AØO fordypningen høsten 2023

Anvendt økonomi og optimering - fordypning

Fordypningstilbudet til studentene er en spesialisering innenfor økonomisk analyse og optimering som hovedsakelig er rettet mot industrielle og teknologiske anvendelser. De som velger denne fordypningen må velge både emnene og prosjektet som hører til fordypningen. Studentene spesialiserer seg ofte innenfor følgende temaer: bedriftsøkonomisk analyse, modeller og verktøy for å styre og koordinere industrielle verdikjeder, selskapsmodeller for analyse og styring av industrikonsern, økonomisk optimalisering av industrielle prosesser, transportoptimering, logistikk, analyse og beslutningstøtte rettet mot energimarkedene, etc.

Fagområde:

De aktuelle veilederne underviser og forsker innenfor

- Bedriftsøkonomi,
- Industriell økonomi,
- Optimering/operasjonsanalyse.

Vi fokuserer spesielt på tverrfaglig forskning som involverer flere av disiplinene over. Vi fokuserer på forskning og undervisning rettet mot industrielle og teknologiske anvendelser.

Mulige veiledere:

- *Professor Henrik Andersson, e-mail: henrik.andersson@ntnu.no*
  I work with developing optimization models and solution methods for different industrial applications. I have worked on applications within transportation and logistics, healthcare and emergency response among others. My main research focus is on exact methods and matheuristics, but I also like to mix this with machine learning and artificial intelligence. I have been at IØT since 2007 and have supervised more than 50 student groups.
- *Førsteamanuensis Steffen Bakker, tlf. 92 14 54 29, e-mail: steffen.bakker@ntnu.no*
  Jeg jobber med å anvende ulike kvantitative metoder (heltalls-/dynamisk-/stokastisk programmering, realopsjoner, økonometri) på problemstillingene som er relevant for industrien/samfunnet. Anvendelsesområdene ligger som regel i grensesnittet mellom transport- og energisystemer. Jeg har en doktorgrad i industriell økonomi / operasjonsanalyse, samt en mastergrad i økonometri, og har både veiledet og undervist på INDØK-studiet.
- *Førsteamanuensis Peter Berling: e-mail: lars.p.berling@ntnu.no*
  In my research I work on developing models and methods to support operational and tactical decision making under uncertainty and risk. A special focus has been devoted to inventory control and the interface between operations and finance, but it also includes research on related fields such as transportation and contracts. I have been at IØT since the summer 2021 and have previous experience from Lund and Linnaeus University as well as MIT/ZLC.
- *Førsteamanuensis Pedro Crespo del Granado, tlf. 458 49 710, e-mail: pedro@ntnu.no*
  Han jobber i skjæringspunktet mellom energiøkonomi, energiomstilling, kraftsystemer, operasjonsforskning, AI (Model Predictive Control) og dataanalyse. Han jobber med virkelige anvendelser av optimaliseringsmodeller ved å koble akademisk forskning med norsk industri og europeiske forskningsprosjekter.
- *Professor Kjetil Fagerholt, tlf. 97 56 84 97, e-mail: kjetil.fagerholt@ntnu.no*
  Han arbeider innen generell operasjonsanalyse/optimering. Anvendelser er ofte innenfor (maritim) logistikk og transport. Typiske oppgaver vil gjerne ha fokus både på modellering av det aktuelle problemet (som gjerne også kan kreve noe ingeniørkunnskap), samt utvikling av løsningsmetoder for dette. På metodesiden er både med eksakte og heuristiske

løsningsmetoder aktuelle, samt ulike metoder for håndtering av usikkerhet om det er viktig i det aktuelle problemet.

- *Professor Stein-Erik Fleten, tlf. 46 69 47 93, e-mail: Stein-Erik.Fleten@ntnu.no*
  Han arbeider innen kvantitativ bedriftsøkonomi; beslutninger under usikkerhet og realopsjoner: teori, casestudier og empiriske analyser. Anvendelser er ofte innenfor kraftsektoren (investeringsanalyse, risikostyring, driftsplanlegging/ produksjonsoptimalisering, prisanalyse) og andre råvaremarkeder. Typiske oppgaver innebærer kombinasjon av mikroøkonomi/finans, optimering og ingeniørkunnskap, gjerne beregningsorientert.
- *Førsteamanuensis Anders N. Gullhav, e-post: anders.gullhav@ntnu.no*
  Jeg jobber med operasjonsanalyse og anvender og utvikler modeller og metoder for å løse reelle planleggingsproblemer. Jeg har jobbet med anvendelser innen flere industrielle sektorer, men har et spesielt fokus på helsesektoren. Oppgavene jeg veileder kan innebære å utvikle deterministiske optimeringsmodeller og avanserte løsningsmetoder (inkl. heuristikker), men kan også innebære å håndtere usikkerhet, for eksempel gjennom å kombinere optimering med simulering. De siste par årene har jeg også interessert meg for problemstillinger knyttet til kombinasjon av optimering og maskinlæring. Jeg har også en bistilling ved St. Olavs hospital hvor jeg jobber som prosjektleder og benytter operasjonsanalyse i praksis.
- *Professor Franziska Holz, e-mail: fholz@diw.de*
  Franziska Holz is an International Adjunct Professor in the NTNU's Energy Transition Programme (NETI). Franziska is an economist by training with a Master degree from Paris 1 University Panthéon-Sorbonne (2003) and a PhD in energy economics from TU Berlin (2009). Franziska's main affiliation is with the German Institute for Economic Research (DIW Berlin) where she is Deputy Head of the Department Energy, Transportation, and Environment and coordinates the research area resource and environmental markets in the department. Her research deals with international natural gas, coal, and oil markets. She focuses on the interaction of these markets with climate policies, mostly by applying OR methods such as numerical equilibrium models (also see www.diw.de/cv/en/fholz).
- *Researcher Kais Msakni, Phone. 73 55 97 83, e-mail: kais.msakni@ntnu.no*
  My research is related to optimization and operations research problems, with focus on deterministic and to a lesser extent, stochastic aspects. My work primarily centers around transportation and logistics applications. I have experience with various exact and solution methods and am currently exploring the use of machine learning models for predictions and their potential for solving combinatorial optimization problems. I have been a part of the IØT department since 2018 and have supervised several master's students.
- *Prof. Dr. Anne Neumann, e-mail: anne.neumann@ntnu.no*
  Anne Neumann is full professor at the Department of Industrial Economics and Technology at NTNU and Director of Research for NTNU's Energy Transition Initiative (NETI). Previously she worked as Senior Researcher in the Department Energy, Transport, Environment at DIW Berlin, was Professor for Economic Policy at the University of Potsdam and Assistant Professor at NHH Bergen. Her research experience of 15+ years draws on industrial organization, competition economics and econometrics and has provided academic as well as policy relevant publications and advice. From 2014 until 2018 she served as Vice-President for Publications in the International Association for Energy Economics (IAEE; *The Energy Journal)*, is currently on the International Advisory Board of *Energy Policy* and on the Editorial Board of *Economics of Energy and Environmental Policy*. She has participated in several interdisciplinary EU projects, projects funded by the German Ministry for Education and Research and commissioned studies. Anne has international teaching experience, (co-) supervised PhD students from several universities and developed research agendas across disciplines. She studied economics at the European University Viadrina in Frankfurt/Oder and holds a PhD in economics from TU Dresden.

- *Forsker Paolo Pisciella; paolo.pisciella@ntnu.no*
  Jeg jobber med økonomiske analyser for avkarboniseringstiltak. Jeg har erfaring med likevektsmodeller, bi-level modeller og stokastiske modeller med applikasjoner innen makroøkonomi, kraftnetts problemer, og fleksibilitet. Typiske analyser som jeg utfører er relaterte på påvirkninger for avkarboniseringstiltak innen Norske og Europeiske økonomi, BNP, utvikling på merverdi i de ulike næringer, pris og etterspørsel etter ulike goder og tjenester. Jeg er også interessert i algoritmer for å lenke økonomiske- og energi-modeller og metoder for å beregne erstattingselastisiteter mellom inngangsfaktorer i næringer.
- *Associate Professor Peter Schütz, phone: 73 59 35 85, email: peter.schuetz@ntnu.no*
  My research focuses on developing and applying methods from Operations Research to deal with uncertainty in real-world decision problems. Students I supervise often use stochastic programming, but other approaches for providing decision support are common too, e.g. combining deterministic optimization with simulation, deterministic optimization in a rolling horizon setting, or machine learning. Applications are usually within the rather wide field of quantitative logistics, covering both production and transportation planning.
- *Professor Magnus Stålhane, tlf. 73 59 08 11, e-mail: Magnus.Staalhane@ntnu.no*
  Han arbeider innen fagfeltet operasjonsanalyse med fokus på anvendelser innenfor transport og logistikk, med særlig interesse for operasjonelle problemer som ruteplanlegging. Interesseområdene metodisk inkluderer eksakte og heuristiske løsningsmetoder for blandede lineære heltallsmodeller. Har siden 2013 veiledet 36 masteroppgaver, med over 70 masterstudenter.
- *Professor Asgeir Tomasgard, e-mail: asgeir.tomasgard@ntnu.no*
  Asgeir Tomasgard forsker på tekno-økonomiske modeller basert på stokastisk optimering. Mange av anvendelsene er innenfor energisystem, energimarkeder, klimapolitikk og energipolitikk. Asgeir er interessert både i modellering, analyser og algoritmeutvikling. Han leder instituttets High Performance Computing lab og har spesiell interesse for dekomponeringsalgoritmer basert på distribuert beregning. Når det gjelder modellering er han spesielt interessert i hvordan usikkerhet påvirker valg både på kort og lang sikt, samt virkemiddelutforming og markedsdesign for industrielle verdikjeder.
- *PhD candidate Felipe Van de Sande Araujo, e-mail: felipe.van.de.s.araujo@ntnu.no*
  My research is focused on market design for flexibility in power systems. This is an important topic, relevant for the energy transition, as flexibility is needed for the integration of greater amounts of renewable generation sources, while new technologic developments are enabling more participation of distributed flexible resources. The integration of those changes requires knowledge of power markets and due to the nature of the subject, there are different possible perspectives to investigate from economic to electric engineering theory. I have a bachelor's degree in Economics and a Master's in Business Administration and apply quantitative methods in different languages such as Python, R and GAMS.

I tillegg vil andre ph.d. stipendiater, postdoktorer og evt. bedriftskontakter kunne inngå som medveiledere.

Forutsetninger for å velge AØO fordypning:

De studentene som høsten 2023 skal ha fordypningen "Anvendt økonomi og optimering" må ha tatt:

- TIØ4130 Optimeringsmetoder med teknisk-økonomiske anvendelser
- TIØ4150 Industriell optimering og beslutningsstøtte
- TIØ4285 Produksjons- og nettverksøkonomi

I tillegg må også fordypningsemnet *TIØ4505 Anvendt økonomi og optimering, fordypningsemne* velges.

Prosjektoppgaver høsten 2023 innen Anvendt økonomi og optimering:

Beskrivelsene av problemene er ment som en hjelp for å velge oppgave. De er ikke ment som komplette oppgavetekster. Det vil heller ikke bli laget noen oppgavetekst. Oppgaven vil bli til underveis i diskusjon mellom studenter, veileder(e) og eventuell bedriftskontakt. Oppgaven som velges skal i utgangspunktet videreføres i masterprosjektet. Erfaring har vist at studenter som gjør prosjekt- og masteroppgave i tilknytning til samme problemstilling blir mest tilfreds. Derfor ønsker vi ikke å gi prosjektoppgaver som vi ikke tror at det finnes en masteroppgave-oppfølging til.

Hver oppgave er beskrevet med en kort tekst. Deretter følger informasjon om eventuell samarbeidspartner samt veileder. En person er listet som hovedveileder og det er denne som skal kontaktes om det er spørsmål knyttet til oppgaven. Videre er oppgaven merket med hvilken eller hvilke av IØTs strategiske forskningsinitiativ oppgaven er koplet mot. De strategiske forskningsinitiativene er; Technology-based organization design, Leading Transitions: Co-create a sustainable future, Green Value Creation – Circular Economy og Health and the Public Sector. Oppgaven er merket med «Sustainability» om bærekraft er et viktig tema i oppgaven.

Det vil bli arrangert workshops relatert til de strategiske forskningsinitiativene og bærekraft. Studenter som får tildelt oppgaver som er merket med forskningsinitiativ eller bærekraft vil bli invitert til disse workshopene. Det er frivillig å delta. Andre studenter vil også kunne delta med forbehold om plass og ressurser.

Valg av oppgave gjøres i et nettskjema. Nettskjemaet innebærer et valg av fem ulike oppgaver i prioritert rekkefølge. Studentene må velge oppgaver med minst tre ulike hovedveiledere. Studentene må forvente å få tildelt hvilket som helst av disse, inkludert 5. valget.

Studenter som vil skrive egendefinert oppgave må avklare oppgaven med veileder før de velger. Studenter med egendefinert oppgave velger AØO01 som en av de fem valgte oppgavene. Se mer informasjon om egendefinert oppgave under AØO01 senere i dokumentet. Det må i så fall også oppgis veiledere i nettskjemaet. Det er ikke sikkert at en student blir tildelt en egendefinert oppgave. Dette avhenger av den totale ressurssituasjonen blant veilederne.

Der det er oppgitt biveileder kan denne på grunn av ressursmessige årsaker bli hovedveileder for oppgaven. Det er ikke mulig å ønske seg eksplisitt en av veilederne blant de som er listet. Der det er angitt kontaktpersoner i samarbeidsinstitusjoner skal disse ikke kontaktes før det eventuelt er gitt klarsignal fra oppgitt hovedveileder (med mindre annet er angitt i oppgaveteksten).

I prosessen med tildeling av oppgaver vil det tas hensyn til fordelingen mellom de ulike veilederne og studentenes prioritering. Der en person står som hovedveileder på mange oppgaver, kan det tenkes at personen ikke vil ha kapasitet til å ha studenter på alle oppgavene. Dersom dette blir tilfelle kan en annen veileder bli tildelt av de som står listet i oppgaveteksten. Vi vil enda en gang understreke at dersom det er mange studenter som har valgt de samme oppgavene, må en være forberedt på at en får tildelt oppgave som står lenger ned på prioriteringslisten. En studentgruppe kan altså bli tildelt sitt femtevalg, til tross for at andrevalget ikke er tildelt en gruppe. En forklaring på dette kan være at veilederen på oppgaven ikke har kapasitet til å veilede flere oppgaver.

Det er sterkt anbefalt at studentene utfører arbeidet i grupper på to studenter, selv om det er mulig å være 1 eller 3 studenter i en gruppe. Vi anbefaler at dere selv finner en student å samarbeide med i prosjektet. Studenter som ønsker å skrive med noen, men som ikke har funnet noen å skrive med, kan oppgi dette i kommentarfeltet i nettskjemaet.

Det kan også være mulighet for å fortsette på doktorgradsstipend i etterkant av mastergraden. Dersom noen ønsker å forhøre seg om muligheten for dette, anbefaler vi at de tar kontakt med de aktuelle veiledere, helst så snart som mulig.

Contents

AØO01: Egendefinert studentprosjekt

Studenter som vil skrive en egendefinert oppgave må avklare dette med en veileder på forhånd. For at dette skal fungere så bra og rettferdig som mulig gjelder følgende

- Studenten må planlegge en egendefinert oppgave i god tid før valget skal tas 4. mai
- Studenten må presentere en tydelig prosjektbeskrivelse til en potensiell veileder
- Veilederen vurderer prosjektbeskrivelsen og om han/hun har kompetanse og mulighet for veiledning
- Studenten bør ha fått godkjent fra veilederen før minglemøtet 26. april
- Studenten kan etter godkjennelse fra veilederen velge AØO01 som ett av sine fem valg. Navnet på veilederen må oppgis i kommentarfeltet i nettskjemaet

AØO02: Advanced heuristics for the Maritime Inventory Routing Problem: applications from the energy sectors and fish feed distribution

Inventory routing problems (IRPs) involve the integration and coordination of two important components of the logistics value chain: inventory management and vehicle routing. The Maritime Inventory Routing Problem (MIRP) is a special class of IRPs that arise in a maritime setting. In the MIRP, given a fleet of vessels and a set of ports divided into production (loading) and consumption (discharging) ports, one must determine each vessel's route and schedule for transporting one or more products between the ports, as well as the amount loaded/unloaded at each port visit. Each port has a production or consumption rate and an inventory for each product. The planning objective is to minimize transportation costs while ensuring that the inventories at the ports are kept within lower and upper limits at all times.

In this project we aim to expand currently existing models and solution methods for the MIRP by integrating vessel sailing speed decisions (i.e., speed optimization) in the planning. In maritime transportation, sailing speeds heavily affect the costs, as the fuel consumption depend non-linearly with the chosen sailing speed. As an example, reducing the sailing speed by 25% will typically reduce the fuel consumption (and hence also the CO2 emissions) along a given sailing leg with 40 - 50%. However, determining the optimal sailing speeds is a delicate trade-off, as reducing sailing speeds implies that a vessel will not be able to do that much transport work over a given planning horizon. In previous studies, it has been shown that incorporating speed decisions in vessel routing problems may have a huge effect on costs/profits, emissions, as well as planning flexibility. However, since the MIRP is known to be a very complex planning problem, even without speed optimization, including speed decisions in the MIRP has yet barely been touched upon.

Due to the complexity of this problem, the students should aim at developing advanced (math-) heuristic solutions methods, possibly also including components from machine learning, for solving it. Therefore, good skills in and an interest for computer programming will be required in this project. The developed solution method(s) will be tested on available test instances based on real applications, both from the energy sector and the fish feed industry. One of the goals with the project is to analyze the effects and gains from including speed optimization in the MIRP.

Relevant activities in this project (both for the project and the master) can be:

- Study the MIRP and maritime speed optimization problems.
- Expand currently existing mathematical (MIP) models for MIRPs to incorporate speed decisions.
- Develop a (math-) heuristic for the MIRP with speed optimization.
- Test the performance of the proposed heuristic on a number of benchmark instances based on real applications from the energy sector and the fish feed industry.
- Analyze the effects from including speed optimization in the MIRP (possibly within a simulation framework).

Main supervisor: Kjetil Fagerholt

Industry Co-supervisor: Lars Magnus Hvattum (Molde University College)

Strategic research initiative: Sustainability

For mer informasjon, ta gjerne kontakt med kjetil.fagerholt@ntnu.no for å avtale et (digitalt) møte.

AØO03: Collective demand flexibility of heterogeneous local energy communities

Local energy communities are legal entities who provide environmental, economic or social benefits to the local community by participating in activities like power generation, distribution and consumption. From a power system perspective, local energy communities can provide better coordination of local resources, better utilization of the distribution network, a more easily accessed flexibility in the distribution network, reduced loss and investment cost in the transmission network and increased innovation opportunities for grid customers.

Flexibility of energy communities could be a major element in reducing the 'burden' of power-grids, by allowing time-shifting of electricity consumption of consumers. However, after onset of the new 'active' grid: i.e., with renewable generation at local households etc., flexibility would also account for distributed generation (as in PV) and their coordinated control for meeting local energy requirements of consumers in a neighborhood. This raises some interesting questions, 'What is the amount of flexible demand available in a local energy community?', 'What is the potential of time-flexible demand in a specified heterogenous combination of local energy communities?'

This project aims to 1) find the combined flexibility of different resources (such as distributed generation plants, smart buildings, EV charging stations) to form an aggregated set of demand flexibility available under a community. The challenge in this task would be to combine 'feasible sets' of flexible demand of different resources to form one larger group of flexibility resource under a community. Moreover, this project will further 2) Use the pre-found (in the previous step) flexibility of demand to suggest the best operational scheduling of generation/demand under a centralized framework by a community manager.

The expected outcome of the project is to find a hierarchical (top down) view of demand flexibility under several local energy communities. Such a study can also be heavily useful in TSO-DSO interactions where TSOs would like to ascertain the aggregated flexible demand available under all its connected DSOs, for better participation in the wholesale (retail?) or balancing markets.

Prerequisites: Programming skills (MATLAB, python or others). Interest in energy systems modelling and operations research.

Industry partner:	SINTEF Energi
Main Supervisor:	Pedro Crespo del Granado
Co-supervisor:	Bakul Kandpal
Industry Co-supervisor:	SINTEF Energi; FINE project https://www.sintef.no/en/projects/2020/fine/

For more information, please contact Pedro Crespo del Granado, pedro@ntnu.no

AØO04: Decision support for patient care at home

Oslo University Hospital (OUS) is the biggest hospital in Norway with more than 24 000 employees and a budget of approximately 27.5 billion NOK. It is a highly specialized hospital in charge of extensive regional and local hospital assignments and the provision of high-quality services for the citizens of Oslo. The hospital also has a nationwide responsibility for a number of national and multi-regional assignments.

OUS is going through a transformation regarding delivery of patient care and treatment. In the future, patients will receive a greater share of the patient care at home through digital monitoring and delivery of i.e. medications, equipment and other materials at the door. In addition, samples from patients must travel from the patients' home and/or decentralized units to the lab for analysis.

There is a need for decision support regarding logistics planning of physical assets from different units at the hospital/in the region to the patients' home and back to the hospital, as well as analyses regarding capacity needed for carrying out a patient friendly, medically sound and economic efficient treatment for patients at home. Connecting input from patients' self-assessment of health indicators and results from sample analyses to determine logistics decisions might be an interesting and innovative topic to cover. Route optimization of cars/trucks combined with resource (personnel, cars etc.) availability is another relevant problem in this project.

The student(s) together with IØT and OUS will define the problem more in detail and narrow down the scope to ensure both academic relevance and value for the hospital. The results of this project will contribute to the future design of the supply chain for the biggest hospital at home concept in Norway.

Research topics may include, but are not limited to, the following:

- Capacity optimization for future hospital at home
- Connecting health data to logistics decisions (procurement, production, transport, storage, delivery)
- Route optimization combined with resource availability

Method/tasks:

- Define the problem (together with OUS and KPMG)
- Review current literature for similar problems
- Optimization models for capacity optimization, logistics/supply chain optimization and route optimization (MIP, Heuristics, VRP/PDP-TW)
- Combining health data to logistics decision support
- Run simulation and optimization models on real-life and/or mock up data and present recommendations.

Industry partners:	Oslo University Hospital, KPMG
Main supervisor:	Henrik Andersson
Co-supervisor:	Anders Gullhav
Industry Co-supervisors:	Mats Mathisen Aarlott (OUS), Kjartan Kastet Klyve (KPMG)
Strategic research initiative:	Health and the Public Sector

For more information, please contact Henrik Andersson, henrik.andersson@ntnu.no, to schedule a meeting.

AØO05: Dynamic scenario generation and reduction for energy system investment planning

Managing long-term and short-term uncertainty is important in optimizing investment decisions for energy systems planning. Failing to model a relevant uncertain parameter may lead to nonoptimal or even infeasible solutions. However, adding too many long-term uncertainty parameters may lead to an explosion in the scenario tree and an intractable model. Therefore, it is important to design the scenario trees carefully.

Traditionally, the scenario generation and reduction process is done before solving the actual problem. In this project, students are expected to work on a novel dynamic scenario generation and reduction approach that allows (1) detecting and removing useless scenarios based on some metrics while solving the problem, and (2) adding new scenarios and uncertain parameters that could influence the investment decision. The method is potentially based on Benders decomposition. The students are expected to implement the dynamic adjustment scheme and demonstrate the method on a long-term energy system planning problem.

Prerequisites: good knowledge of multi-stage stochastic programming, Benders decomposition, and Julia programming (possible to use another language).

Industry Partner:	This is more theoretical work but will be based on case studies from the North-Sea
Collaborators:	FME NTRANS, NTNU Energy Transition Initiative
Main supervisor:	Asgeir Tomasgard
Co-supervisor:	Hongyu Zhang
Strategic research initiative:	Leading transitions: Co-create a sustainable future

AØO06: Dynamisk dispatch og lokalisering av ambulanser i Midt-Norge

I Norge styres ambulansetjenesten av de fire regionale helseforetakene og er den mest desentraliserte delen av spesialisthelsetjenesten. Ambulansetjenesten er en beredskapstjeneste som rykker ut til pasienter som trenger akuttmedisinsk behandling utenfor sykehus, samt til pasienter som trenger transport på båre til undersøkelse eller behandling på en helseinstitusjon eller hos lege. Ambulansetjenesten spiller også en sentral rolle i beredskapen ved større ulykker og katastrofer. I det regionale helseforetaket Helse Midt-Norge, som omfatter fylkene Trøndelag og Møre og Romsdal, har ambulansetjenesten ansvar for å dekke et stort geografisk område med ulike befolkningstettheter og geografiske utfordringer. Ca 1000 ansatte inngår i bemanningen av 105 operative ambulanser, fordelt på 65 lokaliseringer. Tjenesten har i tillegg 35 biler i reserve som kan bemannes opp ved behov.

Ambulansetjenesten i Midt-Norge har i dag beregningsmodeller for å vurdere konsekvenser av endret stasjonslokalisering med tanke utrykningstid og sannsynlighet for samtidighetskonflikter under statiske forhold. Den operative virkeligheten er både dynamisk og stokastisk slik at beregninger på statiske forhold gir ikke et fullstendig bilde. Denne oppgaven vil dreie som om å studere ambulansetjenesten i Midt-Norge under dynamiske og stokastiske forhold og utvikle beslutningsstøtte på strategisk, taktisk og/eller operative nivå. Aktuelle problemstillinger kan være:

- Evaluere dagens lokalisering av ambulansestasjoner og foreslå alternative lokaliseringer.
- Dimensjonere ambulanseflåten og vurdere flåtesammensetning og lokalisering.
- Analysere effekten av å introdusere midlertidige ambulansestasjoner. Gjennom å tillate dynamisk lokalisering av ambulanser gjennom døgnet kan man bedre tilpasse seg forandringer i etterspørsel.
- Dynamisk dispatch og relokalisering av ambulanser for å redusere responstid og øke utnyttelsen av ambulansene

For alle problemstillingen skal det utvikles optimerings- og simuleringsmodeller. I tillegg kan maskinslæringsteknikker være aktuelt å bruke for etterspørselsprediksjoner eller beslutningstaking.

Prosjektet gjennomføres i samarbeid med ambulansetjenesten i Helse Midt-Norge og CARER – Center for advanced research in emergency response ved Linköpings universitet.

Arbeidet kan innebære ulike oppgaver som:

- en studie av litteraturen for liknende problemer;
- beskrive utfordringene i ambulansetjenesten;
- avgrensning av planleggingsproblemet og beskrivelse av dette;
- utvikling av matematisk(e) modell(er) for problemet, herunder optimeringsmodeller og simuleringsmodeller;
- implementering av modellen(e) ved hjelp av egnet programvare, analyse og testing av instanser basert på reelle data fra Helse Midt-Norge.

Collaborator:	Ambulansetjenesten i Midt-Norge, CARER
Main supervisor:	Henrik Andersson
Co-supervisor:	Anders N. Gullhav
Industry Co-supervisors:	Tobias Andersson Granberg (CARER) Jon-Ola Wattø (Ambulansetjenesten i Midt-Norge)
Strategic research initiative:	Health and the Public Sector

For more information, please contact Henrik Andersson, henrik.andersson@ntnu.no, to schedule a meeting.

AØO07: Economic analysis of new aquaculture production concepts

Over the past decades, aquaculture has become one of the most important industries in Norway. Since the1980s, production of farmed salmon has grown from approximately 5300 tonnes to 1.3 million tonnes in 2019, representing a value of 68 billion NOK. To ensure further growth of the industry, salmon farmers are increasingly looking towards new production systems that may complement or even replace the conventional open net pen fish farming at sea. These new systems address important challenges such as the escape of farmed salmon, reduced risk of diseases, improved control over the production system and reduced emissions. Some of the suggested new production systems are:

- Land-based systems,
- Exposed systems,
- Floating closed systems,
- Floating semi-closed systems.

The purpose of this project is to provide an economic analysis for one of the new proposed production systems and compare it to the conventional open net pen system. Cost-benefit analysis can be one of the possible approaches for the analysis. The results of the analysis provide insight into the potential for increased value creation of the new production system. The choice of production system to analyze and which aspects to focus on will be made jointly by the students, SINTEF Ocean and the supervisors after summer.

The following main tasks are usually part of the project work:

- Understand the problem and study relevant literature,
- Examine and select an applicable methodology for the analysis,
- Collect necessary input data and carry out the analysis,
- Discuss the results.

This project is supported by the ongoing research project *Compareit.* Compareit is a collaborative research project involving both research organizations and industrial actors. The project can provide access to data and relevant industry partners.

Collaborators:	SINTEF Ocean, Compareit (www.compareit.no)
Main supervisor:	Peter Schütz
Co-supervisor:	Anne Neumann
Strategic Research Initiative:	Leading transitions: Co-create a sustainable future

For more information, please contact Peter Schütz, peter.schuetz@ntnu.no.

AØO08: Economic and environmental impacts of a transition towards clean public transport in Europe

Public transport vehicles that use old combustion technologies are a significant source of pollution, contributing to poor air quality and a range of health problems. Older vehicles often emit high levels of pollutants such as nitrogen oxides (NOx), particulate matter (PM), and carbon monoxide (CO), which can have harmful effects on both human health and the environment. In this respect, the substitution of public transport fleets towards low emissions is crucial in addressing the negative impacts of transportation on the environment and public health. The transition to low-emission public transport fleets will not only have environmental benefits but also economic consequences. One of the primary economic impacts will be the shift from purchasing fossil fuels to purchasing electricity or hydrogen to power vehicles. Another economic impact of transitioning to low-emission public transport fleets is the potential for increased public demand for sustainable and environmentally-friendly transport options. By offering cleaner and more sustainable public transport services, agencies may be able to attract more passengers and generate increased revenue. On the other hand, transitioning to low-emission public transport fleets may also present challenges for transit agencies, particularly those with limited financial resources. The cost of purchasing new vehicles and developing the necessary infrastructure to support low-emission transport systems can be substantial, and may require significant investment and planning.

In this project the students will use an economic equilibrium model for Europe to assess the impact of a transition of public transport towards a low-carbon structure. The analyzed impacts will involve the value of the transport sectors and related sectors, the impact on the employment level and on the price and demand of energy commodities.

Collaborators:	TØI
	FME MoZEES on zero emission mobility
Main supervisor:	Asgeir Tomasgard
Co-Supervisor:	Paolo Pisciella

Strategic research initiative: Leading transitions: Co-create a sustainable future

AØO09: En generell matheuristic for rute-problemer

I operasjonsanalyse og optimering er noen av de viktigste problemene vi ser på såkalte rute-problemer. Her skal man ofte distribuere varer fra et depot til ulike kunder og sette opp ruter for ett eller flere kjøretøy. Opprinnelig så man mest på rene ruting-problemer slik som The Travelling Salesman Problem (TSP) og The Capacitated Vehicle Routing Problem (CVRP). Det har etter hvert blitt vanligere å se på såkalte «rich vehicle routing problems», hvor man inkorporer flere aspekter slik som produksjon hos depotet, lagerstyring og tidsvinduer inn i problemet. Disse problemene blir fort så komplekse at man er nødt til å bruke heuristikker til å løse de. De seneste årene har det blitt mer vanlig å integrere matematiske solvere med heuristikker og bruke det som blir kalt Matheuristics til å løse denne typen problemer.

I forskningsprosjektet AXIOM har vi blant annet sett på slike rute-problemer og kommet opp med en ruteforbedringsmodell som vi har brukt til å finne nye beste løsninger på flere benchmark instanser for ulike rute-problemer. Dette inkluderer CVRP, The Inventory Routing Problem (IRP) og The Production Routing problem (PRP). Modellen går ut på at man har en gitt mengde med startruter, eller et «pool med ruter», som man bruker til å løse et problem. Forbedringsmodellen kan kort sagt forbedre disse rutene samt løse det opprinnelige ruteproblemet. Dette har vært så lovende at vi nå ønsker å generalisere metoden. Er det mulig å lage en generell matheuristic for å løse ulike klasser av ruteproblemer? Hvordan skal vi da opprette mengden med startruter?

Det er flere ulike retninger denne prosjektoppgaven (og evt. masteroppgave) kan ta:

- Kan man bruke maskinlæring eller andre metoder fra kunstig intelligens til å si noe om hvilke ruter man burde inkludere i mengden med startruter?
- Kan man utvikle en egen generell heuristikk for å opprette rutene?
- Kan man forbedre ruteforbedringsmodellen?
- Kan man komme opp med en helt ny heuristikk for å løse rute-problemer?

Planen er at man på høsten starter med et velkjent ruteproblem, slik som for eksempel The Location Routing Problem, før man på våren prøver å generalisere arbeidet. Denne prosjektoppgaven er svært åpen og målet er å slå state-of-the-art på et eller flere problemer. Vi ønsker å sette nye verdensrekoder! Akkurat hvilke rute-problemer man ser på bestemmer vi basert på studentenes ønsker eller preferanser.

Fokuset i denne oppgaven blir naturligvis på algoritmer, så det er en stor fordel å ha en del erfaring innenfor programmering. Python kan brukes til å protype, men ofte er man nødt til å bruke programmeringsspråk som Java, C++ eller Rust i den endelige algoritmen. Det er ikke et krav å kunne programmere i disse språkene, men man må være villig til å sette seg inn i det.

Main supervisor: Magnus Stålhane

Co-supervisor: Henrik Andersson

For mer informasjon, ta kontakt med Magnus Stålhane, magnus.staalhane@ntnu.no, for å avtale et (digitalt) møte.

AØO10: Etterspørselsprediksjon og turnusplanlegging for A&CO, Squeeze

Askeladden & Co er en "startup-fabrikk" som består av blant annet forretningsutviklere, analytikere, markedsførere, programvareutviklere, data science eksperter, finanseksperter, regnskapsførere og HR eksperter. Squeeze, som er en av Askeladden & Co sine selskaper, leverer massasjetimer til en fast lav pris gjennom et månedlig abonnement. Siden lanseringen i 2019 har Squeeze nå over 30 lokasjoner, 150 ansatte og tusenvis av kunder.

Massørene til Squeeze jobber skiftbasert, og på grunn av at arbeidskraft er en av de største kostnadsdriverne så er det kritisk at skiftene settes opp på en slik måte at de tilfredsstiller arbeidsmiljølovens bestemmelser og treffer godt på etterspørselen i markedet. Det har allerede blitt utført noen tester med å bruke blandet heltallsprogrammering (mixed integer programming - MIP) for å løse turnusplanleggingen ved Squeeze, men tidskompleksiteten peker i retning av å bruke heuristikker - i hvert fall i de områdene med mange lokasjoner som for eksempel Oslo-området.

Studentene vil ha tilgang til historisk data, og vi tror særlig at booking- og bemanningsdata vil være relevant. Et interessant tema å utforske er hvordan man kan håndtere sensurert data (censored data). Med andre ord, hvordan kan metoden for prediksjonen av etterspørsel (og/eller optimeringsmetoden) ta hensyn til "tapt etterspørsel" som følge av at den historiske bookingdataen er begrenset (upper bounded) av historisk bemanning?

Flere av selskapene til Askeladden & Co møter et lignende turnusplanleggingsproblem, så det kan bli relevant å se på problemet for disse selskapene også (eksempelvis Dr. Dropin, Blid, Olio og Digg Pizza).

Noen relevante temaer som kan være en del av fordypningsprosjektet (og/eller masteroppgaven) er

- **Etterspørselsprediksjon** ved bruk av maskinlæring eller statistiske metoder.
- Lage en presis **matematisk formulering** av turnusplanleggingsproblemet til Squeeze.
- **Studere løsningsmetoder** for problemet både med tanke på etterspørselsprediksjon og turnusplanlegging (Hvordan håndtere censored data? Hvordan håndtere den iboende stokastisiteten til problemet?)
- Implementere **heuristiske løsningsmetoder** til problemet.
- Gjennomføre **backtesting** med valgt(e) løsningsmetode(r).
- Utforske hvordan løsningsmetoden(e) kan **generaliseres** på tvers av ulike industrier med minimale endringer.

Industry partner:	Askeladden & CO
Main supervisor:	Anders N. Gullhav
Co-supervisor:	Henrik Andersson
Industry Co-supervisor:	Tomas Spangelo (Askeladden & CO)

For more information, please contact Anders N. Gullhav, anders.gullhav@ntnu.no to schedule a meeting.

AØO11: Fleet renewal for a zero-emission fishery fleet

The Norwegian fishing fleet consists of approximately 6000 fishing and utility vessels that predominantly use marine diesel for propulsion and auxiliary power. Their annual fuel consumption constitutes emissions amounting to about 1.1 Mt CO2-equivalents or 23.4% of the total CO2 emissions from domestic shipping. Reaching Norway's ambitious emissions reduction goals of 50% by 2030 will therefore require a significant number of vessels to be replaced by or converted to zero-emission fuels in the years to come.

Optimization models for fleet renewal decisions typically maximize company profits (or minimize total company cost) over a given planning horizon, while considering a set of strategic and operational requirements. These requirements usually cover the need to satisfy some customer demand, required transportation capacity and/or the maximum lifetime of the ships.

The purpose of this project is to extend the existing fleet renewal models taking into account emission reduction targets and to apply the new model to a fleet of fishing vessels. The goal is to determine which vessels to convert to zero-emission fuels, which vessels to replace and when to do so, such that the national emission reduction targets are achieved.

The following main tasks are usually part of the project work:

- Understand the problem and study relevant literature
- Develop a mathematical formulation for the problem
- Examine applicable solution methods
- Collect data and set up test instances based on available data
- Implement and solve the model
- Analyze and discuss the results

This project is part of the ongoing research project *ZeroKyst KSP – Decarbonising the fisheries and aquaculture industry through hydrogen-electric propulsion.*

Collaborators: ZeroKyst-project (ZeroKyst - SINTEF), SINTEF Ocean

Main supervisor: Peter Schütz

Strategic Research Initiative: Leading transitions: Co-create a sustainable future

For more information, please contact Peter Schütz, peter.schuetz@ntnu.no.

AØO12: Forretningsmodeller og kontraktsdesign i fremtidens energimarked

Innføring av avanserte målings- og styringssystemer og annen type teknologi i energimarkedet åpner for innovative konsepter som kan gi gevinster for miljøet, for samfunnet og for ulike aktører i verdikjeden. Et viktig område de neste årene blir fleksible tjenester for lading av elbiler, der prisen for lading avhenger av hvor hurtig det må skje og av ledig kapasitet i distribusjonsnettet, men annen fleksibilitet i både private og næringsbygg spiller og en rolle sammen med fleksibilitet i industri. Per i dag er insentivene, for eksempel i form av kortsiktige prisvariasjoner på kraftkontraktene og dynamikk i nett-tariffer, ikke sterke nok til å motivere til differensiert kvalitet på ladetjenester eller å utløse nok fleksibilitet i andre deler av systemet. Vår hypotese er at nye forretningsmodeller og nye tjenester, kanskje levert av nye typer aktører, kan være med på å utløse potensialet. Mye av fokuset i bransjen er i dag knyttet til de teknologiske løsningene, mens det foreløpig er lite fokus på hvordan tjenester, forretningsmodeller og kontrakter kan utformes.

Oppgaven vil bestå i å foreslå og analysere forretningsmodeller og samarbeidskontrakter i det framtidige energimarkedet med minst ett av følgende fokusområder: 1) Nettselskapene og modeller for hvordan de kan utnytte fleksibilitet på sluttbrukersiden til å oppnå gevinster som økt driftssikkerhet og utsatt behov for nettforsterking. 2) Nye tjenesteleverandører for lading av el-biler og deres forhold til sluttbrukerne på den ene siden og nettselskapet på den andre siden. 3) Fleksibilitetstjenester fra industri eller bygg

Oppgaven vil gjøres i samarbeid Smart Innovation Norway

Fordelaktig: Kjennskap til energimarkedet er en fordel. Faget TIØ 4285 Produksjons- og nettverksøkonomi er en forutsetning.

Industry Partner:	Smart Innovation Norway. Oppgaven vil kobles mot et av energiselskapene som er med i senteret FME NTRANS
Main supervisor:	Professor Asgeir Tomasgard
Industry Co-supervisor:	Stig Ødegaard Ottesen, Smart Innovation Norway

Strategic research initiative: Leading transitions: Co-create a sustainable future

AØO13: Integration of natural gas, hydrogen and renewables in the European energy system

Europeisk energisektor står midt oppe i omfattende endringer der andelen fornybar og ikke-planleggbar kraftproduksjon øker (vind og sol). Volumet av gass levert fra norsk sokkel er rekordhøyt, men vil antagelig reduseres fra 2030 om ikke nye felt utvikles. Samtidig er store mengder russisk gass borte fra markedet. I denne situasjonen skal Europa dramatisk øke sin fornybare produksjon og har samtidig store ambisjoner om en hydrogenøkonomi.

For det norske gass-systemet vil det være mulig å tilby fleksibilitetstjenester til et europeisk energisystem med økende behov for balansering av ikke-planleggbar produksjon. En annen mulighet er å produsere hydrogen for varme, kraft og transport. Hydrogen kan også komme fra fornybar energi og spesielt storskala utbygging av havvind er interessant å se i sammenheng med grønn hydrogenproduksjon.

Usikkerhet både på kort og lang sikt virker inn på hvordan resterende gasseksport fra Norge bør disponeres, både for å bidra inn mot omlegging til et grønnere energisystem og for å maksimere verdien av den norske eksporten. Samtidig må norsk fornybarutbygging sees sammenheng med egen bruk til ny industri, eller eksport i form av kraft og hydrogen.

Vi vil benytte multi-horizon stochastic programming for å analysere disse problemstillingene. Vi kan basere oss på EMPIRE modellen som er utviklet ved IØT, og utvikle nye moduler i denne. En rekke aktuelle problemstillinger er mulig å velge:

- Utbygging av CO2 fangst, transport og lagring verdikjeder i Europa og Norge. Både design av verdikjeden og forretningsmodeller knyttet til disse.
- Produksjon av hydrogen fra naturgass med CCS og samspillet mellom industri, transport kraft og varme sektorene
- Bruk av gassrør som store energilager på 1-2 døgns horisont. Både koblingen til kraft og varmesystem samt utvikling av nye tjenester i markedet er interessant. Aktuelle problemstillinger vil både være å finne gode løsninger for kapasitetstjenester for norsk naturgasseksport
- Studier av utbygging av norsk havvind
- Studier av hydrogenproduksjon fra vindkraft og fra gass

Nødvendig bakgrunn og interesser: optimering, modellering, planlegging under usikkerhet

Industry partners:	Gassco, Equinor
Collaborators:	FME NTRANS, NTNU Energy Transition Initiative
Main supervisor:	Professor Asgeir Tomasgard
Co-Supervisor:	Forsker Hongyu Zhang
Strategic research initiative:	Leading transitions: Co-create a sustainable future

AØO14: Dynamic management og energy storages in a large scale energy system model

The EMPIRE model is a stochastic European power market model developed at NTNU. It manages both capacity expansion, in terms of investments in cables and generation and operations of the power system in Europe. It can be categorized as a large scale multihorizon stochastic linear programming model. In this project we would like to improve the management of assets that has a seasonal perspective, like storages and hydro power reservoirs. The work is motivated by the substantial role of hydropower in an evolving power system. With increasing volumes of renewables in Europe and Norway and the links between the power sector and hydrogen production, the seasonal dimension in security of supply is increasingly important. We introduce dynamic modelling of energy storages and hydro reservoirs as well as pumped hydro generation into a separate module in EMPIRE.

Needed background: strong interest in large scale optimization, modelling and stochasticity

External Partner:	Statkraft
Collaborators:	FME NTRANS, NTNU Energy Transition Initiative
Main supervisor:	Professor Asgeir Tomasgard
Co-Supervisor:	Forsker Hongyu Zhang
Strategic research initiative:	Leading transitions: Co-create a sustainable future

AØO15: Investigating the value of predictive maintenance planning at offshore wind farms

The world stands in front of a major task of transitioning to renewable energy to solve the climate crisis at hand. With the goal of turning Europe into the first climate neutral continent by 2050, EU launched the Green Deal in July 2021. Offshore wind is a young industry that is in rapid development and is expected to constitute an important part of the future energy system. Hence, among other initiatives within renewable energy, the ambitions are to meet the European Green Deal partly by reaching 300 GW of installed offshore wind capacity by 2050. 1 GW of electricity is enough to support 750,000 homes. It is estimated that 16-24 % of the total costs related to offshore wind stem from operations and maintenance (O&M). O&M costs for offshore wind ranged between 70-129 USD/kW in 2018. For onshore it was 33-56 USD/kW. These higher O&M cost for offshore wind is related to the harsh conditions at sea which makes maintenance planning a complex task. To ensure that the ambitions of offshore wind are viable, it is crucial to decrease the maintenance costs.

This project is connected to work-package 2: "Marine operations and Logistics" within the FME NorthWind and will focus on effective logistics planning to reduce the cost of maintaining offshore wind farms, while at the same time maximizing the energy output. Until recently maintenance at offshore wind farms have been conducted using a preventive- or condition-based maintenance strategy. However, as more information becomes available, and better prediction models are developed, the goal is to further reduce the cost of energy from offshore wind farms by moving to a predictive maintenance strategy. In such a strategy, probabilistic models of the future conditions of each component of a wind turbine are used as a basis for planning the maintenance. The goal is to develop a solution methodology that combines probability distributions on failures, data on vessel capabilities and logistics planning to create optimal maintenance schedules. To develop the methodology new exact and/or heuristic solution methods must be developed, based, e.g., on existing methods from mixed integer stochastic programming and/or discrete event simulation.

In this project the aim is to quantify the value of pursuing a predictive maintenance strategy. The idea is to develop a stochastic programming model of a maintenance planning problem for an offshore wind farm addressing the uncertain underlying parameters such as failure rates and weather conditions. Solving the model using yearly averages for the uncertain parameters and comparing with the solution assuming perfect information makes it possible to assess the value of predictive maintenance.

Some relevant topics that may be included in the project (and/or Master thesis) are:

- Investigate the problem and study existing models and solution methods for related problems
- Develop precise mathematical model formulation(s)
- Consider methods for handling the problems underlying uncertain parameters
- Implement solution method for the problem
- Test the implemented solution method on problem instances and analyse/discuss the results

Industry partner:	Potential partners in FME NorthWind
Main supervisor:	Magnus Stålhane
Co-supervisor:	Vibeke Hvidegaard Petersen
Strategic research initiative:	Leading transitions: Co-create a sustainable future
	Green Value Creation - Circular Economy

For more information, please contact Magnus Stålhane, magnus.staalhane@ntnu.no, to schedule a meeting.

AØO16: Koordinering av delt eierskap i norsk vannkraft

Mange norske elver er bygd ut for vannkraftformål. Delt eierskap på tvers av kraftselskaper er vanlig. Samtidig er prisprognoser og andre kriterier som er relevante for produksjonsbeslutninger, bedriftsintern informasjon. Denne prosjektoppgaven fokuserer på optimering av kraftproduksjon i en situasjon der produksjons/tappebeslutningene må koordineres på tvers av selskaper som ikke nødvendigvis ønsker å produsere like mye neste dag.

Et mulig rammeverk for å studere slik koordinering av driftsoptimering er komplementaritetsmodeller-/likevektsmodeller (mathematical programming with equilibrium constraints).

Et viktig første skritt i denne prosjektoppgaven er å kartlegge hvordan ulike norske elver, med fokus på større vannkraftanlegg, løser dette koordineringsproblemet. Hva er beste praksis, og hva er fordeler og ulemper med de ulike løsningene. Det forventes at studentene er aktive og tar kontakt med eksperter og selskaper i bransjen for å foreta denne kartleggingen.

Deretter skal vi modellere dette problemet formelt, og beregne fordeler og ulemper med utvalgte løsninger. Her vil bruk av optimering og komplementaritetsmodeller/likevektsmodeller være det mest aktuelle rammeverket. Det er også aktuelt å foreslå nye løsninger, f eks basert på blokk-kjedeteknologi. Fordeler og ulemper er først og fremst knyttet til driftsøkonomi, men også flomdempetiltak og økologisk/bærekraft-motiverte tiltak kan være relevante.

Forventa læringsutbytte: Oppgaven gir innsikt i norsk vannkraftbransje, drift av magasinkraftanlegg, strømmarkedet, og koordinering av delte ressurser på tvers av selskaper.

Samarbeidspartner:	Oppgaven skjer i samarbeid med NTNU-prosjektet SusHydro.
Hovedveileder:	Stein-Erik Fleten
Medveiledere:	Tor Haakon Bakken (professor i hydrologi) og phd-stipendiat Hossein Babazadeh
Strategisk forskningssatsing:	Bærekraft

AØO17: Large scale techno-economic optimization: Analyzing the European Energy Transition and the role of Norway

The project will investigate how long-term scenarios for transmission expansion and decarbonisation policies influence the evolution of the EU power system infrastructure. The master project will use the EMPIRE model developed at IØT. See: https://www.ntnu.edu/web/iot/energy/energy-models-hub/empire. The model contains 20 million variables and around 33 million constraints. It is solved in a computer cluster at IØT

The EMPIRE model, formulated as a multi-horizon stochastic programme, incorporates long- and short-term system dynamics while optimising investments under operational uncertainty. It is well known that the consideration of renewable technology (wind and solar) in the power generation mix impacts the supply and demand balance, due to the intermittent and uncontrollable nature of these technologies. EMPIRE is designed to handle these challenges. In contrast to other power sector models, the major contribution of EMPIRE is that it simultaneously incorporates short- and long-term dynamics, in conjunction with short-term uncertainty. Dynamics refer to multiple investment periods coexisting with multiple sequential operational decision periods, while uncertainty is enhanced through multiple input scenarios that describe operating conditions. That is, EMPIRE is a capacity and transmission expansion model, designed to determine optimal capacity investments and system operation over long-term planning horizons, extended in a 40–50-year basis.

The EMPIRE model is used in the CleanExport project at SINTEF Energi. This together with other models are mapping case studies to analyze the strategic role of Norway in a decarbonized energy system.

Activities: The project will use the EMPIRE model to analyse different long-term scenarios for the EU energy transition. The specific focus is open for discussion. For example, the project could focus on: i) the role of demand response in various countries, ii) the hydrogen potentials to provide flexibility, iii) ideas of market designs for the power system, and iii) other join ideas from ongoing research projects at NTNU and the student area of interest.

Collaborator: CleanExport project and Open ENTRANCE (European Union project), SINTEF Energi.

Main supervisor: Pedro Crespo del Granado

Co-supervisors: Mostafa Barani, Stian Backe,

For more information, please contact Pedro Crespo del Granado, pedro@ntnu.no

AØO18: Location-Routing for zero-emission, hydrogen-electric aquaculture service vessels

The production of farmed salmon is known for a lower carbon footprint than other animal sources. Still, there is a potential for further reductions in CO2 emissions, for example from the fleet of service vessels servicing the different fish farms. Replacing the existing fleet of vessel with hydrogen-electric vessels will also support Norway's goals for reducing total CO2 emissions from the maritime sector of 40% by 2030 (as compared to 2008).

Despite technological advances, zero-emission vessels still have a shorter range than vessels using fossil fuels. The vessels therefore have to refuel more often. One approach to reduce the time in port for refueling is to use containerized hydrogen and to simply replace the containers during the port visit. However, not all ports may be able to offer containerized hydrogen.

The purpose of this project is to develop an optimization model that finds the optimal locations of ports that offer containerized hydrogen for aquaculture service vessels, taking into account the necessary routing of the vessels to ensure that all fish farms are served. The goal is to find the locations that minimize the total costs of hydrogen supply and fleet operations.

The following main tasks are usually part of the project work:

- Understand the problem and study relevant literature
- Develop a mathematical formulation for the problem
- Examine applicable solution methods
- Collect data and set up test instances based on available data
- Implement and solve the model
- Analyze and discuss the results

This project is part of the ongoing research project *ZeroKyst KSP – Decarbonising the fisheries and aquaculture industry through hydrogen-electric propulsion.*

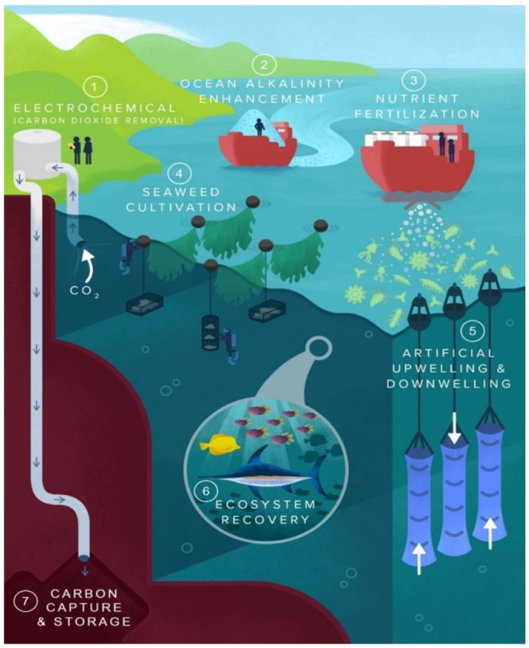
Collaborator: ZeroKyst-project (ZeroKyst - SINTEF), SINTEF Ocean

Main supervisor: Peter Schütz

Strategic Research Initiative(s): Leading transitions: Co-create a sustainable future

For more information, please contact Peter Schütz, peter.schuetz@ntnu.no.

AØO19: Maritime Logistics for Ocean Alkalinity Enhancement



Oceans absorb substantial amounts of CO_2 from the atmosphere, which lets them play an extremely relevant role in the fight against global climate change. However, the already occurred take-up of anthropogenic CO_2 has led to increased ocean acidification (lowering its pH) and has reduced the Oceans' further potential for taking up additional emissions. One measure to counteract this effect is so-called ocean alkalinity enhancement. This means that large amounts of alkaline minerals are distributed into the water in order to reduce the pH through chemical reactions and, thus, improve the take-up potential for atmospheric CO_2, see (2) in figure to the right. Of course, such human-made intervention into complex eco-systems like the oceans requires a vast amount of research from various disciplines to understand and avoid any unintended side-effects. At present, the technology is not understood well enough to put it in operation. Nevertheless, if ocean alkalinity enhancement is to be considered as a means of fighting climate change in the future, there is also the question about how to establish and operate a corresponding maritime logistics system for distributing the minerals over the ocean. Norway owns large deposits of minerals that could be used potentially for ocean alkalinity enhancement (see, for example, Aheim (sibelco.com)).

This master students project is about researching the maritime logistics systems that are required for such an ocean alkalinity enhancement. There are various questions such as the required transshipment capacities at suitable ports, the composition of vessel fleets, the routing of ships, the management of port operations, and many more. Next to the maritime transportation, also questions about the more upstream supply chain structures such as mining capacities and land-based transportation towards the ports might be part of the project. A central goal of the project is to develop optimization models and simulation systems that capture the relevant design questions and the corresponding operations management. Through these developed instruments, annual transport capacities and corresponding transportation cost are to be estimated in order to identify the most suitable solution among the identified options.

The project is conducted in close cooperation of NTNU and partners from Kiel University (Germany) and the Kiel Institute for the World Economy (Germany). One or more visits of the Norwegian research partners to Kiel could be part of the project (funding will be provided) to support a fruitful collaboration.

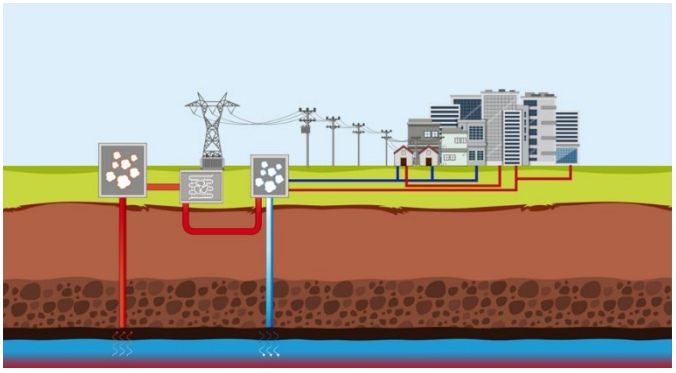
The project includes the following work packages:

- Review of the scientific literature for similar planning problems;
- Problem definition;
- Development and implementation of optimization models (and maybe simulation systems) for the design of suitable transportation systems
- Experimental analysis of potential solutions for estimating annual capacities and corresponding cost per ton of CO_2

Main supervisor:	Kjetil Fagerholt (NTNU)
Industry co-supervisors:	Frank Meisel (Kiel University), Wilfried Rickels (Kiel Institute for the World Economy)
Strategic research initiative:	Sustainability

For mer informasjon, ta gjerne kontakt med kjetil.fagerholt@ntnu.no for å avtale et (digitalt) møte.

AØO20: Modellering av fremtidens energisystem med fleksibel bruk av termiske laster



Beskrivelse: Oppvarming og kjøling står for halvparten av det totale endelige energibehovet i Europa. I motsetning til strømbehovet dekkes størstedelen av oppvarmingsbehovet fortsatt med fossile brensler i Europa: naturgass står for 66 % av produksjonen av rom- og tappevannsoppvarming i Europa. Samtidig, med økende andel av variable fornybare energikilder i kraftnettet, vil det kreves en betydelig mengde sluttbrukerfleksibilitet i fremtiden. For dette formål har fleksibel drift av varme- og kjølelaster et høyt potensial. Nøkkelteknologier i dette samspillet er varmepumper og termisk lagring: varmepumper muliggjør utslippsfri og energieffektiv produksjon av varme og kulde, og med termisk lagring kan produksjon skje i perioder når det er mye fornybar kraft tilgjengelig i kraftnettet.

Oppgave: Prosjektet FLXenabler har som mål å utvikle et modelleringsrammeverk for å analysere samspillet mellom økt fornybar energiproduksjon, avkarbonisering av termiske laster, og bruk av fleksible termiske laster. Hypotesen er at med smart kobling av varmepumper og termisk lagring, vil overgangen til et fullstendig avkarbonisert energisystem kunne skje raskere og med lavere totalkostnad. Utfordringen er at det ikke finnes et dekkende modelleringsrammeverk som kan vise effekten av termisk fleksibilitet i kraftsystemet i sin helhet, både på sentralisert og desentralisert nivå.

Oppgaven består i å:

- Sette seg inn i bruk av eksisterende lineære optimeringsmodell GENeSYS-MOD
- Kartlegge dagens representasjon av termisk fleksibilitet i GENeSYS-MOD og lignende modeller
- Foreslå forbedret representasjon av fjernvarme, termisk fleksibilitet, og termisk energilagring i GENeSYS-MOD
- Implementere forbedret representasjon av fjernvarme, termisk fleksibilitet, og termisk energilagring i GENeSYS-MOD
- Løse noen case med GENeSYS-MOD for å sammenligne og validere påvirkning av modelltilpasninger tilknyttet termisk fleksibilitet.

Forutsetninger: Det er en fordel at studenten har kjennskap til (eller evne til å sette seg inn i):

- Programmering (fortrinnsvis GAMS, Python og Julia er også relevant)
- Operasjonsanalyse, Lineær Programmering
- Energisystemanalyse og Kraftmarkeder

Collaborators: SINTEF Energi og Equinor via prosjektet: FLXenabler - Flexible heating and cooling and geothermal energy storage as an enabler for decarbonized integrated energy systems - SINTEF

Main Supervisor: Pedro Crespo del Granado

Co-supervisor: Stian Backe

Industry co-supervision: Dimitri Pinel (Forsker @ SINTEF Energi), Sturla Sæther (Overingeniør @ Equinor)

AØO21: Multimodal rebalancing of micromobility solutions

Micromobility solutions are becoming an increasingly popular means of transport in cities. This includes light shared vehicles such as e-scooters, mechanical bikes, cargo-bikes and e-bikes. Micromobility fleet operations face some of their most challenging times as interest from investors often comes with a requirement of proven profitability. Each operator in a city has their own crew to ensure availability, order, and uptime for their shared vehicles. They typically operate out of trucks, continuously trying to figure out the most efficient route to fulfill their tasks:

- *Rebalancing* - predicting demand, moving vehicles to where they generate the most trips, and moving vehicles away from full stations.
- *Maintenance* - ensuring that vehicles are safe and functional. Often possible to solve on the spot.
- *Battery swap/charging* - infrastructure availability and/or battery swap management becomes increasingly important with the electrification trend. Often solved on the spot.

To improve profitability, operators can collaborate across these operations. The typical use case will be to investigate the simultaneous rebalancing and swapping of batteries of e-scooters and city bikes.

The envisioned research project focuses on developing optimization models that allow for the multimodal rebalancing, while potentially integrating other tasks such as maintenance or battery swaps. Nevertheless, different research questions can be investigated. The students can build on existing work that has been performed in the last couple of years. Through our collaboration with Urban Sharing, Ryde Technology and Oslo Bysykkel, we are able to work with real life data from a range of cities (including Oslo, Bergen and Trondheim). The developed models can be tested and implemented in these cities and lead to actual improvements.

Regardless of the chosen problem, the following elements will be part of the thesis:

- Identifying the scope and problem description
- Formulation and implementation of an optimization model. Most likely a variant of the stochastic-dynamic bicycle rebalancing problem
- Development of an appropriate solution method. Heuristics tend to be needed.
- Testing of the solution method on problem instances based on real life data

Urban Sharing is a Norwegian startup developing technology for better resource utilization I cities. Their software is being used in the bike-sharing systems Oslo, Trondheim, Bergen, Milano og Verona. Urban Sharing has their main office in Parkveien in Oslo.

Industry partners: Urban Sharing, Ryde Technology, Oslo Bysykkel

Supervisor: Steffen Bakker

Co-supervisor: Henrik Andersson

Strategic research initiative: Leading transitions: Co-create a sustainable future

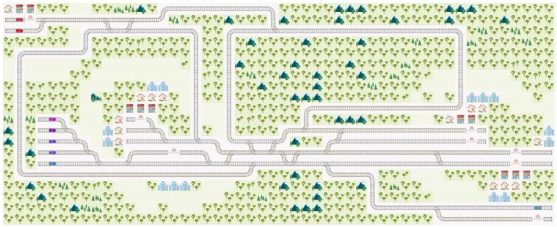
Sustainability

For more information, please contact steffen.bakker@ntnu.no to schedule a meeting.

AØO22: Multi-Agent Reinforcement Learning in Railway Optimization

Multi-Agent Reinforcement Learning (MARL) is a recent paradigm that has been very successful in tackling different types of vehicle scheduling. MARL involves several agents, each learning to develop a strategy for their own actions that maximizes their own utility. While each agent acts independently, maximized combined utility can only be achieved if the agents learn to cooperate towards a common goal. Compared to the single-agent counterpart, MARL can provide a decentralized, parallelizable, and more efficient framework.

MARL is particularly useful in settings dealing with real-time changes in a complex multi-vehicle system, where we constantly get updated information about vehicle positions and need to quickly adjust schedules. For example, in train dispatching we recompute new schedules that minimize total delay every few seconds, and every time a train gets delayed. As another example, in airports, airplanes need exclusive access to the runway when taking off or landing, and their sequence has to be constantly updated in real-time to deal with unforeseen circumstances, such as gate changes, technical problems, or other delays.



Recently, the Flatland (https://flatland.aicrowd.com/intro.html) simulator was developed to provide a realistic train simulation environment that allows testing and comparing different train (re)scheduling approaches. In particular, the initiative makes it easy to implement RL and MARL strategies.

A master thesis of Multi-Agent Reinforcement Learning can investigate one or more of these topics:

- Study the state-of-the-art and build competence on MARL by exploiting the flatland environment and reproducing results from previous competitions.
- Develop new or improved innovative MARL techniques.
- Test established or new algorithmic techniques (see #1 and #2) on real-world example in the Norwegian railway network.

Expected Results and Learning Outcome:

- Insight into applied mathematical optimization, machine learning, and the connection between the two topics.
- Experience with algorithm programming and testing in a real-world application setting.
- The student(s) should have a background or interest in one or more of these topics: mathematical optimization, machine learning, or algorithms and data structures.

Industry partners: SINTEF researchers from the Optimization and Analytics and AI groups in the SINTEF department of Mathematics and Cybernetics will supervise and collaborate on all of the above topics.

Main supervisor: Henrik Andersson

Industry co-supervisors: Giorgio Sartor, Bjørnar Luteberget, Milan de Cauwer (SINTEF)

Literature:

- S. Mohanty, E. Nygren, F. Laurent, M. Schneider, C. Scheller, N. Bhattacharya, J. Watson, A. Egli, C. Eichenberger, C. Baumberger, G. Vienken, I. Sturm, G. Sartoretti, and G. Spigler. Flatland-RL: Multi-agent reinforcement learning on trains, 2020. https://doi.org/10.48550/arXiv.2012.05893
- K. Zhang, F. He, Z. Zhang, X. Lin, and M. Li. Multi-vehicle routing problems with soft time windows: A multi-agent reinforcement learning approach. Transportation Research Part C: Emerging Technologies, 121:102861, 2020.

For more information, please contact Henrik Andersson, henrik.andersson@ntnu.no , to schedule a meeting.

AØO23: Myopic Improvement of Current Operational Policies for Dual Sourcing

It is well known that demand uncertainty sparks the need for safety stock and that the longer the lead-time is the more safety stock is needed. Dual sourcing is a commonly used method to reduce the need for safety stock by using an alternative supplier with a shorter lead-time and a higher cost unit cost as an “emergency” source when the stock is running low.

Determining when and how much to order from the “normal” and “emergency” source is a complicated problem as the optimal decision depends on the exact location of all the units currently in the pipeline. For example, it makes less sense to order from the “emergency” source if there is some units order from the “normal” source that will be available just a short time after any unit ordered from the “emergency” source. The most used policies, e.g., the dual-index policy and standing order policy, are easy and intuitive to implement but make little or no use of the exact information about the current pipe-line inventory.

Simple methods to myopically improve on these policies thus have a great potential of reducing the total cost. Moreover, they serve as a good benchmark and starting point for more advanced methods for optimizing the system such as for example machine-learning approaches.

Tasks within the project can include:

- Study of existing models and solution methods for dual sourcing.
- Developing a method for myopic improvement of some selected policies.
- Evaluation of a heuristic based on this myopic improvement.

Main supervisor:	Peter Berling
Strategic research initiatives:	Leading transitions: Co-create a sustainable future
	Sustainability

For more information, please contact Peter Berling, lars.p.berling@ntnu.no, to schedule a meeting.

AØO24: Nordic Hydrogen Hubs - Roadmaps towards 2030 and 2040

Description: Hydrogen and its derivatives are considered as key pillars in the green transition. Globally, there are significant ambitions and a high number of initiatives to increased usage of hydrogen in the energy sector and as replacement for fossil sources in industrial processes. Hydrogen can also play a critical role as a supplement to direct electrification in hard-to-abate sectors, such as high temperature heat applications in industry, maritime and heavy-duty transport.

In 2019, all the Nordic countries committed to work towards carbon neutrality in the Nordic region by signing the "Declaration on Nordic Carbon Neutrality", which highlights the importance of a Nordic collaboration for decarbonizing the transport sector and removing obstacles to low-emission development. All the Nordic countries have Hydrogen plans, roadmaps and/or strategies as well as ongoing hydrogen related research and demonstration programs. There is a need to understand the implications of different Nordic hydrogen roadmaps in terms of costs, production, transport infrastructure, and storage of hydrogen.

Task: As part of a Nordic research project, the student will use and develop the existing stochastic linear programming model EMPIRE to study the cost optimal investment pathway of the blue and green hydrogen production in the Nordics, as a part of the wider European power system.

The project tasks can include:

- Learning to run and adjust EMPIRE to analyse investments in the Nordic energy system with a European perspective towards 2030 and 2040.
- Collect sector-specific data for the potential hydrogen value chains in Norway, Sweden, Denmark, and Finland based on national roadmaps/strategies.
- Solve EMPIRE in several cases to study how the development of different Nordic hydrogen roadmaps impact investment decisions regarding power supply for electrolysis, gas reformation with carbon capture and storage, and hydrogen infrastructure.

Prerequisites: The student should be familiar with (or have capacity and interest to learn):

- Programming/coding (Python)
- Stochastic programming (decision making under uncertainty)
- Energy system analysis
- Power markets and sector coupling

Collaboration: SINTEF Energi via Nordic project **"NordicH_2ubs"**

Main Supervisor: Pedro Crespo del Granado;

Co-supervisor: Stian Backe

For more information, please contact Pedro Crespo del Granado, pedro@ntnu.no

AØO25: Optimal planning for a green transition of the fishing fleet

The fishery industry is heterogenous and spans two main value chains; *demersal fisheries* targeting cod haddock and saithe and *pelagic fisheries* targeting herring, mackerel, Norwegian pout and blue whiting. Current licence and quota regulations have created a diverse sector dominated by large vessels in pelagic fisheries and small vessels in demersal fisheries.

Norway aims to reduce its greenhouse gas (GHG) emissions by at least 50 to 55 percent relative to 1990 levels by 2030, and to become a low-emission society by 2050. In 2021, the Government developed a Climate and Environment Plan to put Norway in a leading role regarding adoption of green vessel technologies and to halve domestic maritime transport emissions by 2030.

Compared to conventional diesel propulsion, zero-emission technologies such as hydrogen are handicapped by limited range and high infrastructure costs. This is challenging for the fishing industry, where larger vessels are mobile and spend several days at sea before landing the fish. For bunkering infrastructure developers, seasonality in fishing and the dispersion of vessels among a large number of fishing ports could be a barrier to exploitation of economies of scale and therefore preculde economically viable infrastructures for low- and zero-emission fishing vessels.

The aim for this master thesis project is consequently to establish a Mixed-Integer Programming (MIP) model to identify the *optimal* energy transition of the fishing fleet to comply with the Government's environmental policy aims while upholding current operational profile of the fishing fleet. The objective is to *minimize* the system costs of the green transition. This complex problem encompasses *strategic* decisions regarding the mix of technical (e.g., energy carrier and shore power) and operational (e.g., slow steaming) measures to be applied to fleet segments alongside bunkering infrastructure characteristics and location, *tactical* decisions in terms of solutions for energy delivery, and operational decisions regarding supply of energy at different ports. The MIP model will enable abatement cost estimation associated with implementation of an environmental policy scenario.

This student project will be linked to the FAME project – managed by Transportøkonomisk institutt (TØI). Main research tasks include: Identifying key model parameters (e.g., CAPEX and OPEX) in cooperation with the FAME research team (e.g., ABB, Corvus); Develop and implement the optimization model, and to develop a specialized solution algorithm if the problem size is beyond the capabilities of commericial solvers; Demonstrate and evaluate the model through a use-case in cooperation with key stakeholders (e.g., Fiskarlaget, Kystrederiene and Fiskebåt). The output of the master thesis research will be further exploited in the FAME project and for providing policy support to the Norwegian Environment Agency, Directorates of Fisheries and Norwegian Maritime Authority.

Collaborator:	TØI and other partners from the FAME project
Main supervisor:	Kjetil Fagerholt
Industry co-supervisor:	Kenneth Løvold Rødseth (TØI)
Strategic research initiative:	Sustainability

For mer informasjon, ta gjerne kontakt med kjetil.fagerholt@ntnu.no for å avtale et (digitalt) møte.

AØO26: Optimal schedule of maintenance and production activities

Scheduling maintenance activities is a crucial task in any production system. It amounts in finding the best way to sequence and perform certain operations which require some amounts of limited resources (including work force) and must satisfy a number of technological constraints. Finding a feasible schedule of all activities can be very complex, and companies have dedicated units to this end. An even more challenging task would be to connect maintenance schedule and production schedule, that is, finding a feasible schedule of maintenance activities which minimizes production losses.

Research Topic: The specialization project and Master's thesis aim at implementing mathematical optimization models and algorithms for maintenance operations and production scheduling, with particular emphasis on combinatorial methods and integer programming approaches.

Methods:

- Understand and describe the problem and its setting.
- Review current literature and methods on integrated maintenance and production scheduling.
- Investigate what mathematical optimization and machine learning methods can be used.
- Implement a prototype.

Play an active role in ongoing research projects with industry partners (Visavi, Kongsberg digital, ERJU, https://www.sintef.no/en/digital/departments-new/applied-mathematics/optimization/operationsresearch/optiplan-optimisation-engine-for-visavi-liveplan/).

Expected Results and Learning Outcome:

- Insight into use of applied optimization.
- Develop an understanding of activity and production scheduling problems.
- Evaluation of the prototype with real business use cases.

Industry partner:	SINTEF
Main supervisor:	Henrik Andersson
Industry co-supervisors:	Atle Riise (SINTEF), Carlo Mannino (SINTEF)

For more information, please contact Henrik Andersson, henrik.andersson@ntnu.no , to schedule a meeting.

AØO27: Optimering av samkjøring som løsning på køproblematikk: Case fra Sotra

De fleste som har bodd i eller vært en lengre tid i Bergensregionen kjenner til «Sotrakøen», som i rushtrafikken strekker seg 10 kilometer i hver retning mellom øyen Sotra (Øygarden kommune) i vest og Bergen i øst, og fører til en mangedobling i reisetid for rundt 30 000 reisende som passerer over Sotrabroen, den eneste fastlandsforbindelsen, hver eneste dag. Som løsning på problemene skal det bygges en ny og større bro, og *Sotrasambandet* blir norgeshistoriens største veiprosjekt (https://www.nrk.no/vestland/lyser-ut-noregshistorias-storste-vegkontrakt-1.14835367). Oppstart av prosjektet er høsten 2023, med en anleggsperiode på 5-6 år.

Det finnes ingen omkjøringsalternativer, noe som vil føre til enorme trafikale problemer gjennom anleggsperioden. Nyttetrafikk og utrykningskjøretøy vil slite med å komme frem, og øvrige reisende vil bli kraftig forsinket til sine avtaler. Beskjeden fra både veimyndigheter og politisk hold er derfor klar: Tallet på passerende kjøretøy må ned med 20-25% fra dagens nivå – og det må skje raskt. Det vil bli nødvendig med radikale endringer i folks reisevaner, men hittil vet ingen hvordan dette skal foregå.

Denne oppgaven tar derfor for seg tiltaket med en bedre utnyttelse av ledig kapasitet i køene gjennom økt grad av samkjøring (ride-sharing). Potensialet er enormt, for undersøkelser har vist at rundt 95% av bilene som passerer på strekningen kjører uten passasjerer. Det mangler imidlertid kvantitative analyser for hvordan man skal gjennomføre slik samkjøring mest mulig effektivt, noe som kan skyldes manglende modelleringskunnskaper og verktøy/løsningsmetoder for å løse det som veldig fort blir et komplekst planleggingsproblem som balanserer ulike hensyn - hva er optimal utnyttelse av ledige seter i køen, og hvem skal samkjøre med hvem for å redusere trafikken mest mulig effektivt?

Overordnet kan problemstillingen formuleres: *«Hvordan kan sjåfører og passasjerer effektivt knyttes sammen med en optimeringsmodell for samkjøring, og hvor stor vil effekten av et slikt tiltak være på en vei med sprengt kapasitet?»*. Aktuelle oppgaver kan være å:

- Gi en matematisk formulering av samkjøringsproblemet
- Utvikle en effektiv heuristikk, gjerne med komponenter fra maskinlæring, for å løse større instanser for problemet
- Generere virkelighetsnære testinstanser, basert på tilgjengelige reisevaneundersøkelser og trafikkdata – her har vi allerede fått oversendt en god del relevant data fra området
- Simulere effekten av ulike måter å organisere samkjøringen på i ulike scenarier: Hvilke insentiver vil gi mest samkjøring? Hvordan integrere samkjøring med øvrig kollektivtilbud?

Denne oppgaven vil kreve en del programmering (av heuristikk), så en bakgrunn og interesse for dette er ingen ulempe. Ideen om at masterstudenter ved IØT fra høsten av kan bruke prosjekt- og masteroppgaven sin til å lete etter løsninger på disse problemene er allerede «plantet» hos lokale politikere og næringsliv – og både ordfører, samferdselssjef i kommunene og Statens Vegvesen har uttrykt god og positiv respons. Resultatene fra denne oppgaven vil være av stor interesse og kan være et viktig bidrag til å løse en av de store utfordringene for trafikken i Bergensregionen dette tiåret, og derfor være av stor samfunnsverdi. Samtidig har samkjøring en udelt positiv klimaeffekt gjennom reduserte utslipp. Overføringspotensialet til andre byer med lignende infrastruktur er også stort, og oppgaven kan vise vei mot en helt ny måte å tenke på rundt organiseringen av persontransport.

Samarbeidspartnere:	Øygarden kommune, Bergen kommune
Hovedeileder:	Kjetil Fagerholt
Medveileder:	Ph.d.-stipendiat Andreas Ormevik
Strategic research initiative:	Sustainability

For mer informasjon, ta gjerne kontakt med kjetil.fagerholt@ntnu.no for å avtale et (digitalt) møte.

AØO28: Optimizing a zero-emission truck fleet

The transport sector in Norway stands for around 30% of national greenhouse gas emissions. When considering road transport (which is responsible for more than half the total transport emissions), heavy duty transport accounts for around 33% of the emissions. As such, transport companies are facing a paradigm shift towards zero-emission fuel technologies. On short to medium distances the transport sector is moving towards battery-electric trucks (BET). For long distance trucking fuel-cell electric trucks (FCET) and biogas-powered trucks are serious alternatives to BETs due to their higher driving range and shorter refueling time.

This project takes the perspective of a transport company that must decide on the composition of a fleet of zero emission trucks consisting of BETs and FCETs (strategic planning level) and charging and routing strategies for the trucks (tactical/operational level). The project can build on ongoing research and focus on new areas:

- Better utilization of the (capital intensive) fleet through:
    - Synchronization of charging with driving breaks (resting periods, loading/unloading)
    - Using multiple drivers on a single truck
- Consideration of uncertainty (e.g., charging queues)
- Impact of bottlenecks in the charging infrastructure (at the depot)

Specific task within the project can include:

- Identifying the scope and problem description (together with our partners) as well as key model parameters
- Study of existing models and solution methods
- Formulation and implementation of an optimization model. Potentially a scheduling problem or an (electric) vehicle routing problem
- Development of an appropriate solution method
- Computational study and evaluation of the model results with our industry partners.

Collaborator:	We have an open dialogue with several transport companies through the research centers FME NTRANS, FME MoZEES that can be utilized
Supervisor:	Steffen Bakker
Co-supervisor:	Magnus Stålhane
Strategic research initiative:	Leading transitions: Co-create a sustainable future Sustainability

For more information, please contact steffen.bakker@ntnu.no to schedule a meeting.

AØO29: Optimizing jack-up vessel chartering strategies to support maintenance at offshore wind farms

The world stands in front of a major task of transitioning to renewable energy to solve the global climate crisis. With the goal of turning Europe into the first climate neutral continent by 2050, EU launched the Green Deal in July 2021. Offshore wind is a young industry that is in rapid development and is expected to constitute an important part of the future energy system. Hence, among other initiatives within renewable energy, the ambitions are to meet the European Green Deal partly by reaching 300 GW of installed offshore wind capacity by 2050. 1 GW of electricity is enough to support 750,000 homes. It is estimated that 16-24 % of the total costs related to offshore wind stem from operations and maintenance (O&M). O&M costs for offshore wind ranged between 70-129 USD/kW in 2018. For onshore it was 33-56 USD/kW. These higher O&M cost for offshore wind is related to the harsh conditions at sea which makes maintenance planning a complex task. To ensure that the ambitions of offshore wind are viable, it is crucial to decrease the maintenance costs.

This project is connected to work-package 2: "Marine operations and Logistics" within the FME NorthWind and will focus on effective logistics planning to reduce the cost of maintaining offshore wind farms, while at the same time maximizing the energy output. Until recently maintenance at offshore wind farms have been conducted using a preventive- or condition-based maintenance strategy. However, as more information becomes available, and better prediction models are developed, the goal is to further reduce the cost of energy from offshore wind farms by moving to a predictive maintenance strategy. In such a strategy, probabilistic models of the future conditions of each component of a wind turbine are used as a basis for planning the maintenance. The goal is to develop a solution methodology that combines probability distributions on failures, data on vessel capabilities and logistics planning to create optimal maintenance schedules. To develop the methodology new exact and/or heuristic solution methods must be developed, based, e.g., on existing methods from mixed integer stochastic programming and/or discrete event simulation.

In this project the focus is on major maintenance tasks where a specialized jack-up vessel is required. Due to long lead times related to both ordering of wind turbine components and vessel chartering, decisions regarding these must be taken well in advance of the actual maintenance period. However, taking these decisions early is linked to a high degree of uncertainty. Relevant uncertainties could be weather conditions governing when the vessel can operate as well as the number, and timing, of component failures.

Some relevant topics that may be included in the project (and/or Master thesis) are:

- Investigate the problem, study existing models and solution methods for related problems
- Develop precise mathematical model formulation(s)
- Consider methods for handling the problems underlying uncertain parameters
- Implement solution method for the problem
- Test the implemented solution method on problem instances and analyse/discuss the results

Industry partner:	Potential partners in FME NorthWind
Main supervisor:	Magnus Stålhane
Co-supervisor:	Vibeke Hvidegaard Petersen
Strategic research initiative:	Leading transitions: Co-create a sustainable future
	Green Value Creation - Circular Economy

For more information, please contact Magnus Stålhane, magnus.staalhane@ntnu.no, to schedule a meeting.

AØO30: Optimization and design of future Power Grids: Challenges and Opportunities for the Bolivian TSO

With plans to be the energetic heart of South America, Bolivia has ambitious plans to become a primary net exporter of energy to the region. Bolivia plans significant investments in conventional and renewable energy projects in the next decades. Deployment of large hydro-power, wind and solar projects are foreseen in the investment agenda. However, and despite the large renewable potential in the country non-conventional renewable technologies are not yet expected to be a main source of energy. The Bolivian government has established the following policy guidelines for the energy sector: energy sovereignty, energy security, energy universalization, energy efficiency, industrialization, and energy sector integration. The characteristics of such an energy development have been defined as including increased production and consumption of natural gas, reduced importation of diesel oil, increased use of renewable energy (RE) for electricity generation, increased use of electricity, and exportation of energy (Natural Gas and electricity).

Project focus

In the last year, climate awareness and the rise in oil prices have set new priorities for the government in accelerating the deployment of solar PV and wind power. By 2030, it is expected a 100% rate in rural electrification and 75% share of renewables as part of the energy mix. This ambitious challenge has raised numerous questions for the Bolivian TSO, such as: What grid reinforcement will be needed, do we need new power lines? Stimulating Solar PV will create microgrids, should this be built bottom-up and later interconnected to the main grid? Where should the TSO incentivize power production, how to handle flexibility needs in space and time? This project will evaluate the flexibility of the Bolivian power generation system in terms of energy balancing, electricity generation costs and power plants scheduling in a scenario that considers large solar and wind energy technology deployment. Assessment of Sustainable development Goals could also be relevant in the study.

Activities

The project will apply the PyPSA model (https://pypsa.readthedocs.io/en/latest) to analyze the Bolivian power grid. Modelling should account and test investment decisions to determine the optimal placement of infrastructure (network or generation expansion) that comply with grid standards and operations. The project will have a strong interaction with the Bolivian TSO to discuss results, model assumptions, and policy recommendation. As the project is hands-on and collaborative, a potential travel to Bolivia might be arranged in the spring semester (2024).

External Partner:	UMSS (University in Bolivia), ENDE (Bolivian TSO), U.Liege (Belgium)
Main supervisor:	Pedro Crespo del Granado
Co-Supervisor:	Mostafa Barani
Strategic research initiative:	Sustainability

For more information, please contact Pedro Crespo del Granado, pedro@ntnu.no

AØO31: Optimization for a fresher and healthier future

Faced with the demand for ever fresher products and more effective logistics, BAMA is investing in a supply chain powered by data, predictions and optimization. The key challenges we address are how to reduce food wastage as well as increasing the consumption of fruits and vegetables in Norway through fresh and healthy products.

BAMA is the largest wholesaler of fruits and vegetables in the Nordics, has more than 3000 employees and an annual turnover of 20 BNOK. Through a large logistic operation, we import products from 85 different countries, make around 5200 daily deliveries to our customers and handle more than 500.000 tons of product every year. A subsidiary of BAMA called BAMA Industri, develops, processes and package fresh products like pre-cut salad and other ready-to-eat meals.

Throughout Norway we have more than 1000 producers and 330 pickup points. Finding the ideal product assortment, supporting Norwegian farmers and increasing the consumption of healthy products is part of our strategy. Route planning, assortment optimization and pallet allocation are three examples of optimization problems faced by BAMA.

In this master thesis you will get the task of building a mathematical optimization model to address one of BAMAs key challenges. The problem could be related to route planning, assortment optimization and/or capacity planning. Either way, the model should minimize the cost of transportation while at the same time reduce food waste and maximize product freshness.

This project will be conducted in close collaboration with BAMA, and the students will be invited to join in on relevant workshops at BAMA offices in Oslo and to visit some of our logistic facilities.

Relevant activities in the master project could be:

- Study the BAMA supply chain design and logistic operation
- Look into existing methods and describe industry best practices
- Develop, implement and test a mathematical optimization model
- Develop a simulation framework to perform back-testing used to compare different strategies and model parameters
- Evaluate the results and present a recommended optimization model that can be used by BAMA to improve our operations

Industry partner: BAMA Gruppen AS

Main supervisor: Kjetil Fagerholt

Co-supervisor: Henrik Andersson

Industry co-supervisor: Hans Martin Espegren (Data Science Lead in BAMA)

For more information, please contact Henrik Andersson, henrik.andersson@ntnu.no , to schedule a meeting.

AØO32: Planning logistics for the Norwegian aluminum industry

In 2021, Hydro Aluminium changed the logistics set-up for the 5 Norwegian smelters. To improve efficiency and flexibility as well as the CO2-footprint of the logistics system, the old set-up with different types of vessels and many different handling methods was changed to a set-up where the products are loaded on standardized load carriers and shipped using Roll-on Roll-off (RoRo) vessels. The RoRo vessels have weekly port calls at all the 5 Norwegian smelters.

Using standardized load carriers is expected to lower the logistics costs of transporting cargoes to and from the smelters. The introduction of RoRo vessels allows for efficient loading and unloading of cargoes, as the cargoes are rolled on and off the vessel. This reduces handling and minimizes the risk of damage to the cargoes. Still, this new logistics set-up introduces a new set of challenges for the logistics planning.

The scope of this project is to use optimization/operations research to analyse one of the important logistics challenges for Hydro. Some interesting planning problems to consider are:

- Optimal stowage planning for the RoRo vessels: Similar to a ferry, load carriers are rolled on board the RoRo vessels via ramps and stored on multiple decks. An optimal stowage plan minimizes the time spent moving the load carriers to enable loading or unloading the load carriers. At the same time, stability constraints and weight limitations for the different decks on the vessel have to be observed.
- Planning the flow of containerized cargo: The flow of unitized containerized cargo is unbalanced, i.e., the number of cargoes sent from the smelters is not equal to the number cargoes to the smelters. The aim of this project is to find the optimal flow of containers such that each smelter has the right number of containers available at any point in time.
- Maximizing the utilization of load carriers: Hydro's products vary in dimensions and weight. The goal is to minimize the number of used of load carriers by combining different cargoes on the load carriers such that neither available space nor carrying capacity are exceeded.

Which problem to focus on will be decided after summer by the students, Hydro, and the supervisor.

The following main tasks are expected to be part of the project work:

- Understand the problem and study relevant literature
- Develop a mathematical formulation of the problem
- Collect data and set up relevant test cases based on real-world-data
- Implement and solve the model
- Analyze and discuss the results.

Collaborator: Hydro (www.hydro.com)

Supervisors: Peter Schütz

Strategic Research Initiative: Leading transitions: Co-create a sustainable future

For more information, please contact Peter Schütz, peter.schuetz@ntnu.no.

AØO33: Predicting the effect of altered optimization problems in the aluminum industry

Hydro has a complex production and distribution network for the global production and sales of aluminum products. In cooperation with SINTEF, Hydro has developed an optimization model incorporated in a decision support tool for the tactical planning of order allocation to casthouses. This model is based on a mixed integer linear approach considering known orders and expected future demand. It is in active use for several product groups and geographic regions.

The model can have a considerable running time for regions with a large number of customers, and it is therefore not feasible to rerun the model on the arrival of each new order. It is therefore of considerable interest to examine methods that can be used as fast surrogates for the optimization model when doing the initial allocation of an order to a casthouse.

Research topic: A mixed integer linear optimization model of the problem has been developed and is in active use, but its use in an operational setting is limited by its running time. The focus of this project is to assess if there are methods based on machine learning, trained on many optimized solutions, that can accurately estimate the optimal decisions for altered instances. Particularly, the allocation of a new order to a casthouse given its characteristics and the optimal solution to the unaltered problem.

Methods/tasks:

- Understand the existing optimization model for the downstream logistics.
- Review the current literature on how to use machine learning methods as surrogates for optimization problems.
- Implement solutions based on one or more machine learning methods to predict the effect of an altered optimization problem.
- Carry out experiments to assess the performance of the above solutions, both in terms of solution quality and running time.
- Describe the problem, the methods, and the results in a way that can be published.

Expected Results and Learning Outcome:

- An understanding of how machine learning can be used to predict the result of an optimization after a minor change to the optimization problem.
- A prototype software that has been tested for realistic problem instances.
- A publishable description of the work.

Recommended prerequisites: Good competence in optimization modelling and machine learning. Programming experience.

Industry partner:	SINTEF/Hydro
Main supervisor:	Henrik Andersson
Industry Co-supervisor:	Truls Flatberg (SINTEF)
Collaborators:	Pål Rist (Hydro)
Strategic research initiative:	Leading transitions: Co-create a sustainable future
	Green Value Creation - Circular Economy

For more information, please contact Henrik Andersson, henrik.andersson@ntnu.no, to schedule a meeting.

AØO34: Ressursplanlegging ved Fødeavdelingen ved St. Olavs hospital

Fødeavdelingen ved St. Olavs hospital bistår om lag 3700 fødsler per år, og er en av landets største fødeavdelinger. Avdelingen består av ulike enheter, blant annet fødestuer, sengeposter og poliklinikk. De ansatte ved klinikken har ulike yrkesbakgrunner, hovedsakelig leger, sykepleiere, jordmødre og helsefagarbeidere. Disse har ulike kompetanser, og gjør derfor ulike oppgaver.

Demografiske endringer vil medføre en mangel på helsepersonell om få år. For å kompensere for mangelen må vi endre på måten vi organiserer helsetjenestene, blant annet ved å se på sammensetning av personell og oppgavedeling mellom yrkesgrupper. God ressursplanlegging er en annen forutsetning for å kunne tilby effektive helsetjenester. Kompetansesammensetning og ressursplanlegging kan studeres hver for seg eller integrert, og det vil være ulike problemstillinger relatert til disse ved fødeavdelingen.

Det fins ulike planleggingsproblemer som kan studeres ved fødeavdelingen. For å nevne noen:

1. Kapasitetsplanlegging ved poliklinikk. Barselpoliklinikken håndterer både planlagte og akutte henvisninger, og ansatte med ulike yrkesbakgrunner kan være involvert i konsultasjonene. Det kan være utfordrende å håndtere akutte henvendelser på kort varsel, og samtidig opprettholde et godt tilbud til de planlagte pasientene.
2. Bemanningsplanlegging ved sengeposter. Sengepostene bemannes døgnet rundt av ansatte med ulike yrkesbakgrunner. Det skal til enhver tid være tilstrekkelig kompetanse tilgjengelig, samtidig som det skal foregå opplæring og kompetanseoverføring mellom ansatte. Arbeidsbelastningen vil variere basert på antall fødende kvinner, grad av komplikasjoner ved fødslene, samt sykefravær hos de ansatte. Relevante problemstillinger kan relateres til sammensetning av ansatte på skift, samplanlegging av personell mellom seksjoner, eller daglig replanlegging av ansatte til skift og seksjon.

Om lag 25% av alle fødsler settes i gang ved hjelp av såkalt induksjon, og andelen er økende. Starttidspunkt, samt intervallet for medisinering kan brukes til å styre når en fødsel skal skje, og bedre planlegging bidra til å flate ut behovet for ressurser.

Punktene over er eksempler på problemstillinger, men endelig problemstilling vil utarbeides i samtaler mellom studenter, veiledere og ansatte ved St. Olavs hospital.

Arbeidet kan innebære ulike oppgaver som:

- beskrive utfordringene med ressursplanlegging ved Fødeavdelingen;
- studere litteraturen for liknende problemer;
- avgrense av planleggingsproblemet og beskrive av dette;
- utvikle av matematisk(e) modell(er) for problemet;
- implementering av modellen(e) ved hjelp av egnet programvare, analyse og testing av instanser basert på data fra St. Olavs hospital.

Collaborator: St. Olavs hospital

Main supervisor: Anders N. Gullhav

Co-supervisor: Thomas Reiten Bovim

Strategic research initiative: Health and the Public Sector

For more information, please contact Anders N. Gullhav, anders.gullhav@ntnu.no, to schedule a meeting.

AØO35: Scenario reduction for multi-stage stochastic programming

Stochastic programming problems are usually difficult to solve. This is often due to the number of scenarios needed to appropriately represent the uncertainty in the underlying problem and the corresponding increase in problem size. This increase in problem size is even worse when the problem involves sequences of decisions over time, formulated as a multi-stage stochastic programming model.

A standard approach to solving large optimization problem is to reduce the problem size, e.g. through decomposition approaches. In stochastic programming, problem size can also be reduced by first sampling a subset of scenarios and then solving a smaller problem with fewer scenarios. In Sample Average Approximation, this process is repeated multiple times, solving multiple of smaller stochastic programming problems.

If we were able to establish in advance which scenarios matter the most for the optimal solution, we could solve the stochastic programming problem only for these scenarios and (quickly) provide a near-optimal solution. This is the general idea behind scenario reduction. The latest approach to scenario reduction for two-stage problems is based on solving a set of deterministic problems, evaluate their solutions in the different scenarios and then cluster the scenarios according to similarity (see e.g., Hewitt et al., 2022). Solving the two-stage problem with one scenario from each cluster often results in near-optimal solutions with somewhat reasonable run time.

The purpose of this project is to extend the ideas of scenario clustering for two-stage problems to the multi-stage case. Using scenario clustering to reduce the number of scenarios in the problem is one approach, but other approaches can be studied as well. Work will concentrate on solving a multi-stage, multi-period facility location problem with capacity expansion and uncertain demand.

The following main tasks are usually part of the project work:

- Understand the problem and study relevant literature
- Examine applicable solution methods
- Implement method and solve the model
- Analyze and discuss the results

Supervisor: Peter Schütz

Co-supervisor: Paolo Pisciella, Sarka Stadlerova

For more information, please contact Peter Schütz, peter.schuetz@ntnu.no.

Hewitt, M., Ortmann, J. & Rei, W. (2022). Decision-based scenario clustering for decision making under uncertainty. Annals of Operations Research, (315), 747–771. https://doi.org/10.1007/s10479-020-03843-x

AØO36: Shortest path problems with decreasing inter-dependent resource consumption

A prerequisite for successfully applying Branch-and-price to a given problem is that the pricing problem can be solved efficiently with integral requirements on the variables. A large class of pricing problems with integral requirements can be modelled as shortest path problems with resource constraints (SPPRC), where the objective is to find the shortest path between two nodes in a network where a vector of "resources" are accumulated when traversing each arc. The resources are accumulated according to resource extension functions (REFs), and are constrained to take values within certain intervals, referred to as resource windows, at each node/arc along the path. The goal is to minimize the accumulation of one resource, while the other resources stay within the resource windows at all nodes/arcs along the path.

The SPPRC can be efficiently solved using dynamic programming (DP) given that one has an effective method for decreasing the state space by removing partial paths that cannot be part of an optimal solution. The criterion by which partial paths are removed is usually referred to as a dominance criterion, and is unique for a given SPPRC. However, for all SPPRC problems where the REFs are non-decreasing, a general effective dominance criterion exist, and the problem can be solved in pseudo-polynomial time.

In this project, we will study the SPPRC with inter-dependent decreasing REFs. For a given (partial) path, and assuming that the REF's are continuous, the optimal resource consumption becomes a multi-objective (non-)linear program (MO(N)LP). When (at least) two resources are inter-dependent and the REF connecting them is decreasing, there exist multiple pareto-optimal resource vectors, making dominance more difficult.

In this project, the students will select one problem where the above properties hold, and attempt to solve the selected problem using dynamic programming. It may also be possible to extend the solution method to branch-and-price. Possible applications include (but are not limited to):

- The split delivery vehicle routing problem
- The pollution routing problem
- The pickup and delivery problem with split loads
- Ship routing and scheduling problem with speed optimization
- Electric vehicle routing problem

Possible tasks in the project include:

- Study the selected problem and its properties
- Study relevant literature both on VRP, BP and multi-objective (non)-linear optimization
- Formulate the problem as a labeling algorithm
- Find effective ways to calculate and store the set of pareto optimal resource vectors.
- Develop effective ways of checking (partial) dominance among labels
- Implement the algorithm
- Extend the solution method to a branch-and-price framework

Prerequisites: Good knowledge of a programming language such as c++ or Java

Main supervisor: Magnus Stålhane

Ta gjerne kontakt med Magnus Stålhane (magnus.staalhane@ntnu.no) for et kort møte dersom dere har spørsmål vedrørende oppgaven.

AØO37: Solving the Feeder Network Design with inventory as a buffer mechanism

Liner shipping is the world's most important mode of freight transport, accounting for about 60% of the total volume of international trade. Typically, large container vessels sail regular routes to connect major hub ports on different continents. Containers are then transported from a hub port to regional (feeder) ports using medium and small vessels. The process of establishing liner routes from/to feeder ports and assigning vessels (in terms of number and size) to deploy these routes on a regular basis is called *Feeder Network Design*. This process is at a tactical level and the routes are planned to be used over several months.

The Feeder Network Design has been solved using optimization methods, considering various problem characteristics, from integrating homogeneous fleet of vessels to adopting a more complex routing structure. Although more realistic characteristics are considered when solving the problem, the demand for containers between the hub and feeder ports is considered to be known and weekly fixed for the whole planning period. However, in practice, the demand is usually uncertain, making the problem even more complex. In fact, if weekly demand is lower than expected, vessels operate at a lower capacity. Conversely, higher demand leads to a need to chartering excess capacity, delayed deliveries or lost sales. In all cases, additional (unplanned) costs are incurred by the logistics company. To cope with the demand uncertainty, safety measures must be determined, e.g., safety-stock or excess transport capacity.

This project aims to study the Feeder Network Design with demand control. Two aspects of the problem can be considered:

- Optimal/efficient inventory policy given limitations of transport capacity.
- Creating feeder routes that are more robust to the demand variations.

The case studies will be based on realistic data for a feeder network between the port of Rotterdam and Norwegian ports.

The following main tasks are expected to be part of the project work:

- Understand the problem.
- Write a literature review of related works.
- Formulate the problem mathematically and possibly propose a specialized solution method.
- Conduct a computational study.
- Discuss and analyze the results.

Main supervisor:	Peter Berling (NTNU)
Co-supervisor:	Kais Msakni (NTNU) and Kjetil Fagerholt (NTNU)
Strategic research initiatives:	Leading transitions: Co-create a sustainable future, Sustainability.

For more information, please contact Peter Berling, lars.p.berling@ntnu.no, to schedule a meeting.

AØO38: Solving the tactical production planning problem in the aquaculture industry

Over the past decades, aquaculture has become one of the most important industries in Norway. Since the1980s, production of farmed salmon has grown from approximately 5300 tonnes to 1.3 million tonnes in 2019, representing a value of 68 billion NOK. This increase is largely due to an increase in salmon prices rather than an increase in salmon production. Using the existing production system more efficiently might allow for further growth of production. The possibilities for increasing production capacity are limited and improving the utilization of existing production capacity has therefore become critical for the industry to ensure further growth.

Existing optimization models for tactical production planning can capture uncertainty in both growth of biomass and market prices, account for the risk profile of the fish farmer, and much more. The number of scenarios that can be included however, is rather limited. The purpose of this project is therefore to study, analyze and apply one or more advanced solution methods to solve the tactical production planning problem in the aquaculture industry. The solution methods can come from exact methods, heuristics, incorporate machine learning or combine some of these elements.

Students considering this project should have an interest in programming (Python, C#, C++), developing, implementing and analyzing solution methods for stochastic programming problems. Existing coding experience will be beneficial.

The following main tasks are usually part of the project work:

- Understand the problem and study relevant literature
- Develop a mathematical formulation for the problem
- Examine applicable solution methods
- Collect data and set up test instances based on available data
- Implement and solve the model
- Analyze and discuss the results

Supervisor: Peter Schütz

For more information, please contact Peter Schütz, peter.schuetz@ntnu.no.

AØO39: Staff scheduling for the Rehabilitation center of Trondheim Kommune

The rehabilitation center of Trondheim municipality operates various rehabilitation services, ranging from day-to-day assistance to physiotherapy services. These services are carried out by different staff members, including nurses, healthcare workers and assistant physiotherapist. In order to provide better rehabilitation services, the municipality needs to implement effective planning to ensure that costly resources are used to the best effect. Schedules are established for a typical 26-week period and ensure that suitably qualified staff are in place at the right time.

The workforce is central to staff scheduling operations. Not only are they essential to ensure that patients receive high-quality care, but they also represent a substantial portion of costs, with labor costs accounting more than 40% of healthcare institution budgets. As a result, planners are under constant pressure to manage their workforce at their highest utilization. However, the major drawback of focusing solely on this criterion is that it has a negative impact on service performance and quality of care. Unappealing schedules or heavy workloads are major factors that contribute to staff dissatisfaction and high turnover rates. In the case of the rehabilitation center of Trondheim municipality, staff representatives and unions are involved in the planning and staff scheduling process to adopt policies that support satisfactory working conditions, such as staff preferences, fairness and balance between staff workloads, and individual needs that may put pressure on the schedules of other colleagues.

This thesis aims at solving the staff scheduling at the rehabilitation center of Trondheim municipality problem using mathematical optimization model. This thesis also aims to analyze the consequences and outcomes of implementing different policies in staff scheduling.

The following main tasks are expected to be part of the project work:

- Understand the scope, describe the problem, and collect data.
- Review related works in the literature.
- Develop a mathematical model for the problem.
- Perform a computational study based on realistic cases.
- Assess the results in comparison to the existing schedules and policies.

Industry partner:	Trondheim Rehabiliteringssenter
Collaborator:	Gyrd Thrane
Main supervisor:	Kais Msakni
Co-supervisor:	Anders Gullhav
Strategic research initiative:	Health and the Public Sector

For more information, please contact Kais Msakni, kais.msakni@ntnu.no, to schedule a meeting.

AØO40: Stochastic and dynamic production optimization

When operating a production process, good estimates of Key Performance Indicators (KPIs) are imperative to make good operational decisions over time. Measuring KPIs is typically complex, and the quality of the data from the measurements is often mediocre. Either the measurements are of high quality but scarce, or they are noisy but frequent, depending on the process and measurement techniques. In addition, the system that is measured is dynamic and changes over time. Making reliable decisions under these circumstances, therefore, means facing three major challenges: a small data regime, poor measurement quality, and non-stationary underlying processes.

Optimizing production under such circumstances is extremely complex and developing methods for decision support is challenging. Insight into how stochastic and dynamic production systems behave, how the uncertainty can be modeled and the interaction between uncertainty models and production optimization is lacking. Solution Seeker is developing system simulators that allow for a realistic description of production systems, but where the underlying uncertainties can be controlled. This enables the development of methods that can be rigorously tested and that can give new insight into stochastic and dynamic production systems and how uncertainty can be handled.

Solution Seeker (https://www.solutionseeker.no) develops and delivers AI-as-a-service to among others, the petroleum industry, including technology for optimizing the production of oil and gas assets. They have been the industrial partner for more than 10 MSc theses at IØT. This project is linked to RICO - Robust Intelligent Control, an ongoing project funded by the Research Council of Norway. Partners in the project are NTNU, SINTEF, Solution Seeker, TrønderEnergi among others, see https://www.ntnu.edu/ailab/rico for more information.

Using machine learning to model uncertainty and combine these models with production optimization models is a key challenge in this project. More specifically, neural networks will be used in modeling the production process as these models are highly flexible. Despite their enormous potential, neural networks are facing major challenges when modeling physical processes. While the main focus of the master project will be on optimization using neural network models, researchers in the RICO project and in Solution Seeker are constantly working on the challenges of modeling physical processes with neural networks, and the master student will get the possibility to gain insight in how these challenges are addressed.

The case study of this master project is likely to be conducted on simulation models of petroleum wells. However, the general nature of the AI and optimization methods that will be used in the project means that the outcome of the research is likely to be transferrable to other domains and production processes.

The following main tasks are usually part of the project work:

- Understand, define, and describe the problem and its setting
- Investigate what mathematical optimization and machine learning methods can be used
- Design and implement a solution method
- Set up a computational study where the solution method is tested using the simulator
- Analyze the results from the computational study to gain insight

Recommended prerequisites: A strong background in artificial intelligence/machine learning

Industry partner:	Solution Seeker
Main supervisor:	Henrik Andersson
Co-supervisor:	Erlend Torje Berg Lundby
Industry co-supervisor:	Bjarne Grimstad (Solution Seeker)

For more information, please contact Henrik Andersson, henrik.andersson@ntnu.no , to schedule a meeting.

AØO41: Strategiske og taktiske beslutninger for Oda's distribusjonsnettverk

Oda er et norsk teknologiselskap innen online dagligvare som nylig har ekspandert til Finland og Tyskland. Selskapet ble startet i 2013, og er i dag blant verdens mest effektive leverandører av dagligvarer på nett. Dette muliggjøres av en unik verdikjede som gir håndplukkede varer på kundenes dørmatte til samme pris som i de billigste matbutikkene.

Å levere et bredt utvalg av høykvalitets matvarer til flere hundretusen av kunder er en krevendeprosess, og denne må stadig forbedres for å videreutvikle selskapet. Verdikjeden består av en rekke interessante operasjoner som kan optimeres ved hjelp av klassiske teknikker innenfor operasjonsanalyse. En av de viktigste operasjonene er transport fra Oda sine lager hjem til kundene.

I distribusjonsleddet til Oda møter man flere utfordrende taktiske og strategiske beslutninger. Eksempler på dette er hvor man skal ha distribusjonspunkter, hvilke tidspunkter man tilbyr levering til kunden, og hvilke områder man skal levere til. Problemstillingene er tett knyttet til et operasjonelt routing-problem som løses daglig med en egenutviklet algoritme, og de blir ofte krevende å løse eksakt.

I lys av vår geografiske ekspansjon i Tyskland er det særlig aktuelt å finne mye metoder som kan støtte beslutninger rundt hvilke områder Oda skal ekspandere til. Denne beslutningen kan gjerne kombineres med å bestemme hvor Oda skal ha distribusjonspunkter, som vår forrige masteroppgave handlet om.

Endelig problemstilling utarbeides sammen med studentene, og studentene oppfordres til å utvise selvstendighet i prosessen med å finne gode problemformuleringer og løsningsmetoder. Oda vil bidra med innsikt i domenet og relevante data. Når det gjelder nye områder, har Oda metoder for å generere syntetiske kunder basert på sosiodemografiske data.

Følgende hovedelementer vil inngå i prosjektoppgaven:

- Sette seg inn i konteksten og formulere relevant problemstilling
- Formulere en matematisk modell for problemet og studere relevant litteratur
- Utvikle og teste aktuelle løsningsmetoder på reell data fra Oda
- Analysere og diskutere resultatene

Det er naturlig at prosjektoppgaven forlenges inn i en masteroppgave med dypere analyse av problemet og utforskning av metoder for å håndtere økt problemstørrelse og kompleksitet.

Oppgaven vil gjennomføres med veiledning fra instituttet. I tillegg stiller Oda med med-veiledere med bakgrunn fra optimering på NTNU, samt god tilgang på reell data fra deres operasjon.

Industripartner: Oda

Veileder: Magnus Stålhane

Industriveileder: Ivar Masvie Brekkå

For mer informasjon, ta kontakt med Ivar Masvie Brekkå (ivar.brekka@oda.com).

AØO42: Techno-economic aspects of optimal building retrofit path towards zero emissions

Buildings generate a considerable share of the energy demand and their effective management can greatly contribute to the development of the resilience of the energy system. In this respect, improving the building efficiency is a particularly challenging task for Norway, due to cold climate conditions and high heating needs. A key role to achieve an effective improvement is offered by structural adaptations such as energy retrofitting operations. Nevertheless, creating sustainable solutions for renovating existing buildings, requires the implementation of cost-efficient upgrade schemes. The objective of this project is to analyze what could be the optimal retrofitting pattern for Norwegian buildings both in terms of energy savings and expected cost. The study will shed light on what is the potential impact of an energy retrofitting scheme on the energy system and will provide projections on the required costs. This information can be useful both to the energy system planner and to the regional and national institution to define possible incentive schemes.

The study will adopt optimization techniques, such as Linear Programming, to derive an optimal retrofitting path and assess the economic feasibility as well as the energy savings impact.

Possible future extensions of the work might involve the integration of the module in an energy system model or on a macroeconomic model.

Industry Partners: Trøndelag Fylkeskommune and SINTEF Community

Main supervisor: Pedro Crespo del Granado

Co-Supervisor: Paolo Pisciella

Strategic research initiative: Sustainability

For more information, please contact Pedro Crespo del Granado, pedro@ntnu.no

AØO43: The connectedness of the European gas grid since the Nord Stream explosion

Topological measures from graph theory have become a much used tool in social sciences (e.g., Bailey et al., 2018). Even though energy networks are connected graphs, there have been only a handful of applications of topological measures to energy grids. Atkins et al. (2009a) applied topological measures such as connectedness and centrality to an exemplary electricity grid. Atkins et al. (2009b) and Chen et al. (2009) expand this analysis by investigating locational market power.

The European high pressure pipeline network for natural gas transport is characterized by a relatively small number of pipelines with very large capacity (ENTSO-G 2021). In contrast to electricity grids, the natural gas pipeline grid is made of directed arcs, i.e. pipelines with a flow direction. It can be assumed that the European pipeline network has fundamentally changed since the Russian attack on Ukraine and the related repercussions on European energy markets, in particular the explosion of the Nord Stream pipelines in September 2022 which cut the direct link between Russia and Germany. Germany used to be a central transit node in the European pipeline grid.

The aim of the project is for students to apply topological measures to the European high pressure pipeline network before and after the Nord Stream explosions. If time permits, locational market power of specific nodes in the network can be analyzed. Activities include:

- Familiarization with the topic, relevant literature and methods, including software tools;
- Familiarization with the European natural gas network data;
- Application of relevant topological measures to the European natural gas network data;
- Analysis and discussion of results.

There will be an opportunity to spend time in Berlin and work as guest researcher at the German Institute for Economic Research (DIW Berlin) in downtown Berlin within walking distance to Brandenburg Gate, Gendarmenmarkt, HU Berlin, Checkpoint Charlie, Potsdamer Platz….

Collaborator: DIW Berlin (German Institute for Economic Research)

Main supervisor: Franziska Holz (adjunct professor, supervision mainly online)

For more information, please contact Franziska Holz, fholz@diw.de, to schedule a meeting.

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Bailey, Michael, Rachel Cao, Theresa Kuchler, Johannes Stroebel, Arlene Wong (2018): “Social Connectedness: Measurement, Determinants, and Effects”. Journal of Economic Perspectives 32(3): 259-80.

Chen, Jiangzhuo, Matthew Macauley and Achla Marathe (2009): “Network Topology and Locational Market Power." Computational Economics 34:21-35.

ENTSO-G (2021): “The European Natural Gas Network 2021”. Brussels.

AØO44: The effectiveness of solution methods in surgery planning

The Control Tower project is an innovation project between Oslo University Hospital and KPMG with ServiceNow to develop a unique digital tool for surgery planning (video link). The first version of the product is being developed until spring 2023, with expected pilot projects and implementations in the following months, before a worldwide product launch.

We wish to analyze the difference in quality of different solution methods for realistic cases within surgery planning. A possible extension of the problem is to consider uncertainty modelling, especially uncertainty in the duration of surgeries and the sudden arrivals of emergency patients.

The assignment will involve developing algorithms and/or heuristics, which are not based on LP programming, to solve a complicated surgery planning problem within given time limits. The same problem must then be solved using optimization methods to find an optimal solution or solutions with very low optimality gaps.

We want insight into the differences in quality of the solutions that are identified within a certain time limit, and an understanding of which constraints and parameter values affect this, and possibly what strategies can be implemented to enhance the quality of surgery plans as uncertainty is realized.

Research topic: Develop algorithms and optimization models of a surgery planning and perform technical tests with them. Ideally the problem solved closely resembles real-life surgery planning problems. Furthermore, students should in cooperation with industry supervisors identify the most important considerations and constraints to enable analyses on the most relevant problem types in Norway and internationally.

Methods/tasks:

- Understand the nature of real-life surgery planning
- Review the current literature for similar problems (similar applications, and also problems from other applications of a similar structure).
- Understand the current KPMG models for surgery planning
- Develop an algorithm/heuristic not based on LP-programming
- Use an optimization/computer science method for solving realistic surgery planning problems
- Possibly incorporate uncertainty modelling
- Design tests and perform analyses to provide insights for academic and industry use
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Recommended prerequisites: Knowledge of Optimization. Programming skills. Interest in health care industry. Experience with or interest in ServiceNow technologies and/or javascript is an advantage.

Industry partner:	KPMG
Main supervisor:	Anders Gullhav
Co-supervisor:	Henrik Andersson
Industry Co-supervisor:	Kjartan Kastet Klyve/ Einvald Serigstad/ Colleagues (KPMG)
Strategic research initiative:	Health and the Public Sector

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AØO45: Towards sustainable zero-emission offshore logistics

Norway is one of the world's leading oil and gas exporters through high activity at drilling and production platforms in the North Sea. Due to the current energy crisis in Europe, Norway has over the last year become the single most important supplier of natural gas to the European continent. Despite expected reductions in oil and gas demand over the coming decades, the activity level in the North Sea will remain high. Several projects exist on large-scale hydrogen production using natural gas (with carbon capture and storage, CCS), and major efforts will be required in the tasks of plugging and abandoning wells in older fields reaching the end of their lifetime. Simultaneously, new industries will emerge, e.g., within offshore wind, which will require many of the same complex maritime operations.

Many of these activities in the North Sea are supported by the large fleet of platform supply vessels (PSVs). These vessels are currently a large contributor to Norwegian domestic greenhouse gas emissions, emitting 1-2 tons of CO_2 per hour of operation or approximately 1 million tons (nearly 2% of Norway's total emissions) annually. To meet the industry's ambitious goals of 50% emission reduction within 2030 and zero emissions in 2050, it is crucial to find new ways of reducing emissions from offshore logistics. New fuel technologies combined with new vessel concepts will therefore be necessary.

There is currently a lack of knowledge on how to reach the defined emission reduction targets, and technology development is subject to a large degree of uncertainty. Furthermore, the timing of the decisions is important. A large fleet of conventional PSVs is still in operation, many of them will continue to operate for several years. In addition to building new and more environmental-friendly PSVs, another option is to modify the fuel and propulsion systems of the current ones to more sustainable alternatives ("retrofitting"). The question, however, is to decide which changes to the fleet to make and when to make these changes?

The main objective of this project thesis is to provide optimization-based decision support for fleet owners and key actors in Norway's offshore industries to guide their transition towards more sustainable and low emission logistics. Some relevant tasks and topics that may be included in the project (and/or Master) thesis are to:

- Quantify the effects of different fuel technologies to a fleet of offshore supply vessels – what limitations are imposed with regards to speed, range and cargo capacity?
- Formulate a strategic "offshore vessel fleet renewal and retrofitting" optimization problem with a planning horizon stretching towards 2050, providing decision support on how to succeed in the transition towards zero-emission logistics.
- Develop solution methods to realistically sized instances of the formulated planning problem. Decomposition and heuristics are relevant modeling approaches that might be required in order to provide high-quality solutions, due to the complexity of the problem.
- Generate scenarios for future development of costs and other key parameters related to technologies, alternative fuel supply chains, and offshore activity level. Based on the scenarios, find and evaluate optimal fleet renewal and retrofitting strategies that lead to large emission reductions while at the same time are economically sustainable for the involved actors.

Collaborator: SINTEF Ocean

Industry partner: Equinor

Main supervisor: Kjetil Fagerholt

Co-supervisor: PhD candidate Andreas Ormevik

For mer informasjon, ta gjerne kontakt med kjetil.fagerholt@ntnu.no for å avtale et (digitalt) møte.

AØO46: Transportstyringssystem for veibasert godstransport

Haste AS er et programvareselskap som jobber med å utvikle et transportstyringssystem for godstransport på vei. På sikt vil et slikt system måtte håndtere et bredt spekter av problemer innenfor ruteplanlegging, lagerstyring, multimodal transport, timeplanlegging for sjåfører, osv. I dette prosjektet vil det derfor være flere aktuelle problemstillinger og de(n) som blir tildelt prosjektet vil være med å utforme disse i samarbeid med Haste AS og veiledere.

Tidligere masteroppgaver og case fra Haste AS vil være et naturlig utgangspunkt der man jobber med algoritmeutvikling for å løse eksisterende problemer, utvider tidligere problemstillinger, eller jobber med en kombinasjon av disse. Typiske problemstillinger ligger under kategorien Vehicle Routing Problems (VRPs), med nærliggende rikere varianter slik som pick-up and delivery problemer, multi-periode problemer, ruteplanleggingsproblemer med lagerstyring, osv. Aktuelle utvidelser kan blant annet være håndtering av usikkerhet, inkludere mer detaljerte pakke- og lagerstyringsbeslutninger, komplekse tidsvinduer, osv.

Caset fra Haste AS omhandler en lokal transportør som videredistribuerer ulike vareflyter i sin region. Her er målet å maksimere profitt, samtidig som servicekvalitet og klimagassutslipp overholder en gitt standard. Den mest nærliggende problemstillingen er å se på en variant av et multi-periode VRP med lagerstyring og tidsvinduer. Uansett valg av problemstilling vil følgende hovedelementer inngå i prosjektoppgaven:

- Sette seg inn i problemstillingen.
- Studere relevant litteratur.
- Matematisk formulering av planleggingsproblemet.
- Studere løsningsmetoder for planleggingsproblemet, både eksakte og heuristiske optimeringsmetoder kan være av interesse.
- Implementere aktuell løsningsmetode.
- Teste løsningsmetode på probleminstanser basert på virkelig data fra en norsk logistikkaktør. Analysere og diskutere resultater.

Industripartner:	Haste AS
Veileder:	Magnus Stålhane
Industrimedveildere:	Martin N. Digernes, Jørgen Skålnes
Strategisk forskningsområde:	Leading transitions: Co-create a sustainable future
	Sustainability

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AØO47: Using machine learning to predict values of variables in binary integer programming problems

With the successful application of machine learning (ML) in various domains, it is not surprising to see a growing interest in the integration of learning capabilities into solving combinatorial optimization problems. While ML techniques have not proven effective as a means of solving optimization problems by themselves, some studies have been able to use ML to enhance existing optimization methods. This project aims to explore such opportunities in the context of solving binary integer programming problems.

Some heuristics and matheuristics for solving binary optimization problems rely on categorizing variables into three sets: one set for variables that are likely to take the value 1 in an optimal solution, one set for variables that are likely to take the value 0 in an optimal solution, and one set for variables whose values in an optimal solution are hard to predict. The latter has been described as the core of a problem: if we fix the variables in the other two sets, the remaining set still constitutes a difficult optimization problem, but since it is (in some cases) much smaller than the original problem, it can be dealt with more efficiently, as in [1]. Alternatively, instead of fixing the variables, they can be assigned weights that influence a local search method, as in [2].

The research questions here can be: 1) can ML be used to predict which variables are going to take the value 1 (or 0) in an optimal solution of a binary integer programming problem? 2) What information is useful to make such predictions (e.g., objective function coefficients, properties of the constraints in which the variables are included, reduced costs in the LP-relaxation of the problem, values taken in randomly sampled local optima, or values when solving an LP-relaxation or surrogate relaxations)?

The following tasks can be included in the project:

- Study the relevant literature that uses ML when solving optimization problems
- Study the relevant literature for solving binary integer programming problems
- Design a test set and a training set, and define and calculate features to be used
- Develop and implement one or more ML techniques for predicting optimal variable values
- Incorporate the predictions in a matheuristic for solving binary integer programming problems
- Perform computational experiments to test hypotheses derived from the chosen research questions

Main supervisor: Kais Msakni

Industry Co-supervisor: Lars Magnus Hvattum (HiMolde)

Strategic research initiative: Leading transitions: Co-create a sustainable future

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References

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[2] F. Rodrigues, A. Agra, L. M. Hvattum, and C. Requejo, “Weighted proximity search,” Journal of Heuristics, vol. 27, no. 3, pp. 459–496, Jan. 2021, doi: 10.1007/s10732-021-09466-0.

AØO48: Using Sales data to the Accuracy of Inventory Records

Inventory inaccuracies is a large problem in practice and empirical studies have shown instances where as many as 65% of the inventory records were incorrect. Securing a perfect (or near perfect) accuracy typically requires costly auditing processes where one manually count the amount of goods in stock for each product. Some methods have been developed where one use the observed sales data to improve the accuracy of the inventory record based on Bayesian updating.

There are some inherent problems with the original methods developed which includes:

- The updating is done product by product and thus ignores correlation and substitution effects.
- For products with a high service level, which one can argue are the majority of products, the value of the Bayesian updating is limited.

There has been some later work that remedy some of the drawbacks linked to the first point above but there is still room for additional improvement.

To remedy the problem linked to the second point one need to develop a policy which in an efficient manner ensures that target service level is achieved in the long run while still having periods with high likelihood of shortages to ensure that Bayesian updating provides a substantial reduction of the inventory inaccuracy.

Tasks within the project can include:

- Identifying current best practice when it comes to inventory accuracy using sales observation.
- Developing method that balance the cost of physical audits, the cost of safety stock under planned shortages.

Main Supervisor:	Peter Berling
Strategic research initiatives:	Leading transitions: Co-create a sustainable future
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