Integrating Vehicle Routing, Vehicle Scheduling and Crew Scheduling

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Integrating Vehicle Routing, Vehicle Scheduling and Crew Scheduling

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Problem Description

- Problems involving a Vehicle Routing and a Vehicle and Crew Scheduling component
- e.g.
  - Delivering mail/parcels in metropolitan areas
  - Delivering general merchandise from distribution centres to retail outlets
  - Transporting cargo and passengers by aircraft
  - 3PLs
An example: Vehicle Routing, Vehicle Scheduling and Crew Scheduling

- Depots
- Customers: Pick Up and Deliver
- Vehicle Types
- Driver Shift

Time

Vehicle Scheduling and Crew Scheduling
Similar Research

**VRCP**
- Savelsbergh and Sol [1998]
- Xu et al. [2003]

**MTVRSP**
- Fleischman [1990] (Sav. Heur.)
- Taillard [2003] (Tabu S)
- Zhao [2003] (Tabu S)
- Hollis et al. [2005]

**SVCSP**
- Haase et al. [2001]
- Freling et al. [2003]
- Huisman et al. [2003]
- Hollis et al. [2005]
- TW Hollis and Forbes [revision]

**SVRCSP**
- Brandao and Mercer [1997,8] (Tabu S)*
- Hollis [2005]
- Hollis et al [working paper]

**Integrated Airline Planning**
- Klabjan et al. [2002]
- Klabjan and Sandhu [2006]
- Cordeau [2001]
Devil is in the detail

- Vehicle Routing Problem is the General Pick Up and Delivery Problem and Time Windows
- Multi-depot, many vehicle types, many driver types
- **Drivers may change vehicles in a shift**
  - Operational compatibility restrictions, vehicle type – (location/product)
  - Heterogeneous vehicle fleet
- Driver breaks (empty/full, here there everywhere!)
- Transshipping / Consolidation
- Multiple pick up and delivery windows
- Large numbers of orders
The Advantages of Simultaneous Vehicle and Crew Scheduling

A legal driver shift covering 3 tasks using 3 different vehicle types

Tasks (start/end time, start/end location)
- Routes that have to be covered by vehicles and drivers

Best possible solution uses 5 vehicles, 3 drivers \textit{minimum}

Different vehicles types assigned to cover tasks
The Advantages of Simultaneous Vehicle and Crew Scheduling

Scheduling Vehicles and Drivers Together you can exploit the properties of the transport network to find a better combined solution…

- Slidability – Tasks may be able to be retimed and still meet delivery times
- Vehicle Substitution – A larger vehicle than strictly necessary may be able to cover certain tasks
Exploiting slidability and vehicle substitution and allowing drivers to change vehicles (only once in a shift) at a depot different from their own depot…

**2 Driver, 2 Vehicle Solution** – shifts are constructed in such a way that all vehicles return to base even though drivers change vehicles at intermediate depots.
Integrating Vehicle Routing with Simultaneous Vehicle and Crew Scheduling

Drivers
- Expensive!
- 7.5 hr max before break
- 4 hr max after break
- Must break at depot

Vehicle Types
- V₁ : Cap = 2, $100/hr
- V₂ : Cap = 4, $110/hr

Shipments
- S₁ : D – A, Vol = 1
- S₂ : D – B, Vol = 1
- S₃ : D – C, Vol = 3

Vehicle Types
- V₁ : Cap = 2, $100/hr
- V₂ : Cap = 4, $110/hr

Sequential Approach
R₁ = V₁ : Pi(S₁) Dr(S₁), 6hrs, $600
R₂ = V₂ : Pi(S₂) Pi(S₃) Dr(S₂) Dr(S₃), 5hrs, $550
Cost = Shift₁(R₁), Shift₂(R₂), V₁, V₂ $1150

Integrated Approach
R₃ = V₁ : Pi(S₁) Pi(S₂) Dr(S₁) Dr(S₂), 7.5hrs, $750
R₄ = V₂ : Pi(S₃) Dr(S₃), 4hrs $440
Cost = Shift₃(R₃, R₄), V₁, V₂ $1190
Min $\sum_{i \in I} h_i y_i + \sum_{j \in J} f_j n_j + \sum_{m \in M} g_m q_m$

Subject to:

- $\sum_{i \in I_{shp}} y_i \geq 1 \quad \forall s \in S$
- $\sum_{i \in I_{std}} y_i = n_j \quad \forall j \in J$
- $n_j \leq JMAX_j \quad \forall j \in J$
- $\sum_{j \in J_p} n_j \leq PMAX_p \quad \forall p \in P$

$N_{mlt} - \sum_{i \in I_{fr}} y_i - \sum_{i \in I_{bp}} y_i = N_{mlt} \quad \forall m \in M, l \in L, t \in T$

- $\sum_{i \in I_{mlt}} y_i = q_m \quad \forall m \in M$
- $q_m \leq MMAX_{mlt} \quad \forall m \in M$
- $\sum_{m \in M_v} q_m \leq VMAX_v \quad \forall v \in V$
- $N_{mlt} \geq 0 \quad \forall m \in M, l \in L, t \in T$
- $y_i \in \{0, 1\} \quad \forall i \in I$

Objective

Set Covering

No. Shifts per Type-Depot

Max Shifts per Type-Depot

Max Shifts per Type

Circulation for Vehicles using Shift Variables

Slice Circulation to Count Vehicles

Max Vehicles per Type-Depot

Max Vehicles per Type

Non-Negativity

Binary

Sets

$T$ Time
$L$ Locations
$V$ Vehicle Types
$M$ Vehicle Type-Depot
$P$ Shift Types
$J$ Shift Type-Depot
$I$ Shifts
$S$ Shipments

Variables

$y_i$ Shift

$n_j$ Shifts per Type-Depot

$q_m$ Vehicles per Type-Depot

$N_{mlt}$ Unused Vehicles

Costs

$g_m$ Vehicle Type-Depot Fixed

$h_i$ Vehicle and Crew Cost

$f_j$ Shift Type-Depot Fixed
Existing Manual Planning Process


Solve the Vehicle Routing Problem

• Xu, H., Chen, Z., Rajagopal, S. Arunapuram, S., 2003. Solving a Practical Pick up and Delivery Problem, Transportation Science 3(37) 347-364.

Integrated Vehicle Routing and Vehicle and Crew Scheduling

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Solve the Simultaneous Vehicle and Crew Scheduling Problem

• Xu, H., Chen, Z., Rajagopal, S. Arunapuram, S., 2003. Solving a Practical Pick up and Delivery Problem, Transportation Science 3(37) 347-364.

Questions ?

Existing Manual Planning Process

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Solve the Vehicle Routing Problem

Integrated Vehicle Routing and Vehicle and Crew Scheduling

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