DMS639 : ANALYTICS IN TRANSPORT AND TELECOMMUNICATION

COURSE PROJECT

GROUP 1

VeRoLog Solver Challenge 2019

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Problem Description:

The problem of the VeRoLog Solver Challenge 2019 is based on a problem that combines distribution and subsequent installation of equipment, such as vending machines. The machines must be delivered within a customer-dependent delivery window and must be installed by a technician as soon as possible after delivery.

The planning horizon consists of a period of consecutive days, numbered 1, 2, and so on. There are different kinds of machines, each having its own size, expressed in the same unit.

There are machine requests from customers that all have to be satisfied. A request consists of a number of machines of one kind, and a delivery window within which these machines have to be delivered. Each delivery window consists of a number of consecutive days within the planning horizon. If a customer needs more than one kind of machine, a separate request is defined for each kind. For example, there can be a request for two machines of kind 5 that have to be delivered on day 8, 9 or 10.

Machine Delivery: There is one depot location where all the machines are located at the start of the planning horizon. There are enough machines of each kind available to satisfy all the requests. Trucks are hired to transport the machines from the depot to the customers. There is no limit on the number of trucks that can be hired. All trucks are identical. A truck can accommodate any combination of machines whose total size does not exceed the truck's capacity, where the capacity is expressed in the same unit as the machine sizes. The delivery of a request cannot be split, i.e., all machines of a request must be delivered simultaneously by one truck. In the provided instances, none of the request sizes exceeds the vehicle capacity.

The daily route of a truck starts and ends at the depot, i.e., a truck that picks up a machine from the depot on a certain day must end its route at the depot that same day. A truck can return to the depot several times during a day to pick up machines. The total distance a truck can travel per day is limited to a given maximum. It does not take any time to load a machine at the depot or to unload a machine at a customer.

Machine Installation: After delivery, each machine must be installed by a technician at the customer location. Installation of a machine cannot take place on the day the machine is delivered. For every full day a machine is 'idle', i.e., delivered at the customer but not yet installed, a fixed penalty is charged. This penalty is specified for each kind of machine. For example, suppose a request with three machines of type A is delivered to a customer on day 4 and installed on day 7. Then the penalty for machine type A is charged $3 \cdot 2 = 6$

times, as three machines were idle on days 5 and 6. If the machines are delivered on day 4 and installed on day 5, no penalty is charged.

Each technician has a skill set that determines which kinds of machines he/she can install. Installing a machine does not take any time. The maximum number of consecutive days a technician can work is 5. If a technician has worked for five consecutive days, he/she must have two days off. If a technician has worked for less than five consecutive days, a single day off suffices. All days outside the planning horizon are days off. The daily route of a technician must start and end at his/her home location. The total distance a technician can travel per day is limited to a given maximum. The same holds for the number of requests a technician can carry out per day, where carrying out a request means installing all the machines for that request.

Objective: In a solution all requested machines are delivered and installed within the planning horizon. The objective is to minimize the total cost. There are costs per unit of distance traveled by truck, for using a truck for a day, and for using a truck at all during the planning horizon. Additionally, there are costs per unit of distance traveled by a technician, for using a technician for a day, and for using a technician at all during the planning horizon. Finally, there are costs for every full day a machine is idle, specified for each kind of machine. In order to determine the traveled distances, integer coordinates are provided for the depot, the customer locations, and the technician's home locations. The distance between coordinates (x1, y1) and (x2, y2) is defined as the ceiling of the Euclidean distance.

Format of the instance data:

We now describe the format of the instance data, which is available in text format. Within each section, the entries are sorted by their (consecutive) IDs. We point out that all IDs in the input are positive integers, and that the depot has location ID 1 in every instance

An example of an instance file in text format follows below.

```
DATASET = VeRoLog solver challenge 2019NAME
= testInstance

DAYS = 7
TRUCK_CAPACITY = 6
TRUCK_MAX_DISTANCE = 250

TRUCK_DISTANCE_COST = 1
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TRUCK_DAY_COST = 100
TRUCK_COST = 100000
TECHNICIAN_DISTANCE_COST = 1
TECHNICIAN_DAY_COST = 100000
TECHNICIAN_COST = 100

MACHINES = 4
1 2 200
2 1 200
3 3 500
4 2 100

LOCATIONS = 9
1 10 50
2 20 10
3 50  5
4 33  7
5 40 40
6 70 40
7  1 35
8 10  5
9 25 60

REQUESTS = 7
1 2 1 7 1 1
2 3 3 6 3 1
3 4 2 3 4 2
4 5 5 7 1 3
5 6 1 4 2 1
6 7 1 6 4 1
7 7 3 5 2 4

TECHNICIANS = 5
1 3 100 2 0 1 1 1
2 8 100 1 1 1 0 0
3 8 100 5 0 0 1 0
4 9 100 2 1 1 0 1
5 1  50 1 1 1 1 1
```

Explanation of example instance

Here we give an explanation of the input file. The different sections in the text file will always appear in this given order. However, additional line breaks or spaces may be present. Entries in a line are separated by spaces.

DAYS (integer) gives the number of days in the planning horizon. Recall that the days are num- bered 1, 2, and so on.
TRUCK_CAPACITY (integer) denotes the capacity of one truck.
TRUCK_MAX_DISTANCE (integer) is the maximum distance that one truck can travel on

a day.

The next section defines the weights for the costs related to the delivery trucks and the technicians.

TRUCK_DISTANCE_COST (integer) is the cost per unit of distance traveled by truck. TRUCK_DAY_COST (integer) denotes the cost per route, i.e., the cost per used truck per day. TRUCK_COST (integer) is the cost for using a truck during any day of the planning horizon. This cost should be multiplied by the maximum number of trucks needed on a day; recall that all trucks are identical.
TECHNICIAN_DISTANCE_COST (integer) is the cost per unit of distance traveled by a technician.
TECHNICIAN_DAY_COST (integer) is the cost per used technician per day.
TECHNICIAN_COST (integer) is the cost for using a technician during any day of the planning horizon. This cost should be multiplied by the number of different technicians used during the planning horizon.

The following four sections start with a name, followed by the number of entries in that section. For example, MACHINES = 4 indicates that there are 4 machine kinds, the details of which are described in the following 4 lines.

Under MACHINES, the different machine kinds are listed. The first entry is the machine kind ID. The second entry gives the size of one machine of this machine kind (integer). The third entry denotes the penalty that is charged for every full day a machine of this kind is idle.

Under LOCATIONS, the coordinates of the depot location, the customer locations, and the technicians' home locations are given. The first entry is the location ID, the second and third entries denote the actual x- and y-coordinates, respectively, of the location (integers). Recall that the depot always has location ID 1. It is possible that a technician has location ID 1, too; in that case, the technician is based at the depot. Customers cannot have location ID 1.

Under REQUESTS, one can find all machine requests by the customers. The first entry is the request ID. The second entry denotes the location ID of the customer that created this request. The next two entries specify the first and last day of the delivery window for this request. The last two entries give the machine kind ID and the number of requested machines of this kind.

Under TECHNICIANS, the different technicians are listed. The first entry is the technician ID. The second entry is the location ID. Note that a technician's location ID can coincide with the location ID of the depot or a customer, and that different technicians can be based at the same location and thus have the same location ID. The third entry denotes the maximum distance the technician can travel per day, the fourth entry denotes the maximum number of requests the technician can carry out per day. The remaining entries, one for each machine kind, specify which machines the technician can (1) and cannot (0) install. For example, if there are 4 machine kinds and the last 4 entries of a technician are 1 1 0 1, then this technician can install machine kinds 1, 2, and 4, but cannot install machine kind 3.

Formulation:

Decision variables

- *X*_t_i_j_k: 1, if vehicle *k* visits {request *j*}/depot right after {request *i*}/depot on day *t*; 0, otherwise.
- Z_i_j_s_t: 1 if technician *s* visits {request *j*}/home right after {request *i*}/home on day *t*; 0, otherwise.
- *M_k*: 1 if vehicle *k* is used during the planning horizon; 0, otherwise.
- *R_s*: 1 if technician *s* is used during the planning horizon; 0, otherwise.

- *V_t_k:* 1 if vehicle *k* is used during day *t*; 0, otherwise.
- *P_t_s*: 1 if technician *s* is used during day *t*; 0, otherwise.
- W_t_i: 1 if request *i* is delivered on day *t*; 0, otherwise.
- Y_t_i: 1 if request *i* is installed on day *t*; 0, otherwise.
- q_*t_i*: upper bound on the weight of the machines on vehicle *k* right after leaving {request *i*}/depot.
- *g_i_s*: number of visits done by technician *s* before visiting {request *i*}/home.
- b_*i*: number of days installation of request *j* is delayed after its delivery.

Parameters:

- T: number of days in the entire planning horizon.
- H0 : location of the depot. (stored on request id 0)
- D: maximum distance a vehicle can travel per day.
- d_i_j: distance between request/depot/home i and j.
- e_i: earliest (first) day that request i can be delivered.
- l_i: latest (last) day that request i can be delivered.
- C: vehicle capacity.
- ci: capacity needed to deliver request i.
- H_s: home location of technician s.

- D_s: maximum distance that technician s can travel per day.
- N_s: maximum number of installations that technician s can do per day.
- CI_i: cost of delaying the installation of request i per day.
- CV: cost of using a vehicle any day during the planning horizon.
- CT: cost of using a technician any day during the planning horizon.
- CVU: cost of using a vehicle per day.
- CTU: cost of using a technician per day.
- CVT: cost of traveling unit distance by a vehicle.
- CTT: cost of traveling unit distance by a technician.

Parameters to select:

- M_t: upper bound on the number of visits a vehicle can do to depot on day t.
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Iterating Set:

- R: requests no.
- R0 : requests no. and the depot (H0).
- K: vehicles no.
- S: technicians.
- Rs[i]: requests that technician s can install and the home location of technician s (i : if technician has skill to install request ∪ Hs).

Objective Fuction:

$$\min \overbrace{\sum_{k \in K} \mathrm{CV} m_k + \sum_{t=1}^{T} \sum_{k \in K} \mathrm{CVU} v_k^t + \sum_{t=1}^{T} \sum_{\substack{k \in K, \\ i,j \in R_0, i \neq j}} \mathrm{CVT} d_{ij} x_{ijk}^t}^{\text{vehicle cost}}$$

$$+ \underbrace{\sum_{s \in S} \mathrm{CT} r_s + \sum_{t=1}^{T} \sum_{s \in S} \mathrm{CTU} p_s^t + \sum_{t=1}^{T} \sum_{\substack{s \in S, \\ i,j \in R_s, i \neq j}} \mathrm{CTT} d_{ij} z_{ijs}^t}_{\text{technician cost}} + \underbrace{\sum_{i \in R} \mathrm{CI}_i b_i}_{\text{idling cost}}$$

Constraints:

Constraint 1: Arc Balance Requirement for Vehicle Routes

$$\sum_{i\in R} x^t_{H_0ik} = \sum_{i\in R} x^t_{iH_0k} \leq M_t v^t_k \quad \forall k \in K, t \in [1, T]$$

Constraint 2: Depot Start/End Requirement and Vehicle Capacity Bound

$$\sum_{i\in R} x^t_{H_0ik} = \sum_{i\in R} x^t_{iH_0k} \leq M_t v^t_k \quad \forall k \in K, t \in [1, T]$$

Constraint 3: Daily Total Travel Distance Limit for Vehicles

$$\sum_{i,j\in R_0, i\neq j} d_{ij} x^t_{ijk} \leq D \quad \forall k \in K, t \in [1, T]$$

Constraint 4: Hire Before Utilization Requirement for Vehicles

$$v^t_k \leq m_k \quad \forall k \in K, t \in [1, T]$$

Constraint 5: Hiring Requirement for Traveling between Requests in a day

$$x^t_{ijk} \leq v^t_k \quad \forall i, j \in R_0, k \in K, t \in [1, T]$$

Constraint 6: Relationship between Routing and Service for Vehicle Deliveries in a horizon

$$\sum_{k\in K, j\in R_0, i\neq j} x^t_{ijk} = w^t_i \quad \forall i \in R, t \in [e_i, l_i]$$

Constraint 7: Delivery Time Window and Assignment Requirement

$$\sum_{t=e_i}^{l_i} w^t_i = 1 \quad \forall i \in R$$

Constraint 8: MTZ constaint

$$q_{ik} \leq q_{jk} - x_{ijk}^{t}(C + c_j) + C \quad \forall i \in R_0, j \in R, i \neq j, k \in K, t \in [1, T]$$

Constraint 9: Arc Balance Requirement for Technician Routes

$$\sum_{j \in R_s, i \neq j} z_{ijs}^{t} = \sum_{j \in R_s, i \neq j} z_{jis}^{t} \quad \forall i \in R_s, s \in S, t \in [1, T]$$

Constraint 10: Home Start/End Requirement for Technician

$$\sum_{i \in R} z_{H_s is}^{t} = \sum_{i \in R} z_{iH_s s}^{t} = p_s^{t} \quad \forall s \in S, t \in [1, T]$$

Constraint 11: Daily Total Travel Distance Limit for Technician

$$\sum_{i,j \in R_s, i \neq j} d_{ij} z_{ijs}^{t} \leq D_s \quad \forall s \in S, t \in [1, T]$$

Constraint 12: Maximum Installations per Technician per Day

$$\sum_{i \in Rs, j \in Rs, i \neq j} z_{ijs}^{t} \leq N_s \quad \forall s \in S, t \in [1, T]$$

Constraint 13: Hire Before Utilization Requirement for Technician

$$p_s^{t} \leq r_s \quad \forall s \in S, t \in [1, T]$$

Constraint 14: Hiring Requirement for traveling between Requests in a day

$$z_{ijs}^{t} \leq p_{s}^{t} \quad \forall i, j \in R_s, s \in S, t \in [1, T]$$

Constraint 15: Relationship between Routing and Service for technician installation in a horizon

$$\sum_{s \in S, j \in R_s, i \neq j} z_{ijs}^{t} = y_i^t \quad \forall i \in R, t \in [e_i + 1, T]$$

Constraint 16: Installation Time Window and Assignment Requirement

$$\sum_{t=e_i+1}^{T} y_i^t = 1 \quad \forall i \in R$$

Constraint 17: MTZ constraint for technician

$$g_{is} \leq g_{js} - z_{ijs}^{t}(1 + N_s) + N_s \quad \forall i \in R_s, j \in R, i \neq j, s \in S, t \in [1, T]$$

Constraint 18: Technician Working Day Restriction (5 consecutive days)

$$\sum_{u=t}^{t+5} p_s^u \leq 5 \qquad \forall s \in S, t \in [1, T-5]$$

Constraint 19: Technician Working Day Restriction (4 or fewer consecutive days)

$$\sum_{u=t}^{t+4} p_s^u \leq 5 - p_s^{t+6} \quad \forall s \in S, t \in [1, T-6]$$

Constraint 20: Technician Working Day Restriction at the End of Planning Horizon

$$\sum_{u=T-5}^{T} p_s^u \leq 5 \qquad \forall s \in S$$

Constraint 21: Idling Time Calculation and Minimum Installation Delay

$$\sum_{t=e_i+1}^{T} ty_i^t - \sum_{t=e_i}^{l_i} tw_i^t - 1 = b_i \quad \forall i \in R$$

Input Data

DATASET = ORTEC Small VeRoLog 2019

NAME = Instance 1

DAYS = 4

TRUCK_CAPACITY = 18

TRUCK_MAX_DISTANCE = 1090

TRUCK_DISTANCE_COST = 10000

TRUCK_DAY_COST = 1000

TRUCK_COST = 1000

TECHNICIAN_DISTANCE_COST = 10000

TECHNICIAN_DAY_COST = 10000

TECHNICIAN_COST = 10

MACHINES = 3

1	7	315
2	6	580
3	5	620

LOCATIONS = 5

1	349	370
2	297	246
3	670	662
4	495	150
5	227	326

REQUESTS = 6

1	4	1	3	3	3
2	4	1	3	2	1
3	2	1	2	2	2
4	3	1	3	3	2
5	2	1	2	1	1
6	3	1	3	3	3

TECHNICIANS = 5

1	3	930	5	0	1	1
2	2	440	10	1	1	0
3	5	370	8	1	0	0
4	1	530	5	1	1	1
5	2	970	9	1	1	1

Solutions :

We use branch and bound method to solve problem.

Result:

- Day 1
- Day 2

  D-1-D → V2

  D-3-D → V2

  D-5-2-D → V3
- DAY 3

  D-4-D → V2

  D-6-D → V3

  H5-5-3-1-2-H5 → T5
- DAY 4

  H0-4-6-H0 → T1

Interpretation of the result:

On Day 2 :

Vehicle no. 2 will travel to fulfil the demand at request location 1 and return to depot. Then again go to fulfil the demand to request 3 and return to depot.

Vehicle no. 3: Start from depot then go to request location 5 and then to request location 2 and return to depot afterwards.

No technician movement.

On Day 3:

Vehicle no. 2 will travel to fulfil the demand at request location 4 and return to depot.

Vehicle no. 3: Start from depot then go to request location 6 and then return to depot.

Technician 5 will start from his home go to request location 5 then after installing, then move to request locations 3, 1, 2 respectively and then return to his home.

On Day 4:

Tecnician 1 will start from his home and go to request location 4, from 4 to 6 and return back to his home.

Reference :

Kheiri, A., Ahmed, L., Boyacı, B., Gromicho, J., Mumford, C., Özcan, E. and Dirikoç, A.S., 2020. Exact and hyper-heuristic solutions for the distribution-installation problem from the VeRoLog 2019 challenge. Networks, 76(2), pp.294-319.

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