it validation through testing in real cases and by comparing it to other frameworks.

PROJECT DESCRIPTION: This is a research-based MSc. thesis that will introduce the student to a scientific research process through case studies. This project requires a planning phase, an operational (data gathering) phase and an analysis phase. The student will interact with a case company or companies, where operational data identified in a planning phase will be gathered. It is expected that the student will develop a literature review of the current resilience evaluation frameworks, and will use one or more of these frameworks, together with the Wave-analogy framework in the analysis of a cyber-event or a cyber-resilience framework in a case company. The analysis should identify aspects where the Wave Analogy presents advantages, disadvantages or is equivalent to the other frameworks chosen for the analysis, and thus produce a recommendation about the applicability of the Wave-Analogy framework. Finally, this project expects the delivery of a paper in a condition to be submitted to a journal.

PROJECT PURPOSE: The purpose of this project is to contribute towards the scientific validation of the Wave Analogy framework for understanding cyber-resilience, to potentially to extend its use to other industries, or other process in the supply chain.

PREREQUISITES: Supply Chain Management Course, some knowledge about IT Systems.

NUMBER OF STUDENTS: 1 MSc. student (Projects of 30-35 ECTS Credits).

REFERENCE
https://doi.org/10.1109/IEEM.2018.8607563
Machine Learning to detect cyber-attacks in shipping (MSc)

PROJECT SUPERVISORS: Associate professor Michael Bruhn Barfod, and PostDoc Daniel Sepulveda.

BACKGROUND: Information Technology Systems (ITS) are a fundamental part of many modern shipping activities. The interconnectivity and automation enabled by ITS has increased the speed, scope and accuracy of the information shared between ships and with the ports. Yet these characteristics have also increased the attractiveness for others to intervene and use these systems for their own ends (hacking), such as through the transmission of fake information or the jamming of systems by an overflow of fake instructions. The shipping industry is requiring better ways to identify these malicious flows (Cyber Attacks) and contain them before these interrupt operations.

PROJECT DESCRIPTION: This is part of a 2 year project called CyberShip, aimed at providing shipping companies and regulators with a reference framework and decision support model to better cope with disruptions originating from a cyber attack. This project is being developed jointly between DTU Compute and the Department of Management Engineering at DTU.

PROJECT PURPOSE: The purpose of this project is to identify machine learning techniques that are relevant for identifying cyber-attacks, test these techniques and give recommendations on their scope of use and relevance.

PREREQUISITES: Basic programming skills in e.g., MATLAB, Python, R. Ideally some knowledge about machine learning.

NUMBER OF STUDENTS: 1-2 MSc students (2 projects of 30-35 ECTS Credits).
Testing of IT architectures to cyber-attacks in shipping (MSc)

PROJECT SUPERVISORS: Associate professor Michael Bruhn Barfod, Postdoc Daniel Sepulveda.

BACKGROUND: Information Technology Systems (ITS) are a fundamental part of many modern shipping activities. The interconnectivity and automation enabled by ITS has increased the speed, scope and accuracy of the information shared between ships and with the ports. Yet these characteristics have also increased the attractiveness for others to intervene and use these systems for their own ends (hacking), such as through the transmission of fake information or the jamming of systems by an overflow of fake instructions. The shipping industry is requiring better ways to design ITS to contain malicious hacking (cyber attacks) them before these interrupt operations or lead to losses.

PROJECT DESCRIPTION: This is part of a 2 year project called CyberShip, aimed at providing shipping companies and regulators with a reference framework and decision support model to better cope with disruptions originating from a cyber-attack. This project is being developed jointly between the DTU Compute and the Department of Management Engineering at DTU.

PROJECT PURPOSE: The purpose of this project is to model a series of different ITS architectures, test the behavior of these models during a cyber attack, and represent, compare and analyze these behaviors through the use of performance measures.

PREREQUISITES: Basic programming skills in e.g., MATLAB, Python.

NUMBER OF STUDENTS: 1-2 MSc students (2 projects of 30-35 ECTS Credits).
Autonomy in Taxi/Car-sharing Systems

PROJECT SUPERVISOR: Professor Allan Larsen (alar@dtu.dk) and PostDoc Satya Malladi (samal@dtu.dk).

BACKGROUND: Car-sharing systems such as DriveNow and GreenMobility are gaining popularity in urban environments such as the Copenhagen area. Furthermore, large companies are currently studying how to set-up and implement intra-company car-sharing concepts. The vision of such systems is to provide the users (citizens or employees) with a high degree of mobility (access to transport) by efficient use of the vehicle fleet available.

Over the coming years we expect to see gradually increased automation of road vehicles ultimately leading up to the fully-automated self-driving car/vehicle enabling the introduction of the autonomous taxi. The new approach to mobility will be capable of serving dynamic requests for service in a fully automated manner.

PROJECT DESCRIPTION: The exact thesis topic can be scoped to match the interest of the individual student(s). For some of these specific topics it may be relevant to collaborate with a commercial company.

Examples of relevant issues to study and analyze via either optimization or simulation include (but is not limited to):

- Real-time fleet management – where should the vehicles be parked overnight to serve the demand in the beginning of the day best as possible?
- Re-charging incentives – how could users be encouraged to re-charge the vehicle after their trip has ended?
- Balancing parking, charging and flow of trips by dynamic pricing

The project may – if possible – be based on real-life data from a car-sharing service.

PROJECT PURPOSE: The thesis work should build on the newest knowledge from the scientific literature. The thesis should produce an analysis of issues as mentioned above to enlighten future potentials and challenges of car-sharing.

PREREQUISITES: The student(s) should have experience with either applied optimization or simulation modeling. This could for instance have been obtained through the courses such as the optimization courses 42881 Optimisation and Public Transport or 42885 Maritime Logistics or for the simulation methodology via 42417 Simulation in Operations Management (or a similar course).

NUMBER OF STUDENTS: 1-2 MSc students (30-35 ECTS). The project topic may also be scoped to the requirements of a BSc thesis.
Autonomy in Freight Transport and Logistics

PROJECT SUPERVISOR: Professor Allan Larsen (alar@dtu.dk)

BACKGROUND: The freight transport and logistics domain is by many researchers believed to be the first area to take up fully autonomous vehicles due to the nature of freight/goods as well as the continuous urge to cut operational costs in the supply chain.

PROJECT DESCRIPTION: This thesis topic will be scoped after discussions with the student(s) in order to match the methodological background and interest of the student(s). However, this thesis should focus on one of the following parts of the transport and logistics chain:

1) **Autonomous warehouses** – already today highly automatic warehouses exist and creates opportunities for further automation of the interface between the warehouse and the land transport side. Autonomous loading of trucks, autonomous intra-terminal transport movements, auto-guided vehicles etc. plays an important role.

2) **First-mile logistics** – the first steps in the transport chain linking the production/warehousing operations to the transport to a consolidation center, a freight hub or to partner up in a truck platoon.

3) **Last mile logistics** – the last steps in the transport chain bringing the freight/goods into the final destination, such as the inner part of a big city or a sub-urban mall. This part needs to consider city logistics issues and discuss how automation can be achieved in

This project can either look in to small-sized deliveries such as distribution of parcels in e-commerce or large-sized freight transports from/to or between freight terminals.

PREREQUISITES: The student(s) should have experience with either applied optimization or simulation modeling. This could for instance have been obtained through the courses such as the optimization courses 42881 Optimisation and Public Transport or 42885 Maritime Logistics or for the simulation methodology via 42417 Simulation in Operations Management (or a similar course).

NUMBER OF STUDENTS: 1-2 MSc students (30-35 ECTS). The project topic may also be scoped to the requirements of a BSc thesis.
Fleet Composition Design of Mobile Hub Systems

PROJECT SUPERVISOR: Professor Allan Larsen (alar@dtu.dk) and PostDoc Satya Malladi (samal@dtu.dk).

BACKGROUND: In urban freight logistics (groceries delivery, e-commerce), for last mile distribution/first mile collection, in a fleet consisting of large and small vehicles, a large vehicle may meet with a small vehicle at some customer location to transfer some of the small vehicle’s load and/or swap the small vehicle’s battery. Such a large vehicle is referred to as a mobile hub.

PROJECT DESCRIPTION: This thesis may aim to estimate the value of mobile hub system over a mixed fleet with the same composition and develop methods (simulation-based, decomposition-based) for determining the composition of such a system.

PREREQUISITES: The student(s) should have experience with either applied optimization or simulation modeling. This could for instance have been obtained through the courses such as the optimization courses 42881 Optimisation and Public Transport or 42885 Maritime Logistics or for the simulation methodology via 42417 Simulation in Operations Management (or a similar course).

NUMBER OF STUDENTS: 1-2 MSc students (30-35 ECTS).
City logistics and urban freight transport

PROJECT SUPERVISOR: Professor Allan Larsen (alar@dtu.dk)

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

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

The student(s) will be invited to be part of the research and demonstration project EUFAL, which deals with efficient planning and optimization methods for demonstrating the potentials of using electrical vehicles for commercial urban transport, such as city logistics.

The Danish side of the EUFAL project includes external partners such as MT Højgaard and Region Hovedstaden, which will contribute with case studies from real-life.

PREREQUISITES: The student(s) should have experience with either applied optimization or simulation modeling. This could for instance have been obtained through the courses such as the optimization courses 42881 Optimisation and Public Transport or 42885 Maritime Logistics or for the simulation methodology via 42417 Simulation in Operations Management (or a similar course).

NUMBER OF STUDENTS: 1-2 MSc students (30-35 ECTS). The project topic may also be scoped to the requirements of a BSc thesis.
Reliable and Predictable Bus Transit in Metro Copenhagen

PROJECT SUPERVISOR: Assoc. Professor Steven Harrod (stehar@dtu.dk)

PROJECT ADVISORS: no formal advisors but we have an ongoing relationship with Movia

BACKGROUND: As the Copenhagen transport network becomes more complex and customers attempt to make more complicated journeys (directed by Rejseplanen.dk), the real measure of ride quality is the quality of the connections between services. What makes a reliable journey by bus in Copenhagen? How can Rejseplanen offer more accurate and reliable advice for journeys by bus? Where are the “hotspots” in the bus network?

PROJECT DESCRIPTION: DTU is a participant in the IPTOP research project and has access to years and millions of rows of bus operating data. This data should be studied to find interesting patterns of delay, and significant factors in the reliability of connections at major hubs like Hillerød, Nørreport, and Hørsholm Midpunkt. Using database and statistical analysis tools, the data should be organized and studied to find causes of delay by route, time of day, and bus operator. The results of the analysis could actually be applied in real management of the bus network through the IPTOP project. Students will be introduced to contact persons at Movia.

PROJECT PURPOSE: The overall project purpose is to a) identify critical transfer points in the network, b) identify bus route performance trends that require management attention, and c) look for mathematical methods to better predict the journey times and connection reliability of likely customer journeys.

PREREQUISITES: Knowledge of statistics and hypothesis testing. Skills in at least one of: database management or statistical analysis software.

NUMBER OF STUDENTS: 1-2 MSc Students (30-35 ECTS)
MSc Thesis Project in Maintenance Planning at Banedanmark

Title: Planning of Major Track Renewal Projects

Description: Banedanmark is the owner and manager of most of the railway track in Denmark. Every year, some segments of track require significant renewal over many kilometers, and this work cannot be accomplished during a few hours of low train traffic at night. This work is most often performed by contractors, maintenance specialists outside of Banedanmark. These renewal projects require very large and complex automated track removal and installation machines, that also complicate the scheduling because they are difficult to move from place to place.

Each year, the planning process contains two major tasks: identification of the track segments requiring work, and selecting and sequencing the segments into the available work time. There are two objectives: optimal timing for the repair of the track segments, to obtain the longest service life from those segments, and optimal movements of the track machinery, to obtain the most productive use of the machine with the least wasted time in relocation.

Maintenance operations are scheduled to take a variety of parameters into consideration, e.g.:

- Most possible maintenance actions in the time period the heavy machinery is available (maximize utilization)
- Timetabled train traffic operations should be affected as little as possible (minimize line closure)
- Working time rules for the machine crews must be respected (adhere to contract and labor agreements)
- The heavy machinery must not be present on main tracks when the morning rush hour begins (control risk of work delays exceeding agreed line closures)

Project goals: The result of the project should be a planning model, most likely a mathematical model, which can plan either an optimal or improved renewal schedule over a 3 month planning horizon. The model should integrate with other Banedanmark data sources and planning tools.

Qualifications: This project contains elements of planning and optimization. Therefore it is expected that the student(s) has/have experience in the field of operations research (OR). Furthermore it is an advantage to have a basic knowledge of railway operations and railway timetabling. Skills in programming and database (SQL) are also desirable and can be discussed further with the advisor.

Contact person at DTU: Steven Harrod, Department of Management Engineering

Contact person at Banedanmark: Portfolio manager, MSc, Niels Munk Jørgensen
Optimal Inventory in a Job Shop with Forbidden Early Shipment

PROJECT SUPERVISOR: Assoc. Professor Steven Harrod (stehar@dtu.dk)

PROJECT ADVISORS: none

BACKGROUND: Much classical manufacturing, job shop, or flow shop analysis presumes that minimizing flow time and releasing finished product as soon as possible is optimal. However, a true “just in time” supply chain demands that product is NOT shipped early. This is called “forbidden early shipment”. Holding flow back until the promised ship date disrupts the assumptions in classical queuing models, and requires an alternative analysis.

PROJECT DESCRIPTION: The project should include a significant review of existing papers on job shop inventory policy and management. Many of these papers are well known and can be provided at the project start. Some prior work has also been done on this topic, and that can be provided as a starting point.

The problem is that many of the practical, interesting job shop configurations do not easily match simple mathematical formulas, and must be simulated. The simulations should cover a wide range of input values, and the results ideally presented graphically and then examined for patterns. Hopefully, some patterns can be discovered that link various alternate configurations together.

PROJECT PURPOSE: The overall project purpose is to a) create some realistic simulation models of production lines (job shops) that enforce forbidden early shipment, b) propose a variety of input data sets or conditions that represent real world examples, and then c) find some common behaviors among the different real world examples.

PREREQUISITES: Knowledge of discrete event simulation software such as AnyLogic or Rockwell Arena

NUMBER OF STUDENTS: 1-2 MSc Students (30-35 ECTS)
Cause Analysis of Danish Railway Delays

PROJECT SUPERVISOR: Assoc. Professor Steven Harrod (stehar@dtu.dk)

PROJECT ADVISORS: no formal advisors but we have an ongoing relationship with Banedanmark and DSB

BACKGROUND: Railways are complex transport services with many inter-linking parts. It is not always clear what the “cause” of a particular incident is. It is sometimes difficult to take management action because so many problems require attention and it is not clear what the most important task is.

PROJECT DESCRIPTION: DTU is a participant in the IPTOP research project and has access to years and millions of rows of railway operating data. This data has some information on the possible causes of train delays, but it is unclear if the cause originates on the listed train or actually results from other trains at other locations or times. This data should be studied to find interesting patterns of delay, and significant causes of delay that affect other trains through what are called “secondary delays”. Using database and statistical analysis tools, the data should be organized and studied to find causes of delay by route, time of day, and recorded cause. The results of the analysis could lead to management improvements and better timetable design. Students will be introduced to contact persons at Banedanmark and DSB.

PROJECT PURPOSE: The overall project purpose is to a) identify how delays in one train create delays in other trains, b) identify trends in delays by recorded cause label codes, and c) identify critical trains and locations for management action.

PREREQUISITES: Knowledge of statistics and hypothesis testing. Skills in at least one of: database management, OpenTrack, or statistical analysis software.

NUMBER OF STUDENTS: 1-2 MSc Students (30-35 ECTS)
Green and Dynamic Vehicle Routing Problems (MSc)

SUPERVISOR: Professor Harilaos N. Psaraftis (hnpsar@dtu.dk)

BACKGROUND: Dynamic vehicle routing problems (DVPRs) are defined as vehicle routing problems in which problem inputs are received and updated concurrently with the execution of the route. Such problems find applications in many transport contexts, such as city logistics, dial-a-ride systems, courier services and others. DVRPs may or may not involve stochasticity in the input data. Research in this area has grown strongly over the years and many methods and techniques have been developed. A recent survey paper has surveyed more than 100 papers and developed a taxonomy for this class of problems according to 11 criteria. Numerous open problems that merit investigation have been identified. Among them, green vehicle routing problems optimize environmental objectives, for instance minimize vehicle emissions.

PROJECT PURPOSE: The purpose of this project is to advance the state of the art in DVRP methodology by examining variants that have environmental attributes.

PROJECT DESCRIPTION: A thesis in this area will analyze green DVRPs. Work includes defining environmental criteria, exploring alternative objective functions, embedding machine learning methods, better exploiting ICT/ITS/big data technologies and modifying known approaches so as to obtain better solutions, or exploiting any other idea related to green DVRPs.

PREREQUISITES: Knowledge of a programming language (C++, Java, or other). 42887 Vehicle routing and distribution planning.

NUMBER OF STUDENTS: 1-2 MSc students (30 ECTS Credits).
Market based measures (MBMs) for GHG emissions reduction in maritime transport (MSc)

PROJECT SUPERVISOR: Professor Harilaos N. Psaraftis (hnpsar@dtu.dk)

BACKGROUND: International shipping accounts for 2.2% of anthropogenic CO2 emissions, and produces some 796 million metric tons of CO2 per year (2012 fleet data). Much regulatory activity is tasked to find ways to significantly reduce CO2 and other greenhouse gas (GHG) emissions. Shipping is not yet included in the Kyoto protocol, that being the mandate of the International Maritime Organization (IMO). The IMO, on its part, has adopted in 2011 the only mandatory GHG reduction scheme to date, in the form of the Energy Efficiency Design Index (EEDI), and has decided in 2018, among other things, to reduce GHG emissions by 2050 by at least 50% vis-avis 2008 levels. A broad variety of candidate measures have been proposed, but no prioritization among them currently exists. Among these measures, Market Based Measures (MBMs) are an important category. Possible MBMs include a levy on bunker fuel and an Emissions Trading System (ETS).

PROJECT PURPOSE: The purpose of the project is to analyze possible MBMs, appropriately defined, for various shipping markets, tramp and liner, in terms of reducing GHG emissions and other criteria. Short-term and/or long term impacts will be analyzed.

PROJECT DESCRIPTION: This project will examine the potential impacts of MBMs for various scenarios in international shipping. Interaction with project ShipClean is foreseen. Short term impacts are on the logistics of the ship operation and long term impacts are on technologies that can be used to make shipping more energy efficient.

PREREQUISITES: A minimum knowledge of maritime transport. Optionally: 42884 Green Transport Logistics

NUMBER OF STUDENTS: 1-2 MSc students (30 ECTS Credits).
Evidence-based contributions to the ongoing policy dialogue on monitoring CO$_2$ maritime emissions (MSc)

PROJECT SUPERVISOR: Professor Harilaos N. Psaraftis (hnpsar@dtu.dk), Associate Professor Michael Bruhn Barfod (mbba@dtu.dk), Researcher George Panagakos (geopan@dtu.dk)

BACKGROUND: The International Maritime Organisation estimated that the greenhouse gas emissions from international shipping in 2012 accounted for some 2.2% of anthropogenic CO$_2$ emissions and that such emissions could grow by between 50% and 250% by 2050. Two major initiatives, one at regional (EU) and one at global level have been introduced since then, which share the ultimate aim of improving the carbon footprint of the sector. However, they differ in the approach they follow and tools they use. A relevant earlier MSc thesis project used raw data from a large sample of MÆRSK, NORDEN and DFDS ships to analyse the indicators proposed by these two initiatives. The objective of this thesis is to use these earlier results to advance the ongoing policy dialogue on the issue of monitoring the carbon emissions of shipping.

PROJECT PURPOSE: The purpose of this project is to identify the measures that have been proposed for monitoring the carbon emissions of shipping, assess the appropriateness of the corresponding monitoring indicators, and draw conclusions in the form of policy and R&D recommendations.

PROJECT DESCRIPTION: The project will: (i) identify alternative approaches used/proposed for monitoring carbon emissions in shipping and other transport sectors, list their basic suggestions and describe their functionality; (ii) identify the characteristics (e.g. accuracy, robustness, compatibility, etc.) that indicators need to exhibit in order to monitor progress towards meeting policy targets; (iii) use these characteristics as criteria for assessing the appropriateness of the indicators identified above; and (iv) draw recommendations in terms of policy work and future research needs.

PREREQUISITES: A minimum knowledge of maritime transport. Optionally: 42884 Green Transport Logistics

NUMBER OF STUDENTS: 1 MSc student (30-35 ECTS Credits).
Speed models for energy efficient maritime transportation (MSc)

PROJECT SUPERVISOR: Professor Harilaos N. Psaraftis (hnpsar@dtu.dk)

BACKGROUND: The above was the title of a survey paper by Psaraftis and Kontovas (2013), which reviewed some 40 papers that examined the role of ship speed to achieve energy efficient maritime transportation. Since that paper was published, many more papers dealing with ship speed have appeared, and in fact that paper’s Google Scholar citations now exceed 220, which is a good proxy on the number of papers published since. A need for an updated taxonomy clearly exists. This is all the more relevant since at the latest IMO/MEPC 72 landmark decision to aim for at least 50% GHG reductions by 2050, speed reduction and speed optimization were selected in the roster of medium term measures to reduce GHG emissions.

PROJECT PURPOSE: The purpose of the project is to establish an updated baseline on the state of the art in the area of ship speed and its role for optimizing energy usage in maritime transportation. To do so, the project aims to develop an updated taxonomy of papers that look at ship speed, either from an economic or from an environmental perspective (or from both perspectives). Papers that were published from 2012 to date will be reviewed according to a set of criteria.

PROJECT DESCRIPTION: This project will look at the published literature in which ship speed is considered important and classify them according to a number of criteria. These include who is the decision maker, what is the objective function, what is the logistical context, what is the shipping market considered, and several others.

PREREQUISITES: A minimum knowledge of maritime transport and optimization. Optionally: 42884 Green Transport Logistics

NUMBER OF STUDENTS: 1-2 MSc students (30 ECTS Credits).
Optimizing Vessel Speed Reduction Programmes (VSRP) (MSc)

PROJECT SUPERVISORS: Professor Harilaos N. Psaraftis (hnpsar@dtu.dk); Postdoc Thalis Zis (tzis@dtu.dk)

BACKGROUND: Regulatory bodies and port authorities have been developing green agendas that seek to reduce shipping emissions in areas near ports. This can be achieved through the use of clean fuel and technologies, as well as through changing the operating patterns of the vessels near the port and specifically reducing sailing speed. While emissions per vessel call are reduced through compliance to such programs, there may be time penalties and increased operating costs for ships.

PROJECT DESCRIPTION: This project considers the emissions reduction potential of VSRP to enhance the environmental performance of ports. The implications of a complying decision to the ship costs need to be identified (e.g. costs due to delays, technological investments, increased fuel consumption) and compared with the emissions reduced at the port. The option of a convincing monetary incentive provided by the port authority to the ship operator will be considered. It is expected that the value of the incentive will influence the ship operator’s decision to participate or not in the proposed emissions reduction measure. The research question can be formulated as an optimization problem whereby the objective is the maximization of emissions reduction, or the minimization of the cost per abated ton of pollutant.

PROJECT PURPOSE: The purpose of this project are to enhance an existing model that predicts emissions savings from port authority programs with a cost benefit analysis that minimizes the cost per abated ton of pollutant emissions near the port. The decision variables in the proposed optimization problem will depend on the examined policies during the project.

PREREQUISITES: At least one of the following: 42885 Maritime logistics, 42884 Green transport logistics. Some Programming experience desirable.

NUMBER OF STUDENTS: 1-2 MSc students (30 ECTS Credits).
Application of Game Theory for increasing compliance rates in environmental regulation

PROJECT SUPERVISORS: Postdoc Thalis Zis (tzis@dtu.dk); Professor Harilaos N. Psaraftis (hnpsar@dtu.dk);

BACKGROUND: The existing legislative framework poses several challenges, stemming (mainly) from a highly non-homogeneous and spatially differentiated system, with cases where the penalty fines are as low as the benefit that the violator enjoyed from not complying.

PROJECT DESCRIPTION: This project considers the options of ship operators to comply with the low sulphur fuel requirements in place. The ship operator can either use low-sulphur fuel, invest in scrubber systems, or disregard the regulation and risk the penalty if caught. At the same time, a regulatory body has the option to inspect or not, vessels within its jurisdiction to examine whether they comply with the regulation. The task of the MSc thesis will be to analyze the status quo of enforcement in different countries, where the regulation applies, and use a game theoretic approach for a uniform violation fine system.

PROJECT PURPOSE: The purpose of this thesis is to complement work undertaken in a new research project entitled “SulphurGATE”. The main tasks involve data collection and analysis, as well as the formulation of a simplified mixed strategy game to examine improved penalty systems, through identification of the resulting equilibria.

PREREQUISITES: At least one of the following: 42885 Maritime logistics, 42884 Green transport logistics. Some Programming experience desirable.

NUMBER OF STUDENTS: 1-2 MSc students (30 ECTS Credits).
Product configuration

**Supervisor:** Professor Lars Hvam (lahv@dtu.dk)

**Background:** Product configurators are increasingly being used to support sales and engineering for making specifications like quotations, and other product and production specifications. Configurators are a means to control the product assortment and increase efficiency in sales, engineering and production.

**Project description:** A master project on product configuration may cover one or more of these areas:

- Defining scope and business cases for product configurators
- Modelling products for a product configurator
- Making a prototype product configurator
- Modelling and developing sales and engineering processes
- Analyzing impact from using product configurators
Complexity management

**Supervisor:** Professor Lars Hvam ([lahv@dtu.dk](mailto:lahv@dtu.dk))

**Background:** Industry and service companies experience increasing complexity in their products and operations. There is a strong management on reducing complexity and the potential benefits for the companies are significant.

**Project description:** A master project on complexity management may cover one or more of these areas:

- ABC analysis of products and customers
- Identification and quantification of the most significant complexity cost drivers and allocation of complexity costs to products
- Quantification of other impact than costs e.g. impact from complexity on delivery performance or quality
- Identification of initiatives for reducing complexity in products and/or processes
- Quantifying expected and cost benefits from each suggested initiative and plan for implementation
Reducing complexity in the hearing aids product portfolio

PROJECT SUPERVISOR: Professor Lars Hvam (lahv@dtu.dk)

BACKGROUND: William Demant is a global market leader in hearing healthcare, and the company’s core business is the development, production, marketing and service of William Demant products and services under various brands i.e. Oticon, Benafon, Sonic and Philips, which in turn are operated as part of the function DGS (Demant Group Services). In recent years, the company has been dynamically developing, which has led to an increase in the number of product variants at both module and finished goods level. Currently, the William Demant’s product portfolio has more than 12 000 products and more than 69 000 SKUs. Due to this, the company does not have a clear overview of the impact on costs and delivery performance resulted from increased product variety, what the complexity drivers are, and how they impact the company’s performance.

PROJECT DESCRIPTION: A master project on complexity management may cover ABC analysis of products and customers as well as quantification of the most significant complexity cost drivers and allocation of complexity costs to products

PROJECT PURPOSE: The purpose of this project is to identify and quantify complexity cost drivers

NUMBER OF STUDENTS: 1-3 MSc students (2 projects of 30-35 ECTS Credits).

Contact akst@dgs.com for more information about the project.
PROJECTS WITH NCC

Bachelorprojekt - Altaner
Altaner har i dag en betydelig rolle i boligbyggeriet, hvor de bruges som en væsentlig del af det arkitektoniske udtryk og "lækkerhed" af lejligheder. Altanerne herunder altanophængene skal projekteres i forhold til krav til isolering (kuldebroer), statik og arkitektur, dette betyder at projektering af altaner udgør en væsentlig del af særøst statikprojektering. I NCC ønsker vi at ensrette vores måde at arbejde med altaner på. Bachelorprojektet vil handle om at etablere en produktfamilie for altaner, særøst altanophæng, samt at vurdere mulighederne for- at etablere et konfigureringssystem til at støtte projekteringsprocessen. Arbejdet vil foregå under vejledning fra NCC’s afdeling for Innovation og Koncepter og i samarbejde med NCC Konstruktionsprojektering.

Master project – Daylight configurator
NCC has for some time been developing a configuration system for handling of daylight conditions. Daylight is a very important factor of the early design phases of a project. Several master theses have worked on this and have shown good results in relation to the possibility to develop a configuration system that includes parameters such as the window share of the façade, glazing type, room height, room depth, building shape, building height, external shades and more. The daylight requirements in the building code have been updated and therefore the configuration system needs to be updated accordingly and at the same time upgraded with more features, as the current configuration is fairly limited. NCC wants to continue establishing configuration systems in cooperation with DTU students, including the new requirements and calculation methods. The work will be supervised by NCC Engineering based in the sections Innovation and Concepts as well as HVAC design.

Please contact Anders Kudsk aku@ncc.dk at NCC for further details or contact supervisor Professor Lars Hvam lahv@dtu.dk
Modeling of IT services and its complexity impact (MSc)

PROJECT SUPERVISOR: Professor Lars Hvam (lahv@dtu.dk)

BACKGROUND: Today, IT services are becoming a central part of the business strategy for both the service industry and traditional manufacturing companies as IT services are used to enable or support business processes. Compared to the rigid structure of a production system, the IT enterprise architecture and computing infrastructure has the advantage of having a quite flexible setup, meaning that making an extra effort to fulfil a customer request may be an easy step to take and something the customer expects. Given the customized nature of IT services, companies can ultimately increase their service portfolio rapidly without paying much attention to its consequences, especially to a steady increase of complexity and its impact on profitability. Complexity management is therefore becoming a core part of the management agenda aiming to help companies to not miss out on profits due to non-value adding complexity costs.

PROJECT DESCRIPTION: During a case study, the Master thesis student will investigate the design of IT services or IT service management processes at a case company and relate them to cost or complexity impact. DSV A/S could serve as a case company. However, students are very welcome to bring in their own case company or IT project as basis for the thesis.

PROJECT PURPOSE: The purpose of this project is to identify how IT services can be delivered in a cost-transparent way and how non-value adding complexity costs during the lifecycle of an IT service can be identified and reduced. Therefore, different IT service models and IT service management frameworks will be applied to an existing IT service to identify the costs of delivering an IT service.

PREREQUISITES: Affiliation to IT, no coding skills required.

NUMBER OF STUDENTS: 1-2 MSc students (2 projects of 30-35 ECTS Credits).

Contact Franziska Schorr at (frsc@dtu.dk) for more information regarding the project.
MSc Projects at Configit A/S

Background:
Configit is a trusted leader in Configuration Lifecycle Management (CLM), providing market-leading global manufacturers with business-critical solutions for the configuration of complex products. Based on the patented Virtual Tabulation (VT)™ technology, Configit’s solutions enable companies to reduce time to market, increase quality of configurable products, and improve process efficiency.

Assignment:
Configit offers CLM solutions to the market. CLM supports the management of multi model configurations and related data, as it covers the application of configuration and related data in all the different life cycle phases of configurable products and services. Integrating the configuration systems by using a CLM system is expected to lead to better defined outputs from the systems (e.g. Bills-of-material), and consequently to increased efficiency in e.g. the production and after service, as the specifications are more correct, complete and understandable. Since standalone configuration systems are already a proven concept both in theory and practice, this project aims to highlight additional benefits of utilizing a CLM system to improve the economic justification within a feasibility study for its adoption, and consequently sharpen its scope and set-up to improve its success rate.

Focus areas of the projects are, but not limited to:

- Benefits and impact of utilizing a CLM system.
- Scope and set-up a CLM system.
- Integration of CLM system.

Contact info:
Project supervisor: Professor Lars Hvam (lahv@dtu.dk)

Contact Anna Myrodia at amyrodia@configit.com for more information regarding the project.

For more information about Configit and CLM, visit the website: https://configit.com/.
Predictive Maintenance (MSc)

PROJECT SUPERVISOR: Professor Lars Hvam (lahv@dtu.dk)

BACKGROUND: through previous work and analysis performed at ROCKWOOL, a Danish multinational specialized in stone wool production, it was possible to clarify the potential in Predictive Maintenance. A first model has been developed for a special sub-system in an equipment, but not yet tested or optimized. Therefore there’s still yet much to learn in the area, at the same time that there’s knowledge acquired. That said, the project won’t be starting from 0 and the master(s) student(s) will have support and base material to write an excellent thesis. The company has been focusing on smart solutions for common production problems and the results of the project will have a direct impact on the optimization of the ROCKWOOL facilities.

PROJECT DESCRIPTION: the Project focuses on a case study to assess methods previously used, scope the next case, create, test and improve model as well as assessing resulting benefits.

PROJECT PURPOSE: the purpose of this project is to optimize and replicate a predictive model in a real scenario, identifying the best methods, obstacles and assessing possible gains. The student should be able to have a fruitful experience on how the industry handles predictive maintenance.

PREREQUISITES: Background in Machine Learning. Students should be able to sit 3-4 days per week at the company in Hedehusene working directly with our Operations team.

NUMBER OF STUDENTS: 1-2 MSc students (2 projects of 30-35 ECTS Credits).

Contact Lucas Lemes at (lucle@dtu.dk) for more information regarding the project.
Optimization of material consumption through machine learning modelling (MSc)

PROJECT SUPERVISOR: Professor Lars Hvam (lahv@dtu.dk)

BACKGROUND: ROCKWOOL is a big global producer of stone wool and intends to act smarter on how they handle the material consumed in regular maintenance activities. After previous studies were carried out, a big potential has been identified in how can maintenance expenditures be minimized through a better understanding of the production parameters. The company would like to investigate these potentials and trace a plan of action over it.

PROJECT DESCRIPTION: the Project focuses on selecting the greatest potential equipment, extract features from the historical data, select the best method in literature, model the process through machine learning techniques and draw intelligible assumptions on how the materials are consumed along time that will be the basis for the action plan.

PROJECT PURPOSE: the purpose of this project is to identify how variables of a complex system impact on the consumption of materials crucial for maintenance and therefore identify potential in cost reduction by, for example, extending its the life-time or aid planning activities. For the student, the goal is to discuss and build up knowledge in partnership in a real scenario, profiting from pre-existing knowledge.

PREREQUISITES: Background in Machine Learning. Data analytics skills desirable. Students should be able to sit 3-4 days per week at the company in Hedehusene working directly with our Operations team. The results of the project will have a direct impact on the optimization of the ROCKWOOL facilities.

NUMBER OF STUDENTS: 1-2 MSc students (2 projects of 30-35 ECTS Credits).

Contact Lucas Lemes at (lucle@dtu.dk) for more information regarding the project.
Impact of insourced 3D printing in cost reduction (MSc)

PROJECT SUPERVISOR: Professor Lars Hvam (lahv@dtu.dk)

BACKGROUND: 3D printing technologies became easy enough to be used by anyone, in any place at any time, but is still underexplored in the industry. Several components which are usually outsourced could be insourced, reducing costs and improving lead time.

PROJECT DESCRIPTION: the task of the MSc is to map the potential, streamline the costs attached to systems, order handling, purchasing, deliver and stock and define a parallel with the insourced components.

PROJECT PURPOSE: Analyze potential, test 3D prints in pilot equipment/plant, have streamline clarified and present up and downsides of the technology.

PREREQUISITES: Background in Mechanics is preferable.

NUMBER OF STUDENTS: 1 MSc student (1 project of 30-35 ECTS Credits).

Contact Lucas Lemes at (lucle@dtu.dk) for more information regarding the project.
Impact of maintenance activities in losses (MSc)

PROJECT SUPERVISOR: Professor Lars Hvam (lahv@dtu.dk)

BACKGROUND: literature shows that the correspondence of maintenance activities and losses is still fuzzy. It is of extreme relevance to clarify the key points on how key losses are impacted and eliminate variables of the flowing production.

PROJECT DESCRIPTION: the Master Student will identify the main losses in literature, translate it to the reality in the process industry and propose a model based on the current knowledge in operations management.

PROJECT PURPOSE: model correlation between maintenance and losses in: production, energy, resources, among others.

PREREQUISITES:

NUMBER OF STUDENTS: 1 MSc student (1 project of 30-35 ECTS Credits).

Contact Lucas Lemes at (lucle@dtu.dk) for more information regarding the project.
MSc Project at ROCKWOOL International A/S

Postponement/Delayed Differentiation in Production

With over 20,000 finished goods emerging from their global production base, ROCKWOOL is looking to be smarter in the way to deliver product variety to the market with high production efficiency. Postponement (or delayed differentiation) is one of the methods high variety industries utilize to do this, and ROCKWOOL would like to investigate what postponement could bring in their production context.

Your primary task in this project is developing a postponement strategy for ROCKWOOL factories considering the product variety, production setup, stock levels, and market requirements at the company.

Key aspects of this study are:

- Applying Theory of Constraints thinking to identify and protect bottleneck resources with buffer inventory
- Analysis of a suitable customer order decoupling point
- Determining the optimal work-in-process inventory at the decoupling point
- Use strategic thinking to understand consequences of postponement for supply chain and operations (e.g., how will it affect delivery service)
- A case study at one or more ROCKWOOL production lines
- Quantitative analysis of production data

This project will be for a group of 2 MSc students. Students should be able to sit 3-4 days per week at the company in Hedehusene working directly with our Operations team. The results of the project will have a direct impact on the capacity and flexibility of the ROCKWOOL facilities.

If you are interested in the project, please send a short email explaining your motivation along with your CV and grade transcripts to Tina Rytter Nørregaard (tina.noerregaard@rockwool.com).
Vehicle routing with cross-docking

PROJECT SUPERVISOR: Assistant professor Martin Philip Kidd (mpki@dtu.dk)

BACKGROUND: A common problem in real world transport optimization is the option of cross-docking. The production of goods takes place at factories from which the goods can be distributed directly to the customers. Often however it may be fruitful to divide the distribution into two “legs” where the goods are transported to a cross-docking location and then repacked onto a different vehicle and transported to the customers.

It is of great interest to consider the option of cross-docking while solving these vehicle routing problems.

PROJECT ASSIGNMENT: Given real-life VRP data including factory and cross-docking locations. The student should construct an algorithm for solving the VRP which should be able to consider which orders should be cross-docked and which should not.

PREREQUISITES: OR courses, especially useful one is 42887 (Vehicle Routing and Distribution Planning), good programming skills

Vendor managed inventory

PROJECT SUPERVISOR: Assistant professor Martin Philip Kidd (mpki@dtu.dk)

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

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

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

PREREQUISITES: OR courses, especially useful one is 42887 (Vehicle Routing and Distribution Planning), good programming skills

Auction theory

PROJECT SUPERVISOR: Assistant professor Martin Philip Kidd (mpki@dtu.dk), Professor Jesper Larsen (jesla@dtu.dk)

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 tacit knowledge among our auctioneers.

PROJECT 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.

PREREQUISITES: Game theory would be an advantage, but is not essential

NUMBER OF STUDENTS: 1-2 MSc students (2 projects of 30-35 ECTS Credits).
Machine learning for fur quality detection

PROJECT SUPERVISOR: Assistant professor Martin Philip Kidd (mpki@dtu.dk), Professor Jesper Larsen (jesla@dtu.dk)

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.

PROJECT 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

PREREQUISITES: Operations Research, basic knowledge on machine learning. Programming ability is an advantage.

NUMBER OF STUDENTS: 1-2 MSc students (2 projects of 30-35 ECTS Credits).
Creating value for DSB through SAP S/4HANA and redesign of accounting processes aligned with company strategy

PROJECT SUPERVISOR: TBD
CO-ADVISOR: TBD
INFORMATION: Contact Prof. Allan Larsen (alar@dtu.dk).

BACKGROUND:
Can an accounting system based on innovative technology make an organization more competitive and increase efficiency? How is DSB a different organization after the implementation of project FRØ – Fremtidens Regnskab og Økonomi? Replacing a legacy accounting system including related financial/accounting processes was initiated in 2014, however what has been the tangible and intangible effects and results? FRØ is a complex and high-risk project, which affects the core of DSB as an organization and the ability to deliver ‘trains on time’ with a high degree of attention from the board of directors and other important stakeholders. Did the FRØ-project deliver the defined goals and results to DSB as expected?

THE PROJECT:
You will focus on a cost benefits analysis on the FRØ project and its implications and clear value adding benefits. The focus should also be whether the use of new innovative technology aligns with the overall strategy in DSB or not, only supported by a business case. Your focus should be on identifying the tangible and intangible variables of why SAP S/4HANA as a modern accounting system is beneficial and creates competitive advantages for DSB. Applying IT strategy, organizational (e.g. theory of the firm) and corporate managerial economics theory aligned with an economical perspective is recommended.

Alternatively, processes and sub deliveries could also be taken into consideration in the analytical process since a redesign of normative structures and habits has been key part of project FRØ. A managerial approach where organizational and managerial theory can be applied is also seen as potential focus. Your focus should be on identifying tangible variables that has contributed to the current state of DSB Finance department, both negative and positive. Using a process perspective could also include e.g. methodology such as SCRUM or PRINCE 2.

Your job will be to include new ideas on what could have been done differently to optimize efficiency and benefits. That being technology, processes or products. And present what you believe should be a recommendation for future initiatives strategic, technology and product wise. Your job will also include a business case presentation of why FRØ has been a success or a failure. What are the generic business case for choosing the platform of SAP S/4HANA for other organizations?

LEVEL: Best suited for an MSc thesis, however can be applied a BSc project as well.

NUMBER OF STUDENTS: 1 preferred, potentially 2 if agreed upon.
Transport Project Evaluation: Decision Support and Multi-Criteria Decision analysis (MSc)

PROJECT SUPERVISOR: Associate professor Michael Bruhn Barfod (mbba@dtu.dk)

BACKGROUND: Recent research has shown that conventional cost-benefit analysis is inadequate as a decision support tool for appraising transport infrastructure projects as it fails to capture criteria of a more strategic and qualitative character. Multi-criteria decision analysis (MCDA) can be applied to the appraisal scheme to deal with this issue.

PROJECT DESCRIPTION: Current research deals with the difficult task of identifying the most suitable decision aids for supplementing the cost-benefit analysis. Several MCDA techniques have been suggested suitable for decision making in the transport sector when dealing with selections among a limited number of alternatives. However, these techniques become inappropriate when dealing with large a number of alternatives and criteria such as in a screening phase.

PROJECT PURPOSE: The purpose of this project is to look into the possibilities of using outranking methods belonging to the so-called constructive MCDA approach. These methods are able to handle a large number of alternatives and criteria simultaneously using a sort of voting mechanism. The different methods can be applied to a suitable case study and the results can be benchmarked against the outcome of a conventional analysis.

PREREQUISITES: 42879 Decision support & Risk analysis.

NUMBER OF STUDENTS: 1-2 MSc students (2 projects of 30-35 ECTS Credits).
Transport Planning: Decision Support and Planning workshops (MSc)

PROJECT SUPERVISOR: Associate professor Michael Bruhn Barfod (mbba@dtu.dk)
PROJECT ADVISORS: Professor Steen Leleur (stle@dtu.dk)

BACKGROUND: Tendencies in the transport sector has revealed a growing need for involving stakeholders more in the decision support process in order to capture all aspects of the very complex decision problems. Planning workshops has been suggested to deal with this issue by gathering relevant stakeholders and decision makers with the purpose of generating a fruitful discussion to improve the final decision making.

PROJECT DESCRIPTION: Planning workshops consist of three main elements: group processes, decision analysis and information technology. The purpose is to link these three elements and use the best from each of them in the decision support process. The composition of such a workshop will, however, depend on the decision context, the participants’ affiliations, the participants’ level of power, and many other issues.

PROJECT PURPOSE: The purpose of this project is to test how the planning workshop concept can be used for real decision support. The implementation of the concept can be tested through a current running decision problem, where workshops e.g. can be held on different levels (citizens, municipality, regional, or organizational) to improve the actual decision support in form of more diverse and detailed information to the final decision makers.

PREREQUISITES: 42879 Decision support & Risk analysis.

NUMBER OF STUDENTS: 1-2 MSc students (2 projects of 30-35 ECTS Credits).

NB! A smaller version of the project can be aligned to suit both BSc and BEng student theses.
Supporting Copenhagen Green Mobility initiatives with state-of-the-art decision support tools (MSc)

PROJECT SUPERVISOR: Associate professor Michael Bruhn Barfod (mbba@dtu.dk)

EXTERNAL ADVISOR: Annette Kayser, Project Manager, City of Copenhagen, Technical and Environmental Department

BACKGROUND: Sustainable transport appraisal and planning is a complex socio-technical challenge. Copenhagen municipality is currently revising their “Action Plan for Green Mobility” that included 25 initiatives as part of its green mobility package. The selection and prioritization of these measures was complex and difficult to operationalize in practice. A set of criteria for the selection of the initiatives was defined, including green mobility, environment, safety, city life and health. However the qualitative nature of the judgments and the different priorities between stakeholders made it difficult to provide a fact-based approach with clear results to bring to decision-makers. There is thus a need for revisiting revising this case plan by applying a decision-support tools and scenario analysis to prioritize the proposed measures and review the plan according to a more systematic and transparent process. Such tools can help highlight differences but also potential overlaps in preferences between stakeholders – and thus provide maneuver for negotiation and improve the decision-making process. Finally, the approach allows for comparing priorities and decisions with a potential sustainability ‘benchmark’: that of future generations.

PROJECT DESCRIPTION: In this project you will review and assess the current initiatives as described in the “Action Plan for Green Mobility”. With input from the Technical and Environmental Department, the criteria for success will be re-viewed and defined based on sustainability principles and applicable sustainable mobility goals for the municipality. Using AHP (Analytic hierarchy process, or similar complex decision-support tool), the judgments for the prioritization of the criteria for each type of stakeholders will be collected through various means (past data, survey, interviews etc). The expected performance of each initiative will also be assessed through expert evaluations. Finally, the perspective of future generations as a ‘virtual’ stakeholder may also be defined to provide a stronger sustainability perspective. The project concludes with an improved, systematic and transparent decision-support process and impact assessment for Copenhagen’s new “Action Plan for Green Mobility”.

PROJECT PURPOSE: The purpose of this project is to provide the Technical and Environmental Department of Copenhagen Municipality with a state-of-the-art decision-support tool for complex, multi-stakeholder, ‘ex-ante’ assessment of sustainable mobility initiatives.

PREREQUISITES: 42879 Decision support & Risk analysis

NUMBER OF STUDENTS: 1-2 MSc students (2 projects of 30-35 ECTS Credits).
Smart parking in Copenhagen (MSc)

PROJECT SUPERVISOR: Associate professor Michael Bruhn Barfod (mbba@dtu.dk)

EXTERNAL ADVISORS: Annette Kayser and Kasper Brenøe Isbrand, City of Copenhagen, Technical and Environmental Department

BACKGROUND:
Since 1995 the number of cars in Copenhagen has increased with 40% and there are no indications that the development will stop within the near future. On the contrary it seem that the already desperate situation will worsen further in the years to come. A part of the explanation on this development is the extensive urban renewal which has attracted socioeconomically more advantaged families to the city. The establishment of parking spaces has, however, not followed the rapid increase in cars, and Copenhagen is for this reason struggling with problems related to an insufficient number of parking spaces.

PROJECT DESCRIPTION:
The project is focused on establishing a new, smart parking strategy for Copenhagen aiming at optimizing the parking space usage, improving the efficiency of parking operations and help traffic in the city flow more freely. Several technological solutions already exist within private parking companies that allows the users to pay using an app and/or guide the user to a parking house with empty spaces. However, a more comprehensive solution that includes all parking spaces in the city on a common platform does not exist.

PROJECT PURPOSE:
The purpose of this project is to propose a frame for a common, comprehensive platform that aims at improving the issues above. In this respect it will be necessary to consider both current technological options and governance issues related to such a task. The smart system will need to work in an environment with many stakeholders as well as political barriers. A key issue will be to propose a system that can mediate between the different interests of conflict.

PREREQUISITES:

NUMBER OF STUDENTS: 1-2 MSc students (30-35 ECTS Credits).
The feasibility of Molten Salt Reactor technology in ship propulsion (MSc)

PROJECT SUPERVISOR: Associate professor Michael Bruhn Barfod (mbba@dtu.dk), Researcher George Panagakos (geopan@dtu.dk)

BACKGROUND: Nuclear power can become a game changer in marine propulsion not only due to its superior environmental characteristics (zero-CO2 fuel) but also due to important operational features (no need for ships to refuel or carry bunkers). However, a skeptical public that cites concerns with waste handling, safety, nuclear weapons, and costs hampers the widespread use of nuclear fuels. The Molten Salt Reactor (MSR) is a new non-conventional nuclear technology that sufficiently addresses these concerns.

PROJECT PURPOSE: The bibliography on the viability of small modular reactors is very thin. It is even thinner when it comes to marine applications and the MSR technology. The industry is keen to be informed on the potential applications and prospects of this alternative. The project intends to address this need.

PROJECT DESCRIPTION:

The project will:

• undertake an exhaustive literature search on the subject
• identify all public concerns on the use of nuclear power for marine propulsion
• assess the potential that MSR technology exhibits in addressing these concerns (on the basis of information provided by SEABORG – a Danish company specializing in this field)
• quantify operational benefits and costs associated with MSR applications
• draw recommendations to all stakeholders involved (e.g. ship operators; marine equipment manufacturers; governing institutions; research community; general public)

PREREQUISITES: 42879 Decision support & Risk analysis.

NUMBER OF STUDENTS: 1-2 MSc students (2 projects of 30-35 ECTS Credits).
Sustainable highway rating systems – a comparative analysis (MSc)

PROJECT SUPERVISOR: Associate professor Michael Bruhn Barfod (mbba@dtu.dk)

BACKGROUND: There is increased interest in assessment frameworks and tools that can support an evidence-based transition towards a sustainable transport paradigm. In the US, frameworks such as the Federal Highway Administration Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) or The Sustainable Transportation Analysis and Rating System (STARS) are increasingly being used to assess transportation projects. Although one may challenge the concept of a ‘sustainable highway’, departments of transport (DOTs) in the US have been particularly keen to use such systems for highway and bridge projects. In the UK, the sustainability assessment, rating and awards scheme for civil engineering (CEEQUAL) serves a similar purpose. A previous DTU research project for the EU National Road Administration also proposed a Sustainability Rating System Framework (SUNRA).

The increasing number of such tools raises the question: how do they compare, and how strong is the level of sustainability they are likely to provide?

PROJECT DESCRIPTION: You will analyse existing sustainable transport assessment frameworks (minimum 2 of your choice) with regards to their strength and weaknesses. Your analytical framework will cover the conceptualisation, operationalization, and utilization of indicators. How does the framework connect to principles of sustainability? How were these principles translated into indicators? How is this evidence utilized in their context? Depending on the chosen focus between the three themes above, this comparative study will consist of mixed methods (desktop analysis, interviews with practitioners in targeted countries). You will use real cases to illustrate your analysis.

PROJECT PURPOSE: The purpose of this project is to analyse the strengths and weaknesses of existing sustainable transport rating systems with regards to their design and application in real life.

PREREQUISITES: 42879 Decision support & Risk analysis

NUMBER OF STUDENTS: 1-2 MSc students (2 projects of 30-35 ECTS Credits).
Inaccuracy in road transport infrastructure projects (MSc)

PROJECT SUPERVISOR: Associate professor Michael Bruhn Barfod (mbba@dtu.dk)
EXTERNAL ADVISOR: Risk Manager Trine Holst Veicherts, (Danish Road Directorate) (thv@vd.dk)

BACKGROUND: Recent research has proven that construction costs are embedded with substantial degrees of uncertainty, which ultimately can lead to wrongful input to decision support models.

PROJECT DESCRIPTION: Currently, the Danish Road Directorate possess information with regard to construction costs within a large database system. This project seeks to investigate and assess the data material within the database in order to benchmark estimated costs against realized costs for road projects.

PROJECT PURPOSE: The purpose of this project is to structure, validate and verify the huge amount of data within the database and hereby to investigate whether there in fact is bias in the estimating of construction cost within road transport projects.

PREREQUISITES: 42879 Decision support & Risk analysis

NUMBER OF STUDENTS: 1-2 MSc students (2 projects of 30-35 ECTS Credits).
Sustainable Decision Support: Sustainable transport and infrastructure planning (MSc)

PROJECT SUPERVISOR: Associate professor Michael Bruhn Barfod (mbba@dtu.dk)
PROJECT ADVISORS: Professor Steen Leleur (stle@dtu.dk)

BACKGROUND: There is a growing focus on sustainable transport planning in order to reduce CO₂ emissions as well as congestion. This is a global focus which has to be dealt with locally, thus implying challenges in defining the main planning objectives.

PROJECT DESCRIPTION: The project can either take its starting point in a specific case of transport or infrastructural planning or in the development and testing of an assessment methodology. It should consider the different structural and sectorial frameworks related to the planning process and thereby approach the problem of defining and assessing sustainability within infrastructural planning, which so far remains unsolved.

PROJECT PURPOSE: The purposes of this (these) suggested project(s) are to clarify potential obstacles for the implementation and realization of a sustainable transport network as well as to present a possible assessment and evaluation method for advancing and encouraging sustainable development within transport and infrastructural planning.

PREREQUISITES: 42879 Decision support & Risk analysis.

NUMBER OF STUDENTS: 1-2 MSc students (2 projects of 30-35 ECTS Credits).

NB! A smaller version of the project can be aligned to suit both BSc and BEng student theses.
Projects at Banedanmark (Rail Net Denmark)

The following project proposals, submitted by colleagues at Banedanmark, are based on areas of research that are currently of relevance to the organization and could serve as interesting student research projects. Students are more than welcome to share their own project proposals, if they have other creative ideas for how to support the development and operation of a safe, attractive and effective railway in Denmark!

Contact information for all projects:
Project Supervisor, DTU: Associate Professor Steven Harrod (stehar@dtu.dk)
External Supervisor, Banedanmark: Supervisors from Banedanmark will be assigned to individual projects. Contact Banedanmark’s Capacity Development group for more information (kapacitetsudvikling@bane.dk)
1. New connection from Zealand to Jutland across the Kattegat Bay

Description
Politicians have proposed the construction of a new connection over the Kattegat via Samsø. If such a connection is built with railway, it will offer the opportunity to significantly alter the design of the Danish railway map. A fixed Kattegat link will require new railway infrastructure on both sides to connect the link with the existing network. This infrastructure can be designed with varying levels of complexity and size. For example, on the coast of Zealand, a new railroad can be built all the way to Holbæk, parallel to the existing line, or “just” to Kalundborg, where it can be connected to the existing railway network.

If the railway link becomes reality, this type of change to the main channels through Denmark will have a significant impact on rail traffic across the country. There is a large interest in understanding the opportunities that this will provide for operating passenger train traffic in Zealand, Fyn and South Jutland, as well as, how freight traffic may be impacted throughout the country.

Project objective
The goal of this project is to rethink the line structure of the train network and to test your creative solutions by performing a timetable analysis where all possible solutions are evaluated with respect to predefined parameters or performance indicators. The assessment can also include:

- modeling of passenger behavior and passenger potential
- socioeconomic analysis
- project engineering, design and price setting for new infrastructure solutions

Expected qualifications
Basic knowledge of railway traffic and technology is necessary. Experience with microsimulation software will be beneficial. Additional specific qualifications will depend on the full scope of the project.
2. New bridge or tunnel connection between Helsingør and Helsingborg

Description
For many years, there has been interest in building a bridge or tunnel between Helsingør and Helsingborg to better connect the northern parts of the Skåne region in Denmark and Sweden. Multiple infrastructural solutions have been proposed and evaluated through various forms of project assessment.

The goal of this project will be to revisit this idea of a connection between Helsingør and Helsingborg from the perspective of the Danish railway.

The specific components of the project could include:
- Investigating earlier research and relevant reports in the form of a literature search
- Developing one or more proposals for an H-H railway connection that consider both the technical feasibility of the project, as well as, its wider socioeconomic implications
- Evaluating the traffic-related consequences of the implementation of the connection on the Danish railway network
- Using decision support tools and methodologies to assess the socioeconomic costs and benefits of the project
- Presenting your results in the form of a report and presentation to colleagues in Banedanmark

Project objective
The goal of this project is to describe the design-concept of the proposed H-H connection(s), the applied methods for project assessment and the final results of the analysis. The assessment can be based on the traffic-related consequences alone, or it can be extended to also include wider socioeconomic and strategic considerations.

Expected qualifications
Knowledge of railway traffic and technology is preferred. Experience with microsimulation software will be beneficial, but is not necessary. Knowledge of project assessment and decision support is only necessary if that will be included in the scope of the project.
3. Ny Ellebjerg: The new central station

Description
Copenhagen central station has become a bottleneck in the Danish railway infrastructure. There are many restrictions when planning the timetable and this results in suboptimal operations. Therefore, there is a need for finding ways to relieve the central station. One possibility is to reroute some of the long-distance trains from the central station to other stations, such as Ny Ellebjerg station. It could be possible to use Ny Ellebjerg as an end station and/or continue the trains to Copenhagen airport. Ny Ellebjerg is currently connected to the S-train network and in the coming years, it also will be connected to the metro network. This means that there will be good shifting possibilities here.

Passenger demand modeling and analysis could also be incorporated into the design and evaluation of alternative solutions. Copenhagen central station currently functions as a large hub-station and there are many passengers who travel through it enroute to another destination. Therefore, it is possible that by rerouting of some lines through a station like Ny Ellebjerg, the level of service could also be improved such that it matches the demands of the passengers.

There are also possibilities for changing the construction of the timetable in other ways or for identifying and/or designing necessary or useful infrastructure extensions.

Project objective
The project is expected to deliver a description of different timetable variants, which can relieve Copenhagen Central station and upgrade Ny Ellebjerg to a second hub-station in Copenhagen City. It should also include an analysis of the impact on travel times and a simulation of the timetable variants under various delay scenarios. It is also possible to expand the project to include passenger demand analysis and/or suggestions for necessary infrastructure upgrades to Ny Ellebjerg station.

Expected qualifications
General knowledge in rail traffic and technology is necessary. Experience with rail traffic microsimulation is desirable. Experience with traffic demand modeling and analysis could also be useful, if that will be included in the scope of the project.
4. Designing the optimal layout of major stations in Denmark (Aarhus, Fredericia and Aalborg)

Description
Operations at large rail stations are rather complex and include, among other things, the following movements:

- Train arrival, passenger boarding and alighting, train departure
- Train journey end or beginning at the station
- Direction reversal due to the track layout of the station or at a network level
- Variation of train composition, where parked rolling stock is adapted in length to the following service
- Coupling and/or decoupling of train units with different origins/destinations
- Shunting movements between platform tracks and depot tracks and/or to workshop facilities

The complexity of rail operation at stations is further complicated when different railway undertakings operate simultaneously. In fact, every operator has different desired movements and operations that should be coordinated in a global perspective.

The possibility to plan rail operations at a station depends on different factors:

- Track layout: what possibilities for movements are allowed at a given station, and at what speed?
- Platform tracks: number and functionality (max train length, possibility for coupling/decoupling, etc.)
- Safety system: what types of operations can be handled automatically and what type require manual intervention?
- Rolling stock characteristics: length, acceleration and braking performances, etc.
- Timetable: what service intentions are requested by the railway undertakings?

Banedanmark, as Infrastructure Manager, wishes to expand the network to best accommodate its customers’ current and future needs and desires. To achieve this, the flexibility of the infrastructure should be improved. However, all infrastructure projects are subject to the economic constraints defined by the acting political authorities.

Project Goal
The project deliverables are expected to include a review of the design parameters for a given railway station based on investigation of the rail operations that should take place at the station. Analytical and optimization-focused approaches to operations should return the design parameters for the layout of a future-proof-station, which can handle the expected increases of traffic. The project should present a reasoned layout for the given station and a cost estimate for the necessary infrastructure investments. Other project deliverables can be included according to the definition of the scope of the project.

Expected Qualifications
Knowledge of railway traffic and technology is necessary. Experience with microsimulation software is preferred.
5. Alternative utilization of Copenhagen central station

Description
The capacity utilization of Copenhagen central station is currently close to its upper limit and the traffic, in terms of both trains and passengers, is only expected to increase in the future. It is now necessary to solve the challenges in the traffic development at the largest station in Denmark to keep the rail operation robust and punctual.

The challenge can be tackled in different ways. For example, new infrastructure can be built to support new traffic relations. Alternatively, the S-bane network can be extended (e.g. to Roskilde or Helsingør) to reduce the traffic load on the main lines. Other options can possibly be studied.

Project target
An investigation of the previous studies about Copenhagen central station (e.g. from Trafikstyrelsen) is requested, together with a new, in-depth study of one - or more - possible solutions to increase the station capacity.

Expected qualification
Knowledge in rail traffic and technology is necessary. Experience with rail traffic microsimulation software is desired.
6. Separation of traffic at Copenhagen central station

Description
How can the utilization of Copenhagen central station be adjusted to improve the punctuality of the trains in the Danish network? This is a very hot-topic within railway management and operations right now. One approach that is currently being investigated is the separation of traffic at Copenhagen central station. There are many forms of separation, but specific inspiration can be taken from Tokyo and Utrecht stations, both of which have undergone significant infrastructural and operational transformations in recent years. In general, each railway line or traffic service utilizing the station has a dedicated platform and entry/departure routes which are unique to that service. This means that any disruption that occurs on a line will remain on that line and will not be transferred to other lines, as they are no longer integrated. However, it can also mean that there is less flexibility in the system and that infrastructural or mechanical breakdowns will have a more disastrous effect on the ability to plan and run trains around a disturbance. There are many implications and consequences that must be considered in evaluating whether the separation of traffic is a good idea for Copenhagen central station and the wider Danish railway network.

Project objective
The goal of this project is to evaluate which form of traffic separation is infrastructurally and economically feasible and is most beneficial for railway operations at Copenhagen central station and in the wider Danish network. It is possible to focus on the traffic-related elements of this analysis such as timetable design, platform occupation planning, capacity calculations and timetable simulations. It is also possible to investigate the design, construction and financial implications of the various infrastructural elements that would be required for implementing a concept of traffic separation at Copenhagen central station.

Expected qualifications
A knowledge of railway traffic and technology is necessary. Experience with microsimulation software will be beneficial. Experience with railway project design and management will be beneficial, if this will be included in the project’s scope.
7. Expanding the S-train network to increase passenger satisfaction

Description
The Copenhagen S-train network transports more than 350,000 passengers a day and therefore serves as the transit-backbone of the Copenhagen region. The popularity of the suburban railway network stems, among other things, from very high punctuality and frequency.

The network consists of six fingers branching off the central boulevard line between Dybbølsbro and Svanemøllen stations. This central section is operated by different lines with planned headway of 2 minutes in the rush-hour periods. The capacity utilization on the line is particularly high and thus is sensitive to conflicts in case of delays.

Banedanmark, as Infrastructure Manager, wishes to expand the network to best accommodate its customers’ current and future needs and desires. To achieve this, the flexibility of the infrastructure must be improved. Creative solutions are necessary for ensuring a feasible project that increases the attractiveness of the S-train, but does not generate disproportionately high socio-economic costs in the construction or operation phases.

Some possible solutions for expanding the s-train network include:

- New connections from Frederikssund to Carlsberg through the installation of a reversing track between Carlsberg st. and Dybbølsbro st.
- Extension of the Farum line (to Slangerup or beyond)
- Extension of the Høje Taastrup line to Roskilde
- Conversion of the Kystbane regional line (Helsingør – Østerport) to S-tog operation
- Construction of new halts on the existing lines
- Upgrade of the existing ring line (Hellerup – Ny Ellebjerg)
  - Longer platforms to accommodate longer trains
  - Higher frequency
  - Higher speed
  - New connection at Ny Ellebjerg towards Copenhagen Central st. or Køge
  - Reestablished connection at Ryparken to the Farum line
- Completely new ring line, e.g. between Vallensbæk and Lyngby via Glostrup and Herlev

If you have your own idea for how the attractiveness of the Copenhagen S-train network could be improved through an expansion of its infrastructure, we would love to help you devise a plan for designing and evaluating the feasibility and value of the proposed solution.

Project objective
The project deliverables are expected to include a detailed proposal for the s-tog network extension based on one or more combined solutions to increase the attractiveness of the network (better connectivity, higher frequency, shorter travel times, new or upgraded lines). The design of your solution(s) could be based on passenger demand modeling and analysis, if that is in line with your interests and qualifications. The project should present a robust operation plan with the supporting track alignment for the newly proposed or upgraded lines, including a cost estimation for the necessary infrastructure investments. As the project is multidisciplinary by nature, the proposal can be limited in sized to include a combination of track design (e.g. geometry, drainage etc.), electric traction supply design and traffic planning. The project can also include an assessment of the solution’s environmental and socio-economic impacts. If more than one solution is proposed, then the project could also be expanded to include a comparative analysis of the solutions using multi-criteria decision support tools. The project can also be delivered by a student group.

Expected qualifications
General knowledge in rail traffic and technology is necessary. Experience with software for rail traffic microsimulation, and/or railway design is desirable. Other qualifications will depend on the scope of the project.
8. Rethinking the current line structure of the Copenhagen S-train system

Description
The Copenhagen S-train network transports more than 350,000 passengers a day. Many of these passengers are commuters traveling between Copenhagen and the surrounding suburbs, but the system is also used as a local service. How does the current S-train system satisfy these competing passenger demands? Could the existing stations along each line be serviced differently in order to better satisfy passenger demands?

Would you be interested in investigating these questions, finding innovative solutions and evaluating the subsequent traffic-related consequences of one (or a combination of) your ideas?

If the answer is yes, then Banedanmark’s Capacity Development group would like to help you formulate and carry out a project that is interesting to you and relevant for the future planning of the Danish commuter railway.

The specific requirements of this project could include:

- Formulating a focused research question and a complete research plan
- Using railway planning and microsimulation software to design possible timetables and to evaluate their expected performance and robustness
- Comparing various service concepts to determine which solutions could be applied in the future
- Presenting your results in the form of a report and presentation to colleagues in Banedanmark

Project Goal
The goal of this project is to deliver a report which describes possible scenarios for restructuring the lines on Copenhagen’s s-train and addresses the traffic-related consequences of these proposed scenarios. Additional elements of project evaluation and decision support can be included in the project, as well.

Expected Qualifications
Knowledge of railway traffic and technology is necessary. Experience with microsimulation software is preferred.
9. Designing a “real” express train through Denmark

Description
There is growing interest in creating faster railway connections between big cities. A faster connection can be realized by different actions; this could include speed upgrades, building new infrastructure or adjusting the timetables to optimize the travel time between specific origin-destination pairs. A political decision has been made to build new infrastructure and implement speed upgrades throughout the network to provide faster connections between the biggest cities of in Denmark. However, these infrastructure projects have been put on hold. Therefore, it is necessary to look at the timetables. In Denmark, there is a product called the “Lyntog”, which is intended to be a high-class product and should be the fastest, direct connection between the 4 biggest cities in Denmark. However, it is only from Copenhagen to Fredericia that it actually is a faster alternative than the Inter-city trains. From Fredericia to Aalborg, it’s stopping pattern and timetable is comparable with a regular regional train, with stops at nearly every station. If the product is redesigned as a truly express and direct service between Copenhagen, Odense, Aarhus and Aalborg, the travel times between these cities could be drastically reduced. However, this will also likely have consequences for the capacity on Denmark’s mainline and thus will also require adjustments to the other services running throughout the country.

Project objective
The project should include an investigation, design and proposal of different line structures, which could make national train operations more attractive in Denmark. It is necessary to consider the potential time-savings benefits for passengers using this improved service, as well as, the changes required to the rest of the timetable and the consequent negative impacts to the other passengers traveling in the network. It would also be possible to investigate where there are bottlenecks or to identify areas in the existing infrastructure that could be important to upgrade.

Expected qualifications
General knowledge in rail traffic and scheduling is necessary. Experience with rail traffic microsimulation is desirable.
10. Optimizing the regional railway traffic plan in Mid-Jutland based on passenger demand

Description
Today there is a high number of commuters in the region of Mid-Jutland. It is a region in development and is home to many large companies. However, the majority of these commuters opt to travel by car instead of by train. Is it possible to take these commuters out of the cars and into the trains by making railway transport more attractive? Could a new timetable support this movement?

Today, it takes 1 hour and 30 minutes to get from Esbjerg to Vejle by train, whereas it takes 1 hour with by car. Moreover, the train only runs once per hour. Is it possible to make a more attractive timetable in this area by decreasing travel times, increasing frequency and, thus, increasing the level of service?

Project objective
The objective of this project will be to analyze transport demand (i.e. to find out where big companies are located and where their employees are traveling from), and then to propose a solution which raises the transport supply to match this demand and includes a feasible and attractive timetable which will help support the goals of increasing the number of train commuters in the region. A feasible timetable must fulfill requirements of the official traffic contract and fit with the rest of the national traffic plan.

Expected qualifications
General knowledge in rail traffic and technology is necessary. Data analysis and mathematical modelling are particularly relevant, as well. Experience with rail traffic microsimulation is desirable.
11. Planning the future regional railway traffic on Zealand based on passenger demand

Description
In the coming years, a large portion of the railway infrastructure on Zealand will become electrified. This includes the railway segments between Ringsted and Nykøbing Falster, Roskilde and Kalundborg, and Køge Nord and Næstved. This will make it possible to design and operate regional railway traffic in a new way, as it will reduce the restrictions created by mismatches in the infrastructure on different lines and the rolling stock used to service those lines.

Project objective
The goal of this project is to study the flow of passengers on Zealand and to use this information to propose possible line structures and operational timetables that best satisfy the needs and desires of these passengers. These line structures and timetables can be evaluated and compared through traffic analysis and an assessment of their expected performance in situations of disturbance using microsimulation. If relevant, it could also be possible to use the National Traffic Model (LTM) to model passenger flows for each timetable and/or to incorporate socioeconomic analysis into the assessment process.

Expected qualifications
Basic knowledge of railway traffic and technology is a requirement. Familiarity with timetable planning or microsimulation tools could also be beneficial. Further qualification requirements depend on how the scope of the project is defined.
12. Attractive railway solutions for the corridor Stockholm – Copenhagen – Hamburg

Description
Big investments in railway infrastructure have been made to enable and promote international railway traffic. Some examples of this are the fixed Øresund and Great Belt links, as well as, the future Fehmarn Belt tunnel. These projects will enable an international railway corridor between Stockholm, Copenhagen and Hamburg. Until now, the focus has been primarily on freight traffic, but passenger traffic is beginning to gain more attention in the design, implementation and operation phases of these projects.

The classic competitiveness parameters between transport alternatives of travel time, frequency, direct connections and price will play a decisive role if international passenger railway traffic is to see progress in the future.

Attractive railway solutions demand new timetable concepts with related railway infrastructure upgrades that enable traffic improvements, such as increased line speeds and new overtaking opportunities, as well as, rolling stock upgrades that enable higher maximum speeds and better acceleration performance.

How can we design a railway product that is attractive for passengers traveling between these European mega-cities such that they choose railway over other available transport alternatives?

Project goal
The project should contain one or more timetable concepts for international train traffic to/from Denmark. This covers both freight and passenger trains. The proposed timetables must be feasible and conflict free. New requirements to infrastructure and rolling stock must be described and be evaluated economically.

Expected qualifications
Knowledge of railway traffic and technology is necessary. Experience with railway simulation and planning software is recommended.
13. Better and faster freight channels through Denmark

Description
Today, freight trains run through Denmark in both national and international freight corridors. These corridors are often slow, because they are planned with many stops to allow faster passenger trains to overtake them.

There is a fair amount of stations on the main corridor from Sweden to Germany with infrastructure sufficient for the overtaking of freight trains. However, the freight traffic is expected to increase in the coming years and this will also increase the pressure on these overtaking stations, thus creating a demand for either expanding the number of overtaking stations or for constructing faster channels, so less overtaking is needed.

Project Objective
The primary objective of this research project is to analyze the current shortcomings of the railway infrastructure network in terms of freight and passenger traffic interactions and to identify possibilities for improving the railway operations by expanding the infrastructure to include, for example, new overtaking opportunities.

The project can be defined as a timetable study describing different scenarios with or without new infrastructure. Alternatively, a study can be made on how to handle delayed freight trains so that they affect other traffic as little as possible – again, with or without new infrastructure.

Expected qualifications
Knowledge of railway traffic and technology is necessary. Experience with railway planning software is an advantage.
14. Optimal capacity allocation: What is best for Banedanmark?

Description
Banedanmark distributes its network capacity to railway operators according to their requests, which are largely based on the traffic contract they have with the Ministry of Transport, Building and Housing. These requests are not always aligned in a way that supports the creation of a timetable satisfying the objectives of all stakeholders. During the process of designing the yearly timetable, planned train paths are allocated to operators following capacity analysis and a validation of their ability to uphold the expectations for robustness and punctuality.

As Banedanmark is responsible for the distribution of the capacity on their railway network, it is also Banedanmark that handles the application process and therefore can define the specific criteria used to determine the optimal distribution and allocation of capacity and train paths through the network.

Project objective
In this project, you will be expected to evaluate whether it is possible to distribute paths in a different way than is currently done today. The objective is to find a method of capacity allocation that allows for the design of a more robust timetable with respect to punctuality. If the operators’ requests in relation to the current traffic contract are ignored, is it possible to develop an optimal timetable with respect to capacity usage and service frequency?

Expected qualifications
Knowledge of railway traffic and technology is necessary. Experience with microsimulation software will be an advantage.
15. Optimizing the block section lengths on railway lines

Description
As part of the Signaling Program, Banedanmark wants to optimize the block sectioning on the railway network. The optimization depends on several parameters, such as:

- Line speeds: The speed profile for a given line section
- Number of trains: How many trains must be able to run on the line section simultaneously?
- Mix of trains: The mixture of fast and slow trains e.g. InterCity Express (Lyntog), IC-trains (IC-tog), regional trains (Regionaltog) and freight trains
- Track layout: Placement of stations and their functionality, such as passing loops
- Signaling system characteristics: Braking curves, possibilities to update the train driver
- Train characteristics: Length, weight, brake settings and maximum speed

Project goal
The project should contain a thorough description of how signaling/interlocking systems work and, as part of this, the use of block sections on the railway. A presentation of which parameters influence the finding of an optimal block sectioning and how they affect a solution is required. It may be necessary to prioritize between these design parameters. The project should suggest such a prioritization and explain the reasons for this. The proposed design must ensure a future-proof block sectioning. If an analytical approach is used for assessing the operations, the optimization model must take the selected design parameters and their prioritization into consideration.

Expected qualifications
A certain knowledge of railway traffic and technology is necessary. Experience with railway simulation and planning software is recommended.
16. Timetable evaluation and comparison using decision support methodology

Description
In planning the future of the Danish railway, Banedanmark investigates many different scenarios of how the railway infrastructure will, or could, look in the future. It is critical that the traffic-related implications of each scenario are fully understood and evaluated to ensure that all future investments or developments support the goal of delivering the best possible service to railway customers and users.

The analysts in Banedanmark’s Capacity Development group use planning and microsimulation tools to investigate the traffic-related consequences that will be expected to follow proposed changes to the railway infrastructure or operation strategies. Once feasible timetables are created for all relevant scenarios, their performance in the case of small, regular delays is simulated to see how robust each timetable is to these types of expected delays. It is often important to be able to compare how different timetables will perform in future scenarios, but it is not always possible to carry out a direct and fair comparison of different timetables when they are created with respect to different basis assumptions. There are several useful KPI’s (average delay, punctuality, etc.) that are used to measure a timetable’s performance, but there is often a need for incorporating more information about, or implications of, each scenario or timetable into the evaluation process. This is especially true when the evaluation includes the comparison of multiple timetables built to fulfill multiple, varying objectives.

For these reasons, finding alternative methods that can be used to compare timetables and consider a timetable’s performance with respect to multiple criteria, is of large interest to the analysts and planners at Banedanmark.

Project objective
The objective of this project will be to investigate various methods or tools in the decision-support literature and their applications in the planning and analysis of the railway of the future.

Your tasks will include:

- Performing a literature search within the research area of decision support
- Meeting with various stakeholders in the planning process to understand which criteria are, or could be, important in the evaluation of timetables
- Working together with the planners and analysts to understand how the timetables are designed and to get to know the various tools that are used to collect data for the evaluation of a timetable’s structure and performance
- Investigating how the methods you identify in the literature could be used in practice to evaluate and compare timetables
- Presenting your findings in the form of a report and possible presentation

Expected qualifications
Knowledge of decision support theory and practice is necessary. Knowledge of railway traffic and technology, and experience with microsimulation software is beneficial, but is not necessary.
17. Robustness and Punctuality

Description
Banedanmark’s performance is measured, among others, on the customer punctuality. Customer punctuality is Banedanmark’s most visible end-product, which affects the largest audience (passengers and freight customers). Punctuality measures the percentage of arrivals recorded with less than 3 minutes delay from the scheduled arrival time. To calculate passenger punctuality, the train punctuality is weighted with the number of passengers traveling in the train.

The capacity allocation process is based on diverse indicators of the robustness of the timetable. Several scientific articles investigate different methods and measures to forecast the timetable’s tolerance of primary delays and the possibility to absorb disturbances. Robustness and punctuality are inherently intertwined, but their exact relationship is not clearly defined.

From the planner’s point of view, it is important to evaluate how possible changes to the timetable will affect the realized customer punctuality and/or passenger punctuality.

This project should produce a model to forecast the passenger punctuality, in absolute terms or as a range, given input of infrastructure, rolling stock, timetable, historical records and other types of data from operation.

Project objective
The project is probably large enough to motivate a PhD research project. The objective is to produce a model that actually can be used in operations, and not only focused on the theoretical insight.

Expected qualifications
General knowledge in rail traffic and technology is necessary. Data analysis and mathematical modelling are particularly relevant, as well. Experience with rail traffic microsimulation is desirable.
18. Algorithm for train-level delay predictions

Description
The performance of the Danish railway is often measured and assessed by the average delay of all trains in the network. There are some train systems which perform significantly worse than others and therefore drag this KPI value down for the entire network. Some systems are more susceptible to secondary delays, which arise when trains are planned close enough to each other so that the delay of the first train results in the second train also being unable to follow its original timetable. Therefore, there is a large interest in being able to identify these delays and their causes and, furthermore, to use this knowledge to predict future delays. These insights could be used by Banedanmark to adjust planning strategies and reduce the spreading of delays, thereby improving the operation of railway traffic with respect to punctuality.

The project will include the following tasks:
- Familiarize yourself with Banedanmark’s databases and data systems
- Work with the various data which is available to investigate the relationship between relevant parameters and the delays or punctuality of the trains in the Danish network
- Develop an algorithm to predict train-level delays
- Present the results of your analysis in the form of a report and possibly a presentation

Project objective
The objective of this project is to develop an algorithm which predicts future train-level delays under a set of predetermined assumptions and input parameters. This algorithm, its input requirements and its expected application or usefulness in Banedanmark’s long-term planning of the Danish railway should be presented in the form of a report and possible presentation for colleagues in Banedanmark.

Expected qualifications
Familiarity with data management, data analysis and mathematical modeling are necessary. Basic knowledge of railway traffic and technology is preferred.
19. Planning optimal infrastructure maintenance schedules for large machinery using OR

Description
Part of the maintenance of rails includes actions such as by grinding, milling and planing. This maintenance work can be used to correct smaller faults such as developing cracks or narrowing gauges before these errors turn fatal and the rails must be fully replaced. This type of maintenance work requires specific heavy machinery, which is hired by Rail Net Denmark, along with its crews, from private companies. The period of hire can vary from a few days to several months.

These types of infrastructure faults are detected by operating a measurement vehicle on the railway tracks. The measurement vehicle collects data, which can be used to identify any faults in the rails and their severity. The order of maintenance actions is then determined based on a set of parameters and objectives, including:

- Most possible maintenance actions in the time-period the heavy machinery is available
- Timetabled train traffic operations should be affected as little as possible
- Working time rules for the machine crews must be respected
- The heavy machinery must not be present on main tracks when the rush hour begins

Project goals
The result of the project should be a mapping of relevant planning parameters and an optimization model which can provide a three-month schedule for the use of heavy maintenance machinery. To be able to develop such a model that can be used in practice in Banedanmark, it also will be necessary to identify all data, information and planning tools that are available internally in Banedanmark or from other external partners.

Qualifications
This project contains elements of planning and optimization. Therefore, it is expected that the student(s) has/have experience in the field of operations research (OR). Furthermore, it is an advantage to have a basic knowledge of railway operations and railway timetabling as well as SQL, MS Excel and programming.
20. Coordination and optimization of Banedanmark’s projects and maintenance work

Description
Can Banedanmark use their money more effectively? Banedanmark has a lot of maintenance and infrastructural development projects to plan, manage and perform every year. These tasks must be coordinated with each other, as well as, with the ongoing daily operations of the railway. Ideally, all infrastructure work would be able to be performed as quickly as possible, as cheaply as possible and in time periods when the infrastructure is not in use and therefore without any consequences for the customers in daily operation. However, it is not possible to achieve all of these objectives simultaneously, thus making complex planning, management and coordination work essential.

Despite planning and management efforts in recent years, many of Banedanmark’s projects have exceeded their budgets. Why is this? It is clear that improving the planning of Banedanmark’s projects and maintenance work is necessary if all future budgets are to be met. But how can this be achieved? Can any inspiration be found in the literature or from other companies with similar challenges, either within railway or in other fields? Is it possible to use a mathematical approach to maintenance, so that Banedanmark can become more effective in their approach to planning both short-term and long-term maintenance work?

Project objective
The project is expected to include an assessment of Banedanmark’s challenges with planning infrastructure development projects and maintenance work and an identification of ways that Banedanmark can ensure that they can get the most out of their limited budget by improving the coordination of project and maintenance work, increasing the efficiency of all work, reducing potential risks or delays and, thus, reducing individual and overall project and maintenance costs.

This project can be defined more specifically according to the interests and competences of the student. For example, the project can include aspects of economic analysis, strategic planning, project management, operations research, risk management, traffic analysis or other forms of mathematical analysis.

All applied research and analysis methods should be outlined in the report and presented along with the results of the analysis and any final conclusions and recommendations.

Expected qualifications
Data analysis and mathematical modelling are particularly relevant. Experience with rail traffic microsimulation could also be beneficial. Other qualifications will depend on the project scope.
21. Risk analysis and budget planning for Banedanmark’s infrastructure projects

Description
Banedanmark is the biggest infrastructural developer in Denmark, when both the number of projects and the size of these projects are considered. Therefore, budget planning is incredibly important for the financial success and stability of the organization. It is crucial that budgets are planned accurately because one seemingly small deviation within a project can result in drastic financial consequences when the project scope and thus, the project budget, is very large. Risk will always be inherent in any construction project, but minimizing this risk is essential for accurate budget planning. Therefore, risk management and minimization is of utmost importance to Banedanmark’s project managers and administration.

Project objective
The goal of this project is to assist Banedanmark in becoming champions in risk analysis and project management. The project could start with a review of relevant literature, as well as, hands-on research into the current planning practices used at Banedanmark. These initial investigations could then serve as the basis for your own design of creative, new solutions to risk management which could be applied in Banedanmark to help ensure accurate budget planning and project management in the future. All methods and findings should be delivered in a comprehensive report.

Expected qualifications
Experience with risk analysis and project management is desirable. General knowledge in rail traffic and technology is desirable. It could also be useful to have knowledge in economics, mathematical modeling and/or data analysis.
22. An analytical review of the train departure procedure

Description
The departure procedure for all long-distance trains operating on the Danish railway network has been changed to follow the process illustrated below. This procedure has been designed in collaboration with DSB. The question is: Is this the best procedure when it is looked at from Banedanmark’s perspective?

Could the procedure be improved to better satisfy the objectives of Banedanmark? How do other infrastructure managers regulate the departure procedures on their networks? Can we learn something from them?

A simpler standard for departure
In Spring 2018, a large survey of the locomotive drivers and train, preparation and traffic control personnel was conducted. There was a very useful response, which resulted in the design of a simpler departure procedure.

- The steps have not changed, but there are now less steps with exact timestamps. This gives the locomotive and train drivers more freedom to make a natural and dynamic departure.
- The time for signal setting has moved from 90 sec. before departure to 60 sec. before departure. This gives traffic control more flexibility to dispose the traffic.
- The only exact timestamps are now at seconds 60-15-0 for signal, last door and departure times. Besides this, the train should also always arrive 5 min before departure if it comes directly from preparations and therefore starts its journey at that station.

Project objective
The project deliverables should include a comparison of the former and new departure procedures, a description of the pros and cons of the new departure procedure and an investigation into how other European countries manage the departure procedures on their networks. Depending on the results of the initial analysis, proposals for how the procedure could be improved could also be included in the project.

Expected qualifications
Basic knowledge in rail traffic and technology is necessary. Experience with stakeholder management, strategic planning, process management and data analysis could also be relevant.
23. Optimizing the process of planning the yearly timetable

Description
Banedanmark is the primary railway infrastructure manager in Denmark and is the governing authority responsible for distributing railway capacity to operators. Each year, Banedanmark publishes a yearly timetable in which all operators are allocated planned paths through the railway network. The operators plan their services according to the available paths through the network, the minimum requirements of their traffic contract with the Ministry of Transport, Building and Housing and their own financial incentives. The full planning process includes various deadlines and demands for how operators apply for railway capacity on the Danish network and thus how the capacity is ultimately allocated. These application guidelines and deadlines are structured to promote an effective dialogue and exchange between the operators and Banedanmark. The full process is approximately one year long and spans from December to December, when the new yearly timetable goes into effect.

Project Objective
The objective of this project is to critically examine the planning and design process of the yearly timetable. Is it possible to follow a different or smarter process, or can the process be optimized in some way? There are currently many changes made to the yearly timetable in the months between the official allocation of capacity and the timetable’s official release. This creates a chaotic and reactionary last-minute planning process. Is it possible to restructure the full process to strengthen Banedanmark’s authority and role in the process and, ultimately, to ensure that the process is proactive and results in reliable and robust timetables that provide a higher level of service to the users?

Expected qualifications
A knowledge of railway traffic and technology is advantageous. A solid command of process management, particularly within the public sector, is necessary.
24. Opening the rail market: More operators on the rail network

Description
The railway transport in the European Union is undergoing a major reform. Since 2001, several rule packages have been introduced to build a common European railway network. The objective is to increase the railway efficiency and transparency, reducing the operating costs and improving the attractiveness for both freight customers and passengers. The rail market is gradually being opened to competition. The international rail transport market has been open since 2010 and the last European resolution from EU (2016) requires that, from 2020, all operators should also be allowed to operate domestic traffic in competition. This so-called fourth rail package therefore introduces an extensive change in the way transport contracts are designed and operated, and consequently in the way the timetables are planned.

Banedanmark, as Infrastructure Manager, has the role to receive and coordinate all the requests from the operators, which are possibly conflicting with each other. The Infrastructure Manager should produce a robust, conflict free timetable, evaluating and negotiating modifications to the capacity slot requests received from the operators.

Challenges with regards to the current rules can be, for example:

- How the requests from different operators are prioritized, in case of conflicts
- With regards to long term traffic analyses, how the capacity development should be evaluated when different operators are planned to operate the same routes. What should be included in the analysis in addition to the line capacity? Is the flexibility between different operators an added value? How to forecast the number of capacity slots requests under the competition model?
- In operation, how should trains of different operators be evaluated in case of delays and unexpected conflicts?

Project objective
The project deliverables are expected to include a mapping of the current Danish market condition and timetabling process. In the Danish regions where competition is already in place, how is the transport managed: is it tendered out or on a market scheme? (Examples of current multiple operators operating tendered services are Arriva transport in Jutland, Lokalbanen on the line sections Snekkersten-Helsingør, and Aalborg-Skørping). How does the current market condition affect the capacity planning process? The process should be evaluated in relation to its adjustment to fit the new rules. How should requests from different operators be considered in the capacity phase? Possible challenges in the process should be evaluated and solutions should be proposed.

Expected qualifications
General knowledge in rail traffic and transportation rules is necessary. Experience with, or significant interest in, market analysis and economics is necessary.
25. Privatization of Banedanmark

Description
Banedanmark currently has a monopoly over the Danish railway as the infrastructure manager and is financially subsidized by the Danish government. In many countries around the world, railway infrastructure is managed privately without government subsidy. In Japan, the railway industry is completely privatized, meaning that both the infrastructure and the operations are managed and run by private institutions. England has also attempted to establish a similar system with a privatized infrastructure manager, but with less success. They were forced to shift back to a government-supported business model to satisfy the economic demands of maintaining their railway infrastructure. There is a widespread interest in understanding if and how RailNet Denmark could be run as a self-sufficient, private organization. Is this possible and what would it take to do it successfully?

Project Objective
The goal of this project is to address the following questions:

- What would it take to successfully privatize the management of the Danish railway?
- Would there be enough economic incentive for private management, maintenance and operation of the Danish railway infrastructure?
- What would this look like from an organizational perspective?
- What would a potential contract between the Danish state and a private company look like so that a sufficient level of service is maintained for citizens in all corners of the country?
- How will this contract encourage economic competition and incentivize operators to bid on traffic contracts or packages?

Expected qualifications
Knowledge of railway traffic and technology is beneficial. A command of process management and public governance is necessary. An understanding of economics and legislature could be very useful, but the exact scope of the project can be defined after individual interests and competences.