The Norwegian train rEvolution
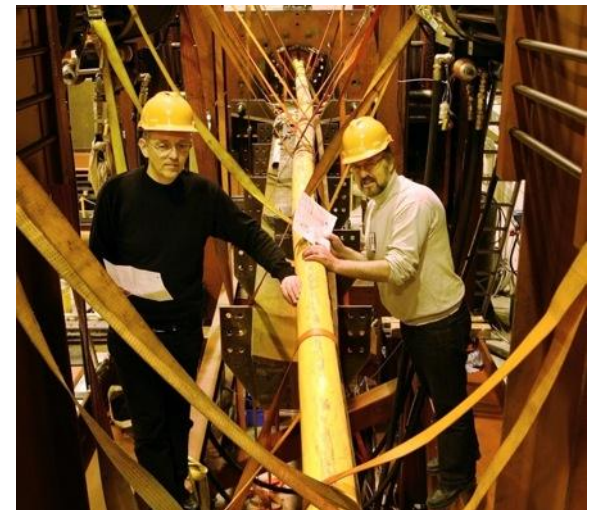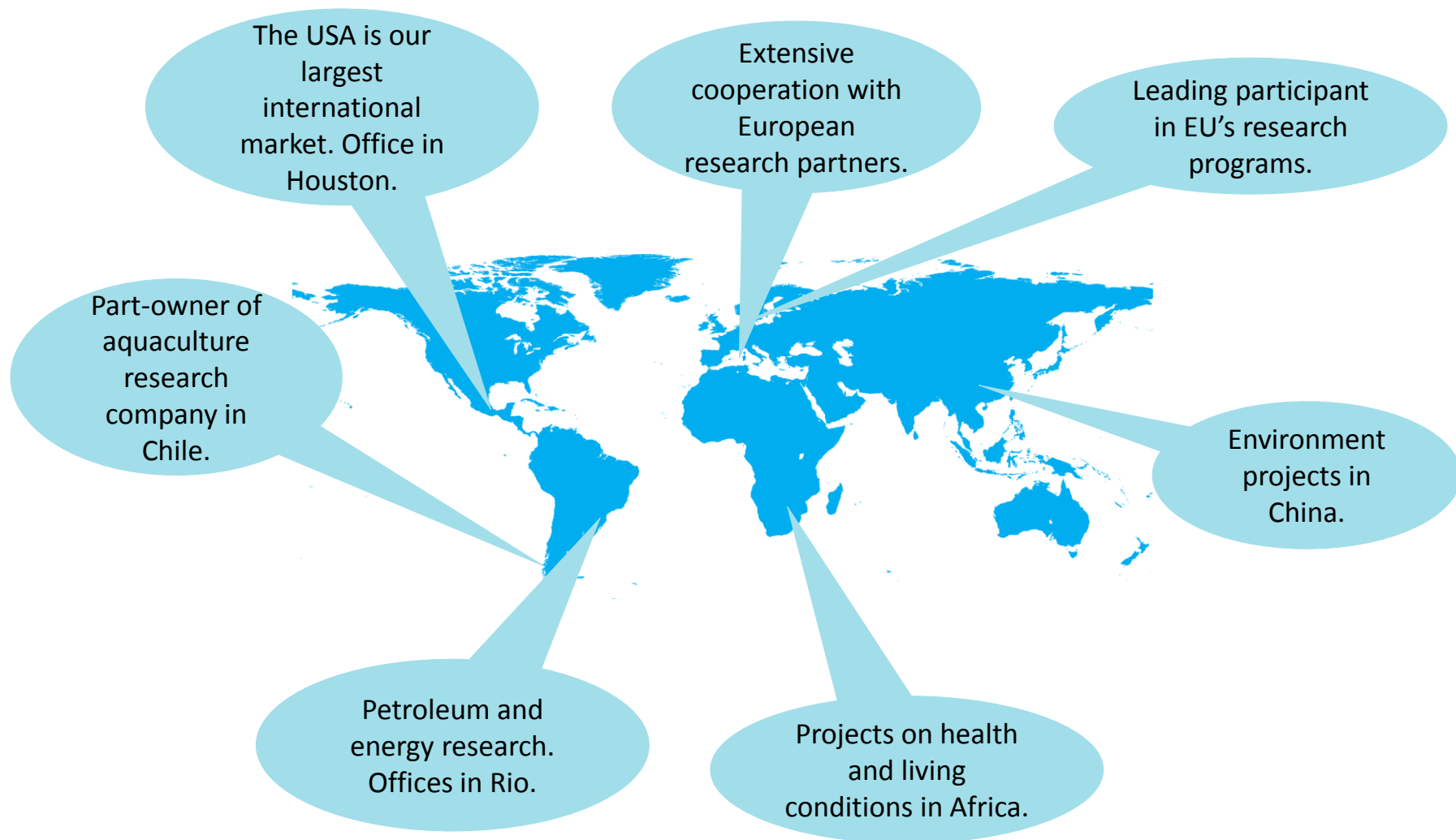
Arnt-Gunnar Lium

Melbourne, 6th of June 2013

SINTEF is the largest independent research organisation in Scandinavia

- Leading expertise in the natural sciences and technology, environment, health and social science
- 2100 employees from 68 countries
- Annual sales of NOK 2,8 billion – customers in 61 countries
- A non-commercial research foundation with subsidiaries

We sell research to customers all over the world

The USA is our largest international market. Office in Houston.

Extensive cooperation with European research partners.

Leading participant in EU's research programs.

Part-owner of aquaculture research company in Chile.

Environment projects in China.

Petroleum and energy research. Offices in Rio.

Projects on health and living conditions in Africa.

SINTEF

Technology for a better society

What if we could use operations research to do things just 1 per cent better?

The Norwegian railroad industry

1246.5 million AUD utility of passenger transport on rail in 2012

Infrastructure manager

Jernbaneverket

880.2 million AUD cost of queues in the largest cities in Norway in 2006

Punctuality: 91 %

Passenger train companies

NSB

Flytoget

Punctuality: 80 %

Cargo train companies

cargolink

CargoNet

59.9 million passengers in 2012

The beginning of a train revolution

Fall 2007: SINTEF is asked by the largest passenger train operator (NSB) to investigate how many 110 meter long trains can be parked in and around Oslo

***The search for the train of the future* (28 May 2008)**
NSB is planning its largest ever order for new trains, and how it has also launched a comprehensive project to upgrade existing rolling stock.

Source: http://www.europeanrailwayreview.com/tag/nsb/
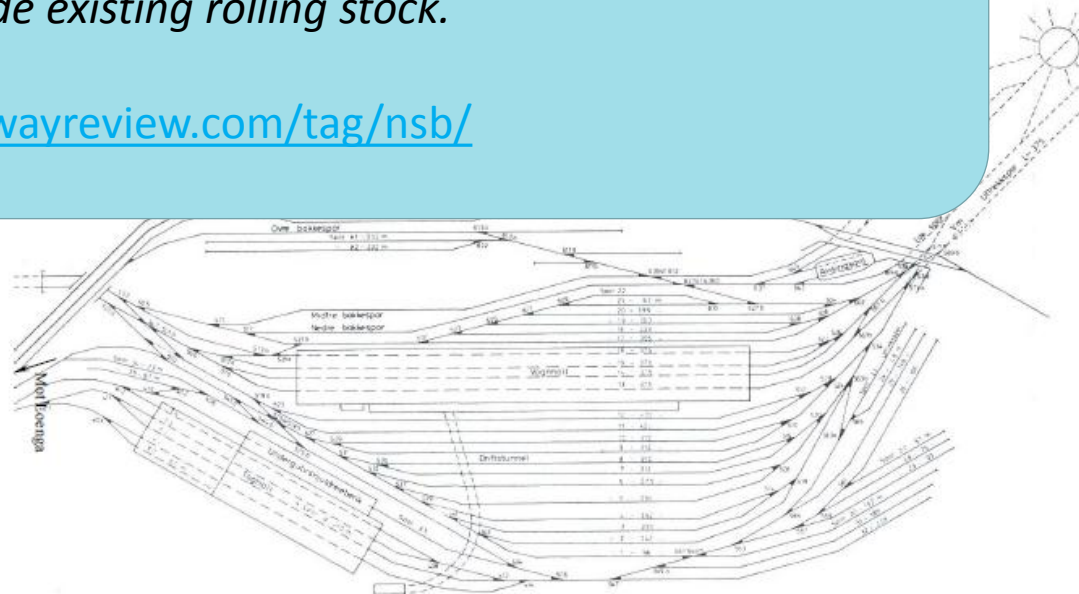
Introducing new trains require some preparation

- Infrastructure

- Maintenance

- Timetable
   - Sharing capacity between competitors

- Crew planning

Crew management

- Crew bases:
  - How many crew bases?
  - Where?
  - How many drivers/guards should be at each base?

- How many drivers and guards should be trained each year?

- How many resources are required to deal with unforeseen events?

- What will the 'final' crew plan cost?

Task 1:
Get an optimization tool up and running, train the planners and use the tool to answer these questions

Technology f
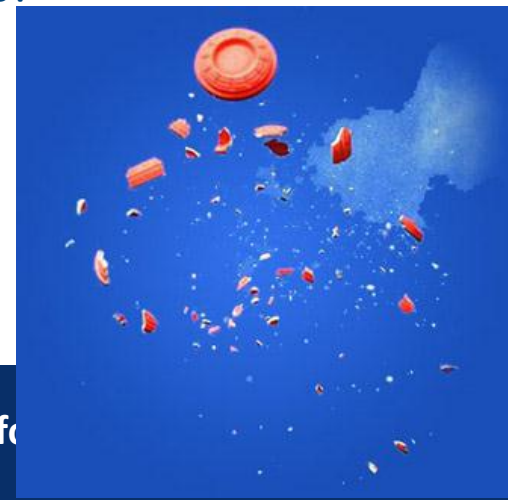
Crew planning at NSB

- The personnel planning tool TPO makes sure that all tasks/trains are planned and no rules are violated.

- The manual planning version of the tool has been in use at NSB for some years where it is used for crew scheduling and crew rostering

Cooperation with the software vendor to adapt their software to NSB's needs
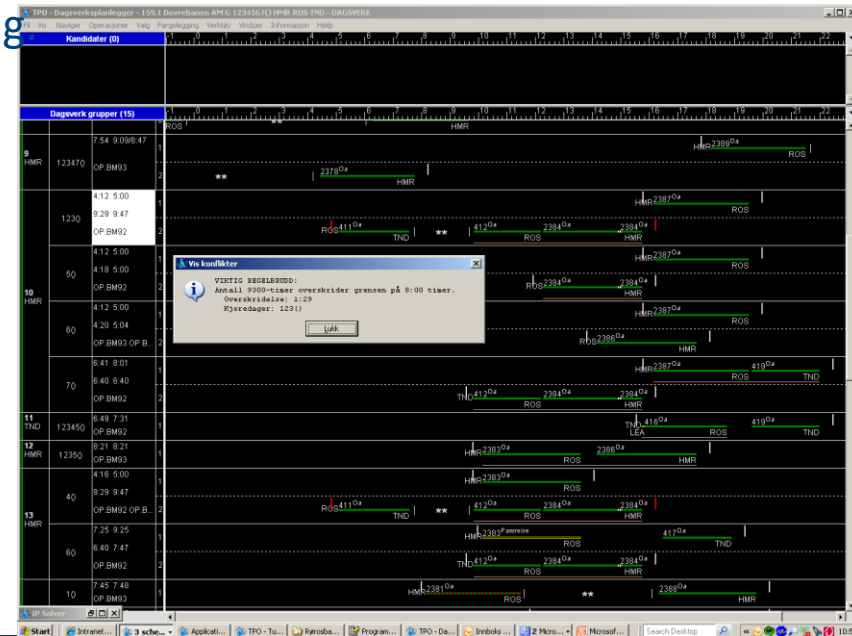
The problem

$$\min \sum_{i=1}^{n} c_i x_i \tag{1}$$
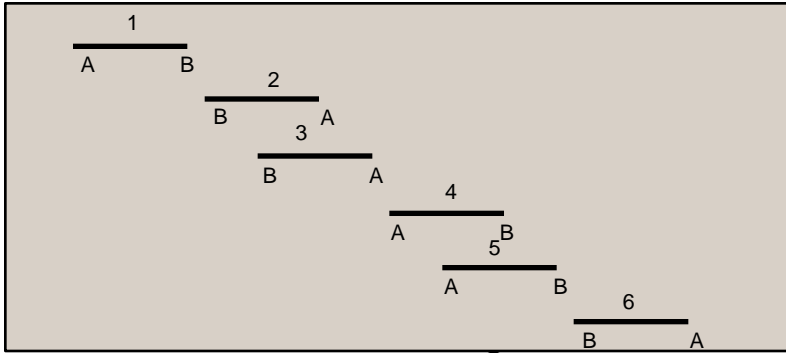
$$\text{s.t. } \sum_{i=1}^{n} a_{ij} x_i \geq 1 \quad j = 1, \ldots, m \tag{2}$$

$$x_i \in \{0, 1\} \quad i = 1, \ldots, n. \tag{3}$$

Or put in a different way:

- How can we make duties that are cost efficient while taking into account the workers protection legislation as well as a plethora of unwritten rules?
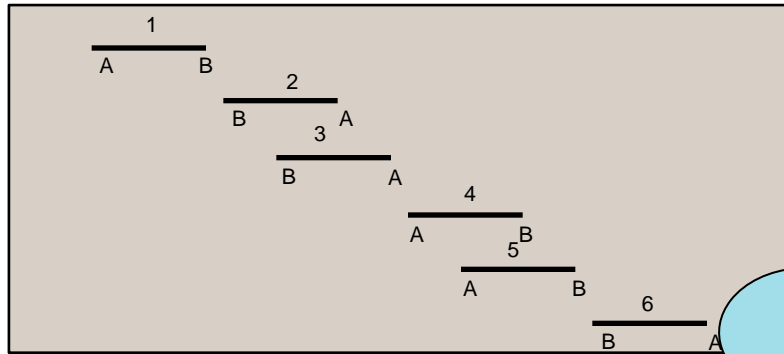
How do we solve the problem? (1/2)

6 tasks to be performed.
The tasks can be performed by personnel from location A or B.

How can we perform all the tasks at the lowest costs possible?

How do we solve the problem? (2/2)

1. Generate all the possible duties
2. Select the combination of duties that gives the best solution (lowest cost)

We may have to generate millions of duties. These can be combined in many different ways...

Helping decision makers

- Which rules have the greatest impact on costs?

- How much does it cost to increase the walking time at station X by Y minutes to improve robustness?

- What is the impact of letting the staff work only every third week-end instead of every second week-end?

- What is the effect of increasing the size of the crew base from X to Y drivers?

- What is the effect of reducing the number of train types / lines that a driver or guard can drive?
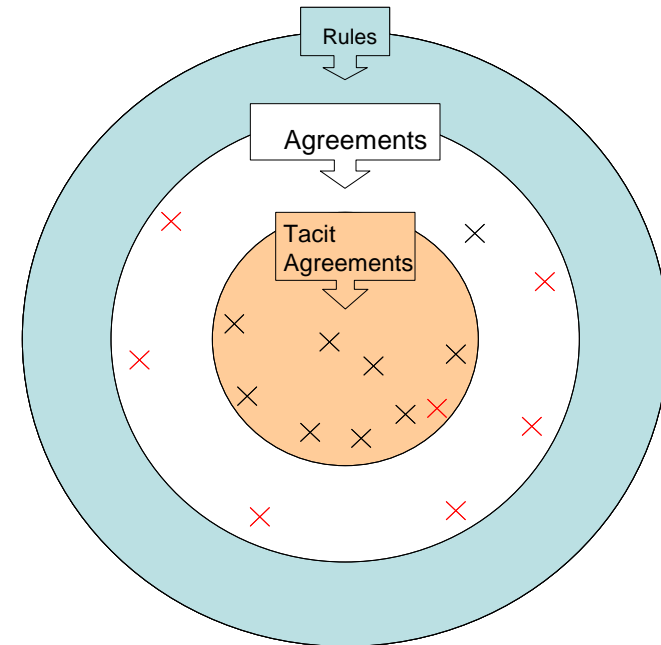
A challenging problem

Technical issues:
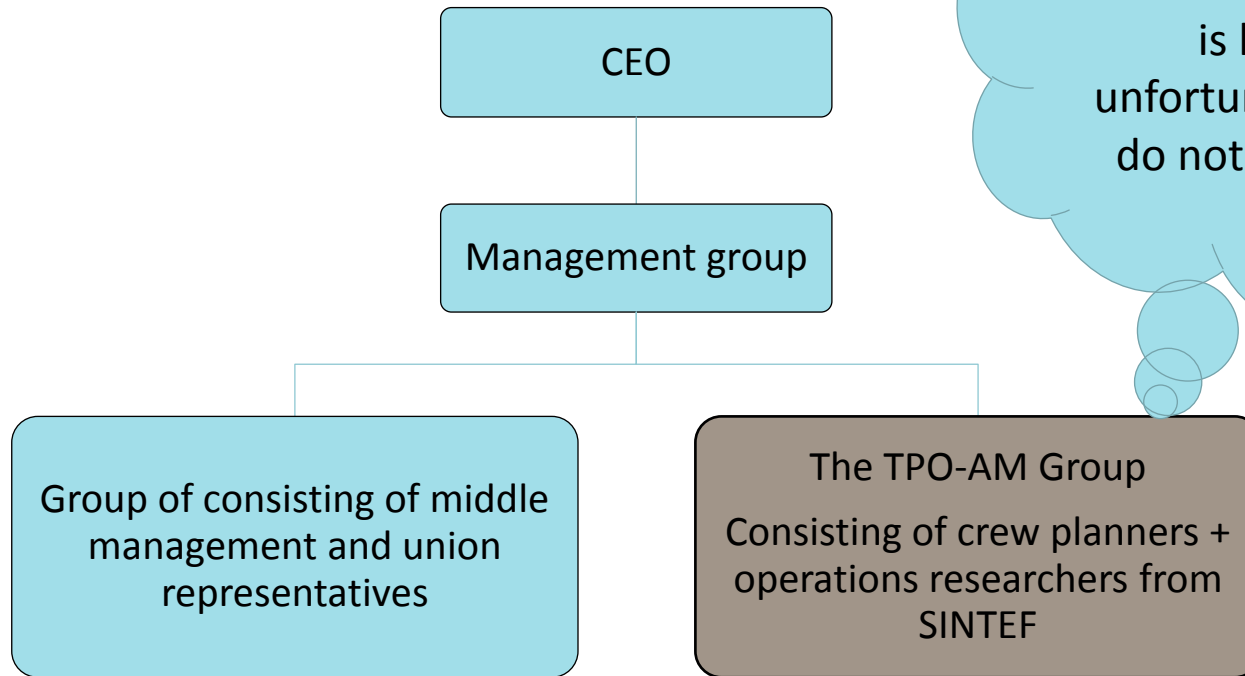
- Norwegian labor rules are numerous, yet complicated
- We have a large NP-hard problem

Non-technical issues:

- Planning practices which vary between regions
- Unwritten and, to a large extent, non-defined labor rules
- An organization with experienced planners, without higher education
- Exceptionally strong unions
- Politics – changes along the way
- Lack of fierce competition

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Project organization

CEO

Management group

Group of consisting of middle management and union representatives

The TPO-AM Group

Consisting of crew planners + operations researchers from SINTEF

Observation:
Large groups make sure that 'everyone' is heard, unfortunately, they do not move fast

Very strong support from upper management provided sufficient resources and made sure that everyone 'was onboard'

How did we overcome the challenges?

- Planners:
    - Were trained in using the optimization module of TPO.
    - Were involved and had the final say when the system was adapted to suit their needs.

- Unions
    - Were involved in evaluating the duty schedules – joint effort with the planners and SINTEF.
    - Provided valuable feedback on how to improve plans – making them easier to be accepted later on.

- Management
    - Was frequently involved when determining which analyses were to be performed.
    - In coordinating the resource situation at NSB, SISCOG and SINTEF

Some results

Planning time for the largest instances

- Manuel planning:
  - 5-8 weeks for drivers
  - 3-6 weeks for guards

- Using optimization:

Tasks	Drivers	Guards
Producing the first plan	3-4 days	2 days
Refining the plans using optimization	2 days	1 days
Further manuel improvements of the crew schedules	1-2 weeks	1-2 weeks
Total planning time	10-15 days	8-13 days

A complete crew schedule (for less critical analysis) can be made in 0,25-5 hours!

Using optimization for real time train dispatching to improve on-time performance and capacity utilization

- Dispatching of trains is currently done by dispatchers following a rule-based regime, to which they can make exceptions. Each dispatcher controls a line, parts of a line or a geographical region.

- Coordinating the dispatch of trains over larger areas using optimization has shown significant improvement in terms of on-time performance.

- SINTEF is currently developing an optimization model which provides new (optimal) solutions for the dispatchers every 30 seconds.

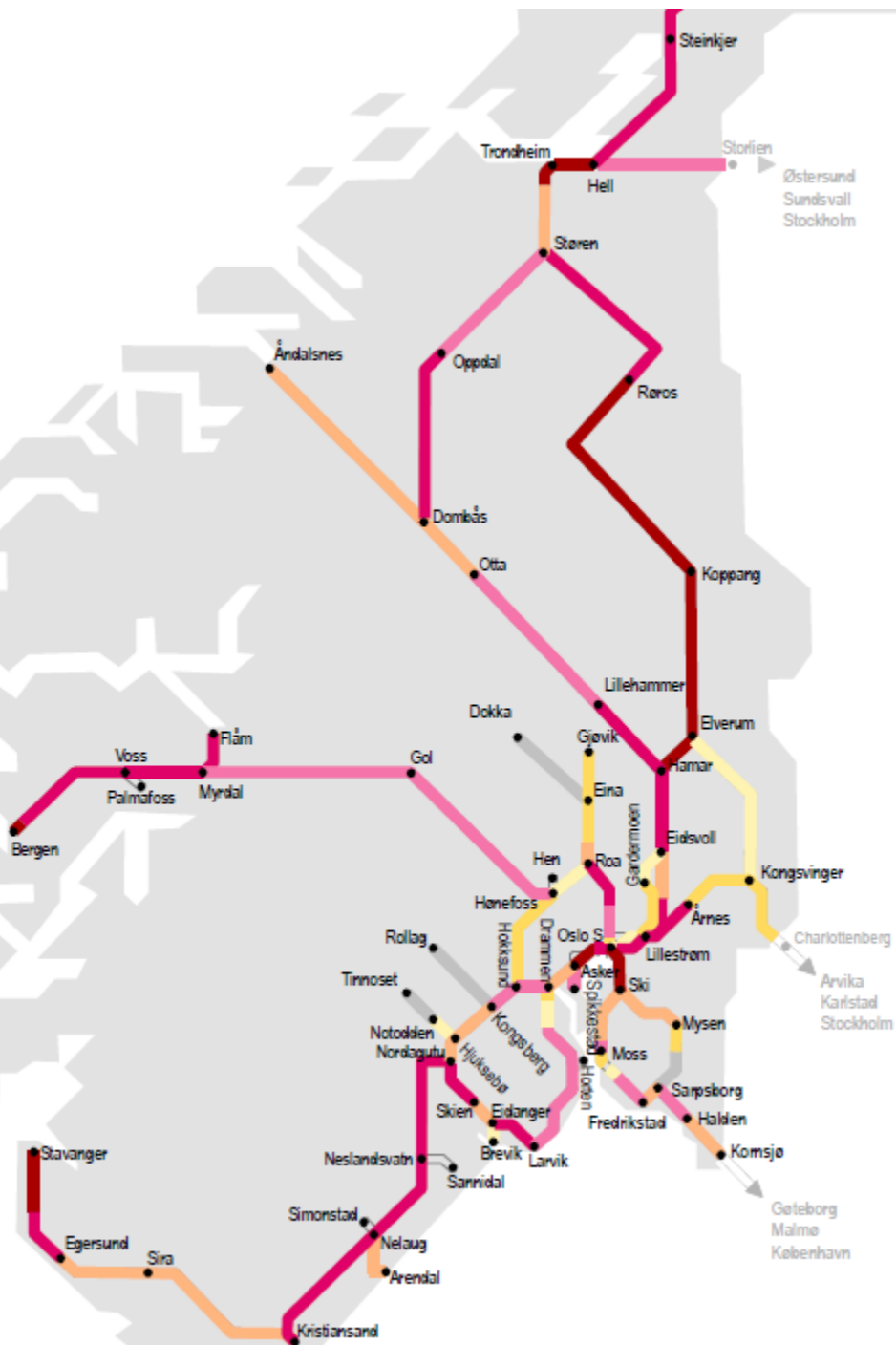# Improving infrastructure utilization with Pigovian taxes

Capacity utilization at peak hour

Average capacity utilization

How do we determine the correct taxes and subsidies?

To determine the correct taxes/subsidies one needs to know how the train operating companies adapt to the taxes/subsidies

To determine the optimal timetable one needs to know what the taxes/subsidies are as well as how the passengers and the freight customers adapt to it

To determine how the customers of the train operating companies will adapt to the timetable one need to know what capacity is offered and the price of the different products
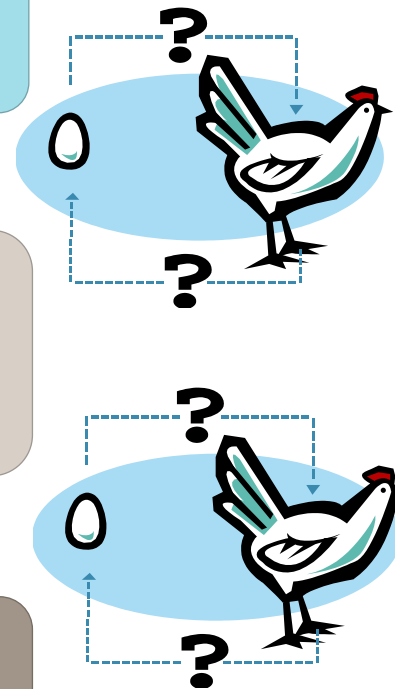
Changes in taxes/subsidies at a given time at one point in the network can affect taxes/subsidies elsewhere in the network at other times…

Strategic infrastructure investments, divestments and maintenance under uncertainty

- Traditional cost-benefit analyses are not well suited to deal with the coordination of a large number of investment opportunities, dependencies in infrastructure or uncertainty.

- SINTEF is currently developing a rich stochastic multistage optimization model to provide advice on where, when and what type of railroad infrastructure should be built over a 30 year planning horizon.

- The model is planned to be used by the infrastructure manager (Jernbaneverket) next year and will play a key role in railroad investment decisions.

Jernbaneverket

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Thank you!

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Technology for a better society

If you are a Train Nut…

- Bergensbanen minute by minute
  - http://nrkbeta.no/2009/12/18/bergensbanen-eng/

- Nordlandsbanen minute by minute
  - http://www.nrk.no/nordlandsbanen/

- Flåmsbana minute by minute
  - http://www.nrk.no/sognogfjordane/folg-flamsbana-minutt-for-minutt-1.7279240

- Holmenkollbanen minute by minute
  - http://nrk.no/holmenkollbanen/

- Bybanen i Bergen minute by minute
  - http://tv.nrk.no/program/dvfj64002010/bybanen-i-bergen-minutt-for-minutt

The team

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