# Problem description

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 foreach 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 *·* 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 (*x*1*, y*1) and (*x*2*, y*2) is defined as *Euclidean Distance = distance ((x, y), (a, b)) =*

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## 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.

**Example instance**

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

DATASET = Sample1

NAME = testInstance

DAYS = 7

TRUCK\_CAPACITY = 6

TRUCK\_MAX\_DISTANCE = 250

TRUCK\_DISTANCE\_COST = 1

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.

## Format of the solution data

The solution file specifies the routes for the trucks and the technicians each day. Solution files should be submitted as text files. We will now explain how a solution file should be constructed.

**Example solution**

An example of a solution file in text format follows below.

DATASET = Sample1

NAME = testInstance

TRUCK\_DISTANCE = 394

NUMBER\_OF\_TRUCK\_DAYS = 3

NUMBER\_OF\_TRUCKS\_USED = 1

TECHNICIAN\_DISTANCE = 312

NUMBER\_OF\_TECHNICIAN\_DAYS = 5

NUMBER\_OF\_TECHNICIANS\_USED = 3

IDLE\_MACHINE\_COSTS = 400

TOTAL\_COST = 601706

|  |  |  |
| --- | --- | --- |
| DAY = 1  NUMBER\_OF\_TRUCKS = 0 NUMBER\_OF\_TECHNICIANS | = | 0 |
| DAY = 2  NUMBER\_OF\_TRUCKS = 1  1 5 3  NUMBER\_OF\_TECHNICIANS | = | 0 |
| DAY = 3  NUMBER\_OF\_TRUCKS = 1  1 6 7 0 1 2  NUMBER\_OF\_TECHNICIANS | = | 1 |
| 1 5 |  |  |
| DAY = 4  NUMBER\_OF\_TRUCKS = 0  NUMBER\_OF\_TECHNICIANS | = | 3 |

1 3 2

2 1

4 7

|  |  |  |
| --- | --- | --- |
| DAY = 5  NUMBER\_OF\_TRUCKS = 1 |  | |
| 1 4  NUMBER\_OF\_TECHNICIANS | = | 0 |
| DAY = 6  NUMBER\_OF\_TRUCKS = 0  NUMBER\_OF\_TECHNICIANS | = | 1 |
| 4 6 4 |  |  |
| DAY = 7  NUMBER\_OF\_TRUCKS = 0  NUMBER\_OF\_TECHNICIANS | = | 0 |

**Explanation of example solution**

Here we give an explanation of the data file.

The first two lines (DATASET and NAME) refer to the instance that the solution file belongs to. The next section, listing some characteristics of the solution (starting with TRUCK\_DISTANCE and ending with TOTAL\_COST) is optional. When included, it should contain the following infor- mation:

TRUCK\_DISTANCE (integer) is the total distance traveled by all trucks. NUMBER\_OF\_TRUCK\_DAYS (integer) is the total number of truck days used. NUMBER\_OF\_TRUCKS\_USED (integer) is the maximum number of trucks used on a single day. TECHNICIAN\_DISTANCE (integer) is the total distance traveled by all technicians.

NUMBER\_OF\_TECHNICIAN\_DAYS (integer) is the total number of technician days used.

NUMBER\_OF\_TECHNICIANS\_USED (integer) is the total number of technicians used. IDLE\_MACHINE\_COSTS (integer) is the sum of the costs resulting from idle machines. TOTAL\_COST (integer) is the total cost of the solution.

This optional paragraph makes it easier to check the total cost of the solution. These results are also returned by the validator and hence can be checked by the user.

After these sections the actual solution is given, day by day. Every section starting with DAY first lists by the header NUMBER\_OF\_TRUCKS the number of trucks used this day, followed by the truck routes. Next, the header NUMBER\_OF\_TECHNICIANS indicates the number of technicians used, followed by the technician routes. All days of the planning horizon should be mentioned in the solution, even when no trucks or technicians are used during that day (such as days 1 and 7 in the example solution). Furthermore, for each day, the NUMBER\_OF\_TRUCKS and NUMBER\_OF\_TECHNICIANS parameters should always have a value, even when the value is 0 for that day.

To explain the format in which the routes should be given, let us consider day 3 in the example solution. On that day, one truck is used for delivering machines. The route for that truck is given as 1 6 7 0 1 2.

* The first integer (1) refers to the ID of the truck. Recall that all trucks are identical, so we can simply number them 1, 2, 3, ...
* The remaining integers (6 7 0 1 2) form the sequence of request IDs the truck is deliv- ering that day, where the integer 0 indicates a return to the depot. So in this example, truck 1 first delivers requests 6 and 7, then returns to the depot to pickup new machines, and finally delivers requests 1 and 2.

Note that all trucks depart from and must return to the depot at the end of the day, so this is not mentioned explicitly in the solution format.

The technician routes are given in a similar way: the first entry refers to the technician ID, the following entries refer to the sequence of the request IDs for the technician’s route. All technician routes must begin and end at the technician’s home location, which is therefore not mentioned explicitly in the solution format.

To conclude this section, we explain some of the parameter values in the example solution:

* NUMBER\_OF\_TRUCK\_DAYS = 0 + 1 + 1 + 0 + 1 + 0 + 0 = 3, the result of summing up

NUMBER\_OF\_TRUCKS over all days in the planning horizon.

* NUMBER\_OF\_TRUCKS\_USED = 1, as this is the maximum number of trucks we use on any single day (or: the only truck we use to deliver all requests is the truck with ID 1).
* NUMBER\_OF\_TECHNICIAN\_DAYS = 0 + 0 + 1 + 3 + 0 + 1 + 0 = 5.
* NUMBER\_OF\_TECHNICIANS\_USED = 3, as the only technicians we use are those with IDs 1, 2 and 4.
* IDLE\_MACHINE\_COSTS = 400, which can be seen as follows. The only machines that are idle are those belonging to requests 3 (idle on day 3) and 6 (idle on days 4 and 5). As we see in the example instance, request 3 consists of two machines of type 4, for which the idle cost per day is 100. Hence, the total idle cost for request 3 is 1 *·* 2 *·* 100 = 200. Request 6 consists of one machine of type 4, so the total idle cost for request 6 is 2 *·* 1 *·* 100 = 200. This yields a total idle machine cost of 400.

- TOTAL\_COST = 394 *·* 1 + 3 *·* 100 + 1 *·* 100*.*000 + 321 *·* 1 + 5 *·* 100*.*000 + 3 *·* 100 + 400 = 610*.*706,

computed using the parameter values given in the second section of the example solution and the weights given in the example instance.