DOMinant

Discrete Optimization Methods in Maritime and Road-based Transportation

Objective:

Improve methods for solving computationally hard discrete optimization problems in maritime and road-based transportation.

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Industrial Aspects and Literature Survey: Fleet Composition and Routing.

Arild Hoff –2008.06.13

PURPOSE OF THE RESEARCH

- Survey on OR literature on combined fleet dimensioning and routing.

- Contrast the literature with aspects on industrial applications.

Focus on Seaborne and Road-based Modalities.

WHY USE A HETEROGENEOUS FLEET?

- Homogeneous fleets are rear in the industry.
- Larger capacity vehicles are often less costly per unit.
- A fleet consisting of vehicles of different size is generally more flexible and cost effective towards demand variation.

WHY USE A HETEROGENEOUS FLEET?

- Vehicles are usually acquired over a long period of time.
- Different characteristics due to technological development and market situation.
  - Carrying capacity (volume, weight, trailer).
  - Operating, maintenance, depreciation costs.
  - Speed.
  - Harbor/terminal costs.
  - Environmental characteristics (noise, emissions).
  - Others.

WHY USE A HETEROGENEOUS FLEET?

- Possible restrictions due to customers and roads/sea.
  - Physical constraints at customers.
  - Narrow streets in urban areas.
  - Weight or size limitations on roads in rural areas.
  - Limitations for inshore vessels.
  - Harbors with draft restrictions or limited berth space.
  - Others.

PLANNING THE FLEET COMPOSITION

- For a homogeneous fleet, fleet dimensioning is reduced to determining the optimal number of vehicles.
- The aspect of fleet dimensioning, resizing, and allocation is general for all transport modalities.

PLANNING THE FLEET COMPOSITION

- Fleet dimensioning and allocation decisions must be based on information on
  - Transportation demand
  - Transportation costs
  - Income rates
  - Vehicle acquisition, depreciation, resale, and leasing prices.

PLANNING THE FLEET COMPOSITION

- A merger or acquisition between two transportation companies will require capacity adjustment, often in the form of fleet downsizing.
- Decisions
  - Which vehicles to keep.
  - Which vehicles to sell or sublet.
  - Selection of number and types of vehicle to buy or lease.

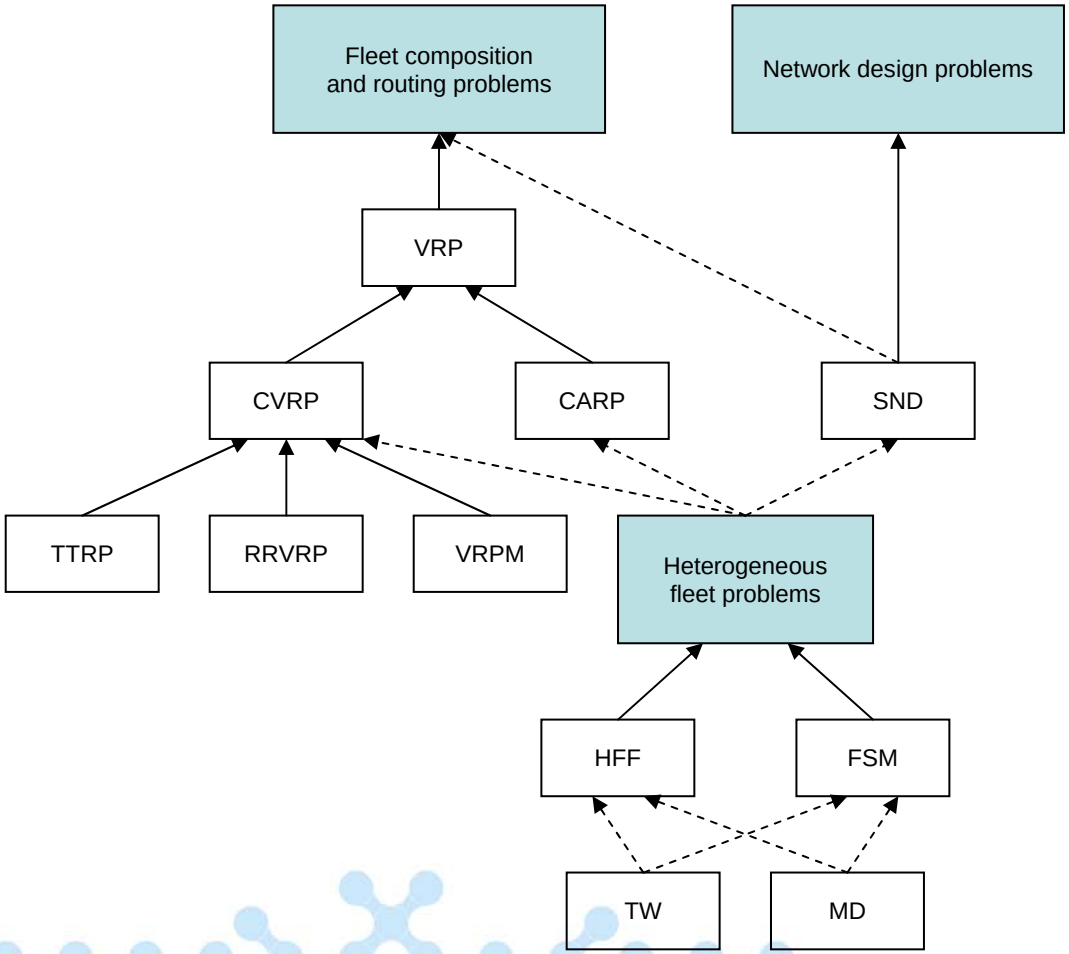
MODAL DIFFERENCES

- Road-based
  - Classical VRP structure with a single depot.
  - Standardized manufacturing of trucks.
  - Normal life-span of a truck is a few years.
- Maritime
  - Continuous pickup/delivery structure without depot.
  - One-of-a-kind ship building.
  - Normal life-span of a ship is several decades.

MODAL DIFFERENCES

- Maritime
  - Longer time constraints.
  - Higher uncertainty in travel/service time.
  - Larger vehicles than in road-based.
  - Less vehicles than in road-based.
  - Much higher capital investments for a ship than for a truck.
  - Large difference within the modalities.

CLASSES OF PROBLEMS CONSIDERED



EARLY PAPERS CONSIDERING FLEET COMPOSITION

DANTZIG AND FULKERSON (1954)

Minimizing the number of tankers to meet a fixed schedule.

Naval Research Logistics Quarterly

KIRBY (1959)

Is your fleet the right size?

Operational Research Quarterly

THE FLEET SIZE AND MIX VEHICLE ROUTING PROBLEM (FSMVRP)

LEVY, GOLDEN AND ASSAD (1980)

Working Paper – *University of Maryland*

GOLDEN, ASSAD, LEVY AND GHEYSENS (1984)

Computers and Operations Research

THE FLEET SIZE AND MIX VEHICLE ROUTING PROBLEM (FSMVRP)

A Vehicle Routing Problem where the vehicles can have heterogeneous capacities, acquisition and routing costs.

The objective is to find the optimal fleet composition of vehicles and a set of feasible routes that minimize the total costs.

CONSTRUCTIVE HEURISTICS

- **Savings-based:** Initially each customer is served by a single vehicle. Then combine two subtours into one step by step.
- **Giant tour:** Route first – Cluster second. Find an optimal TSP-tour, and partition it into subtours.
- **Lower bound:** Trades off fixed costs against routing costs to find the best vehicle fleet mix. Then use a generalized assignment procedure to assign customers to vehicles.

CONSTRUCTIVE HEURISTICS

Salhi and Rand (1993):

Route Perturbation (RPERT).

- Includes a perturbation procedure within existing and constructed routes to reduce the total cost of routing and acquistion by improving the utilization of the vehicles.
  - Reallocation (Move customers to other routes).
  - Combining (Combine routes).
  - Sharing (Split a route into smaller routes).
  - Swapping (Swap customers between routes).
  - Relaxation (Combining and Sharing simultaneously).

TABU SEARCH PAPERS

- **Osman and Salhi (1996):** Modified RPERT and first paper using Tabu Search.
- **Gendreau, Laporte, Musaraganyi and Taillard (1999):** Based on GENIUS and AMP.
- **Wassan and Osman (2002):** Reactive Tabu Search and concepts from VNS.
- **Lee, Kim, Kang and Kim (2006):** Tabu Search and Set Partitioning.
- **Brandão (2007):** Single/double insertion and swap moves, intensification/diversification, penalty for infeasible solutions.

OTHER SOLUTION METHODS

- **Taillard (1999):** A heuristic Column Generation method. Introduced variable unit running cost.
- **Renaud and Boctor (2002):** A sweep-based algorithm which generates a large number of routes that are solved using Set Partitioning.
- **Choi and Tcha (2007):** An IP-model with a linear programming relaxation which is solved by Column Generation.

OTHER SOLUTION METHODS

- **Ochi, Vianna, Drummond and Victor (1998):** A hybrid metaheuristic using Parallel Genetic Algorithms and Scatter Search.
- **Han and Cho (2002):** A generic intensification and diversification search metaheuristic with concepts from Threshold Accepting.
- **Lima, Goldbarg and Goldbarg (2004):** A hybrid Genetic (Memetic) Algorithm.
- **Engevall, Göthe-Lundgren and Värbrand (2004):** Cooperative Game Theory.

EXACT METHODS

- **Yaman (2006):** An Exact approach deriving formulations and valid inequalities to compute lower bounds to the problem.
- **Pessoa, Poggi de Aragão and Uchoa (2007):** Branch-cut-and-price.
- **Baldacci, Battarra and Vigo (2007):** MIP-model to create lower bounds.

FSMVRP WITH TIME WINDOWS

- **Liu and Shen (1999):** Describe several insertion-based savings heuristics.
- **Dullaert, Janssens, Sörensen, Vernimmen (2002):** A sequential insertion heuristic based on Solomon's (1987) heuristic for VRPTW.
- **Tavakkoli-Moghaddam, Safaei and Gholipour (2006):** Hybrid simulated annealing.
- **Yepes and Medina (2006):** Hybrid Local Search, Threshold Accepting.
- **Dell'Amico, Monaci, Pagani, Vigo (2007):** A regret-based parallel insertion procedure and subsequent improvement by ruin and recreate.

FSMVRP WITH TIME WINDOWS

- Bräysy, Dullaert, Hasle, Mester, Gendreau (2007):
  - Multi-restart Deterministic Annealing.
    - Initial solutions are generated by a savings-based heuristic combining diversification strategies with learning mechanisms.
    - Route elimination phase based on a depletion procedure.
    - Improvement on solutions by a set of local search operators that are embedded in a deterministic annealing framework.

FSMVRP WITH TIME WINDOWS

- **Calvete, Gale, Oliveros, Valverde (2007):**
  - FSMVRP with soft and hard Time Windows and Multiple Objectives.
- **Dondo and Cerdá (2007):**
  - FSMVRP with Time Windows and Multiple Depots

ROAD-BASED INDUSTRIAL CASES

- Transportation of workers for an oil company.
- Distributing goods for a grocery chain.
- Delivery of pet food and flour.
- Mail collecting problem.
- Cross-border logistics.
- Milk collection.
- Para-transit service.
- Soft-drink distribution.
- Winter road maintenance.

MARITIME INDUSTRIAL CASES

- Liner routes for container shipping
- Short-haul hub-and-spoke feeder operation in Singapore
- A transport system for companies who depend on sea-transport between Norway and Central Europe
- Off-shore supply vessels in the Norwegian Sea
- Refuse marine transport system in New York City
- Fresh water transport in the Middle East
- Ferry traffic in the Aegean Islands
- Size of a refrigerated container fleet
- Size of the U.S. destroyer fleet in case of a conflict on the Korean Peninsula

CRITIQUE, TRENDS AND DIRECTIONS

- Literature focus on idealized models, rather than rich and industrially adequate models.
- Lack of treatment of uncertainty and the associated concepts of risk and robustness in the literature.
- There is a need for better and richer benchmarks which is real-world based.
- Shift of focus from the individual vehicles to the whole supply chain.
- Lower emissions and increased sustainability might shift the modality of the transport by bonus/penalty systems.

CRITIQUE, TRENDS AND DIRECTIONS

- More and more information and types of information is available for decision makers.
- The world of transportation management is becoming more dynamic.
- Rapid changes in the environment, creates a need for more dynamic plans.
- Some problems (at the operational level) needs fast answers, while others (at the strategic level) can be allowed longer solution times.
- The industry will need Decision Support Systems (DSS) or tools, able to handle these new requirements.