Integrating Vehicle Routing, Vehicle Scheduling and Crew Scheduling

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Operations Research

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Integrating Vehicle Routing, Vehicle Scheduling and Crew Scheduling

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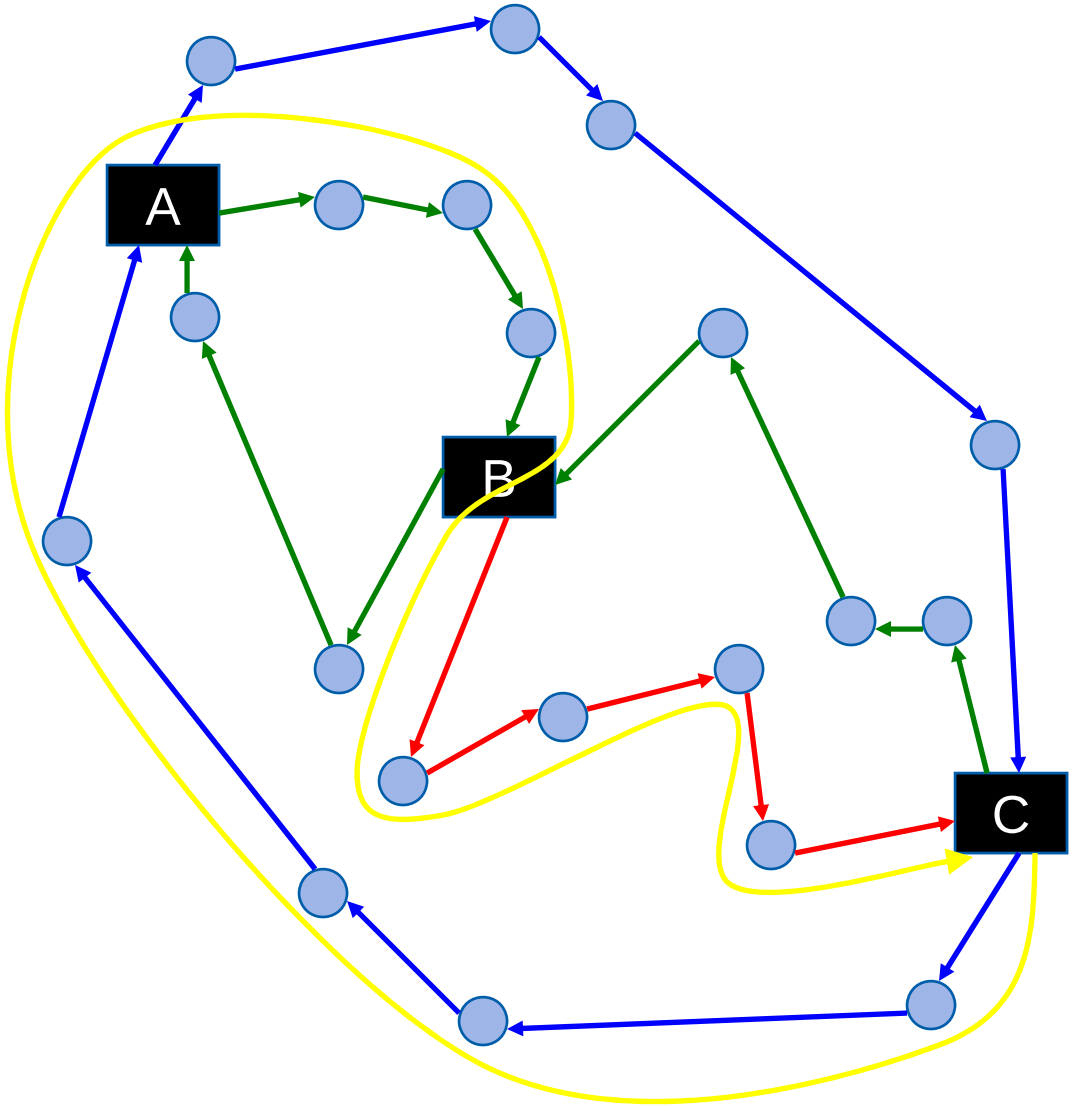
5. Features of the simultaneous vehicle and crew scheduling problem within a shipment delivery context
6. Integrating vehicle routing with simultaneous vehicle and crew scheduling
7. Generating solutions
8. Results and questions

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

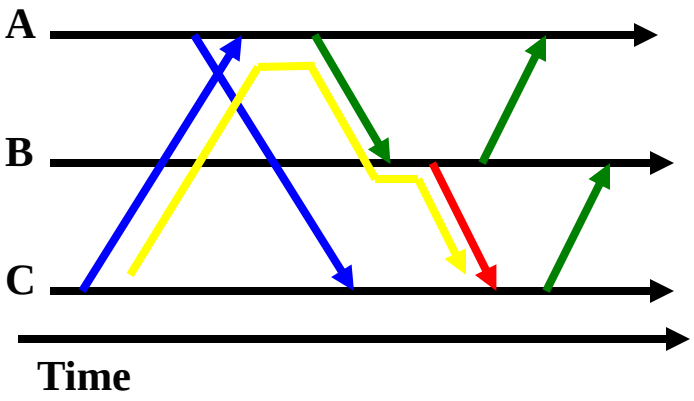


X Depots

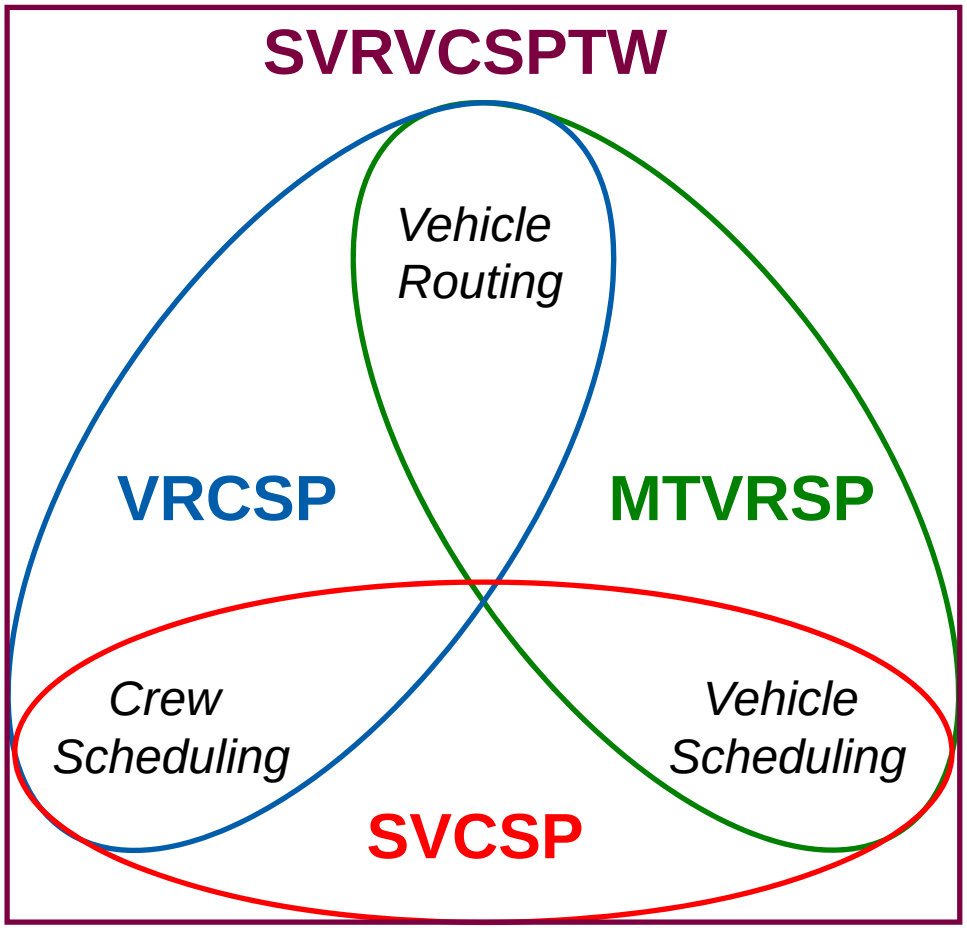
Customers: Pick Up and Deliver

Vehicle Types

Driver Shift



Similar Research



VRCSP
- 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]

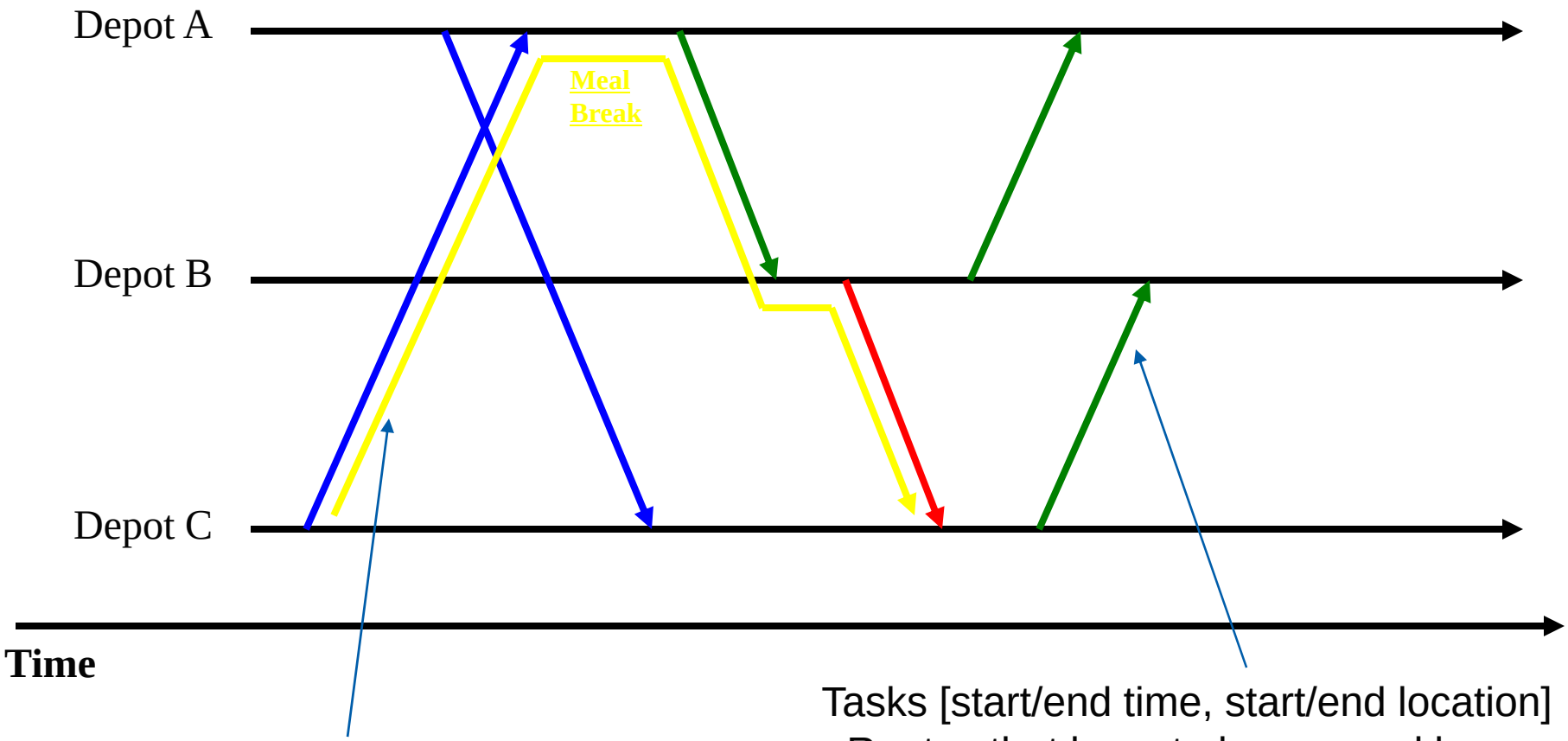
SVRVCSPTW
- Brandao and Mercer [1997,8] *(Tabu S)**
- Hollis [2005]
- Hollis et al [working paper]

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



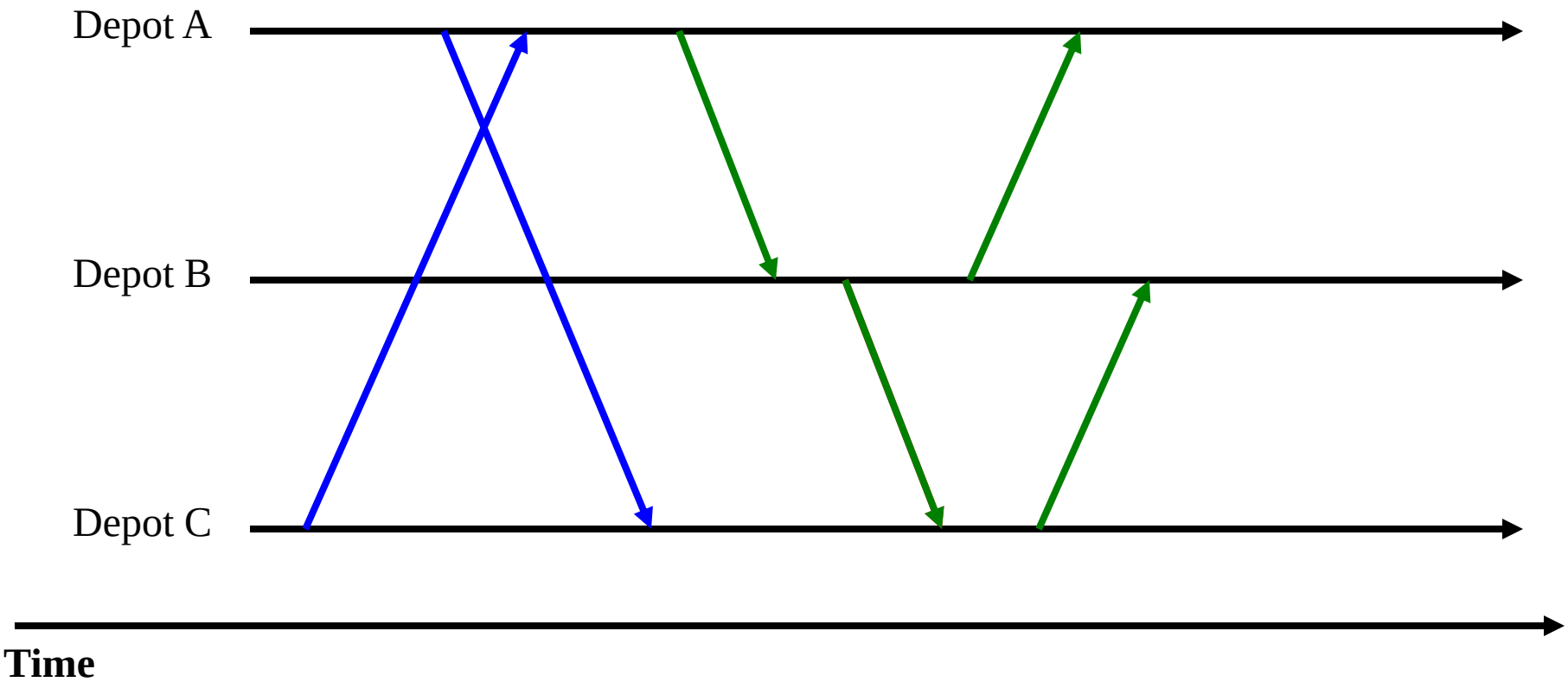
Tasks [start/end time, start/end location]
- Routes that have to be covered by vehicles and drivers

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

Best possible solution uses 5 vehicles, 3 drivers **minimum**

Different vehicles types assigned to cover tasks

The Advantages of Simultaneous Vehicle and Crew Scheduling

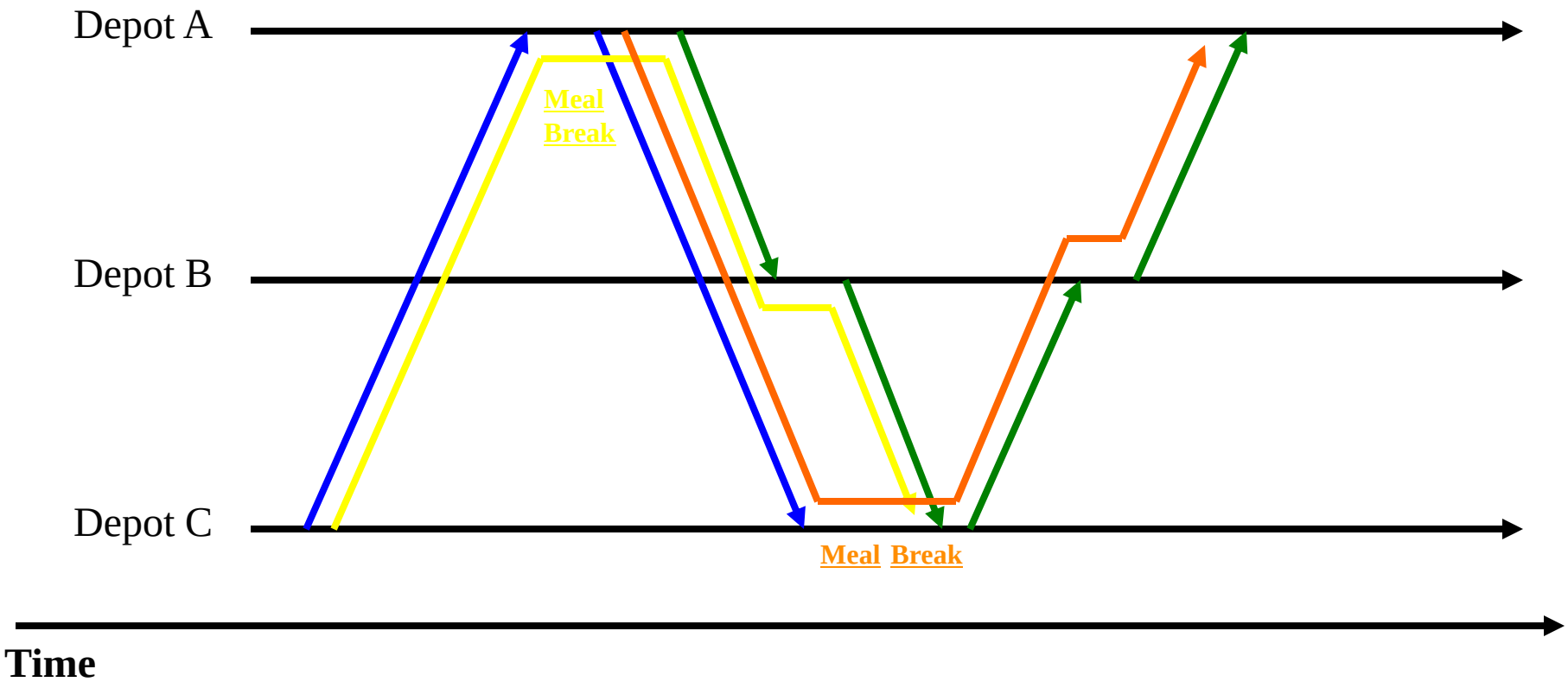


Scheduling Vehicles and Drivers Together you can exploit the properties of the transport network to find a better combined solution…

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

The Advantages of Simultaneous Vehicle and Crew Scheduling

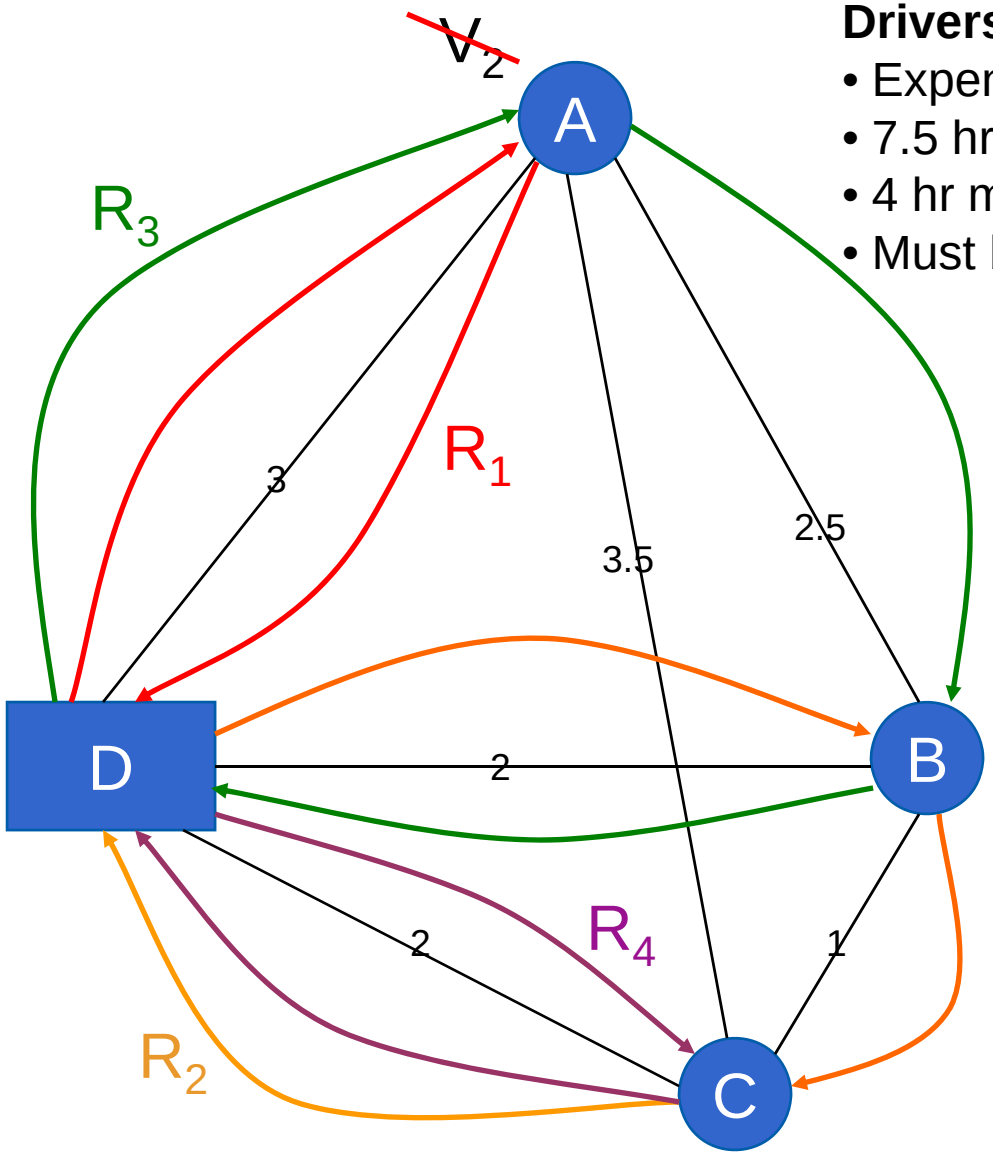


Exploiting slidability and vehicle substitution and allowing drivers to change vehicles (only once in a shift) at a depot different from their own depot…

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

Shift 1 Shift 2

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

V_1 : Cap = 2, \$100/hr
V_2 : Cap = 4, \$110/hr

Shipments

S_1 : D – A, Vol = 1
S_2 : D – B, Vol = 1
S_3 : D – C, Vol = 3

Sequential Approach

R_1=V_1:Pi(S_1)Dr(S_1), 6hrs, \$600

R_2=V_2:Pi(S_2)Pi(S_3)Dr(S_2)Dr(S_3), 5hrs, \$550

Cost = Shift$_1$(R_1), Shift$_2$(R_2), V_1, V_2, \$1150

Integrated Approach

R_3=V_1:Pi(S_1)Pi(S_2)Dr(S_1)Dr(S_2), 7.5hrs, \$750

R_4=V_2 : Pi(S_3) Dr(S_3), 4hrs \$440

Cost = Shift$_3$(R_3, R_4), V_1, V_2 \$1190

$\text{Min} \sum_{i \in I} h_i y_i + \sum_{j \in J} f_j n_j + \sum_{m \in M} g_m q_m$	Objective
$\sum_{i \in I_s^{\text{shp}}} y_i \geq 1 \quad \forall s \in S$	Set Covering
$\sum_{i \in I_j^{\text{ctd}}} y_i = n_j \quad \forall j \in J$	No. Shifts per Type-Depot
$n_j \leq JMAX_j \quad \forall j \in J$	Max Shifts per Type-Depot
$\sum_{j \in J_p} n_j \leq PMAX_p \quad \forall p \in P$	Max Shifts per Type
$N_{mlt^-} + \sum_{i \in I_{mlt}^{\text{fr}}} y_i - \sum_{i \in I_{mlt}^{\text{bp}}} y_i = N_{mlt} \quad \forall m \in M, l \in L, t \in T$	Circulation for Vehicles using Shift Variables
$\sum_{l \in L} N_{mlt_c} + \sum_{i \in I_{mt_c}^{\text{o}}} y_i = q_m \quad \forall m \in M$	Slice Circulation to Count Vehicles
$q_m \leq MMAX_m \quad \forall m \in M$	Max Vehicles per Type-Depot
$\sum_{m \in M_v} q_m \leq VMAX_v \quad \forall v \in V$	Max Vehicles per Type
$N_{mlt} \geq 0 \quad \forall m \in M, l \in L, t \in T$	Non-Negativity
$y_i \in \{0, 1\} \quad \forall i \in I$	Binary

Sets

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

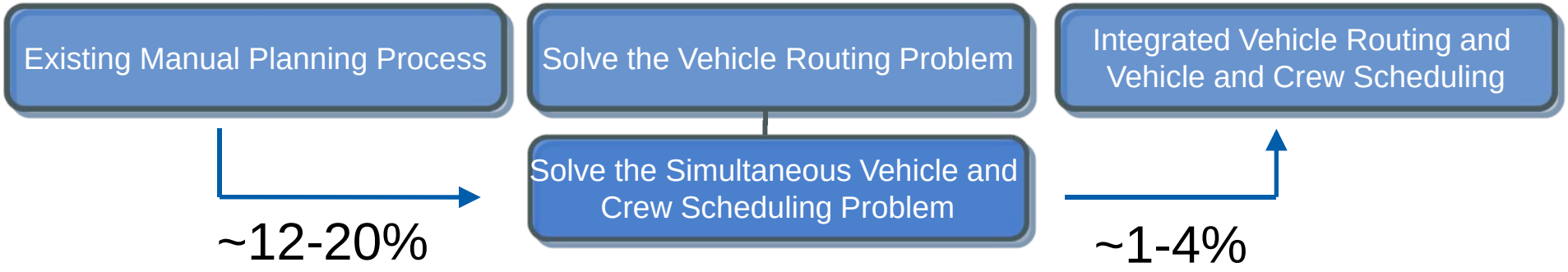
Variables

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

Questions ?



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