A heuristic for maritime inventory routing

Oddvar Kloster, Truls Flatberg
Euro XXIII, Bonn
Overview

- Background
- Model
- Algorithms
- Test example
Invent

- Software library to solve generic Inventory Routing Problems
  - Primary focus on routing and inventories
  - Upstream/downstream activity disregarded
  - Contractual and economic aspects
  - Tramp shipping, industrial shipping and combinations

- Prototype with initial construction algorithm, genetic algorithm and nascent optimization

- Three applications used as pilot studies
  - Cement - multiple products, short horizon, no spot
  - Chemical tankers - tramp and inventory, multiple products, cleaning, tank handling
  - LNG - single product, long term, contracts, full loads
Model features (1)

- Heterogeneous vessels
  - One or more tanks with volume capacities
  - Or, simple stowage (max products)

- Ports, with storages
  - Variable production/consumption rates
  - Partly interruptible
  - Storage capacities

- Per-vessel time/distance/cost table
Model features (2)

- Multiple products
  - Keep track of quantity, weight and volume
  - Fixed or variable densities
  - Cleaning of tanks between products
- Load and discharge rates
- Boil-off
  - Product evaporates during sailing
- Full vessel loads
  - Leave from production ports with full loads
  - Discharge completely in consumption port except for boil-off needs
Model features (3)

- Bookings
  - Transportation demands not related to storages
- Contracts
  - Limit amount delivered to certain ports in certain periods
  - Define prices
Model features (4)

- Priority on storages and contracts
- Arrival and departure load limits (draft restrictions)
- Port closure periods
- Vessel maintenance periods
- Vessel-port compatibility
- Restrict # visits to storage in period
- Inter-arrival gaps
Plan structure
Objectives

Basic objectives

- Income (contract, stream, booking)
- Cost (sailing, port stay, cleaning)
- Performance (quantity transported)
- Penalized constraints

Combined objectives

- Weighted sum
- Lexical (prioritized)
Solution strategy

- Work with concrete plans
- Violate constraints by doing too little → penalize
  - Stockout/overflow
  - Unserviced booking
  - Contract limit not met
  - Too few visits in time period
- Add activities, as efficiently as possibly
- When doing too much, try delaying
Construction: overview

- Start with empty plan
- Identify earliest (highest priority) penalty event
  - Stockout/overflow
  - Unserviced booking
  - Contract limit
  - Too few visits in time period
- Generate journeys
- Rank journeys
- Add best journey and repeat
- If no fix found, forget event
- … until there are no more penalty events
Construction: journey generation

- One storage/booking/contract given
- Choose
  - (Contract)
  - Counterpart storage
  - (Counterpart contract)
  - Vessel
  - Insertion points
Construction: journey insertion

- Large parts of the plan may be affected
  - Schedule for selected vessel changes after new load action
  - Schedules for other vessel are unchanged
  - Schedules may change for storages visited by selected vessel

- Many constraints to satisfy

- Roughly:
  - Assume small quantity and propagate time
  - Find maximum possible quantity (including tank allocation)
  - Set quantity, propagate time and quantities
  - Insert tank cleaning actions
  - Check feasibility
  - If necessary, delay and repeat
Construction: journey ranking

- Evaluate criteria for each journey
  - Transport large quantity
  - Short sailing time
  - Large quantity/vessel capacity
  - Large quantity/sailing time
  - Low cost/quantity
  - ... Random
- Sort journeys for each criterion
- Final score is weighted sum of ranks
Genetic algorithm

- Population of individuals
- Each individual’s genome is a set of weights
- Fitness of each individual is evaluated by applying the construction algorithm
- Weights for new individuals drawn around parents’ weights (+ mutation)
Optimization

- Remove a bit of the solution
  - Any journey starting or ending in random (~10%) interval
- Compact solution
- Regenerate the missing part
  - Use criteria weights from the best GA individuals
- Accept if better or promising
- Avoid known solutions
  - by objective value
Test case

- LNG. 1 product, boil-off, full loads
- 2 production ports
  - Fixed purchase price
  - Fixed production rate
- 2 consumption ports
  - Some interruption allowed
  - Fixed sales price on send-out
- 3 identical vessels
- 360 day horizon
Example run (GA)
Example run (optimization)
A heuristic for maritime inventory routing

Oddvar Kloster, Truls Flatberg
Euro XXIII, Bonn