LogisticsLab

Version 5.4

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Manual

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1 About LogisticsLab and Installation

LogisticsLab is an academic software for decision support in logistics. This software can be classified as a problem-oriented decision support system that can be used to model and solve transportation problems, network flow problems, traveling salesman problems, Chinese postman problems, vehicle routing planning problems and location problems in different variations.

LogisticsLab was originally developed under the name EUS teaching software by DIETER FEIGE for the Business Administration and Logistics courses at the Friedrich-Alexander-University of Erlangen-Nuremberg and fundamentally revised and expanded by MIKE STEGLICH from the Technical University of Applied Sciences Wildau.

LogisticsLab is provided under the LogisticsLab Academic License. It is available for academic use (such as research and teaching or for reproducing case studies in academic textbooks) free of charge and without warranty. It can be downloaded from the website http://logisticslab.org and installed and used on an unlimited number of computers.

The software can only be run under Microsoft Windows (64 Bit, version ≥ 10).

For installation, the first step is to download the software from http://logisticslab.org as a ZIP file `logisticsLab-X-Y-Z.zip`. `X-Y-Z` is the version number. Then unpack the ZIP file. A special installation is not necessary, as the software can be used immediately after un-packing. However, it is advisable to change the path LogisticsLab to `c:\Program Files\LogisticsLab`.

After installation, there are several EXE files in the program path regarding the supported groups of logistical decisions, which are listed below:

- TPP.exe Transportation Problems,
- NWF.exe Network Flow Problems,
- TSP.exe Travelling Salesman and Chinese Postman Problems,
- VRP.exe Vehicle Routing Problems,
- DLP.exe Discrete Location Problems,
- CLP.exe Continuous Location Problems.

2 LogisticsLab in a glance

2.1 Program interface

The structure of the user interface of each part of the program follows a uniform structure, as shown in Figure 1 for LogisticsLab/VRP as an example. In addition to the usual elements, the user interface has a network area on the left-hand side of the program with the graphical representation of the network or the solution found for this network and a data area on the right-hand side in which several areas can be selected via tabs and filled with the necessary data. Generally, interactive data entry and modification takes place in the data area. The network and the data area can be spread over the entire screen.

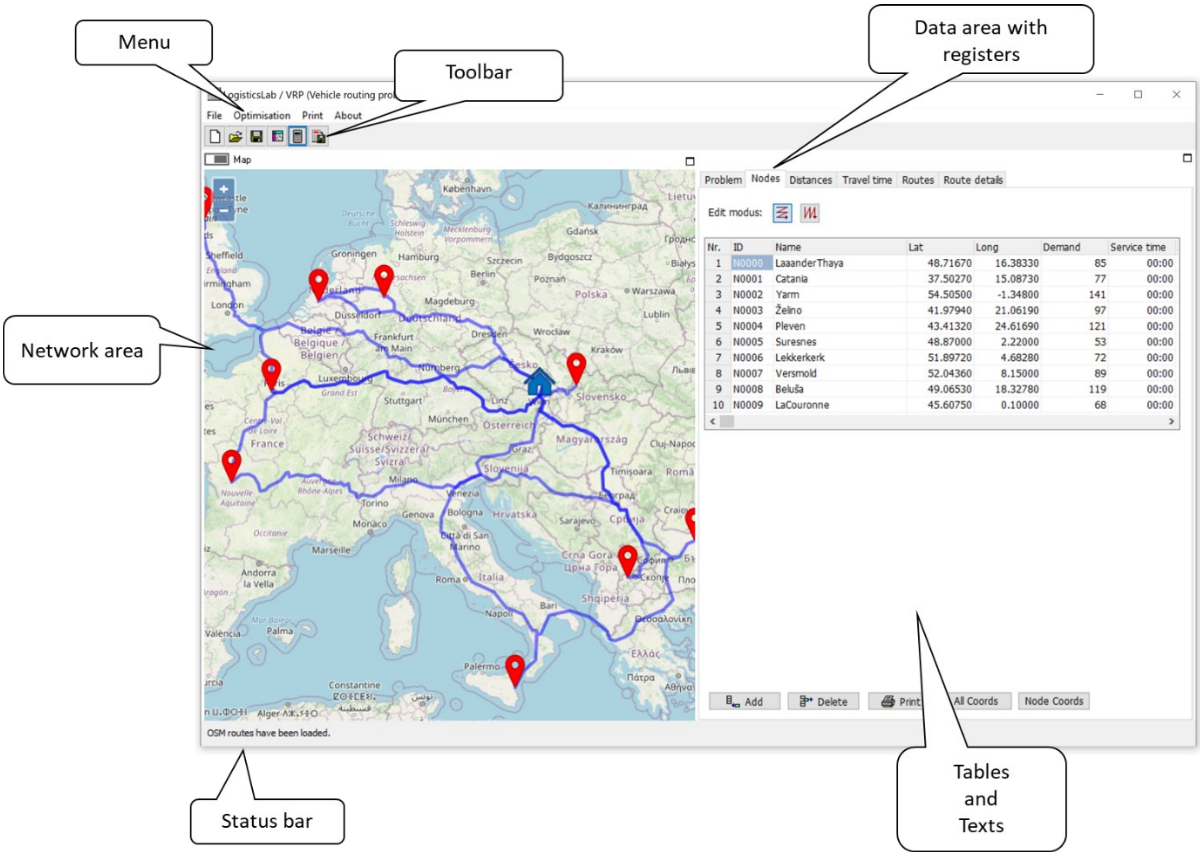

Figure 1: Program interface

There are two ways to display the network representation of the problem and the solution to the problem. If geographical coordinates are used, an OpenStreetMap is shown in the network area. With a mouse over on one of the nodes, a pop-up window appears with additional information.

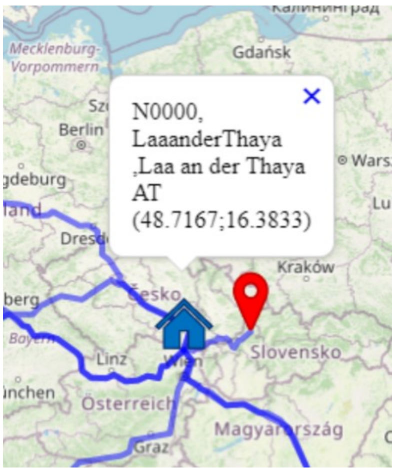

Figure 2: Node pop-up with additional information

The map switch in the upper left corner of the network area allows the user to switch to a simple map.

Figure 3: for changing between the different map types

SimpleMap is also used when the coordinates are not geographical.

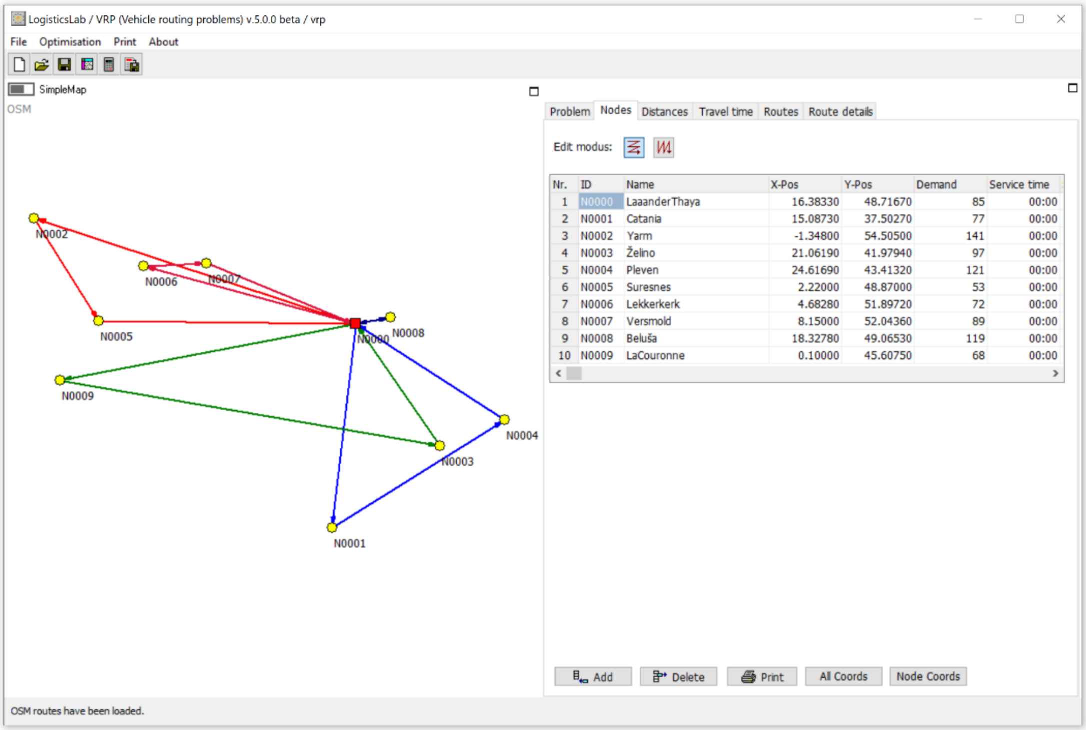

Figure 4: Example of a SimpleMap in LogisticsLab/VRP

2.2 Menu entries

The menus of the individual program packages consist of the unified function groups *File*, *Optimisation* and *Print*. Each menu item can also be quickly accessed via corresponding key combinations (shortcuts).

File:

- *New Problem (Ctrl-N)*
  Create a new problem. New data can be entered. For some programs, a data generator can be optionally started, which generates random-based sample data according to entered specifications.
- *Open Problem (Ctrl-O)*
  Loading the data of a problem from a program-dependent data file.
- *Save Problem (Ctrl-S)*
  Saving the problem data to a file. Either the name under which the data was previously loaded is used or a new file name is requested if the data was newly entered.
- *Save Problem as ... (Shift-Ctrl-S)*
  Before saving the data, the system always asks for a new file name.
- *Save Solution as ... (Ctrl-L)*
  Save the optimisation result under a predefined file name in a text file with the extension *SOLX*.
- *Import nodes (and edges) from Excel Distance Matrix as ... (Ctrl-I)*
  Imports nodes and edges (only TSP and NWF) from Excel.
- *Export nodes (and edges) from Excel Distance Matrix as ... (Ctrl-I)*
  Exports nodes and edges (only TSP and NWF) to Excel.
- *Exit (Ctrl-Q)*
  Exit the program

Optimisation:

- *Create Distance Matrix*
  Opens a dialogue for generating a distance/time/cost matrix.

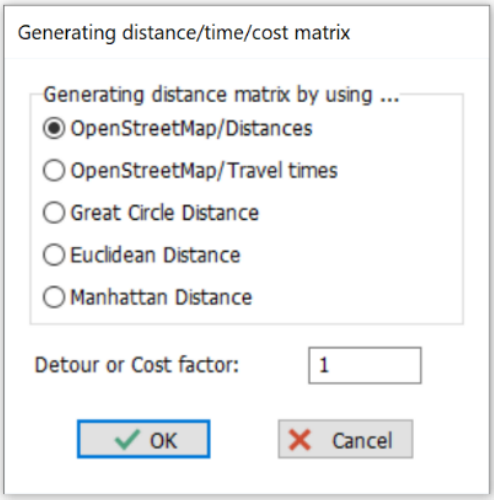

Figure 5: Dialogue for generating a distance/time/cost matrix in LogisticsLab/TSP

- *Start Optimisation*
  Open an optimisation dialogue. After entering certain specifications, the optimisation run is started.

Print

- The results are displayed in the data area can be printed.
- The printable results are also displayed in the *Print* menu and can be started by selecting the appropriate option.

The most important functions of the menu bar can also be reached via the toolbar (Figure 6).

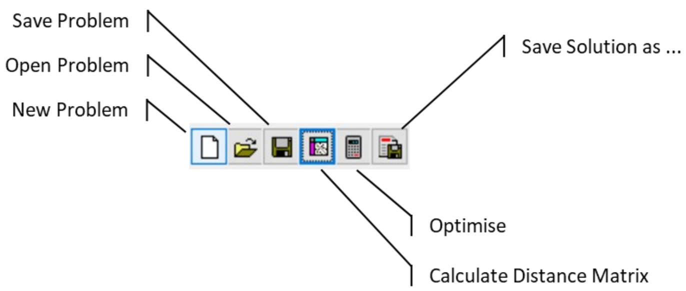

Figure 6: Toolbar in LogisticsLab/VRP

2.3 OpenStreetMap functions

As of version 5, LogisticsLab uses several functionalities of OpenStreetMap to support visualisation and data generation for realistic logistical decision-making problems.

Integration of OpenStreetMap maps

The *OpenStreetMap Foundation* (OSMF) provides map data, e.g. for websites and applications, in accordance with the Open Data Commons Open Database Licence (ODbL)[1]. The maps may be used for any pur-

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[1] OpenstreetMap.org: OpenStreetMap, https://www.openstreetmap.org, as of July 2024.

pose and may be modified and distributed under the same licence. There is a very large community that is constantly improving and expanding the map data. The use of the maps does not require any registration or other collection of user data and is free of charge.

As shown in Figure 7, OpenStreetMap maps are integrated into the network area of the Logistics Lab interface and can be zoomed in and out and rotated. The map is primarily used to visualise the network nodes of a problem. Depending on the type of node, LogisticsLab adds problem-specific markers to these maps. The left-hand map shows a transport problem with blue boxes for providers and red pins for customers. The right-hand map shows a transhipment problem with supply nodes visualised by blue pins, transhipment nodes with pins in ochre and demand nodes with red pins.

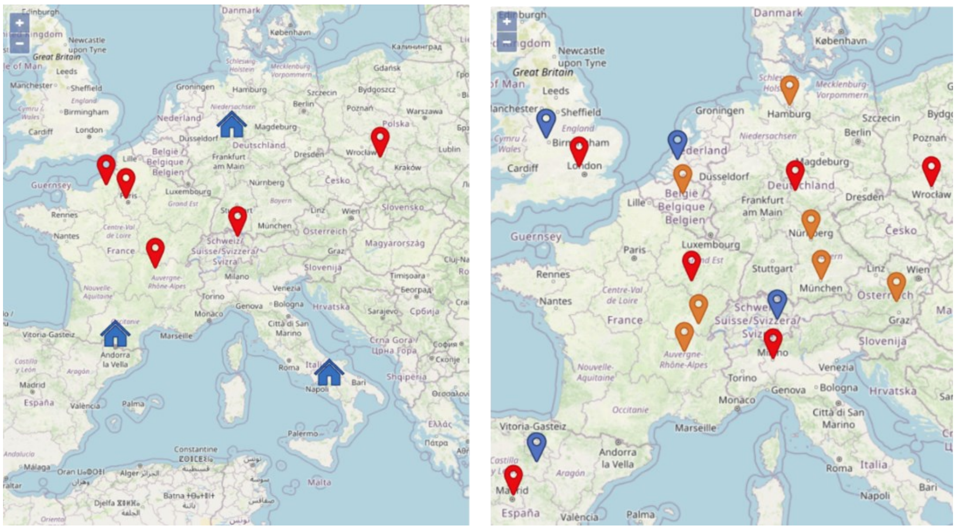

Figure 7: Marker for nodes in LogisticsLab

If a user moves the mouse over a marker, a pop-up window appears with additional information, as shown in Figure 8 for the depot of a route planning problem.

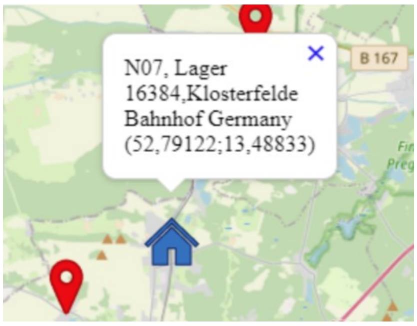

Figure 8: Marker with pop-up

In addition, the maps in LogisticsLab are used to visualise the solutions found by displaying the routes on real roads, which can also be found using OpenStreetMap functionalities, on the map using blue connections. Individual routes or sections can be highlighted with the colour ochre. Figure 9 shows part of the solution for a transhipment problem in LogisticsLab/NWF, where the route between a plant in Soria, Spain and a transhipment hub in Frebuans, Frank has been highlighted.

Figure 9: Illustration of a solution in LogisticsLab/NWF

Integration of geocoding functionalities from Photoon or Nominatim

The collection and input of data from the network nodes is sometimes very time-consuming. The focus here is on the geographical coordinates, which are required on the one hand for display on a map and on the other for determining distances and, if necessary, travelling times between the individual nodes.

A geocoder can be used to determine the geographical coordinates of the node under consideration using an address or an address fragment. LogisticsLab uses the open-source geocoder Photon[2], which works with OpenStreetMap data and can be accessed via a web-based API (Application Programming Interface). As access to the original Photon server can be limited if it is used extensively, a separate Photon server was set up for LogisticsLab, which is hosted by the Technical University of Applied Sciences Wildau. It is also possible to use a Nominatim[3] server.

In LogisticsLab, a Geocoder can be used in two different ways. One option is to enter the addresses or parts of the addresses of the nodes in the corresponding columns of a node list and then determine the geographical coordinates via the Photon server. Figure 10 shows an example of a route planning problem in LogisticsLab/VRP. In the data area of this module, two customers and their addresses have been entered in the *Nodes* tab. The latitude and longitude of all nodes can then be called up via the *All coords* button or for the selected node via *Node coords*.

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[2] Photon, https://photon.komoot.io, as of February 2025.

[3] Nominatim, https://nominatim.org/, as of February 2025.

Nr.	ID	Name	Lat	Long	City	PostCode	Street
1	N01	K1			Schönwalde	16384	Hauptstr. 63b
2	N02	K2			Basdorf	16384	Fuchsienstr. 7

Add | Search & Add | Delete | All Coords | Node Coords | Print

Figure 10: Node list before determining the coordinates in LogisticsLab/VRP

Once the coordinates have been successfully retrieved, they are automatically entered in the node list (Figure 11) and the nodes are displayed on the map using the coordinates.

Nr.	ID	Name	Lat	Long	City	PostCode	Street
1	N01	K1	52,68601	13,44322	Schönwalde	16384	Hauptstr. 63b
2	N02	K2	52,71357	13,44019	Basdorf	16384	Fuchsienstr. 7

Figure 11: Node list after determining the coordinates in LogisticsLab/VRP

It is also possible to use the *Search & Add* button available in all parts of the programme for nodes to search for a complete address and the associated geographical coordinates with an address fragment and add it to the node list as a new node. For example, as shown in Figure 12 you can search for the entry for the Jagdschloss in Groß Schönebeck in the state of Brandenburg. The address and the corresponding coordinates are then added to the node list (see Figure 13).

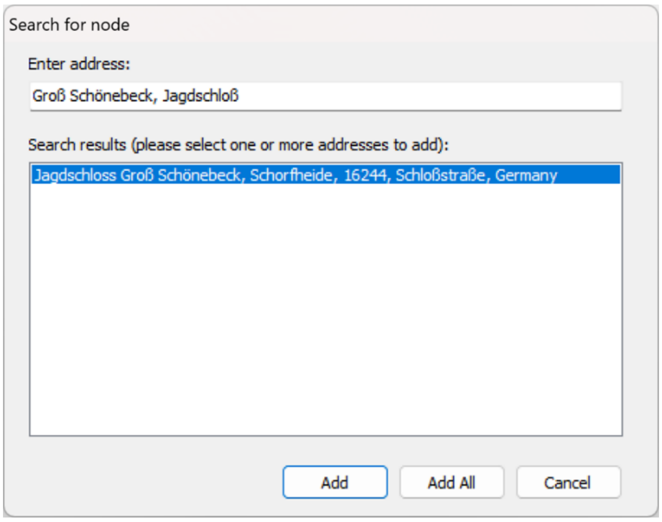


Figure 12: Address search in LogisticsLab

Nr.	ID	Name	Lat	Long	City	PostCode	Street
1	N01	K1	52,68601	13,44322	Schönwalde	16384	Hauptstr. 63b
2	N02	K2	52,71357	13,44019	Basdorf	16384	Fuchsienstr. 7
3	N03	Jagdschloss Groß Schönebecl	52,90501	13,53151	Schorfheide	16244	Schloßstraße

Figure 13: Added node after address search

Determining distances, travel times and routes with Openrouteservice or OSRM

To solve a logistical decision problem, it is necessary to determine the weights of the edges connecting the individual nodes. For tasks with real addresses and roads, the distances and journey times can be retrieved in LogisticsLab via Openrouteservice (ORS). In addition, ORS is used after an optimisation has been completed to retrieve the routes on real roads for the solution and ultimately display them on a map. ORS is an open-source project that uses OpenStreetMap data and can be accessed via a web-based API[4].

LogisticsLab uses ORS *functionalities* to determine the distance and travel time matrices. There are several freely available servers for ORS, whose access can be restricted in the same way as Photon if used extensively. Therefore, a separate ORS server was set up for LogisticsLab, which is hosted by the Technical University of Applied Sciences Wildau. It is also possible to use an Open Source Routing Machine (OSRM)[5] server.

If all nodes are available in LogisticsLab with their geographical coordinates, the dialogue for determining the distance or travel time matrix or, if applicable, the cost matrix based on this, can be opened as shown in 10 for LogisticsLab/VRP as an example. The generated matrices are then automatically inserted in the corresponding data areas (Figure 15).

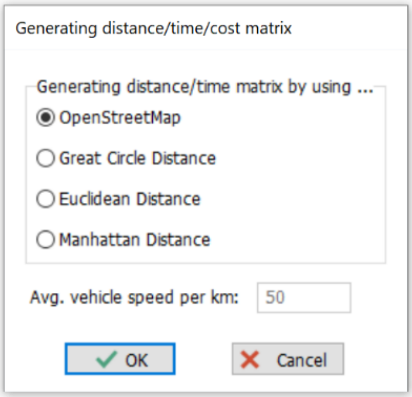
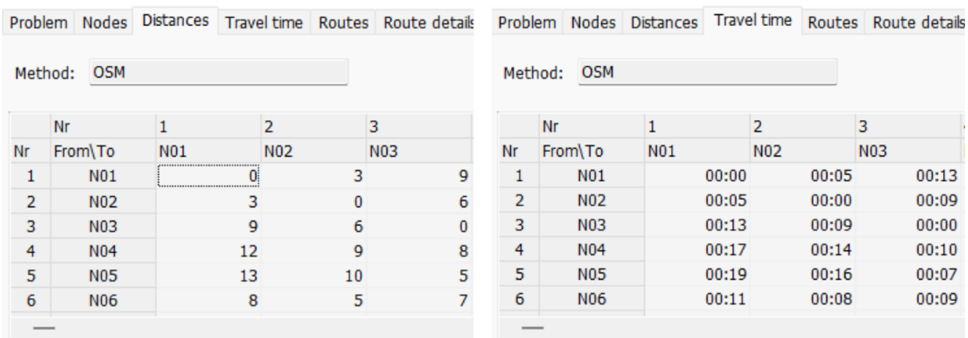


Figure 14: Dialogue for determining distances and travel times in LogisticsLab/VRP



Nr	From\To	1 N01	2 N02	3 N03
1	N01	0	3	9
2	N02	3	0	6
3	N03	9	6	0
4	N04	12	9	8
5	N05	13	10	5
6	N06	8	5	7

Nr	From\To	1 N01	2 N02	3 N03
1	N01	00:00	00:05	00:13
2	N02	00:05	00:00	00:09
3	N03	00:13	00:09	00:00
4	N04	00:17	00:14	00:10
5	N05	00:19	00:16	00:07
6	N06	00:11	00:08	00:09

Figure 15: Distances and travel times in LogisticsLab/VRP

Once all the data for a problem is available, including the distance or travel time or a cost matrix based on this, the problem can be solved. To display the solution adequately on the map, LogisticsLab automatically calls up the *route* functionality of the OSRM server involved to retrieve the routes on the real roads. These are then displayed as shown in Figure 9 on the map and can be highlighted if necessary.

Entering nodes and edges by double-clicking on the map

As of version 5.3 it is possible to enter nodes in all LogisticsLab modules and edges in LogisticsLab/NWF and LogisticsLab/TSP by just double-clicking on the map.

[4] Openrouteservice: https://openrouteservice.org/, as of February 2025

[5] Open Source Routing Machine: OSRM API-Documentation, http://project-osrm.org, as of February 2025.

Nodes can be created by double-clicking when the corresponding tab is open in the data area. As can be seen in Figure 16, after double-clicking, LogisticsLab asks whether a node should be created at this location. If the answer is yes, LogisticsLab determines the geographical coordinates and, if possible, the address of the node using the integrated OpenStreetMap functions. This data is automatically entered in the corresponding columns for the new node.

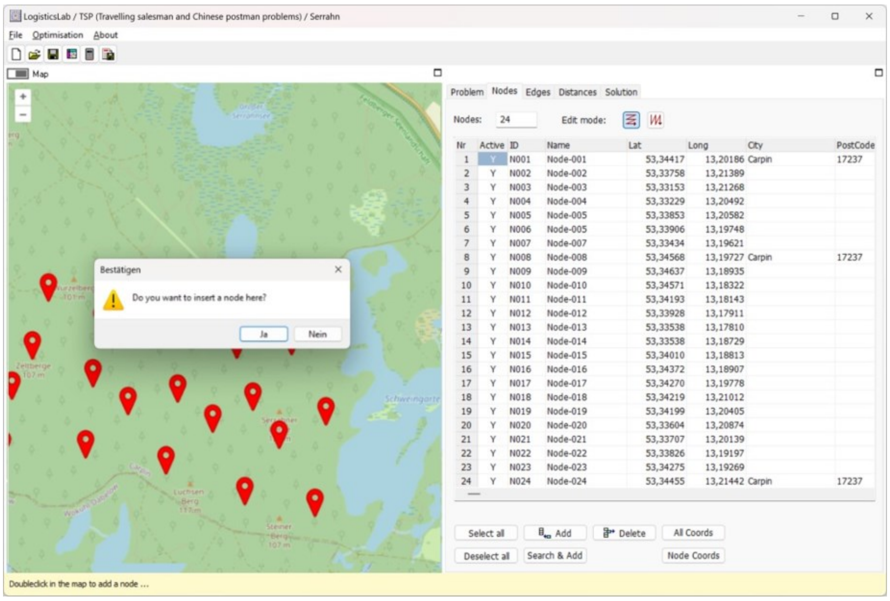


Figure 17: Entering nodes

In LogisticsLab/NWF and LogisticsLab/TSP, when the edge editor is open, an edge can be created directly by double-clicking on the start and destination nodes one after the other on the map, whereby a dialogue appears in which the type of edge can be selected (Figure 17).

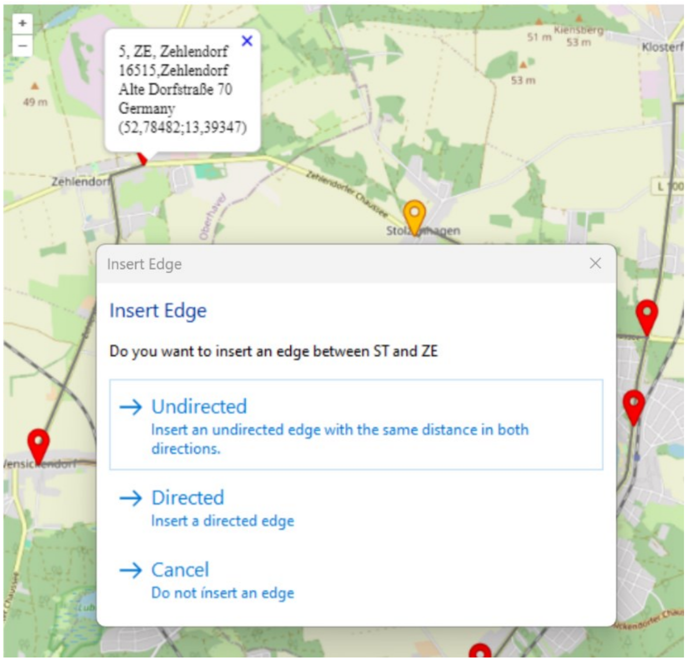


Figure 16: Creating an edge in the LogisticsLab/TSP map

For the edges created, the real road courses are retrieved using OpenStreetMap and displayed in grey on the map (Figure 18).

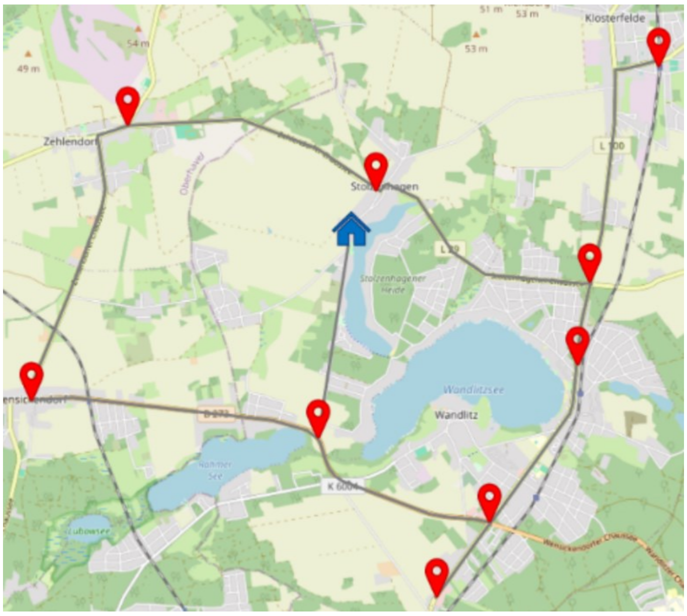


Figure 18: Visualisation of edges in LogisticsLab/TSP

Using OpenStreepMap functionalities with a proxy server

If a proxy server is used, then three corresponding entries have to be entered in the *LogisticsLab.yml* file which is located in the root directory of LogisticsLab. The following example shows the entries for the proxy server of the University of Applied Sciences Wildau. Please use your own proxy entries.

```
proxies:
  http: http://proxy.th-wildau.de:8080
  https: http://proxy.th-wildau.de:8080
```

If no proxy server is used, then these entries must be empty as follows:

```
#proxies:
#  http: http://proxy.th-wildau.de:8080
#  https: http://proxy.th-wildau.de:8080
```

It is strongly recommended to leave all other entries as they are.

2.4 File formats

Problem and solution files

The data of the programs are stored and loaded in text files with a particular format. To distinguish the data for the different programs, the files are given the program abbreviation as file extensions, i.e.: TPPX, NWFX, TSPX, VRPX, DLPX and CLPX.

The following principles apply to data files in text format:

- The records are defined line by line as ASCII text.
- The data fields are separated with a tabulator.
- Each file begins with the particular keyword for the program for identification. This keyword can be followed by information on the date and time on the same line.
- The first line is followed by a comment line, which can be freely described or left blank.

- A section for options begins with the keyword OPTIONS, which is followed by the corresponding options in the following lines.
- The data is divided into data blocks. Each data block begins with a line in which the corresponding keyword (e.g. SOURCES, DESTINATIONS) for the respective data must appear. In most cases, the size specifications for the data block (e.g. number of rows and columns) follow in a subsequent line. The following lines contain the corresponding data.
- The notation of numeric fields follows according to the local language of the computer and is recognized automatically.
- The end of file is expressed with the keyword *EEE* in a last data line.

The data files can be created via the menu function *Save Problem* or *Save Problem as.* The results can also be saved as text files. They are named with the file name of the original problem and the file extension *SOLX*. Further use of the results in texts, tables and presentations is easily possible due to the text format of the solution file.

Excel files for import and export of nodes and edges

In addition to the problem files, LogisticsLab offers the opportunity to export and import nodes and edges to and from Excel[6] for a data exchange between the different LogisticsLab modules. It is also possible to create such a file in LogisticsLab, edit the data in Excel and import it into LogisticsLab. These Excel files have a defined structure that is generated by LogisticsLab during the export of a problem. An example of vehicle routing problem data is shown in Figure 19.

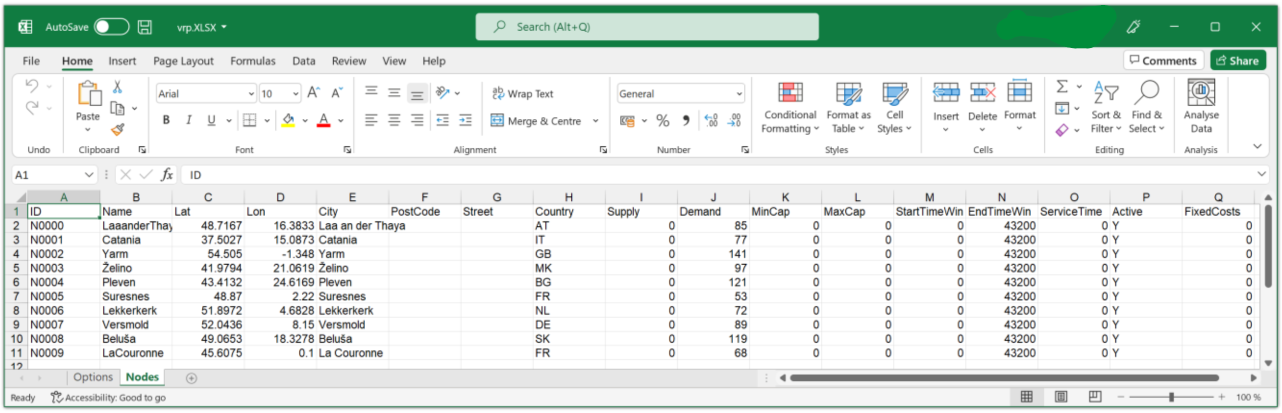


Figure 19: Example of an Excel file with LogisticsLab data

3 TPP – Solving Transport Problems

LogisticsLab/TPP is a software that can be used to solve single-stage classical transport problems and bottleneck transport problems in different variants (capacitated, non-capacitated, single-source, with supply or demand surplus, etc.)[7].

3.1 Program interface

After starting the program, the program window shown in Figure 20 appears, which is divided into four areas:

1. At the top is the menu bar and toolbar for general functions.
2. The left half of the window is used for the map view of the problem.

[6] https://www.microsoft.com/en-us/microsoft-365/excel

[7] Steglich et al. (2016), p. 74, Hillier and Liebermann (2015), p. 319ff., Williams (2013), p. 82ff., Vanderbei (2014), p. 225ff.

3. The right half of the window contains the data area for editing the problem data.
4. There is a status bar at the bottom of the window.

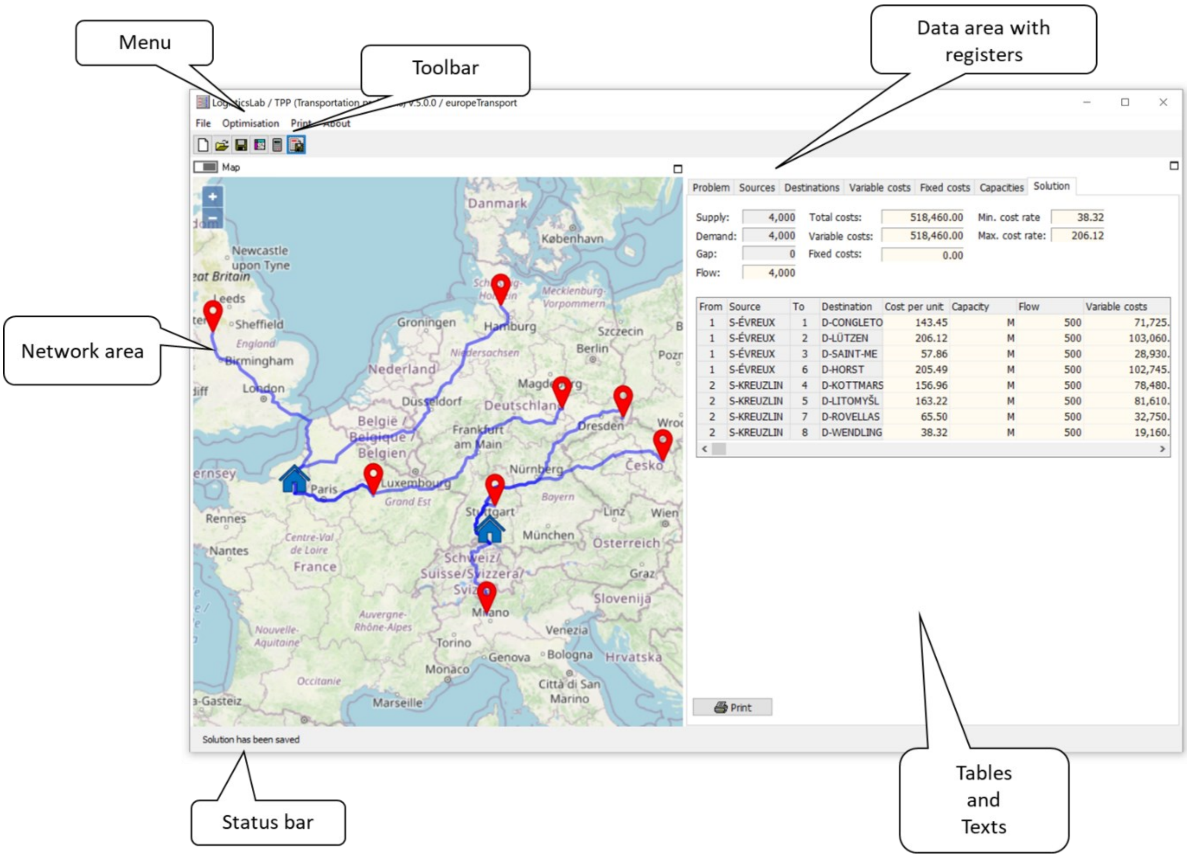


Figure 20: Program interface - LogisticsLab/TPP

The map is used to visualise the data entered and a solution found. The map contains two different types of nodes: *source nodes* (blue) and *destination nodes* (red).

3.2 Entering the problem data

LogisticsLab/TPP is used to solve transport problems, whereby a new problem must be generated in a first step. The menu item *File → New Problem* or the *New Problem* button in the toolbar can be used for this.

The problem data are generated according to the specifications of the data generator (Figure 21). The following specifications can be entered:

- Problem comment,
- Number of sources and destinations,
- Average quantity offered by a source
- average quantity required by a destination,
- average step-fixed cost on an edge between a source and a destination,
- average capacity on an edge between a source and a destination.

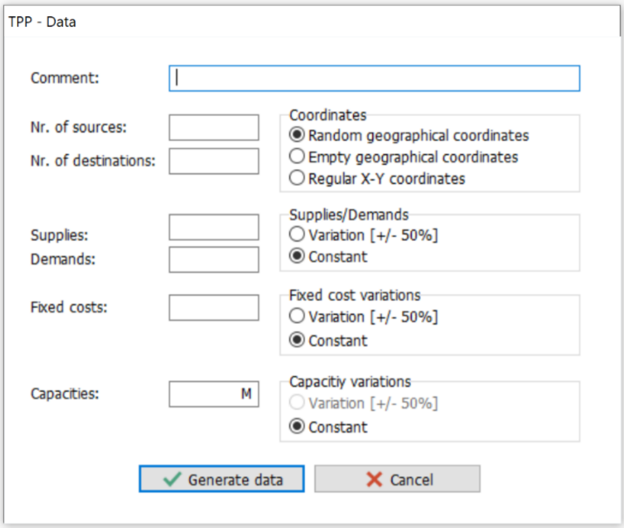


Figure 21: Creating a problem in LogisticsLab/TPP

The data on quantities, costs and capacities can be varied randomly in an interval of [-50 %, +50 %] or left as constant values. If a field has not been edited, the corresponding data fields will not be filled.

Furthermore, one can specify whether the coordinates of the nodes are random or empty geographical coordinates or regular X-Y coordinates. If the geographical coordinates are generated on a randomly, a set of European cities and villages by are used. In the case of a regular (ordered) X-Y generation, SimpleMap is displayed with the sources appear on the left and the destinations on the right.

The generated data can then be changed manually in the data area.

The data area on the right side of the program window contains five tabs for entering and maintaining the problem data (*Problem*, *Sources*, *Destinations*, *Variable costs*, *Fixed costs* and *Capacities*) and a *Solution* tab for the solution.

The ***Problem*** tab (Figure 22) contains only one input field for a short comment. This sheet contains additionally information on the problem data (fields with a grey background) and on the solution of the problem (fields with a yellow background).

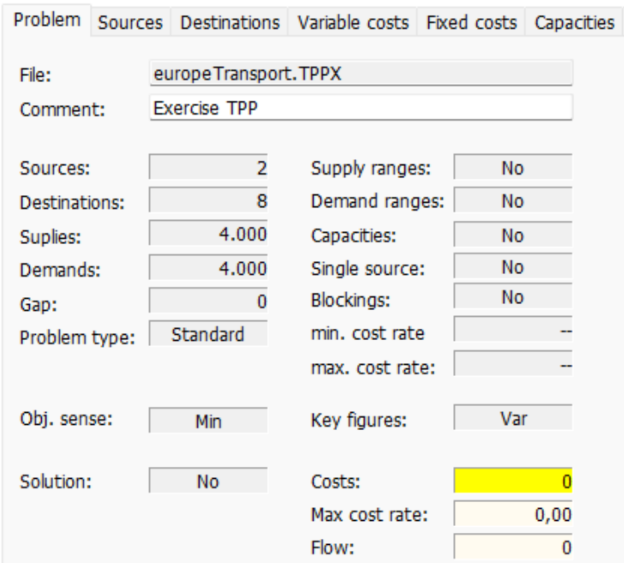


Figure 22: Problem tab in LogisticsLab/TPP

In the tabs ***Sources*** (Figure 23) and ***Destinations*** (Figure 24) all information on the nodes (sources or destinations) is entered. One can either enter the number of nodes first or insert each node individually with the *Add* button.

When creating a new node, default values are entered for the supply (default: 0), lower supply limit (default: 0) and upper supply limit (default: M).

Each node (source or destination) is described by a unique name, a geographical coordinate (or if SimpleMap is chosen, an X and Y coordinate), a quantity (*Supply*, *Demand*), a minimum and maximum quantity (*min. Supply*, *min. Demand* or max. *Supply, max. Demand*). The *Flow* column represents the supply quantities found by the optimisation and the *Gap* column represents the difference between the supply or demand and the supply quantity.

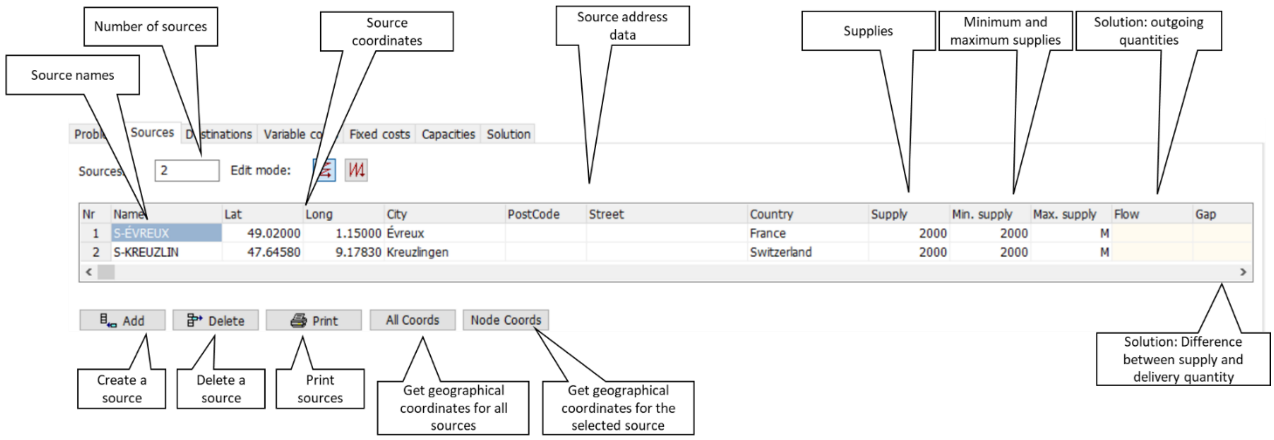


Figure 23: Sources tab in LogisticsLab/TPP

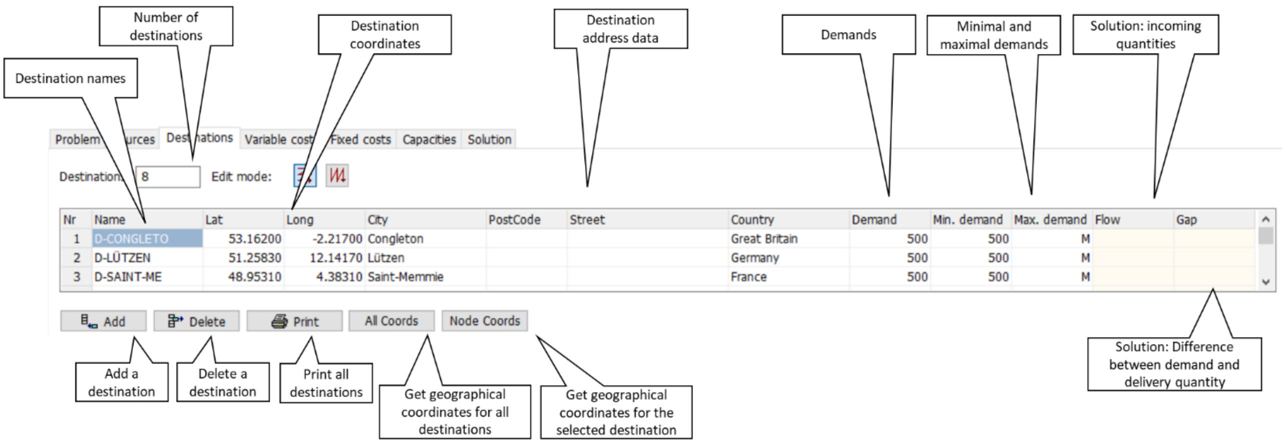


Figure 24: Destinations tab in LogisticsLab/TPP

If a user has entered valid address data, it is possible to retrieve the geographical coordinates of all nodes (*All coords*) or of the selected node (*Node coords*) via a Komoot/Photon server.

The *Delete* button deletes the currently selected node. The entire node list can be printed with the *Print* button.

It is assumed, that the **variable costs** between the source and the destination are proportional to the distances. They can be calculated using different distance functions. This is done by pressing the *Calculate* button in the *Variable costs* tab or the *Calculate Variable Costs* button in the toolbar and the dialogue shown in Figure 25 appears. This calculation can base on distances or travel times provided by OpenStreetMap or on aerial distances (Great Circle, Euclidean or Manhattan distances). To generate the matrix, enter a distance or cost factor in the field *Distance/costs factor per km*. This is multiplied by the distance or travel time.

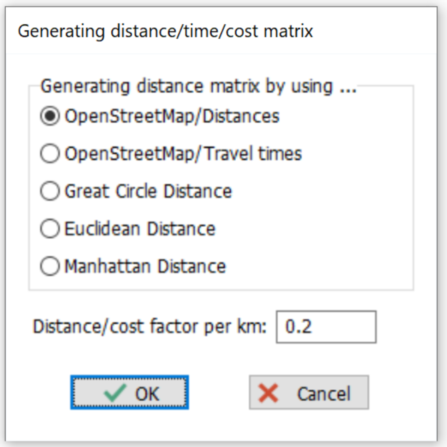
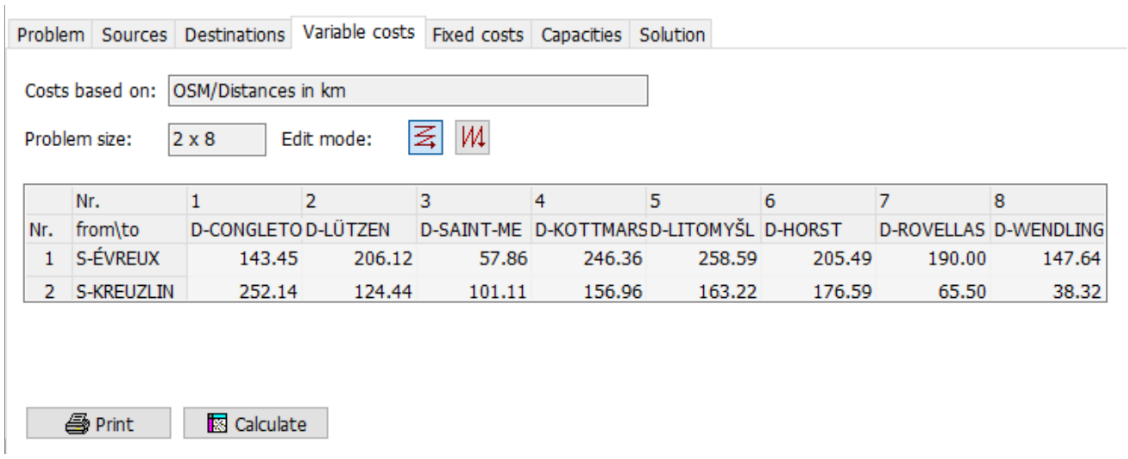


Figure 25: Calculation of variable costs in LogisticsLab/TPP

The result of this calculation is shown in the ***Variable costs*** tab (Figure 26). The values cannot be changed.

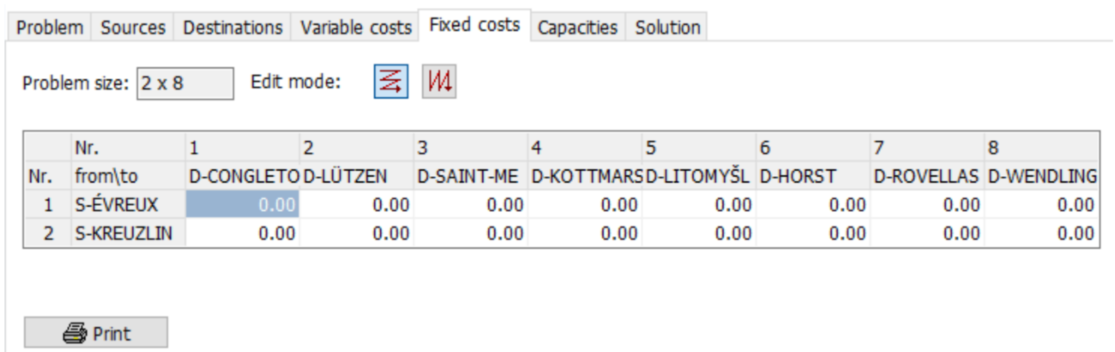


	Nr.	1	2	3	4	5	6	7	8
Nr.	from\to	D-CONGLETO	D-LÜTZEN	D-SAINT-ME	D-KOTTMARS	D-LITOMYŠL	D-HORST	D-ROVELLAS	D-WENDLING
1	S-ÉVREUX	143.45	206.12	57.86	246.36	258.59	205.49	190.00	147.64
2	S-KREUZLIN	252.14	124.44	101.11	156.96	163.22	176.59	65.50	38.32

Figure 26: Variable costs tab in LogisticsLab/TPP

In the ***Fixed costs*** tab (Figure 27), the step-fixed costs can be entered for each edge.

In the ***Capacities*** tab (Figure 28), a capacity can be assigned to each sender-receiver relation. If the capacity is not to be limited, an *M* (for not limited) is entered. By setting a capacity equal to zero, a transport between source and destination can be blocked if *Additional Constraints/Capacities* (Figure 29) is activated in the optimisation dialogue.



	Nr.	1	2	3	4	5	6	7	8
Nr.	from\to	D-CONGLETO	D-LÜTZEN	D-SAINT-ME	D-KOTTMARS	D-LITOMYŠL	D-HORST	D-ROVELLAS	D-WENDLING
1	S-ÉVREUX	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	S-KREUZLIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 27: Fixed costs tab in LogisticsLab/TPP

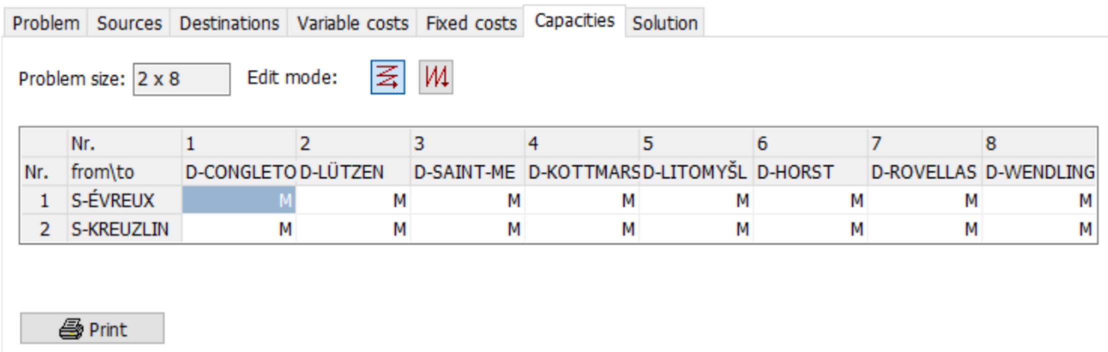


Figure 28: Capacities tab in LogisticsLab/TPP

After entering the data, it should be saved with the menu item *Save Problem* or *Save Problem as.*

3.3 Optimisation and results

If all data is available for a transportation problem, the problem can be solved by selecting either the *Optimisation → Start Optimisation* menu or the *Optimise* button in the toolbar and the dialogue shown in Figure 29 appears.

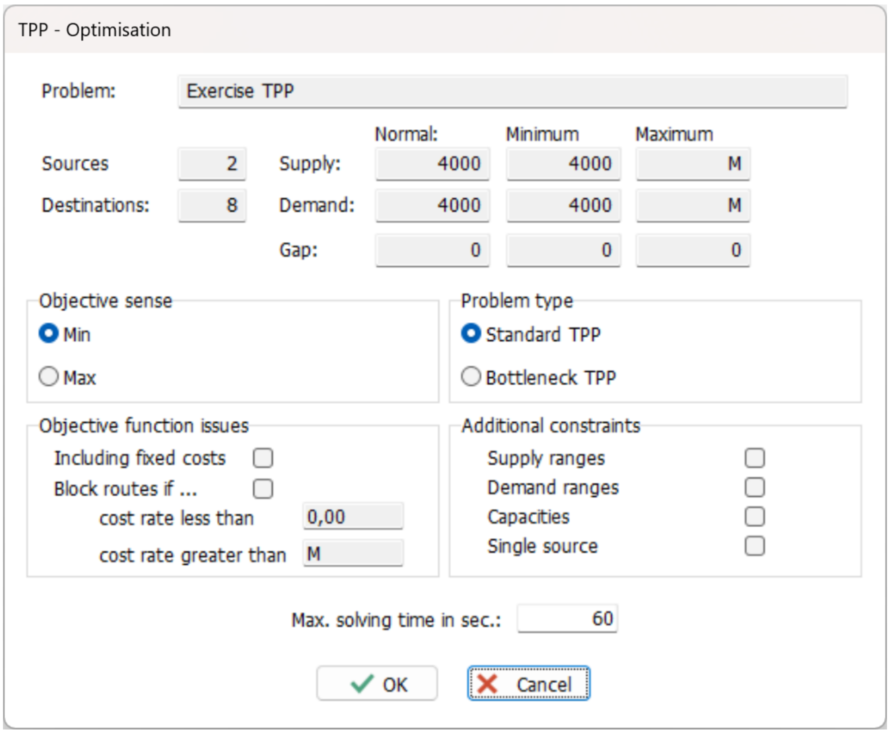


Figure 29: Optimisation dialogue in LogisticsLab/TPP

In this dialogue, various settings can be selected for optimisation:

- *Objective sense:*
  - *Min, Max* - minimisation or maximisation for classic transportation problem
  - *MiniMax* - for bottleneck problems
- *Problem type*:
  - *Standard TPP* - corresponds to the classic transportation problem
  - *Bottleneck-TPP* - Bottleneck transport problem
- *Objective function issues* - additional conditions in the objective function:
  - *Including fixed costs* - The step-fixed costs are included in the objective function in addition to the variable costs.

  - Block *routes if...* - When selected, only those assignments are used whose cost rates lie between the minimum and maximum values specified here.
- *Additional constraints*:
  - Supply *ranges* - comply with supply ranges (two-sided restriction)
  - *Demand ranges* - comply with demand ranges (two-sided restriction)
  - *Capacities* - takes capacities into account
  - *Single source* - Additional condition that a destination can only be supplied by one source.

After solving the transport problem, the best solution found appears as a network graphic in the network area and the numerical solution in the *Solution* tab (Figure 30).

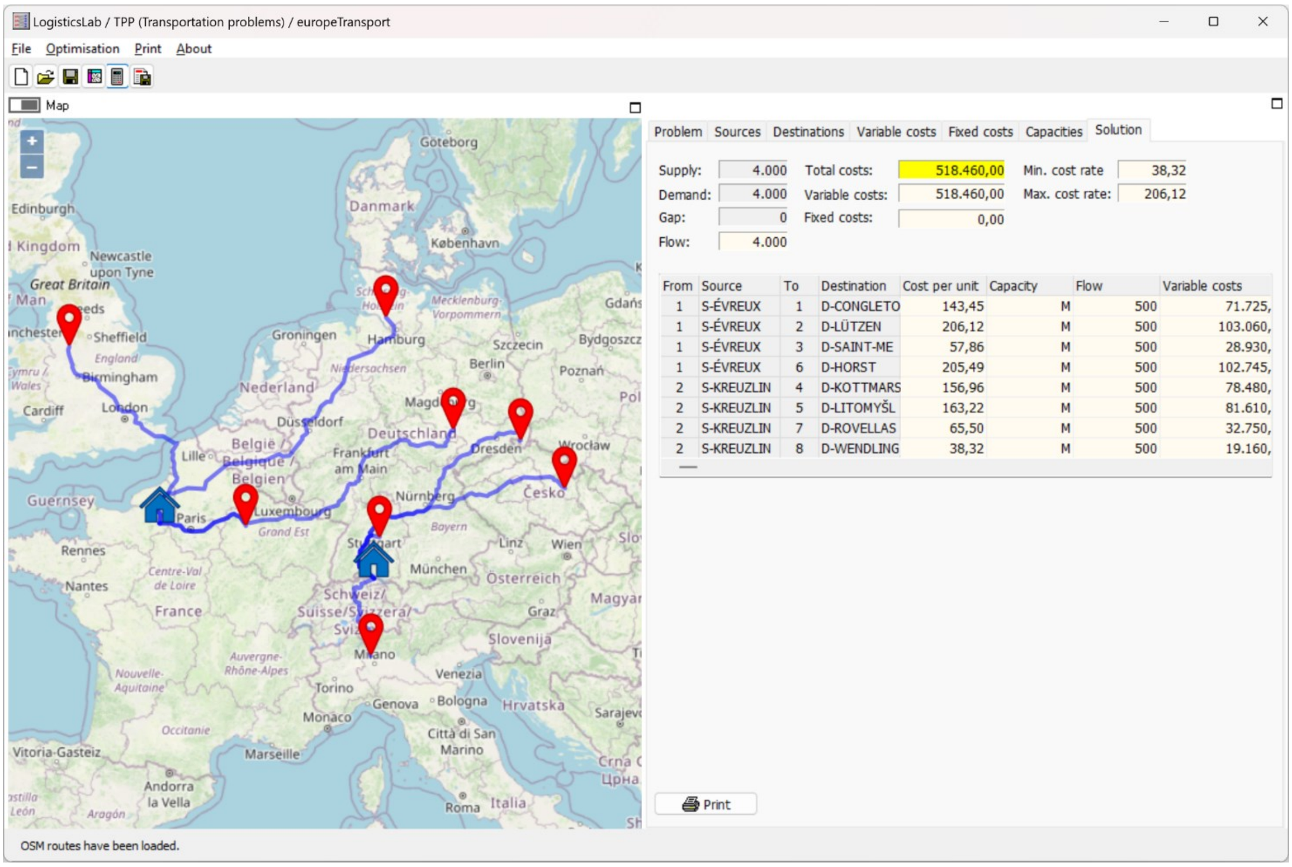


Figure 30: Representation of the solution in LogisticsLab/TPP

A single part of the solution can be highlighted by clicking in one of the first four, grey-coloured columns.

LogisticsLab uses heuristics to solve problems. Therefore, the solutions of different optimisation runs may differ due to the non-deterministic nature of the underlying heuristic.

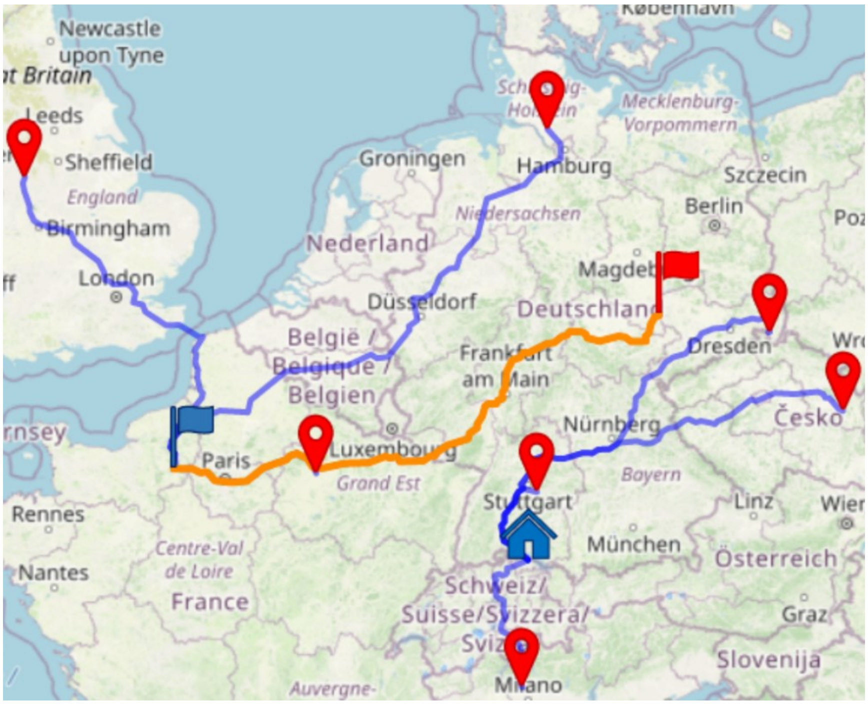


Figure 31: Highlighted part of the solution

The solution can be saved as a text file with the extension *SOLX* and used with other programs. Figure 32 shows the solution matrix of an example as an Excel worksheet.

	A	B	C	D	E	F	G	H	I
1	TPP 5.0.0 SOLUTION		24/06/2022	11:57:31					
2	Exercise TPP								
3	Sources:	2							
4	Destinations:	8							
5	Supply:	4000							
6	Demand:	4000							
7	Gap:	0							
8	Type:	Standard							
9	Objective:	MIN	VarCosts						
10	Status:	optimal							
11	TotalCosts:	518460.00							
12	MinMaxCostRate:	38.32	206.12						
13	TotalFlow:	4000							
14	FLOWS:								
15	From	Source	to	Destination	CostRate	Capacity	Flow	VariableCosts	FixedCosts
16	1	S-ÉVREUX	1	D-CONGLETO	143.45	M	500	71725.00	0
17	1	S-ÉVREUX	2	D-LÜTZEN	206.12	M	500	103060.00	0
18	1	S-ÉVREUX	3	D-SAINT-ME	57.86	M	500	28930.00	0
19	1	S-ÉVREUX	6	D-HORST	205.49	M	500	102745.00	0
20	2	S-KREUZLIN	4	D-KOTTMARS	156.96	M	500	78480.00	0
21	2	S-KREUZLIN	5	D-LITOMYŠL	163.22	M	500	81610.00	0
22	2	S-KREUZLIN	7	D-ROVELLAS	65.50	M	500	32750.00	0
23	2	S-KREUZLIN	8	D-WENDLING	38.32	M	500	19160.00	0
24	SOURCES:								
25	Nr	Source	Flow	Supply	MinSupply	MaxSupply			
26	1	S-ÉVREUX	2000	2000	2000	M			
27	2	S-KREUZLIN	2000	2000	2000	M			
28	DESTINATIONS:								
29	Nr	Destination	Flow	Demand	MinDemand	MaxDemand			
30	1	D-CONGLETO	500	500	500	M			
31	2	D-LÜTZEN	500	500	500	M			
32	3	D-SAINT-ME	500	500	500	M			
33	4	D-KOTTMARS	500	500	500	M			
34	5	D-LITOMYŠL	500	500	500	M			
35	6	D-HORST	500	500	500	M			
36	7	D-ROVELLAS	500	500	500	M			
37	8	D-WENDLING	500	500	500	M			

Figure 32: Representation of a LogisticsLab/TPP solution in Excel

4 NWF – Solving Network Flow Problems

LogisticsLab/NWF is intended for solving network flow problems, which can be modelled as *min-cost flow problems*[8].

4.1 Program interface

Like the TPP program, the NWF program interface is divided into four areas: menu and toolbar, network area, data area and status bar (Figure 33).

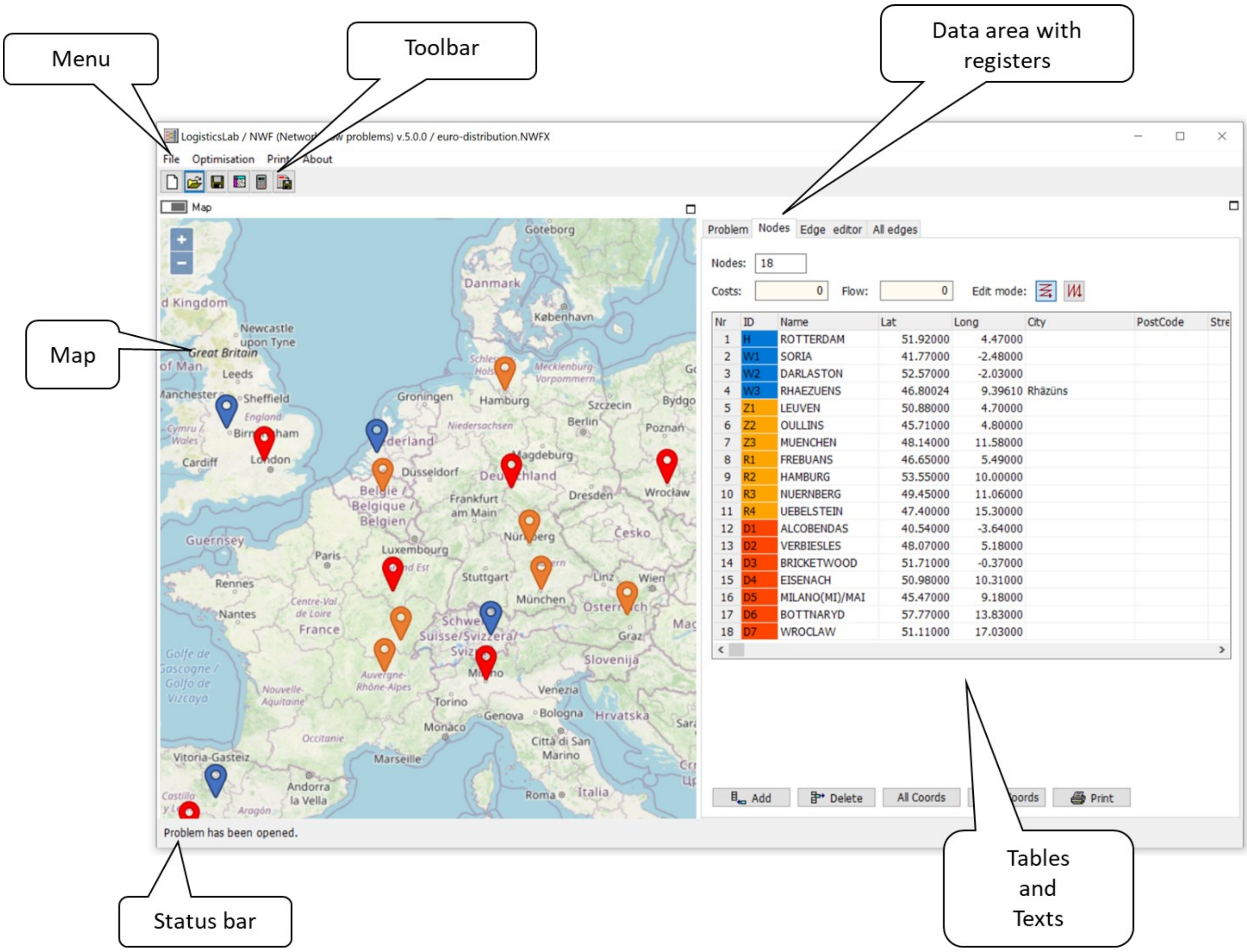


Figure 33: Program interface - LogisticsLab/NWF

On the left side of the NWF window there is a map on which the entered data is displayed as a network. As shown in Figure 33, the network graph contains three different types of nodes: sources (Blue), transhipment nodes (Ochre) and destinations (Red).

4.2 Entering the problem data

The data area on the right side of the NWF program interface contains four tabs for entering data and outputting the optimisation results (*Problem*, *Nodes*, *Edge editor* and *All edges*).

The first step is to generate a new problem. To do this, select the menu item *File* → *New Problem* or the *New Problem* button in the toolbar. In addition to a comment, the number of *nodes* must be entered (Figure 34). Geographical coordinates can be generated randomly based on a set of European cities and villages or as empty geographical coordinates. The generated coordinates can be edited afterwards.

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[8] Steglich et al. (2016), p. 164 ff., Hillier and Liebermann (2015), p. 397., Yildirim (2009), p. 4-3.

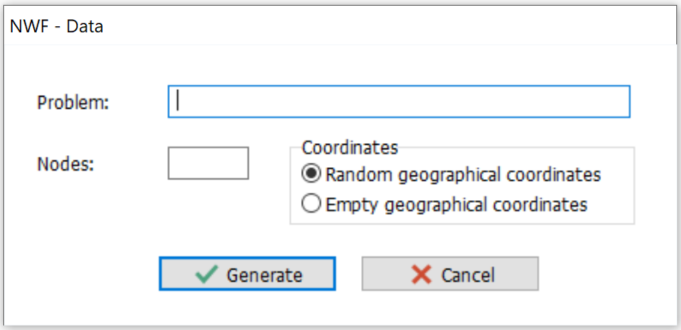

Figure 34: Creating a problem in LogisticsLab/NWF

The ***Problem*** tab (Figure 35) displays information on the current problem and contains an input field for entering a short comment. After an optimisation has been completed, the objective function value (*Costs*) and the total flow quantity (*Flow*) are displayed.

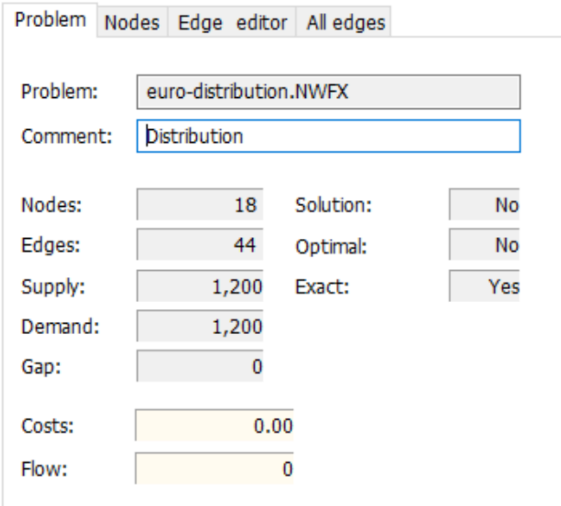

Figure 35: Problem tab in LogisticsLab/NWF

In the tab ***Nodes*** (Figure 36) all information about the nodes is entered. Either enter the number of nodes first or add each node individually with the *Add* button. The selected node can be deleted with the *Delete* button. The entire node list can be printed with the *Print* button. If a user has entered valid address data, it is possible to retrieve the geographical coordinates of all nodes (*All coords*) or of the selected node (*Node coords*) via a Komoot/Photon server.

Each node is described by a unique node identifier (*ID*), a node name (*Name*), geographical coordinates coordinate (or if SimpleMap is chosen, an X and Y coordinate), the supply or demand (*Volume*, only for sources or destination nodes) and lower and upper capacity bounds (*Min. Cap.* and *Max. Cap.*, only for transhipment nodes). It should be noted that LogisticsLab/NWF follows the notation of the flow balance condition of the *min-cost flow model*[9], so that supply nodes are indicated by positive values in the *Volume* column and the demands of the destinations with negative values in this column.

After the optimisation, the *flow* through the node and the costs for the outgoing transports are entered as results.

[9] Steglich et al. (2016), p. 164 ff., Hillier and Liebermann (2015), p. 397., Yildirim (2009), p. 4-3.

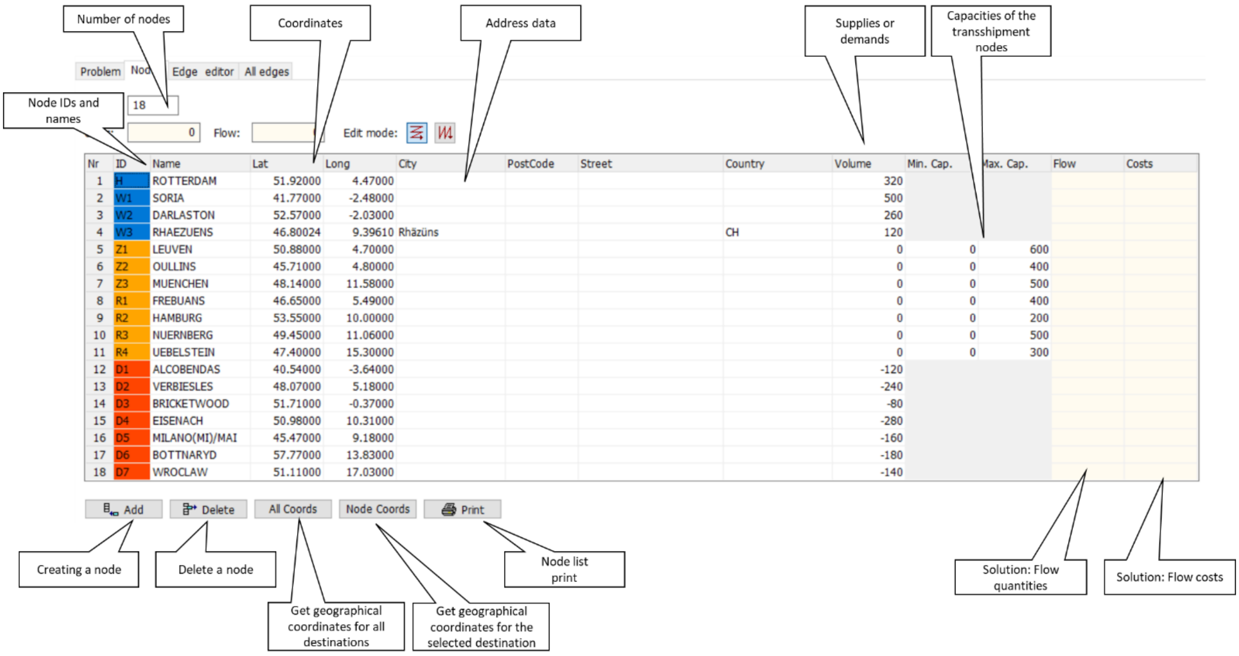

Figure 36: Nodes tab in LogisticsLab/NWF

In the ***Edge editor*** (Figure 37), directed edges can be assigned to a selected start node. In the edge editor the directed edges starting from a node (*From node*) are to be specified with the edge capacities (*Min. Cap.* and *Max. Cap.*). With the symbolic value *M* an edge is defined as not capacitively limited.

Additional edges can be added with the *Add* button. A marked edge is deleted with the *Delete* button.

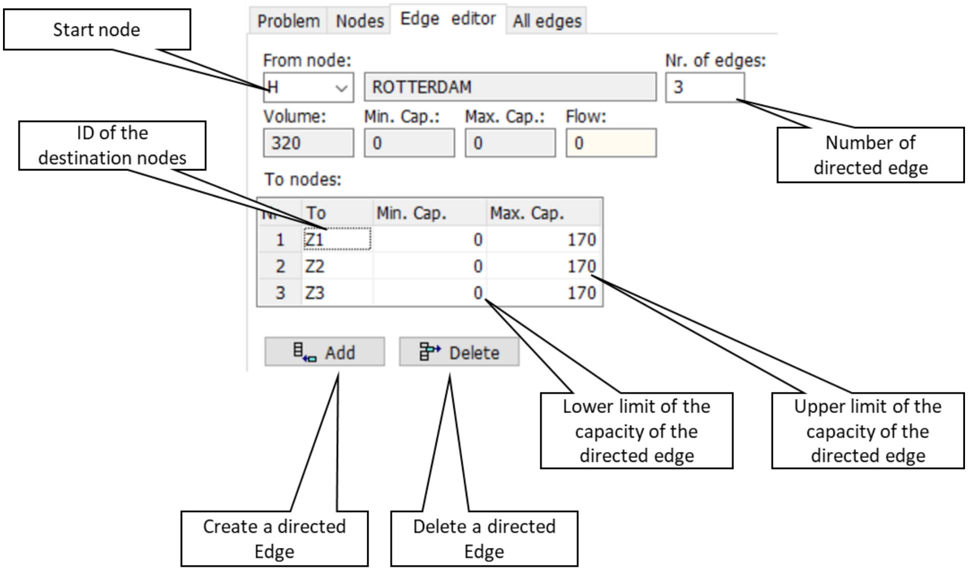

Figure 37: Edge editor in LogisticsLab/NWF

It is not possible to enter the costs per edge manually. They can only be calculated on the basis of distances or travel times and corresponding cost factors. A user can click the *Calculate Variable Costs* icon in the toolbar or via the menu *Optimisation → Calculate Variable Costs* and the dialogue shown in Figure 38 appears. This calculation can base on distances or travel times provided by OpenStreetMap or on aerial distances (Great Circle, Euclidean or Manhattan distances). To generate the matrix, enter a distance or cost factor in the field *Distance/costs factor per km*. This is multiplied by the distance or travel time.

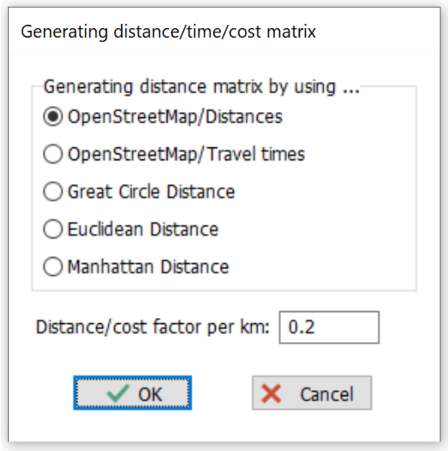

Figure 38: Calculation of variable costs in LogisticsLab/TPP

In the ***All edges*** tab (see Figure 39) all directed edges are listed in a table. In this list, the cost rates and the capacities of the individual directed edges are shown. After the optimisation is completed, the flows and the costs are displayed for the directed edges and as total values.

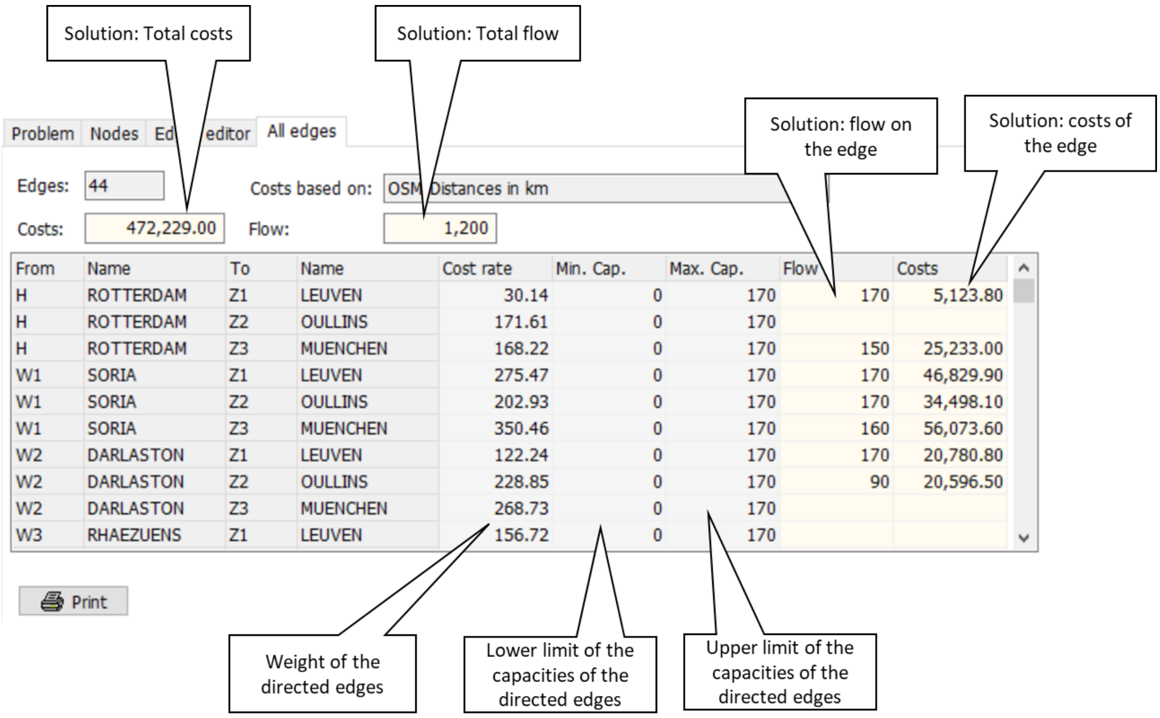

Figure 39: Tab All edges in LogisticsLab/NWF

After entering the data, it should be saved with the menu item *Save Problem* or *Save Problem as*.

4.3 Optimisation and results

The optimisation can be started by clicking the *Start Optimisation* icon in the toolbar or the menu *Optimisation → Start Optimisation.* Afterwards, a window appears informing the user about the progress of the optimisation and showing the characteristic values of the solution found (Figure 40).

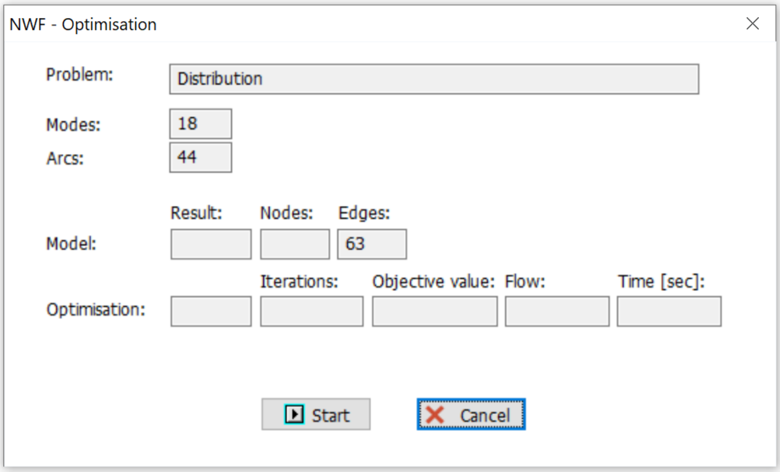

Figure 40: Optimisation dialogue in LogisticsLab/NWF

After clicking the OK button, the solution is entered in the tabs *Nodes* and *All edges* and displayed in the Network area (Figure 41). When a user clicks on one of the first four grey columns, a single part of the solution can be highlighted on the map.

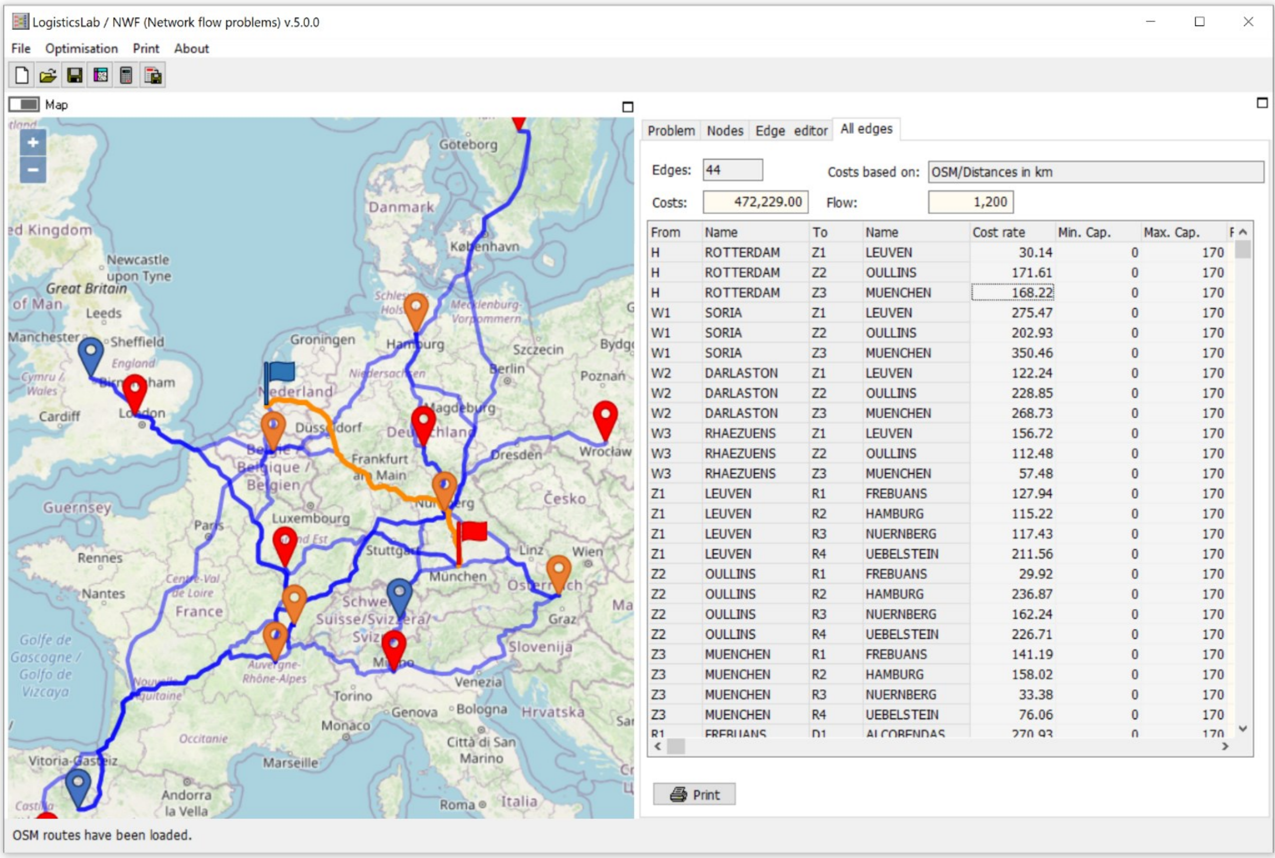

Figure 41: Representation of a solution in LogisticsLab/NWF

LogisticsLab uses heuristics to solve problems. Therefore, the solutions of different optimisation runs may differ due to the non-deterministic nature of the underlying heuristic. The solution can be saved in a text file with the extension *SOLX* and imported into other programs (e.g. Excel or LibreOffice/Calc[10]).

10 https://www.microsoft.com/en-us/microsoft-365/excel and https://www.libreoffice.org/, as of July 2024.

5 TSP – Solving Traveling Salesman Problems

The TSP program is used for solving Traveling Salesman Problems[11], Open Traveling Salesman Problems[12] and Chinese Postman Problems[13] for symmetrical and asymmetrical distances between the locations to be approached.

The Travelling Salesman Problem is characterised by a network with a certain number of nodes to be visited one after the other. Of the many possible sequences, the one that minimises a certain criterion (total distance, cost or traveling time) must be found. The following conditions apply:

- The tour starts and ends at a specific node.
- All nodes must be included in the round trip.
- Each node must be visited at least once.

There are additional problems in which all nodes must be visited, but the starting node and the destination node are different. Such problems are called and Open Traveling Salesman Problems and can be divided into the following four types:

1. Open TSP with fixed start and end node,
2. Open TSP with fixed start node and free end node,
3. Open TSP with fixed end node and free start node,
4. Open TSP with free start and end node.

5.1 Program interface

After starting the program, the program window shown in Figure 42 appears, which consists of a network area and a data area.

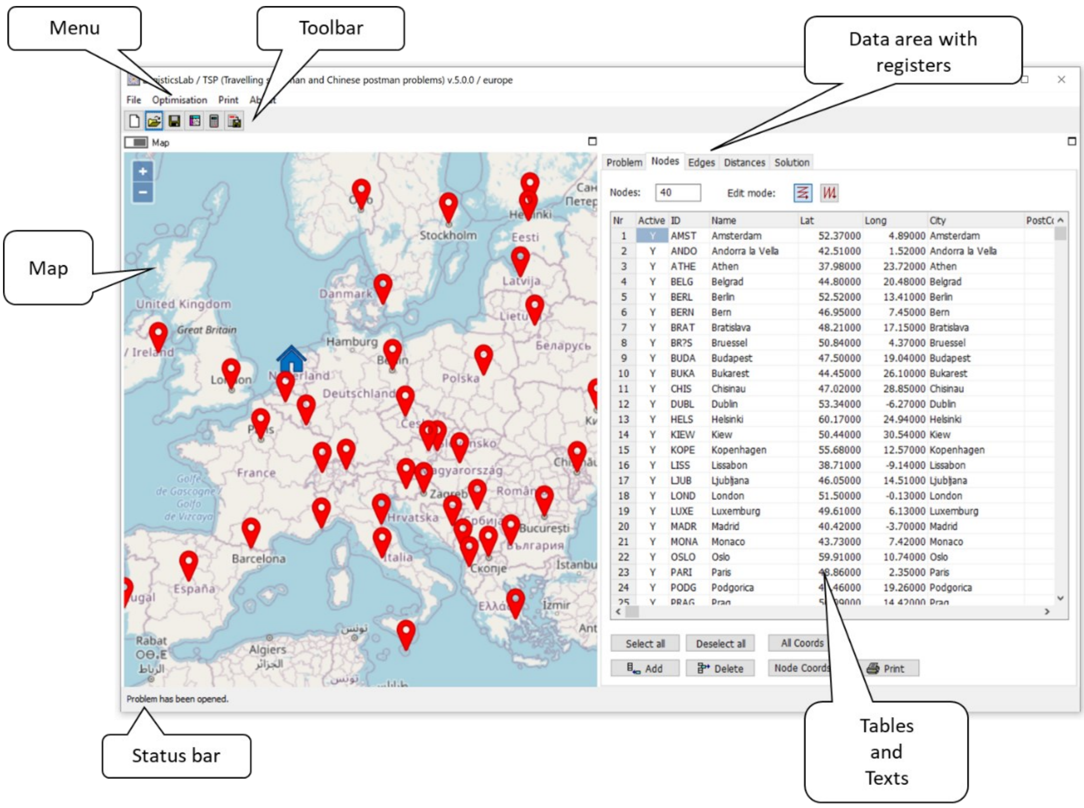

Figure 42: Program interface - LogisticsLab/TSP

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[11] Steglich et al. (2016), p. 281 f., Chen et al. (2010), p. 146 ff., Ghiani et al. (2013), p. 368 ff.

[12] Mattfeld and Vahrenkamp (2014), p. 234ff., Steglich et al. (2016), p. 281 f.

[13] Steglich et al. (2016), p. 321 ff., Ahuja et al. (2013), p.740.

The left side of the TSP window is used to visualise the entered data and the solution (Figure 42). The map graph contains two different types of nodes: the start and destination node (blue house) and the red-coloured other nodes. Nodes can be marked as active or inactive in the *Nodes* tab. Only active (red coloured) nodes can be included in a trip. Inactive nodes are shown in grey. If the network graph contains connections between the nodes, these are shown as edges in the *SimpleMap*.

5.2 Entering the problem data

The data area on the right-hand side of the TSP program interface contains five tabs for entering data and outputting optimisation results (*Problem*, *Nodes*, *Edges, Distances*, *Solution*).

The first step is to generate a new problem. To do this, select the menu item *File → New Problem* or the *New Problem* button in the toolbar. In addition to a comment, the number of *nodes* must be entered (Figure 43). Geographical coordinates can be generated randomly based on a set of European cities and villages or as empty geographical coordinates. The generated coordinates can be edited afterwards.

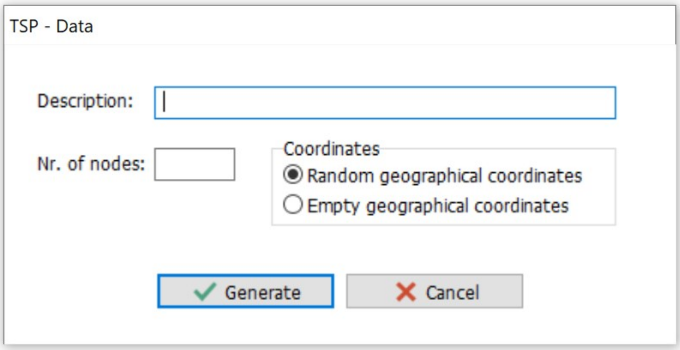


Figure 43: Creating a problem in LogisticsLab/TSP

The ***Problem*** tab (Figure 44) displays information about the current problem and contains an input field for a comment. After optimisation is complete, the *Trip length* field displays the objective function value.

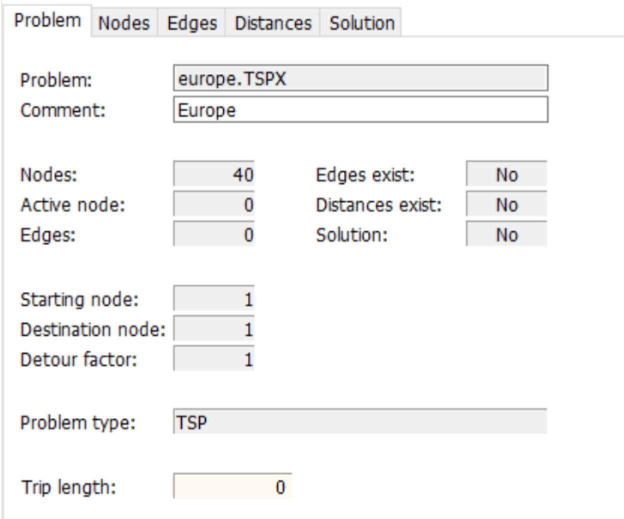


Figure 44: Problem tab in LogisticsLab/TSP

In the tab ***Nodes*** (Figure 45) all information about the nodes of the problem is entered.

One can either enter the number of nodes or add each node individually to the list with the *Add* button. The *Delete* button deletes the currently selected node.

The entire node list can be printed with the *Print* button. If a user has entered valid address data, it is possible to retrieve the geographical coordinates of all nodes (*All coords*) or of the selected node (*Node coords*) via a Komoot/Photon server.

Each node is described by a selection (*Active* - selection for a calculation), a unique node identifier (*ID*), a node name (*Name*), geographical coordinates coordinate (or if SimpleMap is chosen, an X and Y coordinate) and optional address data.

The *Active* field is used to specify the nodes to be included in the tour. With a double click in the column *Nr* of the corresponding node, a *Y* is entered in the field and the node is marked in colour on the network graphic. The entry of *N* or a blank removes the selection of a node.

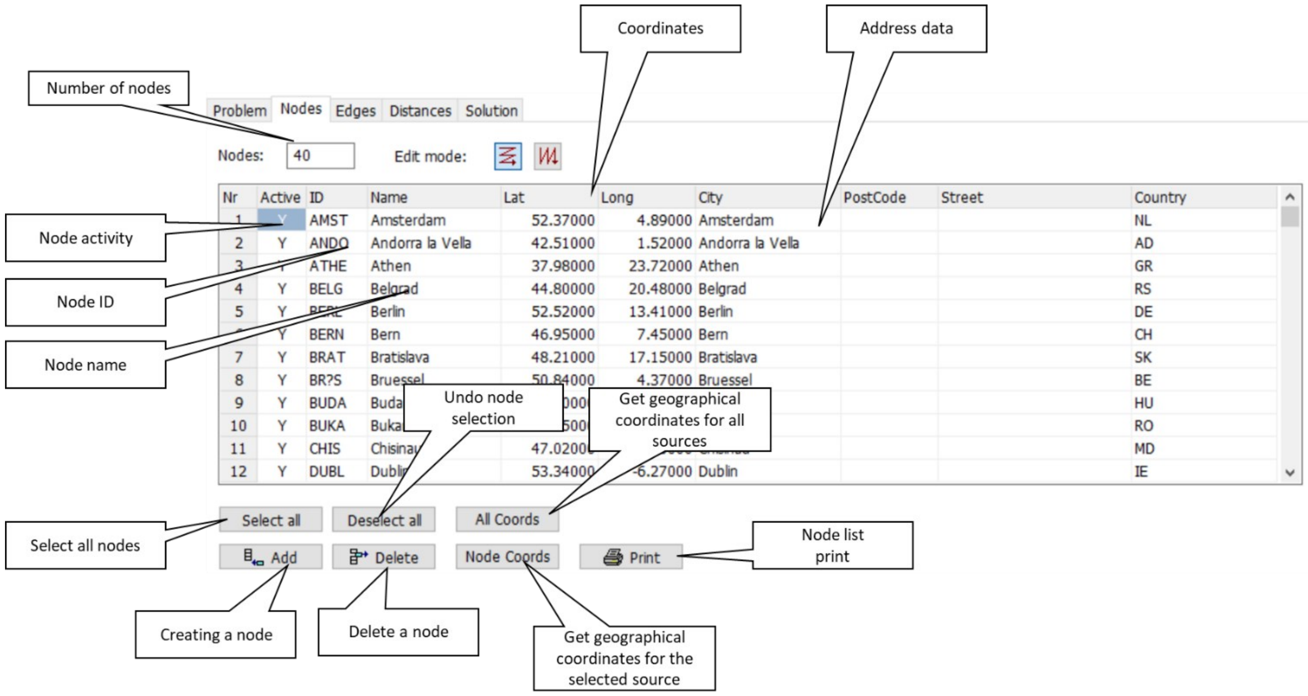


Figure 45: Nodes tab in LogisticsLab/TSP

With the button *Select all,* all nodes are included in the problem. With the button *Deselect all*, the selection of all nodes is cancelled.

It is possible to define edges in the tab ***Edges*** which will be described in the section about the Chinese Postman Problem.

The next step is to calculate the distances between all cities. This can be done either via the menu *Optimisation → Calculate Distance Matrix* or via the Calculate *Distance Matrix* button in the toolbar, whereupon the dialogue for calculating the distance matrix shown in Figure 46 appears. This calculation can base on distances or travel times provided by OpenStreetMap or on aerial distances (Great Circle, Euclidean or Manhattan distances). To generate the matrix, enter a distance or cost factor in the field *Distance/costs factor per km*. This is multiplied by the distance or travel time.

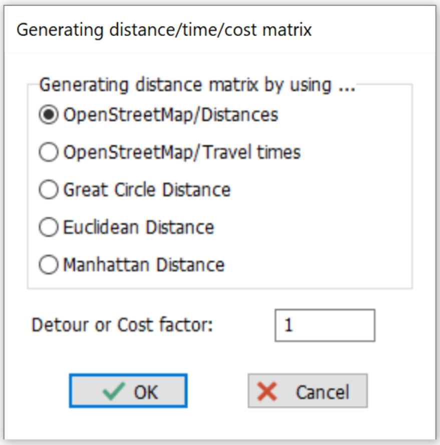
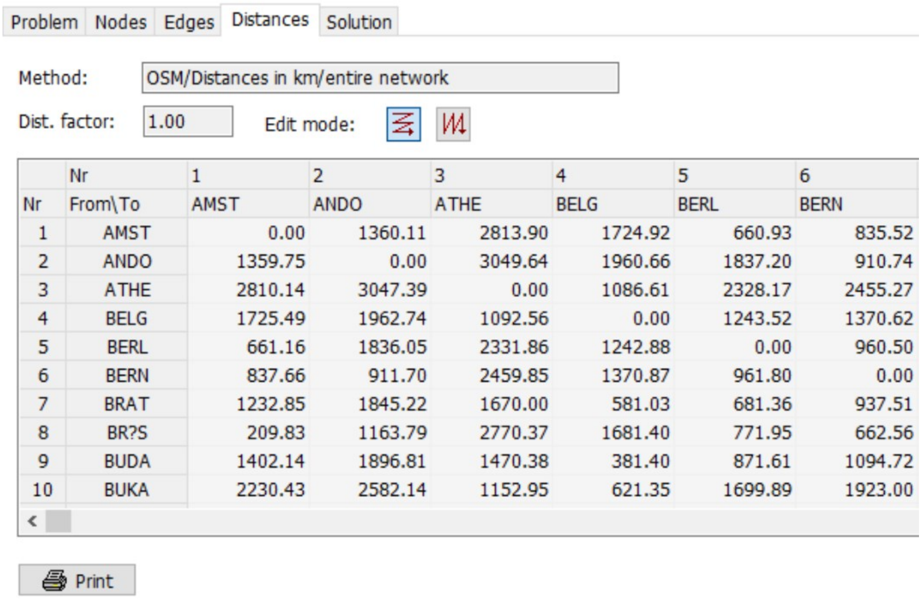


Figure 46: Dialogue for calculating the distance matrix in LogisticsLab/TSP

After the calculations are completed, the distance matrix appears in the ***Distances*** tab (Figure 47). No distances are available for the diagonal elements, as short cycles within a node are not allowed. The obtained matrix cannot be edited.



	Nr	1	2	3	4	5	6
Nr	From\To	AMST	ANDO	ATHE	BELG	BERL	BERN
1	AMST	0.00	1360.11	2813.90	1724.92	660.93	835.52
2	ANDO	1359.75	0.00	3049.64	1960.66	1837.20	910.74
3	ATHE	2810.14	3047.39	0.00	1086.61	2328.17	2455.27
4	BELG	1725.49	1962.74	1092.56	0.00	1243.52	1370.62
5	BERL	661.16	1836.05	2331.86	1242.88	0.00	960.50
6	BERN	837.66	911.70	2459.85	1370.87	961.80	0.00
7	BRAT	1232.85	1845.22	1670.00	581.03	681.36	937.51
8	BR?S	209.83	1163.79	2770.37	1681.40	771.95	662.56
9	BUDA	1402.14	1896.81	1470.38	381.40	871.61	1094.72
10	BUKA	2230.43	2582.14	1152.95	621.35	1699.89	1923.00

Figure 47: Distances tab in LogisticsLab/TSP

After entering the data, it should be saved with the menu item *Save Problem* or *Save Problem as.*

5.3 Optimisation and results

After entering all the data, the problem can be solved by selecting either the *Optimisation → Start Optimisation* menu or the *Optimise* button in the toolbar. In the optimisation dialogue that appears (Figure 48), select the type of problem and the method to be used.

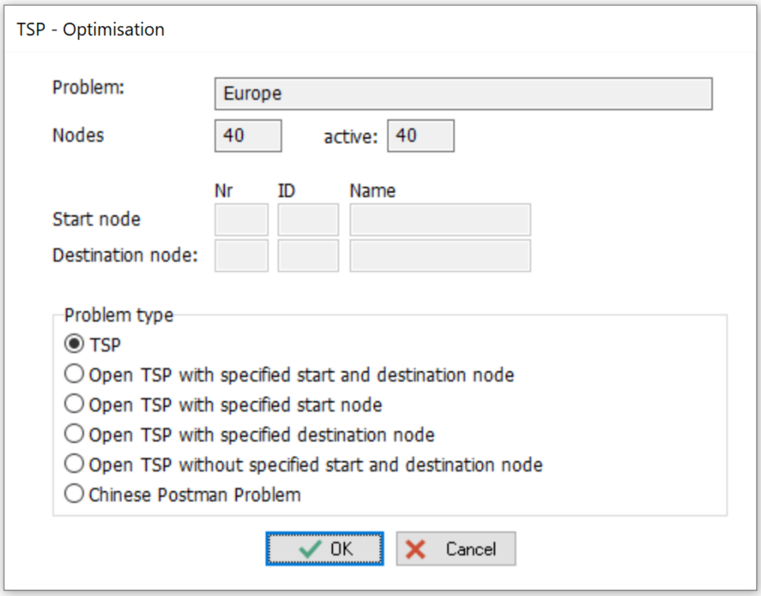


Figure 48: Optimisation dialogue in LogisticsLab/TSP

In addition to *TSP*, *Open TSP* are also available as problem type in the following different variants:

1. *Open TSP with specified start and destination node,*
2. *Open TSP with specified start node,*
3. *Open TSP with specified destination node* and
4. *Open TSP without specified start and destination node.*

After solving the round trip or transit problem, the graphical representation of the solution appears in the *Network* area and the numerical solution appears in the *Solution* tab (Figure 49).

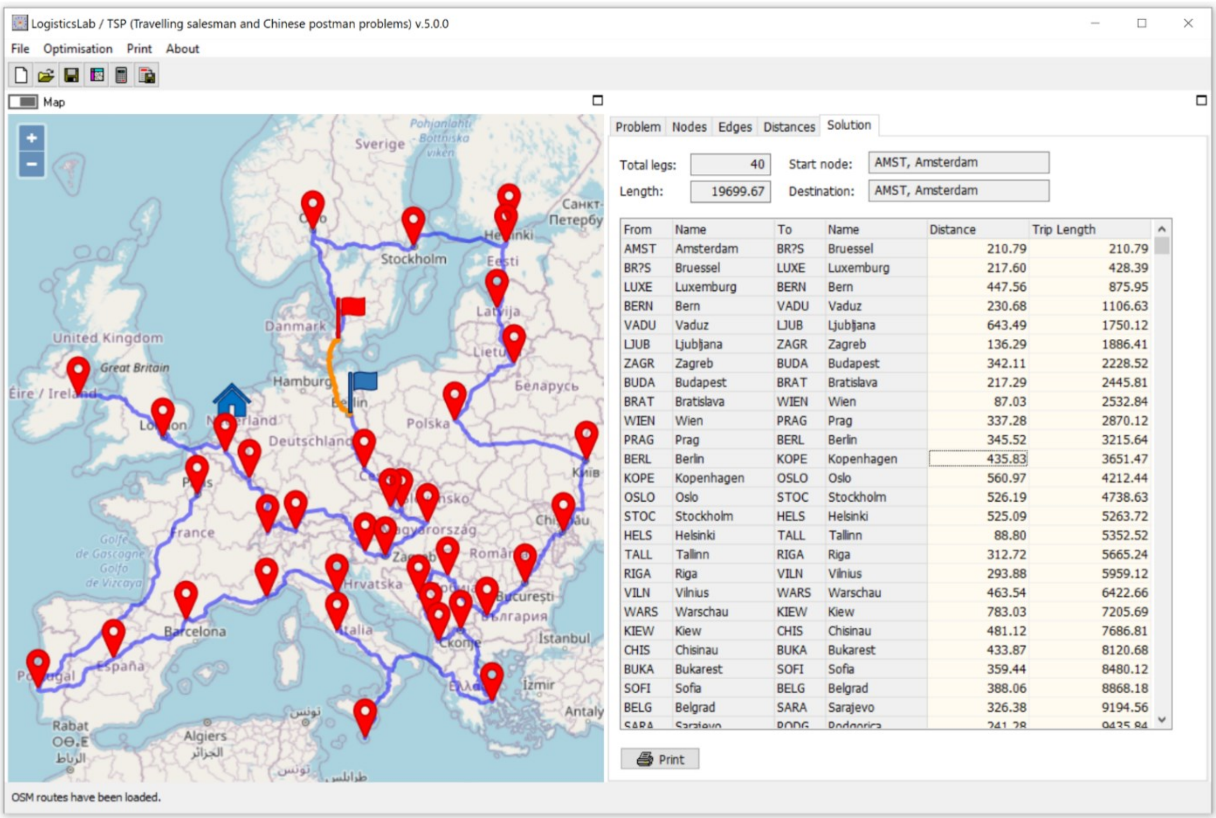


Figure 49: Representation of a solution in LogisticsLab/TSP

When a user clicks on one of the first four grey columns, a single part of the solution can be highlighted on the map.

LogisticsLab uses heuristics to solve problems. Therefore, the solutions of different optimisation runs may differ due to the non-deterministic nature of the underlying heuristic.

The solution can be saved in a text file with the extension *SOLX* and imported into other programs (e.g. Excel or LibreOffice/Calc[14]).

6 TSP – Solving Chinese Postman Problems

LogisticsLab/TSP can be also used to solve Chinese Postman Problems[15] in undirected, directed and mixed networks. Starting from a start node, each edge (directed or undirected) is to be traversed at least once and returned to the start node at the end of the round trip. The edge-oriented round trip to be found should minimise the total distance (or other adequate evaluation).

The Chinese Postman Problem can actually be applied to determine routes for postmen, but also to plan street cleaning or winter service by a vehicle in a given street network or to efficiently design waste collection. For example, a postman has to serve every street in a delivery district. In doing so, it may be necessary to pass through certain streets again after a delivery in order to reach another delivery street due to the street network. Traversing a street without a delivery represents an unproductive leg of the journey. It is obvious that it is in the interest of the postman to minimise these unproductive routes and ultimately the total distance of the delivery route from the starting point via all delivery streets back to the starting point.

6.1 Entering the problem data

Except for the necessary edges, entering the data is identical to editing a Traveling Salesman Problem.

The following example deals with a road survey to be carried out in a defined area in Schultzendorf, a small town in the south-east of Berlin. Each road located in this area must be observed, whereby the distance required should be as short as possible.

The network is defined by the crossings ant the streets joining the crossings. The crossings with their geographical coordinates are listed in the following table.

ID	Lat	Lon
N01	52.34529	13.59296
N02	52.34683	13.59646
N03	52.34817	13.5995
N04	52.34520	13.59273
N05	52.34445	13.59407
N06	52.34593	13.59749
N07	52.34654	13.60172
N08	52.34732	13.60064
N09	52.34517	13.59836
N10	52.34381	13.59525

Table 1: Table with geographical coordinates for the Chinese Postman Example

After editing the nodes, the map and the *Node* tab looks as follows:

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14 https://www.microsoft.com/en-us/microsoft-365/excel and https://www.libreoffice.org/ as of July 2024.

15 Steglich et al. (2016), p. 321 ff., Ahuja et al. (2013), p.740.

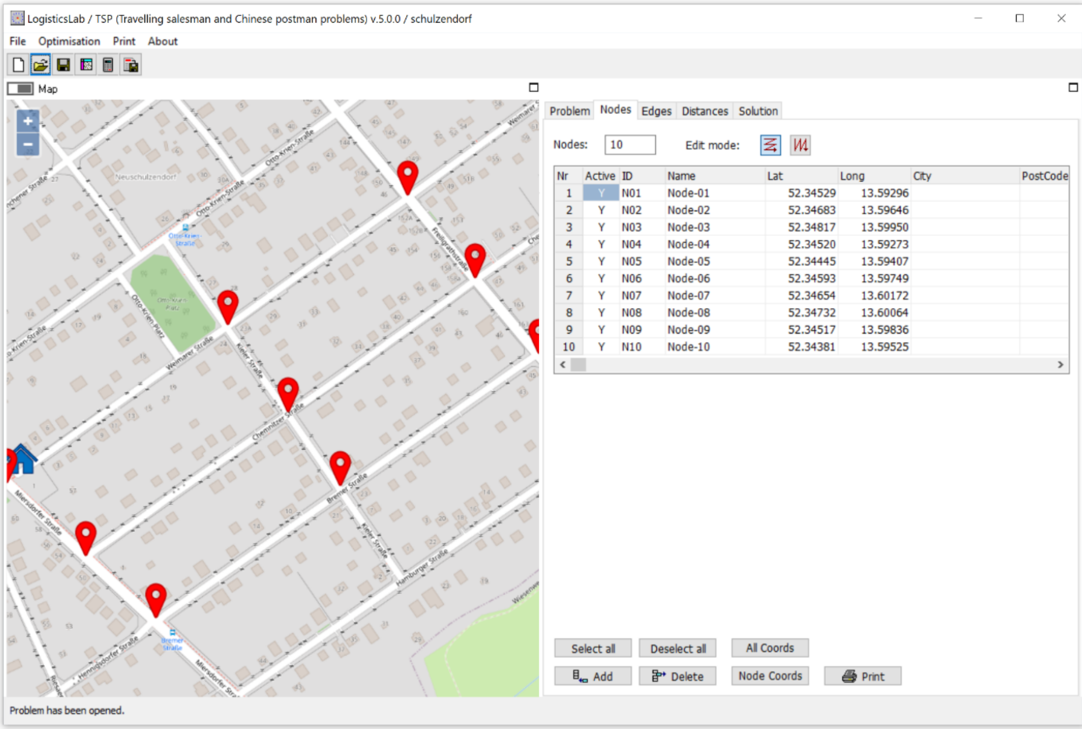


Figure 50: LogisticsLab/TSP with Chinese Postman Example

Afterwards the edges must be entered in the tab ***Edges*** (Figure 51). This can be done by double-clicking on the destination nodes on the map ore by editing the data in the edge editor. To do this, the node from which the edges originate must be specified in the *From node* field. The edges are defined in the *To nodes* list by entering the name and type of the edge. The type can be *U* (undirected) for an undirected edge or *D* (directed) for a directed edge.

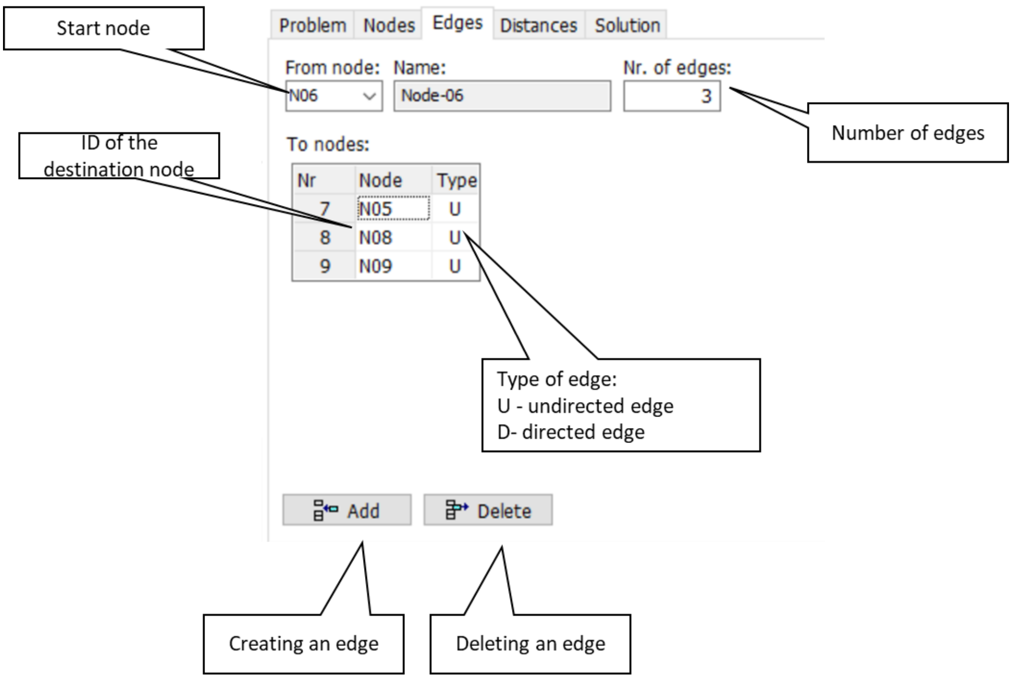


Figure 51: Edge editor in LogisticsLab/CPP

Beside the visualisation of the edges in the map, they can also be displayed when switching to SimpleMap (Figure 52). Directed edges are represented by arrows. Undirected edges do not have arrowheads.

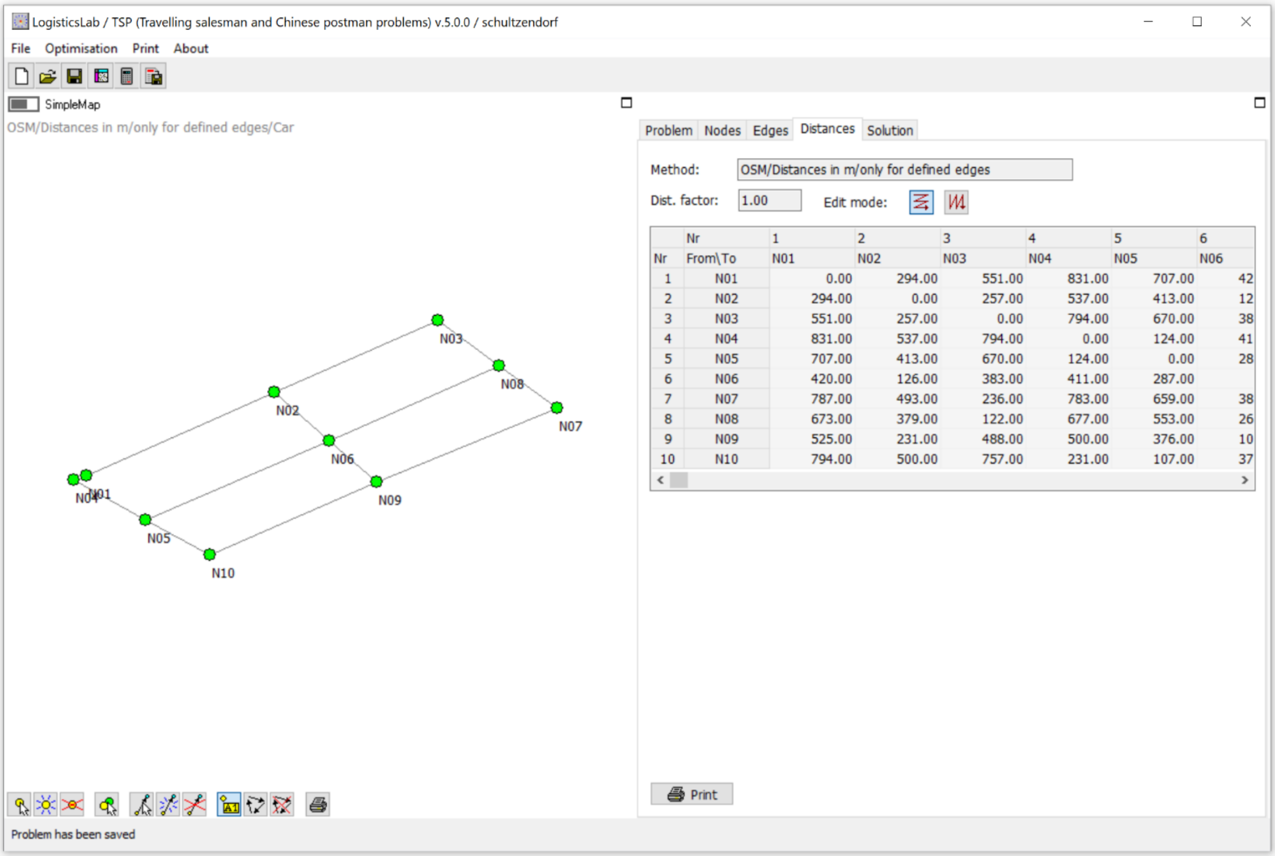


Figure 52: Displaying edges in LogisticsLab/TSP

The next step is to calculate the distances for all edges. This can be done either via the menu *Optimisation → Calculate Distance Matrix* or via the Calculate *Distance Matrix* button in the toolbar, whereupon the dialogue for calculating the distance matrix shown in Figure 53 appears. This calculation can base on distances or travel times provided by OpenStreetMap or on aerial distances (Great Circle, Euclidean or Manhattan distances). To generate the matrix, enter a distance or cost factor in the field *Distance/costs factor per km*. This is multiplied by the distance or travel time.

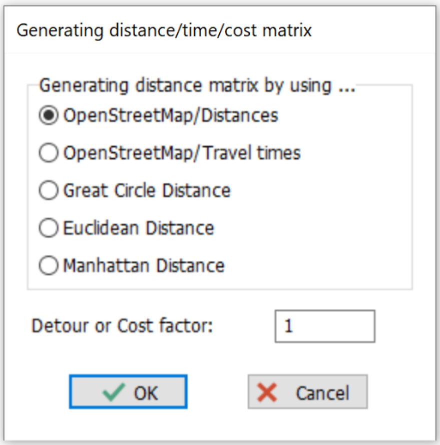
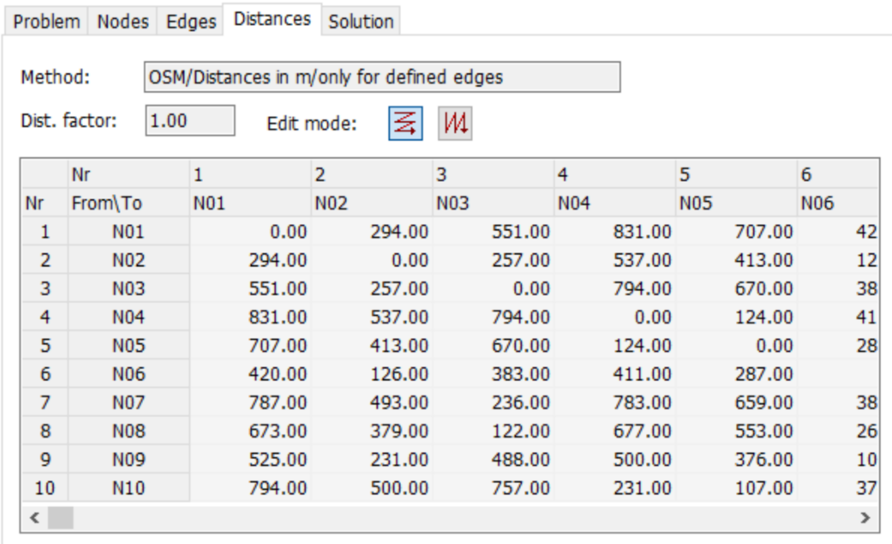


Figure 53: Dialogue for calculating the distance matrix in LogisticsLab/TSP

After the calculations are completed, the distance matrix appears in the ***Distances*** tab (Figure 54). In the algorithm to solve the problem, only the direct distances, cost or times of the edges are used. The obtained matrix cannot be edited.



	Nr	1	2	3	4	5	6
Nr	From\To	N01	N02	N03	N04	N05	N06
1	N01	0.00	294.00	551.00	831.00	707.00	42
2	N02	294.00	0.00	257.00	537.00	413.00	12
3	N03	551.00	257.00	0.00	794.00	670.00	38
4	N04	831.00	537.00	794.00	0.00	124.00	41
5	N05	707.00	413.00	670.00	124.00	0.00	28
6	N06	420.00	126.00	383.00	411.00	287.00	
7	N07	787.00	493.00	236.00	783.00	659.00	38
8	N08	673.00	379.00	122.00	677.00	553.00	26
9	N09	525.00	231.00	488.00	500.00	376.00	10
10	N10	794.00	500.00	757.00	231.00	107.00	37

Figure 54: Distances tab in LogisticsLab/TSP for the Chinese Postman Problem

After entering the data, it should be saved with the menu item *Save Problem* or *Save Problem as.*

6.2 Optimisation and results

After entering all the data, the problem can be solved by selecting either the *Optimisation → Start Optimisation* menu or the *Optimise* button in the toolbar. Then select the problem type *Chinese Postman Problem* in the optimisation dialogue that appears (Figure 55).

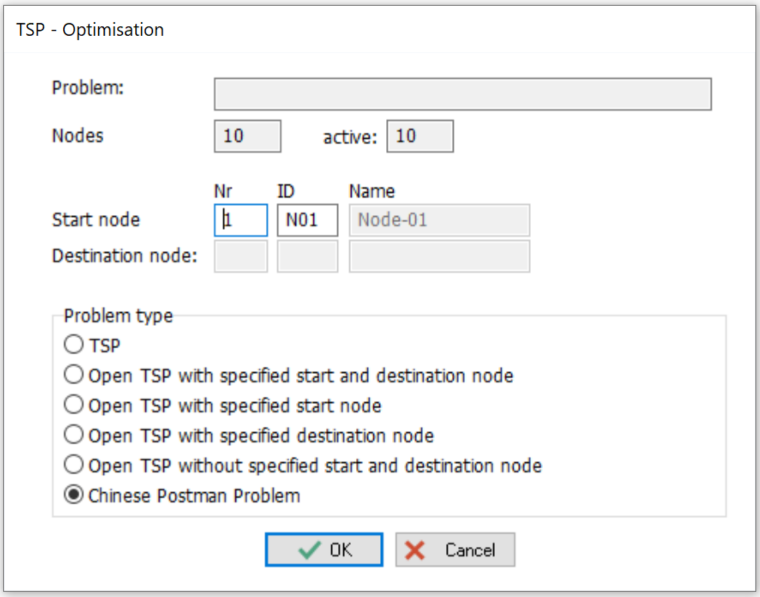


Figure 55: Optimisation dialogue in LogisticsLab/TSP

To solve a postman problem, the following two steps are carried out:

1. Cost- or distance-minimal extension of the network to a Euler network,
2. Determination of the Euler tour.

The solution algorithm for the cost- or distance-minimal extension of the existing network is based on an integer linear optimisation model, the results of which are used by a simple algorithm to determine a Euler tour and thus to solve the postman problem.

After solving the postman problem, the graphical representation of the solution appears in the *Network* area and the numerical solution in the *Solution* tab (Figure 56).

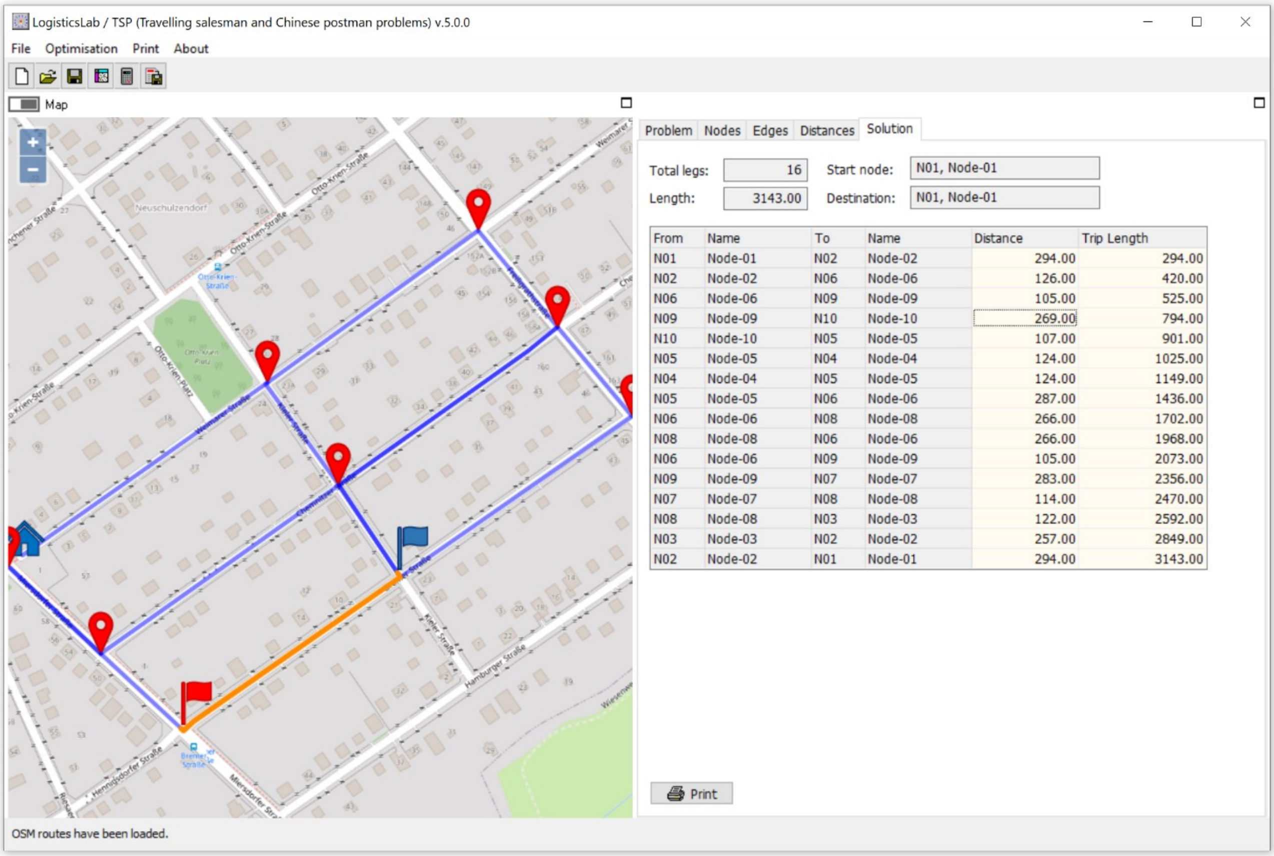


Figure 56: Representation of the solution of the Chinese Postman Problem

In the map, the thickness of the edges indicates whether they have to be traversed several times. The detailed route of the postman can be seen in the *Solution* tab. When a user clicks on one of the first four grey columns, a single part of the solution can be highlighted on the map.

The solution can be saved in a text file with the extension *SOLX* and imported into other programs (e.g. Excel or LibreOffice/Calc[16]).

7 VRP – Solving Vehicle Routing Problems

With a Traveling Salesman Problem, a number of nodes are to be served on the shortest possible route, whereby no capacities are considered. However, if the demands of the individual nodes were included, it would have to be assumed that the capacity of the vehicle used is greater than or equal to the sum of the demands of all nodes. However, if the total quantity to be delivered to or collected from the nodes exceeds the loading capacity of a single vehicle, then the nodes must be supplied on several routes. Problems of this type belong to the group of Vehicle Routing Problems.[17]

In the Vehicle Routing Problem, a number of demand nodes are to be served from a depot. The demand of each individual demand node is known and is less than or equal to the capacity of the type of vehicle used. Furthermore, the weights of the edges (e.g. distances or costs) between the nodes (depot and demand nodes) are known. The demands of the demand nodes are to be assigned to tours in considering the capacities of the vehicles. For the individual tours, the routes from the depot via the demand nodes assigned to the tours and back to the depot are to be found. The total costs or the total distance travelled of all tours is

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16 https://www.microsoft.com/en-us/microsoft-365/excel and https://www.libreoffice.org/ as of July 2024.

17 Steglich et al. (2016), p. 281 f., Chen et al. (2010), p. 146 ff., Ghiani et al. (2013), p. 368 ff.

to be minimised.[18] Maximum distances and times for a tour and customer time windows can also be specified and included in the optimisation.

7.1 Program interface

After starting the program, the program window shown in Figure 57 appears, which consists of a network area and a data area.

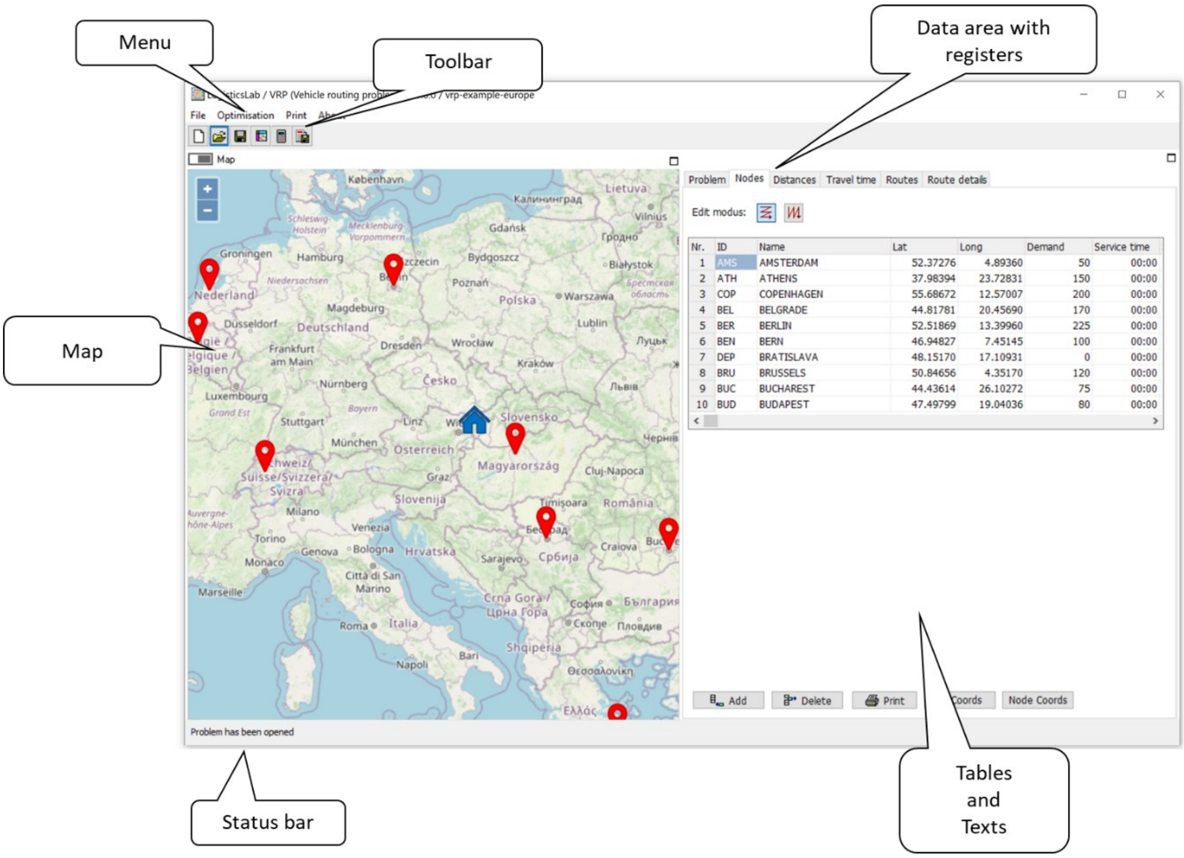

Figure 57: Program interface - LogisticsLab/VRP

The left side of the VRP program window is used to visualise the entered data and the planned tours. The map graph contains two different types of nodes: the start and destination node (blue house) and the red-coloured destinations.

7.2 Entering the problem data

The data area on the right side of the VRP program interface contains seven worksheets for the data (*Problem, Nodes, Distances, Travel time*) and two areas for the output of the solution (*Routes*, *Route details*).

The first step is to generate a **new problem.** To do this, the menu item *File* → *New Problem* or the *New Problem* button in the toolbar can be selected.

In the dialogue that appears (Figure 58), the number of *nodes (*depot plus destinations*)* must be entered in addition to a short description of the *problem.* Geographical coordinates can be generated randomly based on a set of European cities and villages or as empty geographical coordinates. The generated coordinates can be edited afterwards. Regarding the destinations, an average demand (*Demand per node*) can also be entered. This is either assigned to all customers as a constant value if *Volumes* → *Constant is* selected or

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[18] Steglich et al. (2016), p. 338 f., Laporte (1992), p. 352 f., Mattfeld and Vahrenkamp (2014), p. 277f., Williams (2013), p. 198f.

represents the basis of randomly generated demands in the interval of [-50%, +50%] if *Volumes → Variation (+/-50%) is* selected.

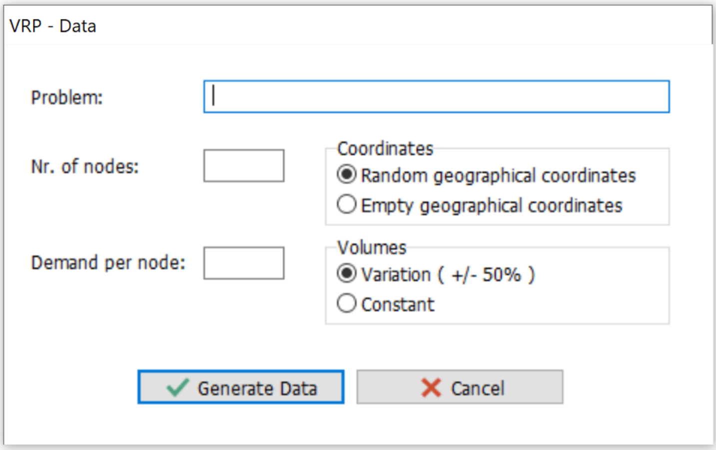


Figure 58: Creating a problem in LogisticsLab/CPP

The ***Problem*** tab (Figure 59) contains, in addition to the field comment, further grey fields with general information on the problem being solved on and yellow fields with information on the solution of the problem.

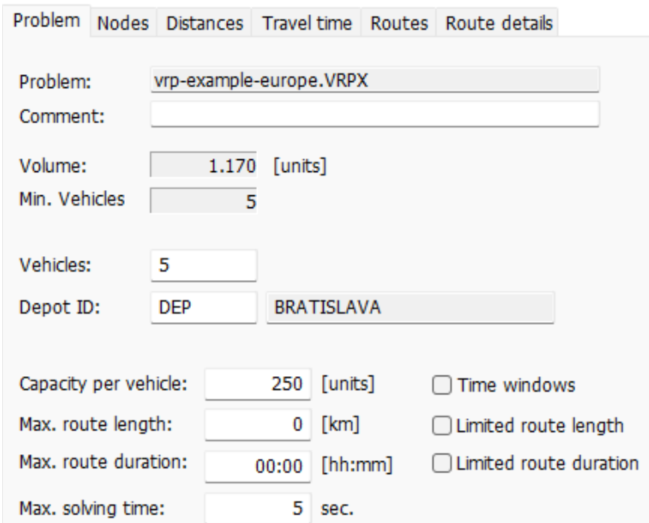


Figure 59: Problem tab in LogisticsLab/VRP

The following specifications for the optimisation are to be entered:

- *Vehicles:* Number of vehicles,
- *Depot ID*: ID of the depot,
- *Capacity per* vehicle: Capacity of the uniform vehicle,
- *Max. route length*: maximum possible distance of a route,
- *Max. route duration*: maximum possible duration of a route,
- *Max. solving time:* Maximum seconds used for optimisation.

Additionally, three constraints (*Time windows*, *Limited route length* and *Limited route duration*) can be invoked in the optimisation by activating the checkboxes.

In the tab ***Nodes*** (Figure 60) all information about the nodes are entered. You can add a node with the *Add* button. It can be deleted using the button *Delete.*

Each node is described by a unique node identifier (*ID*), a node name (*Name*), geographical coordinates coordinate (or if SimpleMap is chosen, an X and Y coordinate), demands, service times and customer time windows for destinations and optional address data.

If a user has entered valid address data, it is possible to retrieve the geographical coordinates of all nodes (*All coords*) or of the selected node (*Node coords*) via a Komoot/Photon server.

The entire node list can be printed with the *Print* button.

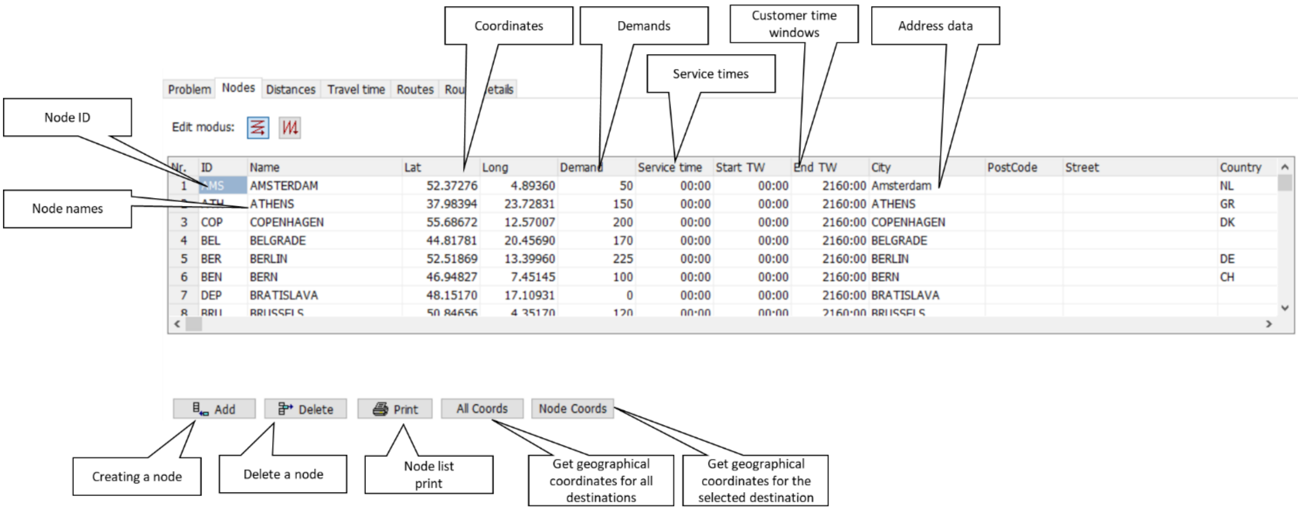


Figure 60: Tab Nodes in LogisticsLab/VRP

The next step is to calculate the distances and travel times between all nodes. This step can be done either via the menu *Optimisation → Calculate Distance Matrix* or via the *Calculate Distance Matrix* button in the toolbar, whereupon the dialogue for calculating the distance matrix shown in Figure 61 appears.

A user can obtain distances and travel times provided by OpenStreetMap or by calculating aerial distances (Great Circle, Euclidean or Manhattan distances). For the latter, an average speed per hour must be specified to calculate depending travel times.

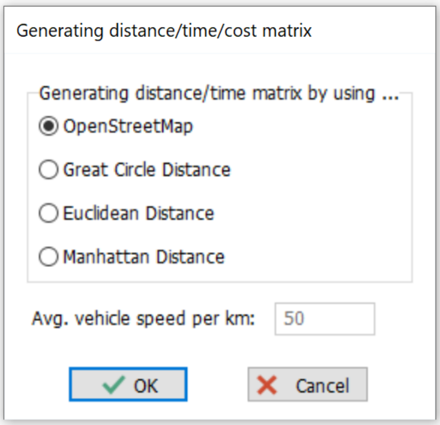
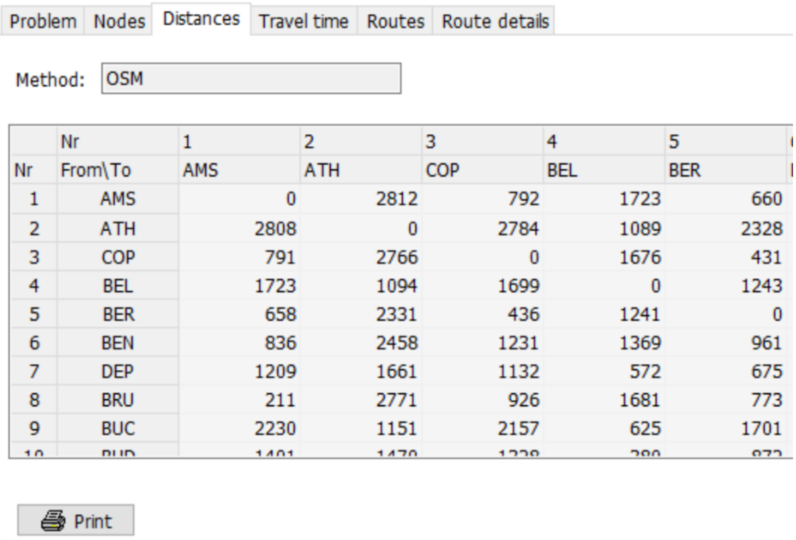


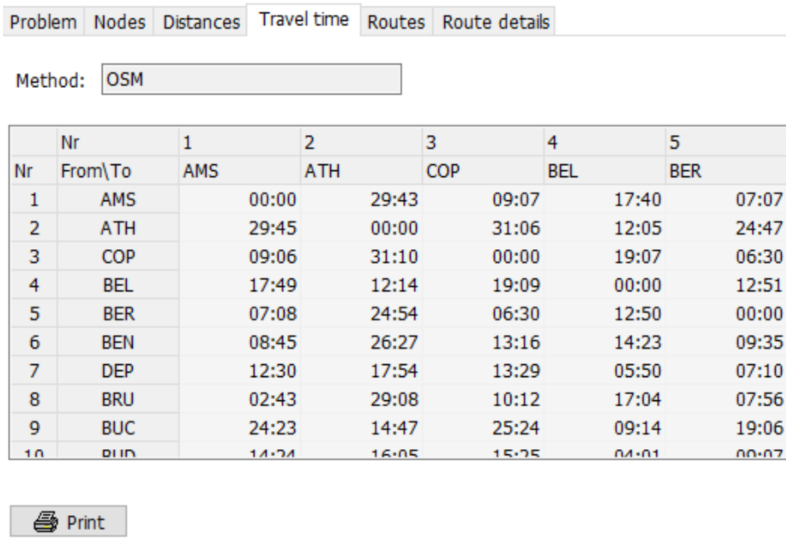
Figure 61: Dialogue for calculating the distance matrix in LogisticsLab/VRP

After the calculations are completed, the generated data appears in the ***Distances*** and the ***Travel time*** tab (Figure 62 and Figure 63). The distances and travel times cannot be changed.



	Nr	1	2	3	4	5
Nr	From\To	AMS	ATH	COP	BEL	BER
1	AMS	0	2812	792	1723	660
2	ATH	2808	0	2784	1089	2328
3	COP	791	2766	0	1676	431
4	BEL	1723	1094	1699	0	1243
5	BER	658	2331	436	1241	0
6	BEN	836	2458	1231	1369	961
7	DEP	1209	1661	1132	572	675
8	BRU	211	2771	926	1681	773
9	BUC	2230	1151	2157	625	1701

Figure 62: Distances tab in LogisticsLab/VRP



	Nr	1	2	3	4	5
Nr	From\To	AMS	ATH	COP	BEL	BER
1	AMS	00:00	29:43	09:07	17:40	07:07
2	ATH	29:45	00:00	31:06	12:05	24:47
3	COP	09:06	31:10	00:00	19:07	06:30
4	BEL	17:49	12:14	19:09	00:00	12:51
5	BER	07:08	24:54	06:30	12:50	00:00
6	BEN	08:45	26:27	13:16	14:23	09:35
7	DEP	12:30	17:54	13:29	05:50	07:10
8	BRU	02:43	29:08	10:12	17:04	07:56
9	BUC	24:23	14:47	25:24	09:14	19:06

Figure 63: Travel time tab in LogisticsLab/VRP

After entering the data, it should be saved with the menu item *Save Problem* or *Save Problem as*.

7.3 Optimisation and results

After entering all data, the problem can be solved by selecting either the menu *Optimisation → Start Optimisation* or the button *Optimise* in the toolbar.

The solution to the problem under consideration is displayed in both the network and data areas (Figure 64). LogisticsLab/VRP has the *Routes* and Route *details* tabs for displaying the planned routes.

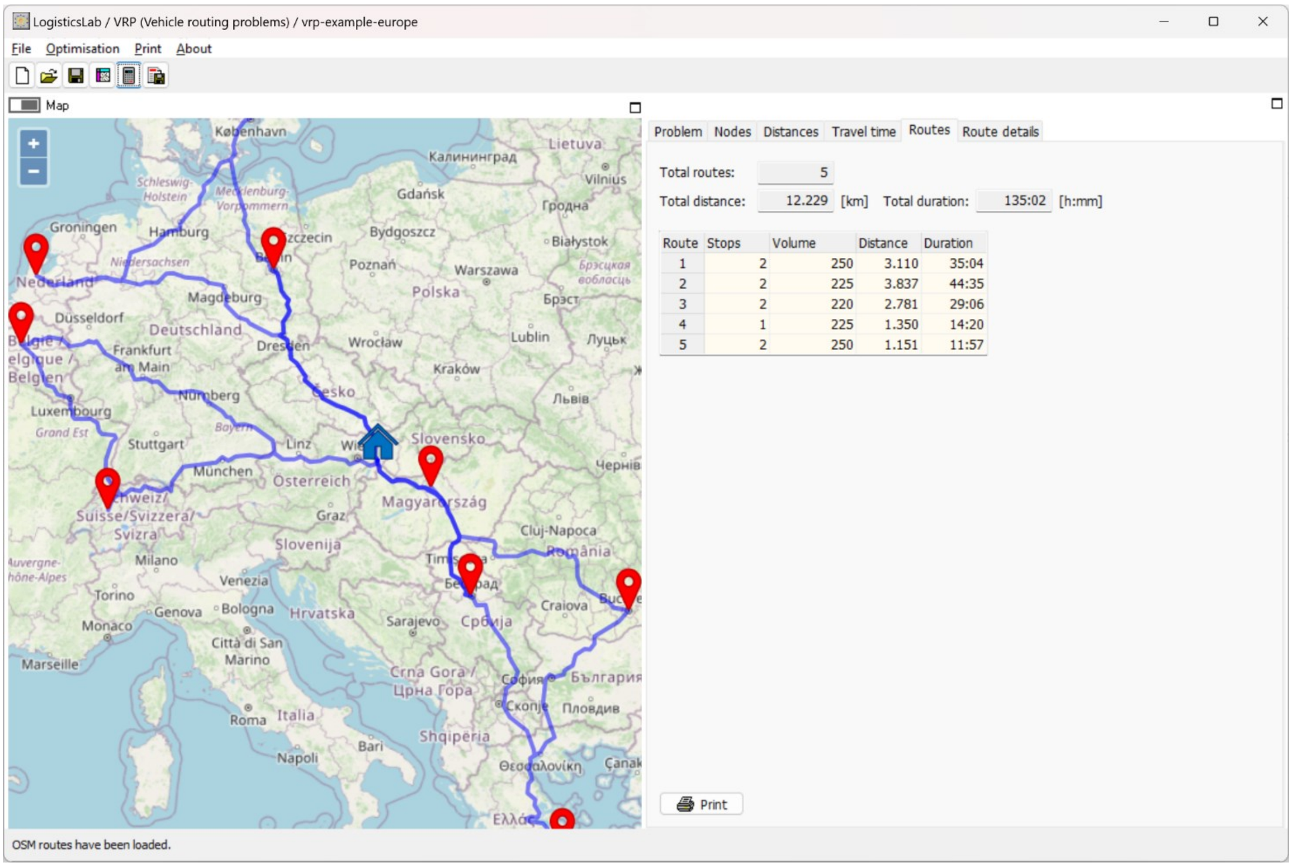


Figure 64: Representation of a solution in LogisticsLab/VRP

In the ***Routes*** tab (Figure 65), all the tours found are displayed in an overview.

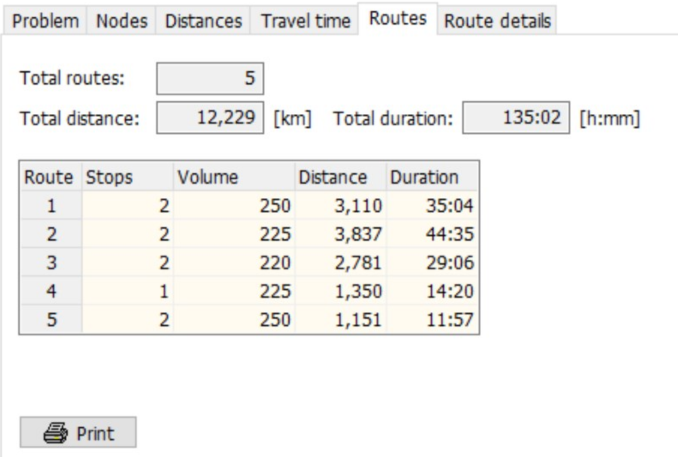


Figure 65: Representation of a solution in the Routes tab in LogisticsLab/VRP

In the ***Route details*** tab (Figure 66 and Figure 67), the destinations to be served, the quantity served, the individual and cumulated distances, travel and service times can be seen for each tour. The desired tour can either be entered directly in the *Route* field or selected by clicking on the up or down button. The selected tour is displayed in the Network area. When a user clicks on one of the first two grey columns, a single part of the solution can be highlighted on the map.

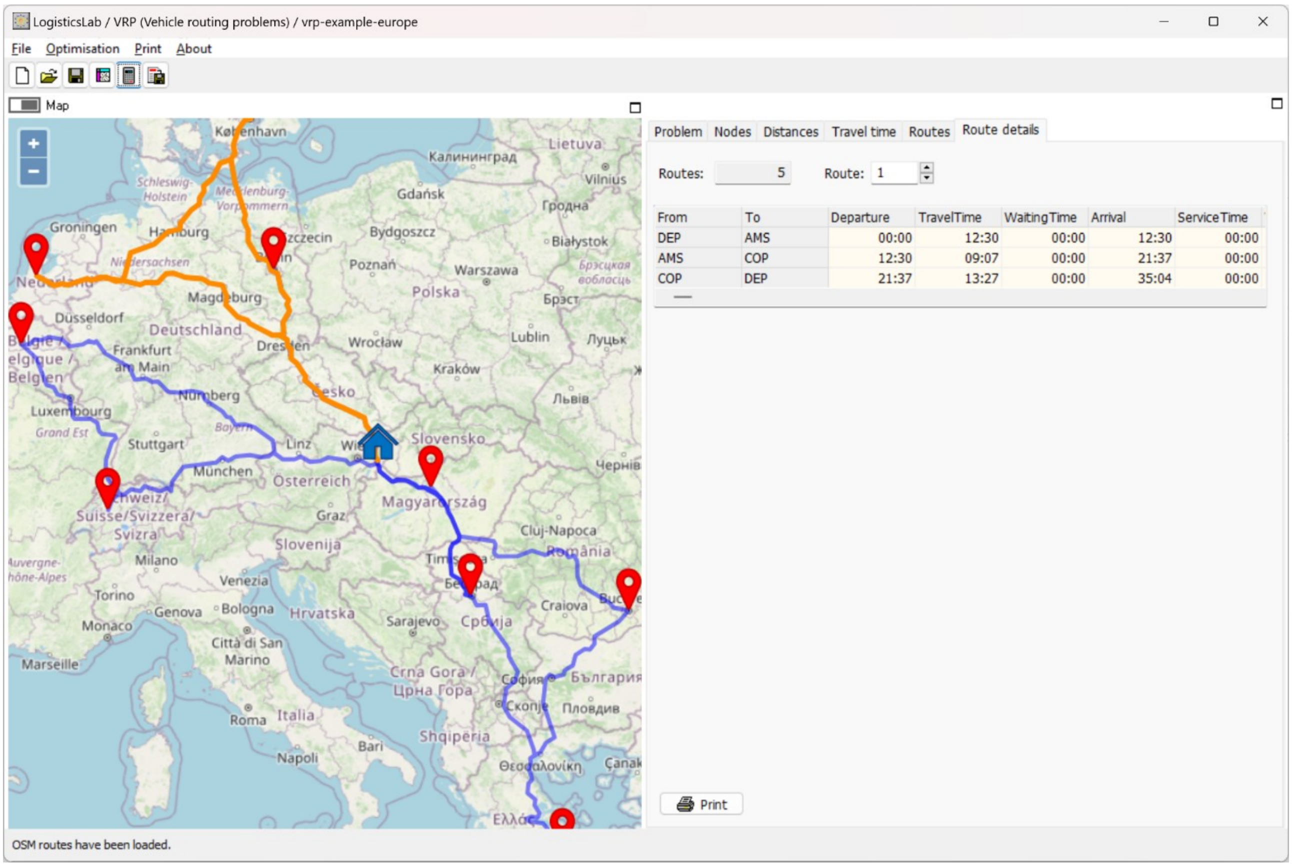
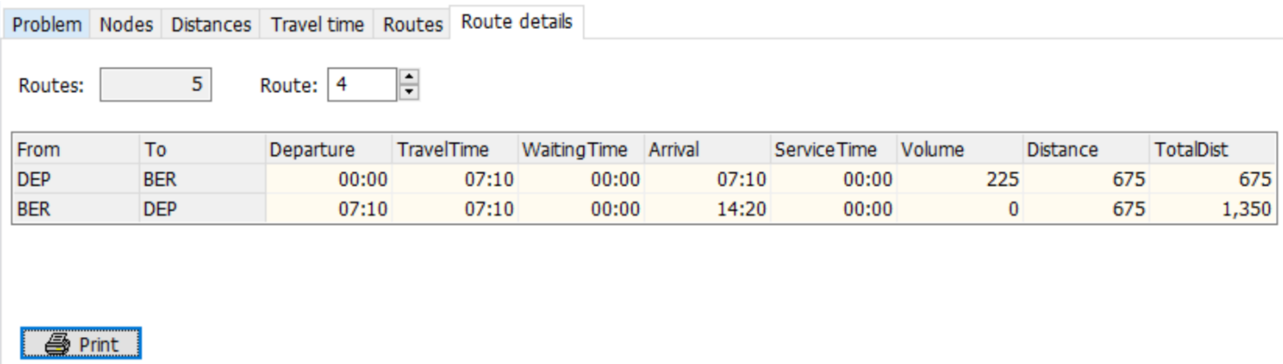


Figure 66: Representation of a solution in the tab Routes details in LogisticsLab/VRP



From	To	Departure	TravelTime	WaitingTime	Arrival	ServiceTime	Volume	Distance	TotalDist
DEP	BER	00:00	07:10	00:00	07:10	00:00	225	675	675
BER	DEP	07:10	07:10	00:00	14:20	00:00	0	675	1,350

Figure 67: Details of a solution in the tab Routes details in LogisticsLab/VRP

LogisticsLab uses heuristics to solve problems. Therefore, the solutions of different optimisation runs may differ due to the non-deterministic nature of the underlying heuristic.

The result can be saved as a text file with the file extension *SOLX.*

8 DLP – Solving Warehouse Location Problems

LogisticsLab/DLP is intended for solving discrete single-source location problems, specifically (capacitated and uncapacitated) Warehouse Location Problems[19], Covering Location Problems[20], Maximal Covering

[19] Steglich et al. (2016), p. 438 ff., Fernández and Landete (2015), p. 50.

[20] Steglich et al. (2016), p. 417 ff., Daskin (2013), Pos. 2479, García and Marín (2015), p. 97f.

Problems[21], p-Median[22] and p-Centre problems[23]. It is always assumed that a demand node can only be supplied from one location at a time (single-sourcing).

Warehouse Location Problems are discrete location problems where both fixed location costs and variable transport costs are included in the location decision.

There is a set of potential locations whose fixed costs are known. For the demand nodes, the demands are available. Furthermore, the variable transport costs between the potential locations and the demand nodes are also available. The objective is to minimise the sum of the transportation costs and the fixed costs of building and running warehouses by deciding which warehouses are established and which customer is delivered by which warehouse.

8.1 Program interface

After starting the program, the program window shown in Figure 68 appears, which, like all other components of LogisticsLab, consists of a network area and a data area.

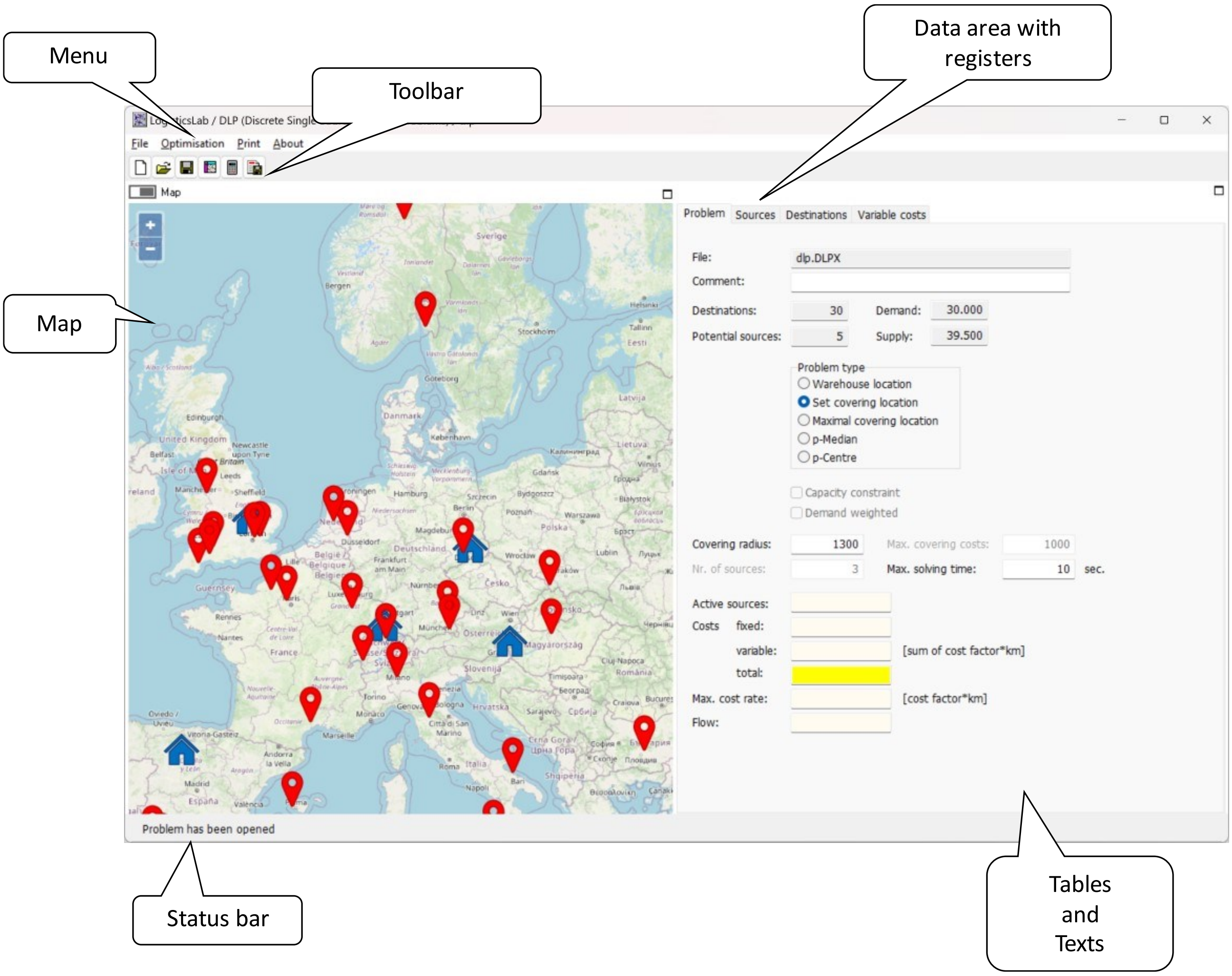


Figure 68: Program interface - LogisticsLab/WLP

The left side of the LogisticsLab/DLP program window is used to visualise the entered data and the results. The map contains two different types of nodes: the potential locations (blue houses) and the red-coloured

21 Steglich et al. (2016), p. 424 ff., Daskin (2013), pos. 3128ff.

22 Steglich et al. (2016), p. 380 ff., Daskin and Maas (2015), p. 25f.

23 Steglich et al. (2016), p. 390 ff., Daskin (2013), pos. 4272.

destinations. If a potential location is not chosen, then it is shown with a light-blue marker otherwise with a blue house.

8.2 Entering the problem data

The data area on the right side of the DLP program interface contains four tabs for entering data (*Problem, Sources, Destinations, Variable costs*).

The first step is to generate a **new problem.** To do this, the menu item *File → New Problem* or the *New Problem* button in the toolbar can be selected.

In the dialogue that appears (Figure 69), in addition to a short description of the *Problem,* the *Nr. of potential sources* and the *Nr. of destinations* must be entered. Geographical coordinates can be generated randomly based on a set of European cities and villages or as empty geographical coordinates. The generated coordinates can be edited afterwards.

Furthermore, the average *Supplies* and *Demands* can be entered. These values are assigned to the potential locations or the demand nodes as a constant value if *Supplies/Demands → Constant* is selected, or random supplies and demands are generated in the interval of [-25%, +25%] if *Supplies/Demands → Variation (+/-25%) is* selected.

An analogous approach can be taken for the average fixed costs of the potential locations (*Fixed costs*) and the average variable transport costs (*Variable costs*) between the locations and the demand nodes.

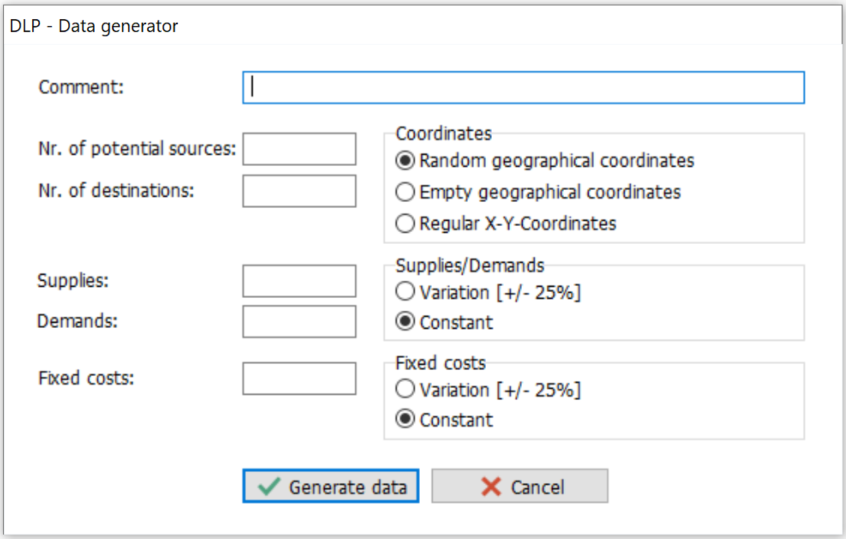


Figure 69: Creating a problem in LogisticsLab/WLP

The ***Problem*** tab (Figure 70) contains an input field for a comment, options for the problem type to be used and output fields with a yellow background for information on the solution. If the problem type *Warehouse location* is chosen, then the user can select whether capacities are to be considered or not (*Capacitaty constraint*). In addition, the maximum time in seconds used for optimisation (*Max. solving time*) can be edited.

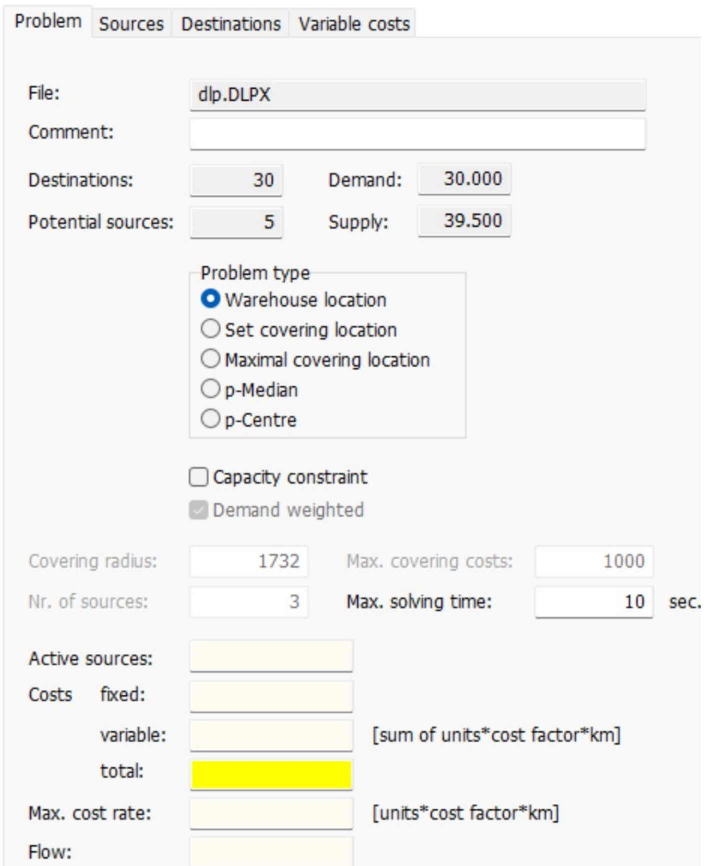


Figure 70: Problem tab in LogisticsLab/WLP

The ***Sources*** tab (Figure 71) contains the details of the potential locations, which are displayed after loading the problem data or can be entered and changed manually.

In the field *Nr. of potential sources, the* number of locations can be entered. The size of the input sheet is automatically adjusted. If the number of sites is reduced, excess entries are deleted.

For the potential locations, the following information can be entered:

- *Name*: Name of the location,
- *Lat., Long*: Coordinates of the location,
- *Fixed costs*: Fixed costs of the location,
- *Supply*: Supply of the location and
- *City, PostCode, Street, Country*: Address data

In the *Act*. column, LogisticsLab enters an *A* (for active) for selected locations after the optimisation has been completed, in the *Nr. of dest.* column the number of assigned customers and in the *Flow* column the delivery quantity. These values cannot be changed manually.

If a user has entered valid address data, it is possible to retrieve the geographical coordinates of all nodes (*All coords*) or of the selected node (*Node coords*) via a Komoot/Photon server.

A new location can be added via the *Add* button. The button *Delete* deletes the selected location. The Print button can be used to print the location list.

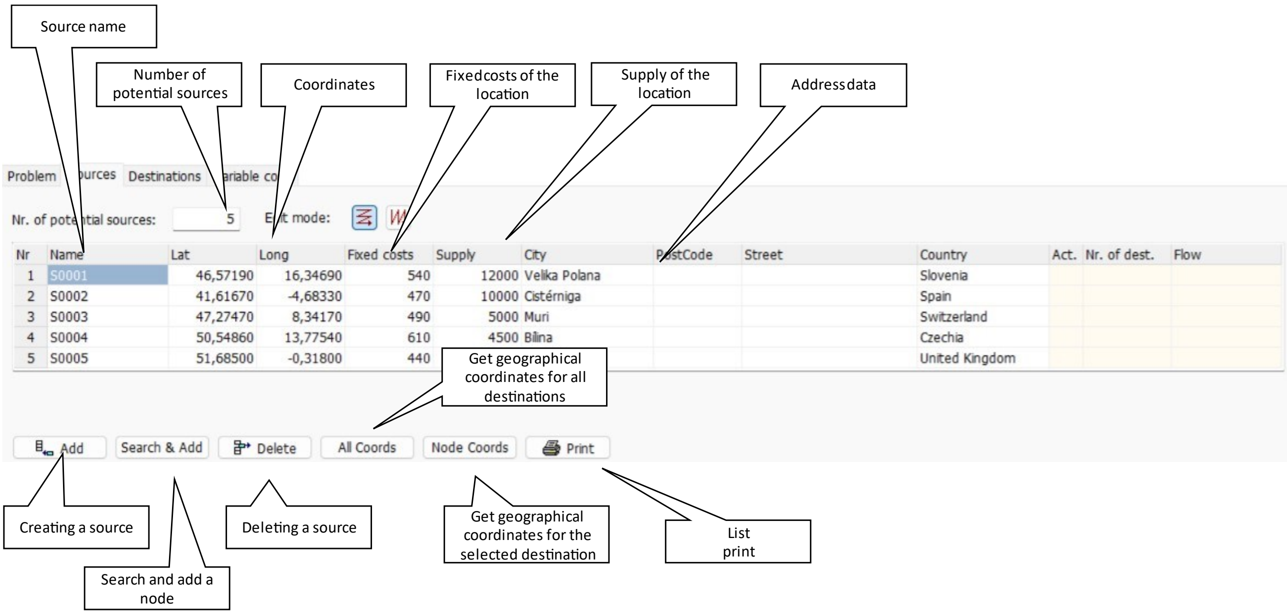


Figure 71: Sources tab in LogisticsLab/DLP

The ***Destinations*** tab (Figure 72) contains the details of the customers. They are displayed after loading the problem data or can be entered and changed manually.

In the field *Nr. of destinations* the number of customers can be entered. The size of the input sheet is automatically adjusted. If the number is reduced, excess entries are deleted.

For each customer, the following information can be entered:

- *Name*: Name of the destination,
- *Lat., Long*: Coordinates of the destination,
- *Demand*: Demand of the destination and
- *City, PostCode, Street, Country*: Address data

After completing the optimisation, LogisticsLab enters the name of the assigned location in the Source column and the variable costs required for it in the Costs column. These values cannot be changed manually.

If a user has entered valid address data, it is possible to retrieve the geographical coordinates of all nodes (All coords) or of the selected node (Node coords) via a Komoot/Photon server.

A new customer can be added via the *Add* button. The *Delete* button deletes the selected customer. The *Print* button can be used to print out the list of customers.

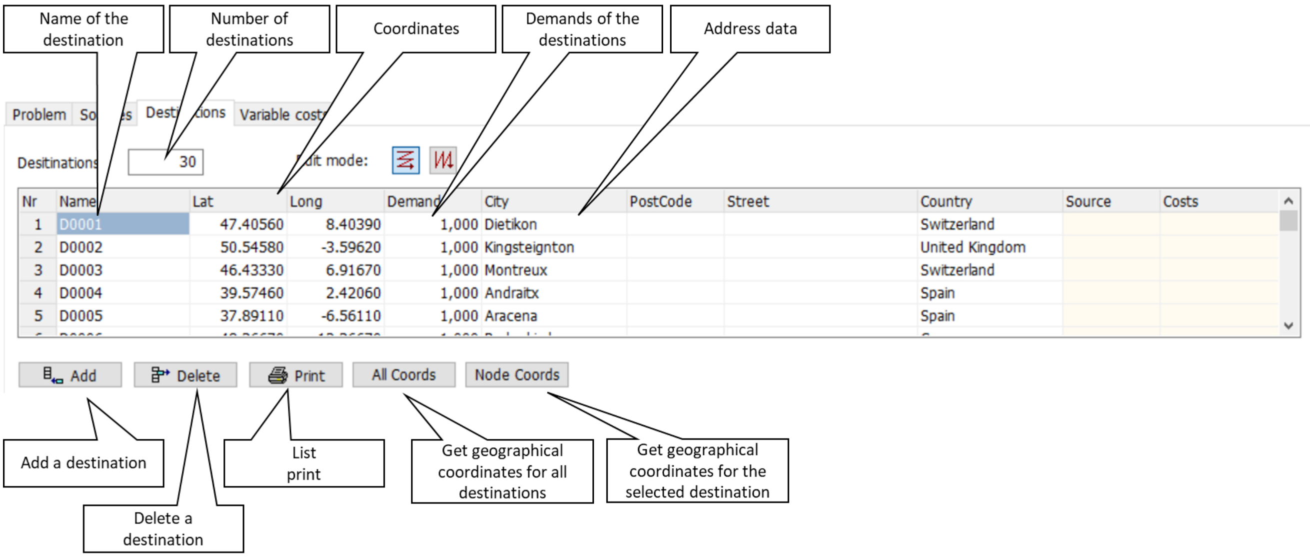


Figure 72: Destinations tab in LogisticsLab/DLP

If you click on a customer in the *No.* column, it is marked with an ochre marker in network area. A mouse click on the upper left grey field *Nr* restores the normal display.

The next step is to calculate the distances and travel times between all nodes. This step can be done either via the menu *Optimisation → Calculate Distance Matrix* or via the Calculate *Distance Matrix* button in the toolbar, whereupon the dialogue for calculating the distance matrix shown in Figure 73 appears.

A user can obtain distances and travel times provided by OpenStreetMap or by calculating aerial distances (Great Circle, Euclidean or Manhattan distances). In addition, a distance or cost factor per kilometre must be entered. In this example, it is assumed that the costs per kilometre are 20 Cent.

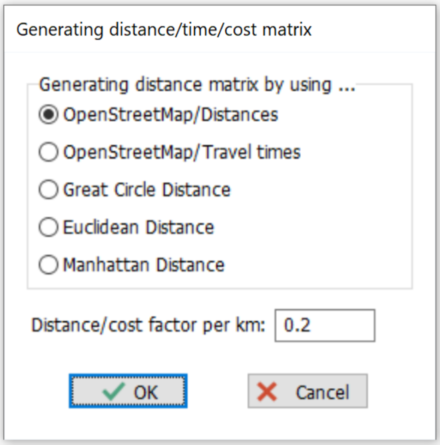


Figure 73: Calculation of variable costs in LogisticsLab/DLP

The results are shown in the ***Variable costs*** tab (Figure 74) which cannot be changed. Use the *Print* button to print the cost matrix.

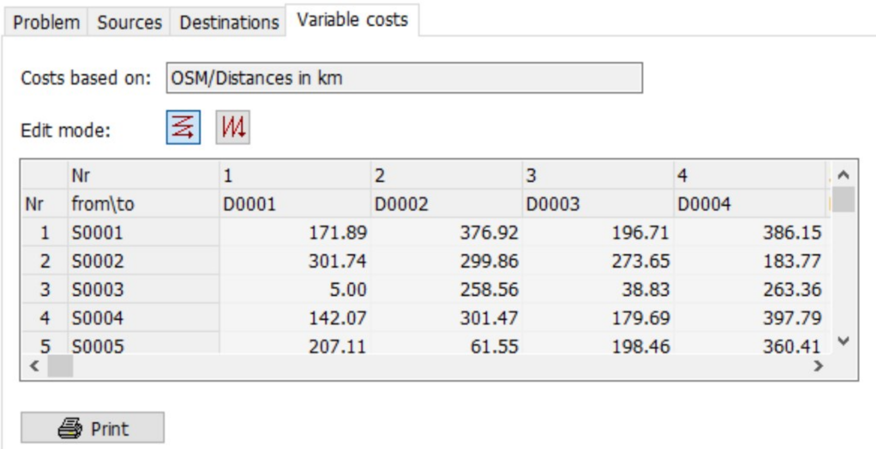


Figure 74: Variable costs tab in LogisticsLab/DLP

8.3 Optimisation and results

The problem can be solved if all data are available. For this purpose, the problem type *Warehouse location* has to be chosen in the tab *Problem* (Figure 70). In addition, a user has to decide to solve the problem considering the capacities of the potential location or not (*Capacitaty constraint*). The optimisation is started by selecting either the menu *Optimisation → Start Optimisation* or the button *Optimise* in the toolbar. The solution is displayed in both the Network and Data areas (Figure 75).

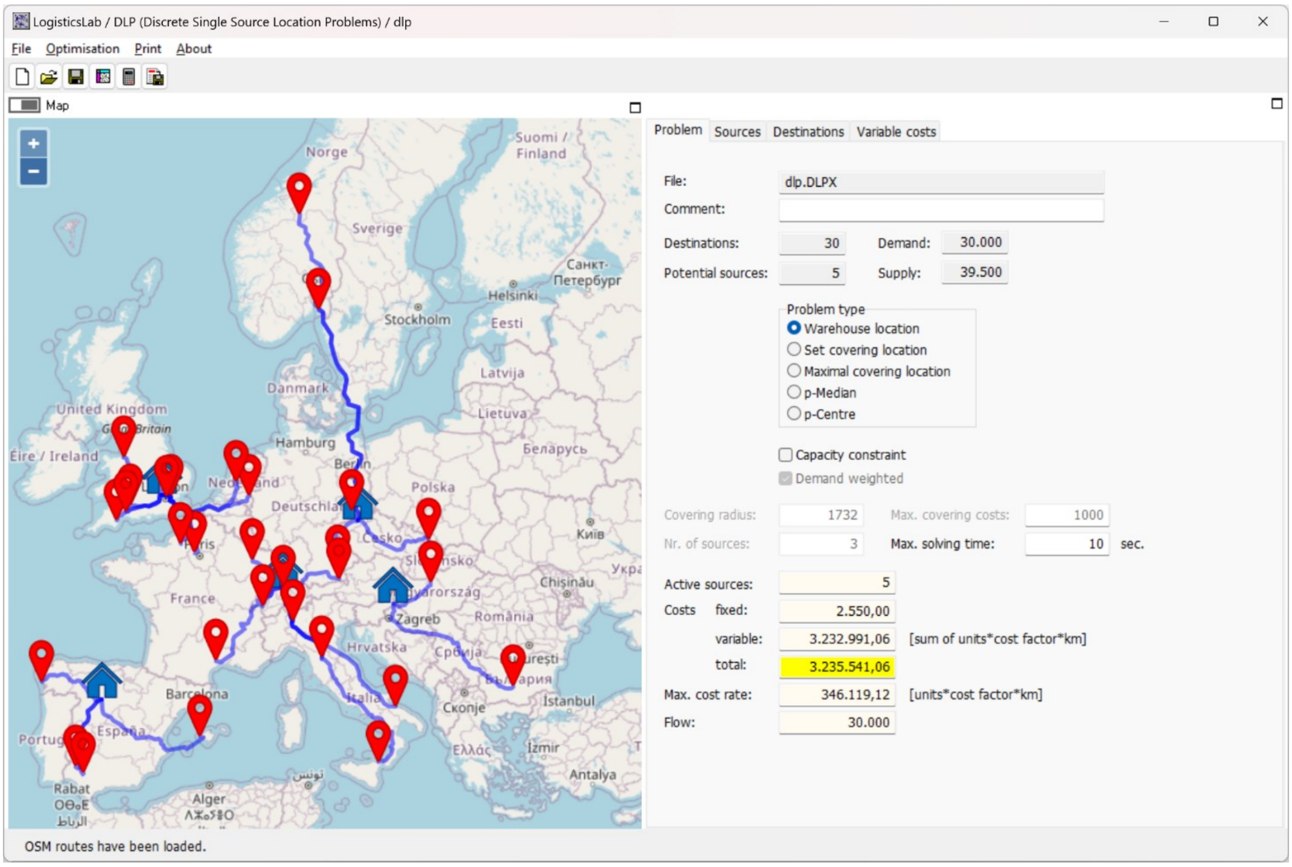
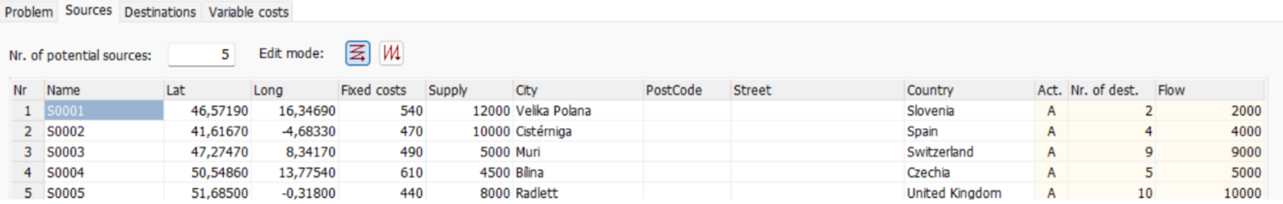


Figure 75: Representation of the solution of the WLP example in LogisticsLab/DLP

The selected locations are displayed in the *Sources* tab (Figure 76) and the customer assignments in the *Destinations* tab (Figure 77).

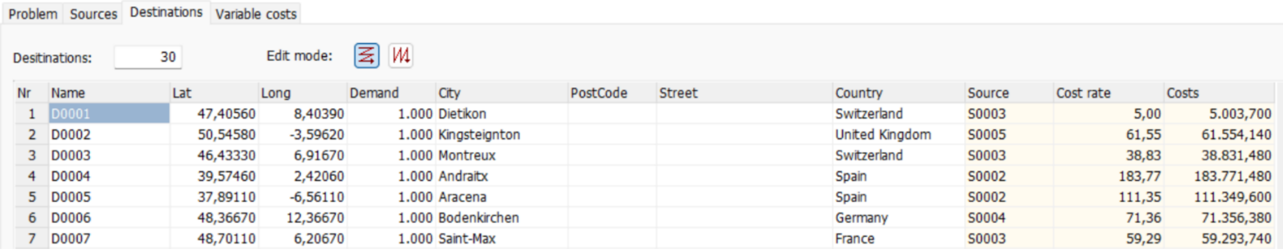


Problem | Sources | Destinations | Variable costs

Nr. of potential sources: 5 Edit mode:

Nr	Name	Lat	Long	Fixed costs	Supply	City	PostCode	Street	Country	Act.	Nr. of dest.	Flow
1	S0001	46,57190	16,34690	540	12000	Velika Polana			Slovenia	A	2	2000
2	S0002	41,61670	-4,68330	470	10000	Cistérniga			Spain	A	4	4000
3	S0003	47,27470	8,34170	490	5000	Muri			Switzerland	A	9	9000
4	S0004	50,54860	13,77540	610	4500	Bilina			Czechia	A	5	5000
5	S0005	51,68500	-0,31800	440	8000	Radlett			United Kingdom	A	10	10000

Figure 76: Representation of the solution of the WLP example in the Sources tab in LogisticsLab/DLP



Problem | Sources | Destinations | Variable costs

Desitinations: 30 Edit mode:

Nr	Name	Lat	Long	Demand	City	PostCode	Street	Country	Source	Cost rate	Costs
1	D0001	47,40560	8,40390	1.000	Dietikon			Switzerland	S0003	5,00	5.003,700
2	D0002	50,54580	-3,59620	1.000	Kingsteignton			United Kingdom	S0005	61,55	61.554,140
3	D0003	46,43330	6,91670	1.000	Montreux			Switzerland	S0003	38,83	38.831,480
4	D0004	39,57460	2,42060	1.000	Andraitx			Spain	S0002	183,77	183.771,480
5	D0005	37,89110	-6,56110	1.000	Aracena			Spain	S0002	111,35	111.349,600
6	D0006	48,36670	12,36670	1.000	Bodenkirchen			Germany	S0004	71,36	71.356,380
7	D0007	48,70110	6,20670	1.000	Saint-Max			France	S0003	59,29	59.293,740

Figure 77: Representation of the solution of the WLP example in the tab Destinations in LogisticsLab/DLP

LogisticsLab uses heuristics to solve problems. Therefore, the solutions of different optimisation runs may differ due to the non-deterministic nature of the underlying heuristic.

The planning result can be saved as a text file with the file extension *SOLX.*

9 DLP – Solving Covering and Maximal Covering Location Problems

LogisticsLab/DLP can also solve Covering Location Problems[24] and Maximal Covering Problems[25].

The covering location problem seeks to find the minimum number of locations (or the minimum of their operating costs) and their optimal locations to cover the demand within a specified area (diameter based on distances, times, service level).

With Maximal Covering Problems, the maximum covered demand of the destinations has to be found subject to an upper bound of locations or their operating costs.

9.1 Entering the problem data

The process of entering the problem data is identical to that of a Warehouse Location Problem, although not all data is used for both covering location problems.

If not the operation costs of the potential locations, but the number of locations shall be considered, then the fixed cost in the tab Sources have to be equal to one.

If real street distances should be used, then the distances have to be generated again with a distance factor equal to one (Figure 78).

[24] Steglich et al. (2016) , p. 417 ff., Daskin (2013), Pos. 2479, García and Marín (2015), p. 97f.

[25] Steglich et al. (2016) , p. 424 ff., Daskin (2013), pos. 3128ff.

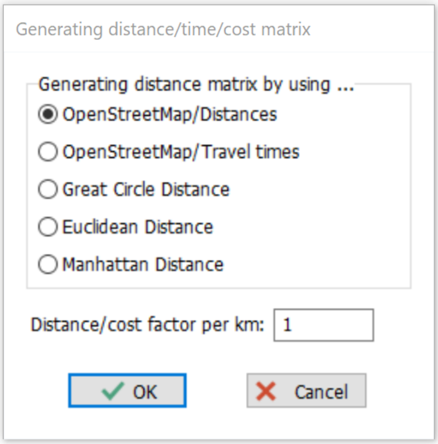
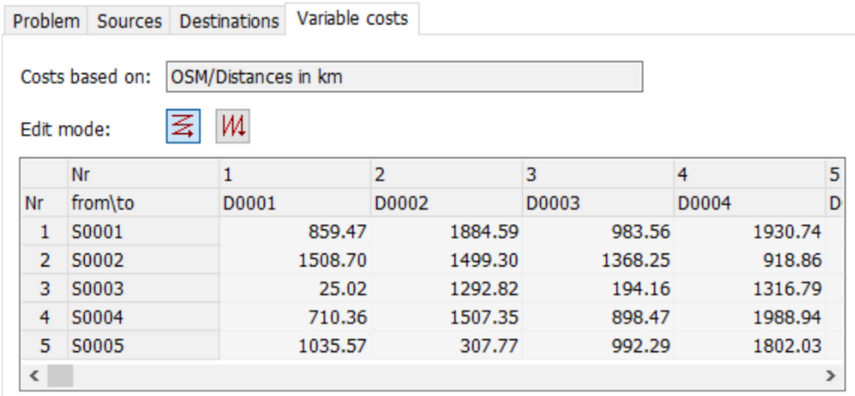


Figure 78: Generating real distances with a distance factor equal to one in LogisticsLab/DLP

The resulting distances can be found in the *Variable Cost* tab (Figure 79).



	Nr	1	2	3	4	5
Nr	from\to	D0001	D0002	D0003	D0004	D
1	S0001	859.47	1884.59	983.56	1930.74	
2	S0002	1508.70	1499.30	1368.25	918.86	
3	S0003	25.02	1292.82	194.16	1316.79	
4	S0004	710.36	1507.35	898.47	1988.94	
5	S0005	1035.57	307.77	992.29	1802.03	

Figure 79: Distance matrix in LogisticsLab/DLP

9.2 Optimisation and results

The problem can be solves if all data are available. For this purpose, the problem type Set covering location or Maximal covering location has to be chosen in the tab Problem (Figure 80 and Figure 81).

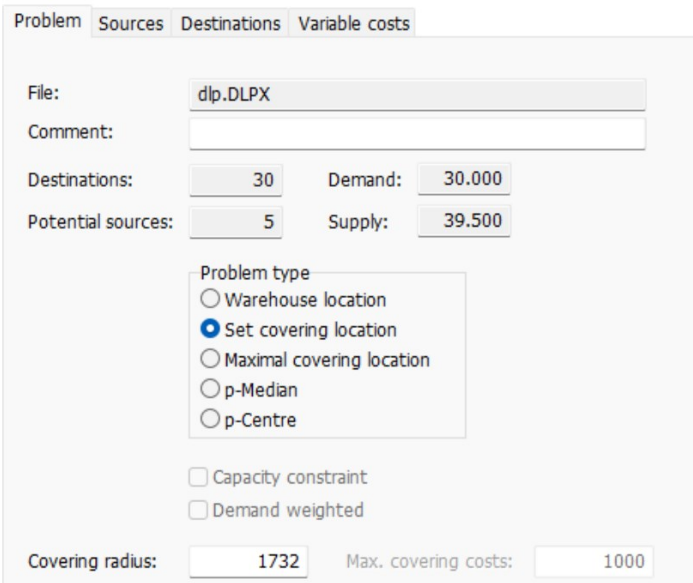


Figure 80: Selection of problem type and covering radius for a Covering Location Problem in LogisticsLab/DLP

Afterwards, a Covering radius for both problems and additionally Max. Coverage costs for the Maximal Covering Location Problem must be entered (Figure 80 and Figure 81). In this example, it is assumed that the locations can only serve destinations within a maximal distance of 1732 kilometres. For the Maximal Covering Location Problem is a requirement, that a budget of only 1,000 is available.

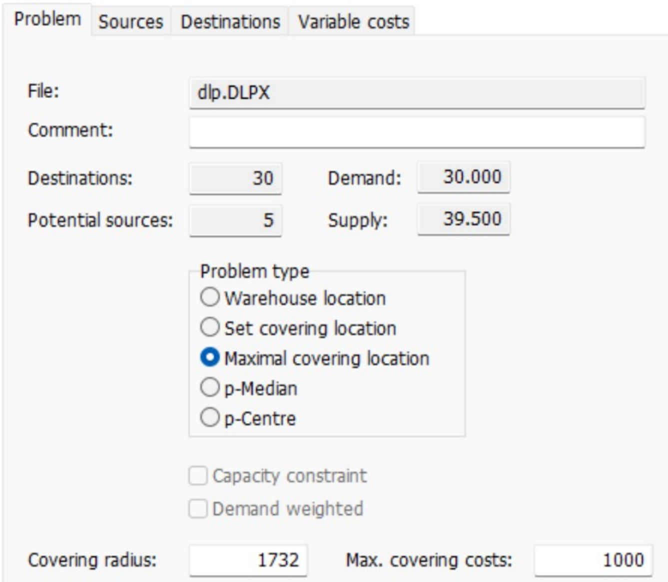


Figure 81: Selection of problem type, covering radius and max. covering costs for a Maximal Covering Problem in LogisticsLab/DLP

The optimisation is started by selecting either the menu *Optimisation → Start Optimisation* or the button *Optimise* in the toolbar. The solution is displayed in the Network and Data areas (Figure 82 and Figure 83).

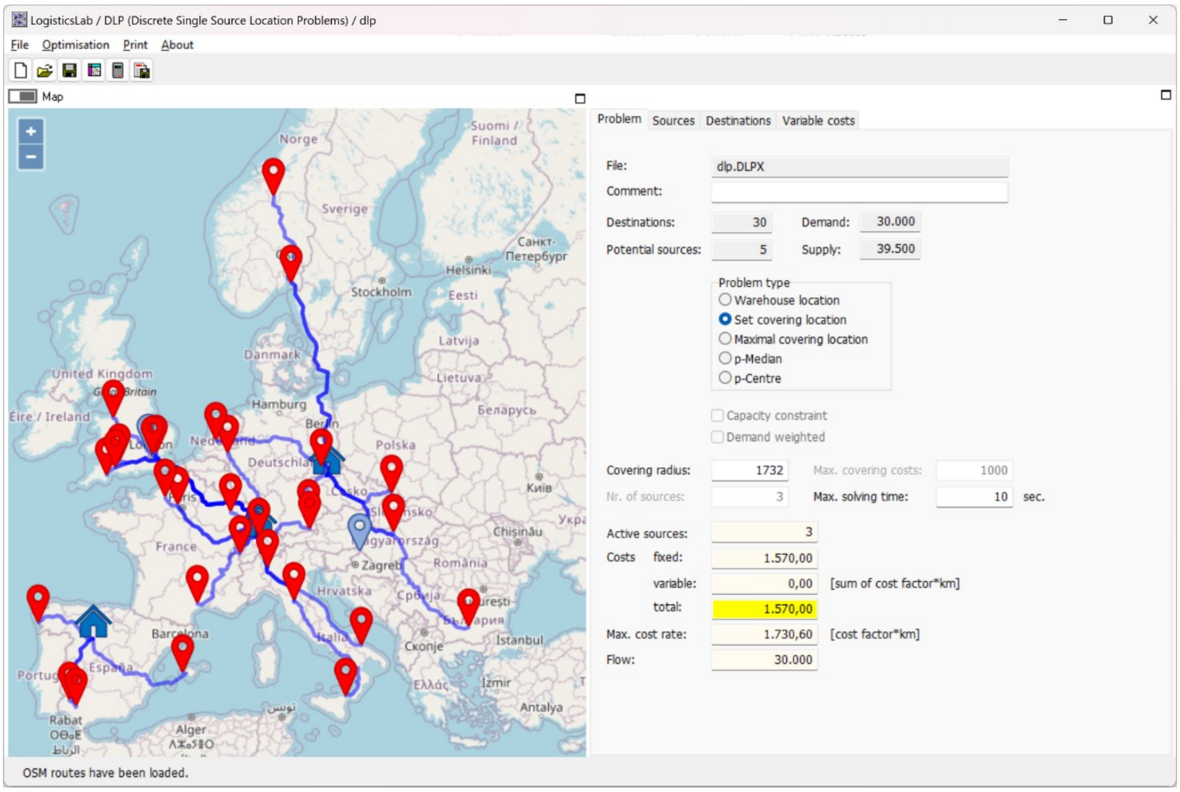


Figure 82: Representation of the solution of for a Covering Location Problem in LogisticsLab/DLP

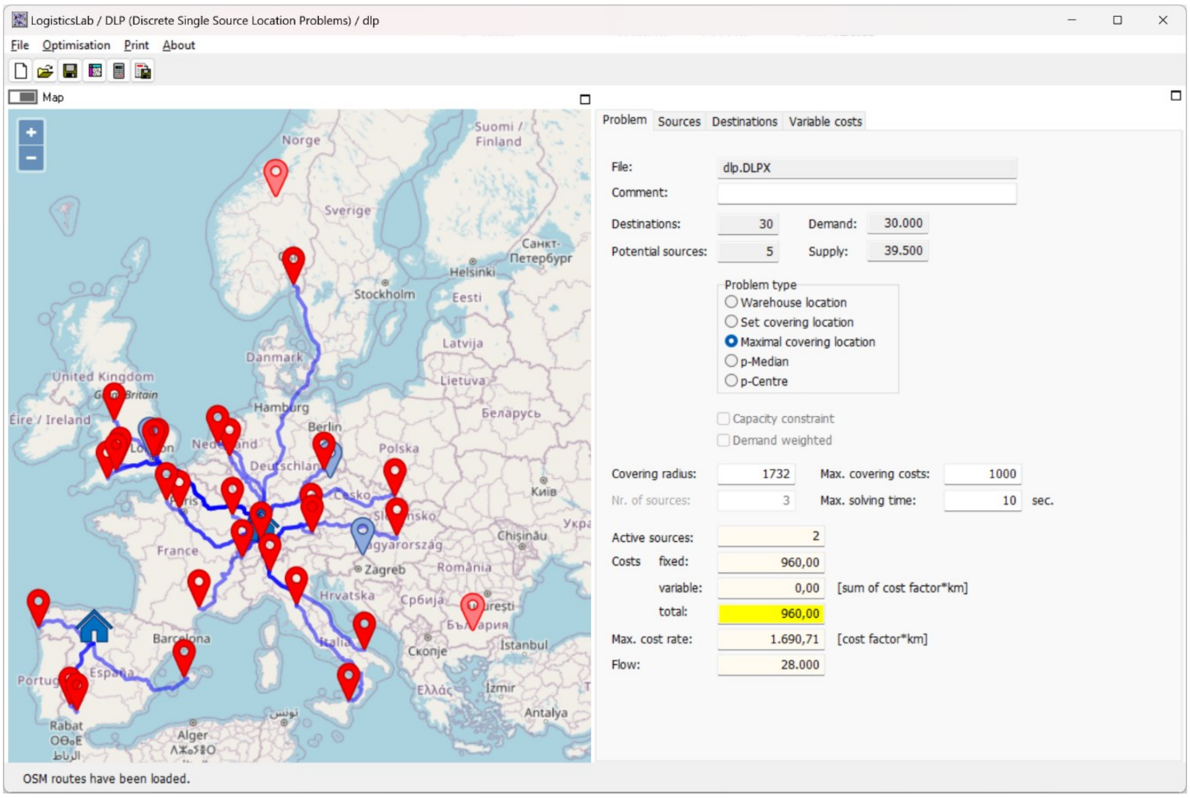


Figure 83: Representation of the solution of for a Maximal Covering Location Problem in LogisticsLab/DLP

It is worth mentioning that there is usually no single-source constraint in the coverage problem. This means that a destination can be covered by more than one location. If this is the case internally in LogisticsLab/DLP, the nearest location is selected and displayed in the solution.

10 DLP – Solving p-Median and p-Centre Location Problems

As of version 5.2, it is possible to solve p-Median[26] and p-Centre problems[27]. P-Median problems aim at minimising the sum of the weighted distances and consists of finding the optimal locations of *p* pre-selected potential sources. The p-Centre problem aims at minimising of the maximum (weighted) distance of the demand locations to the corresponding locations of *p* pre-selected potential sources.

10.1 Entering the problem data

The process of entering the problem data is identical to that of a Warehouse Location Problem, although not all data is used for these problems.

10.2 Optimisation and results

The problem can be solved if all data are available. For this purpose, the problem type *p-Median* or *p-Centre* has to be chosen in the tab *Problem* (Figure 84). In addition, a user has to decide to solve the problem considering the capacities of the potential location or not (*Capacitaty constraint*) and also whether the demands are used to weight the cost rates of the edges (*Demand weights*).

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[26] Steglich et al. (2016), p. 380 ff., Daskin and Maas (2015), p. 25f.

[27] Steglich et al. (2016), p. 390 ff., Daskin (2013), pos. 4272.

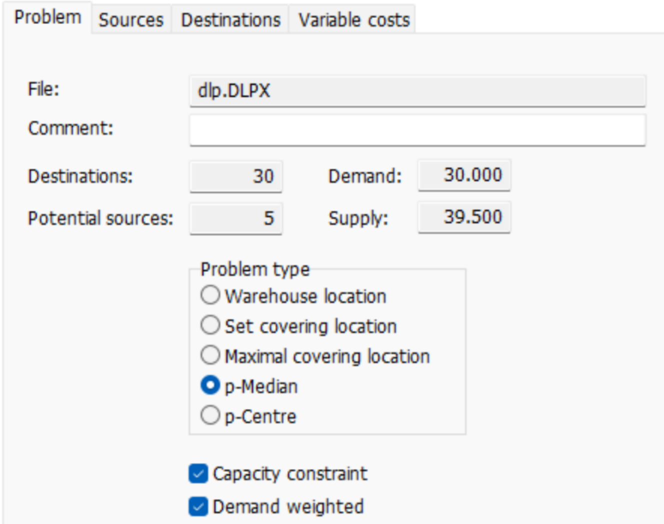


Figure 84: Selection of problem type for a p-Median Problem in LogisticsLab/DLP

The optimisation is started by selecting either the menu *Optimisation → Start Optimisation* or the button *Optimise* in the toolbar. The solution is displayed in both the Network and Data areas (Figure 85).

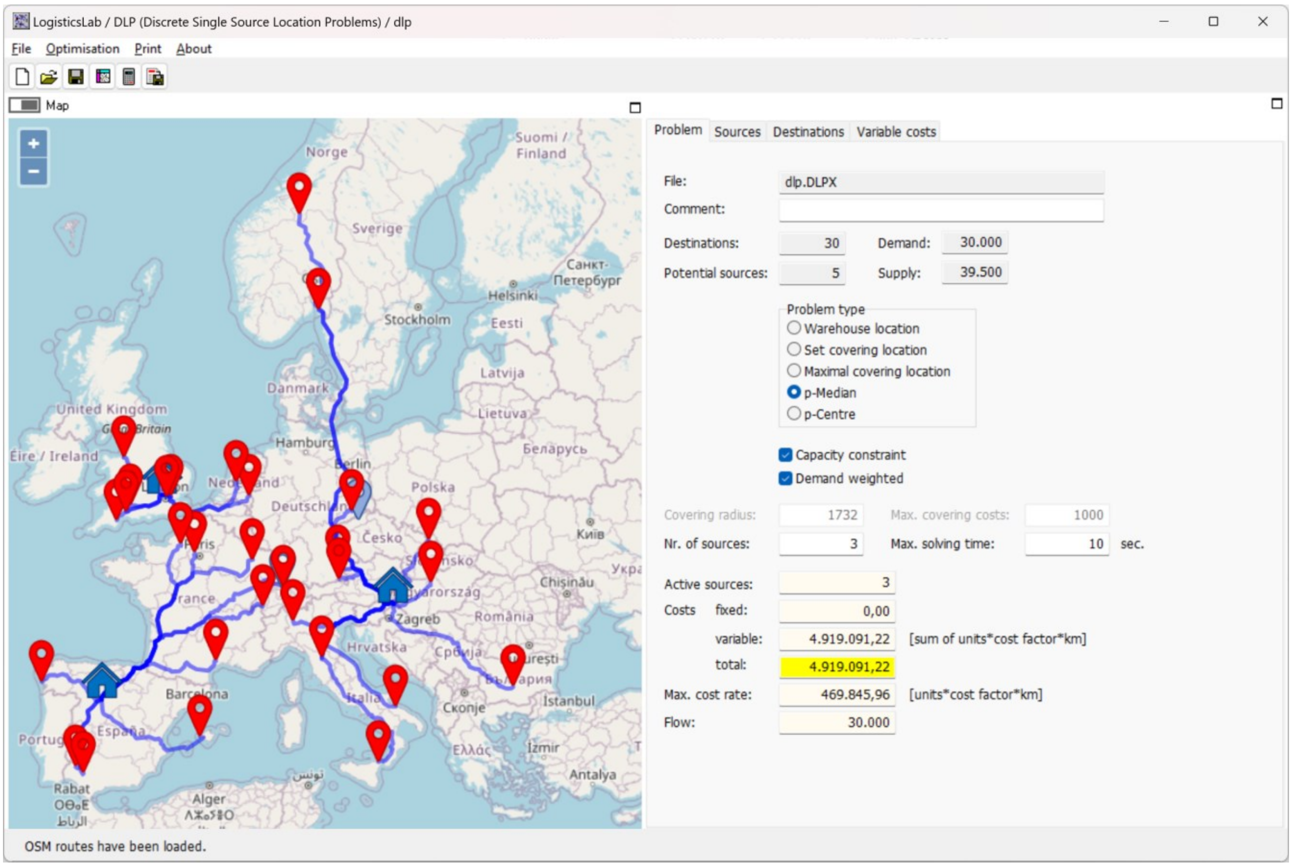
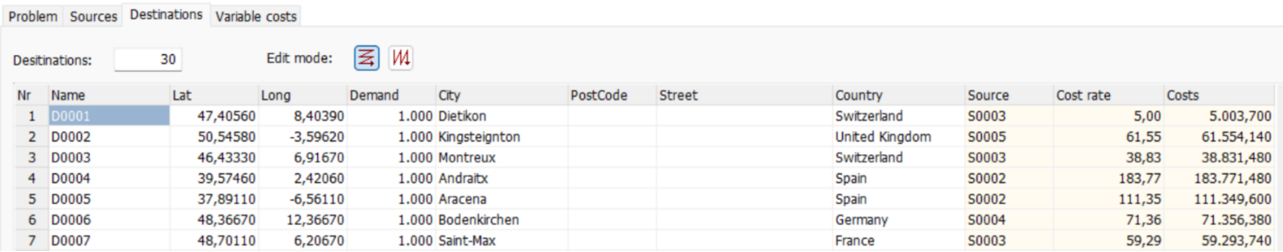


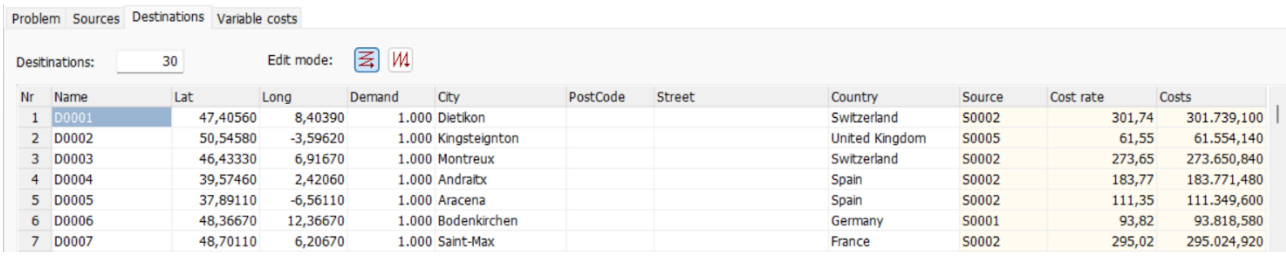
Figure 85: Representation of the solution of the p-Median example in LogisticsLab/DLP

The selected locations are displayed in the *Sources* tab (Figure 86Figure 76) and the customer assignments in the *Destinations* tab (Figure 87).



Nr	Name	Lat	Long	Demand	City	PostCode	Street	Country	Source	Cost rate	Costs
1	D0001	47,40560	8,40390	1.000	Dietikon			Switzerland	S0003	5,00	5.003,700
2	D0002	50,54580	-3,59620	1.000	Kingsteignton			United Kingdom	S0005	61,55	61.554,140
3	D0003	46,43330	6,91670	1.000	Montreux			Switzerland	S0003	38,83	38.831,480
4	D0004	39,57460	2,42060	1.000	Andraitx			Spain	S0002	183,77	183.771,480
5	D0005	37,89110	-6,56110	1.000	Aracena			Spain	S0002	111,35	111.349,600
6	D0006	48,36670	12,36670	1.000	Bodenkirchen			Germany	S0004	71,36	71.356,380
7	D0007	48,70110	6,20670	1.000	Saint-Max			France	S0003	59,29	59.293,740

Figure 86: Representation of the solution of the p-Median example in the Sources tab in LogisticsLab/DLP



Nr	Name	Lat	Long	Demand	City	PostCode	Street	Country	Source	Cost rate	Costs
1	D0001	47,40560	8,40390	1.000	Dietikon			Switzerland	S0002	301,74	301.739,100
2	D0002	50,54580	-3,59620	1.000	Kingsteignton			United Kingdom	S0005	61,55	61.554,140
3	D0003	46,43330	6,91670	1.000	Montreux			Switzerland	S0002	273,65	273.650,840
4	D0004	39,57460	2,42060	1.000	Andraitx			Spain	S0002	183,77	183.771,480
5	D0005	37,89110	-6,56110	1.000	Aracena			Spain	S0002	111,35	111.349,600
6	D0006	48,36670	12,36670	1.000	Bodenkirchen			Germany	S0001	93,82	93.818,580
7	D0007	48,70110	6,20670	1.000	Saint-Max			France	S0002	295,02	295.024,920

Figure 87: Representation of the solution of the p-Median example in the tab Destinations in LogisticsLab/DLP

LogisticsLab uses heuristics to solve larger problems. Therefore, the solutions of different optimisation runs may differ due to the non-deterministic nature of the underlying heuristic.

The planning result can be saved as a text file with the file extension *SOLX.*

11 CLP – Solving Continuous p-Median and p-Centre Problems

LogisticsLab/CLP is a software to solve continuous median and centre problems. Continuous location problems determine the best possible *greenfield* location. The point where a planned logistics node can be optimally placed is to be found within a certain area. The individual points on a flat surface or on a spherical surface represent the positions of a potential location.

The following two approaches are distinguished:

- The *median problem* aims at minimising the sum of the (weighted) distances and consists of finding one or more optimal locations. Depending on the number *p* of locations sought, these problems are also called p-Median Problems[28].
- The *centre problem* aims at minimising of the maximum (weighted) distance of the demand locations to the corresponding locations and consists in the determination of one or more centres. Depending on the number *p* of locations sought, these problems are also called p-Centre Problems[29].

Continuous planning algorithms provide point coordinates for locations, but these can rarely be used unchanged. Usually, the identification of a theoretical location must be followed by an analysis in which the sites located within a certain radius of the found point are examined regarding their suitability for the construction of the facility and a suitable location is selected.

[28] Steglich et al. (2016), p. 402ff., Neema at al. (2011), p. 84, Eiselt and Marinov (2011), p. 9.

[29] Steglich et al. (2016), p. 411ff., Drezner (2011), p. 73f., Calik at al. (2015), p. 89.

11.1 Program interface

After starting the program, the program window shown in Figure 88 appears, which, like all other components of LogisticsLab, consists of a network area and a data area.

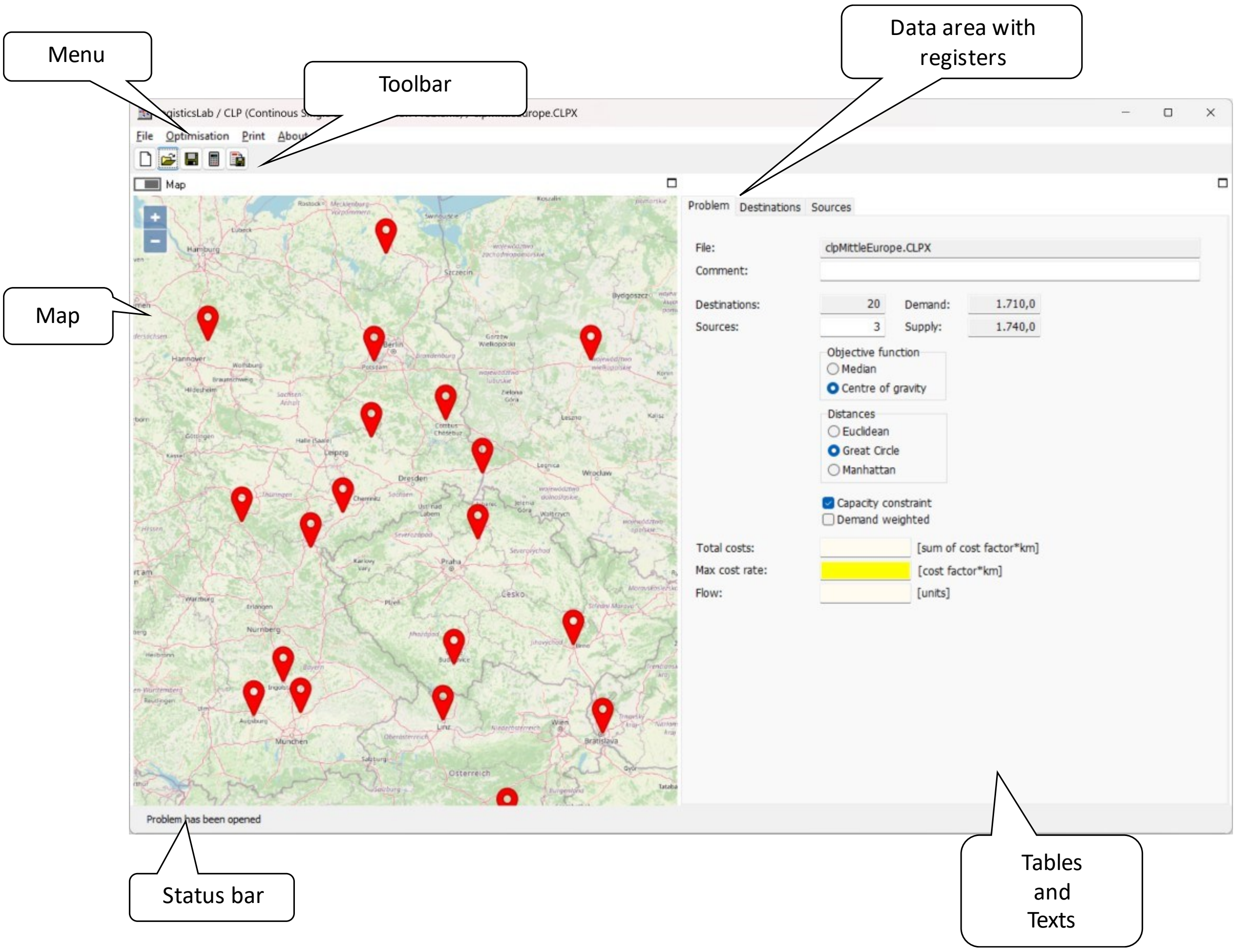


Figure 88: Program interface - LogisticsLab/CLP

The left side of the CLP program window is used to visualise the entered data and the solution of the problem. Destinations are shown as red markers. The determined locations are shown as blue houses

11.2 Entering the problem data

The data area on the right side of the CLP program interface contains three tabs for entering data (*Problem, Destinations, Sources*). The first step is to generate a **new problem.** For this purpose, the menu item *File → New Problem* or the button *New Problem in the* toolbar can be selected. In the dialogue that appears (Figure 89), enter a short description of the *Problem* and the number of *Destinations.*

Geographical coordinates can be generated randomly based on a set of European cities and villages or as empty geographical coordinates. The generated coordinates can be edited afterwards.

Regarding the destinations, an average demand (*volume per destination*) can also be specified. This is either assigned to all recipients as a constant value if *Volume per destination → Constant* is selected or represents the basis of randomly generated demands with an exponential distribution or uniform distributed in the interval of [-50 %, +50 %]. Furthermore, an average distance between the recipients can also be entered (*Max. distance*), which can be randomly varied in an interval of [-50 %, +50 %] or left as a constant value.

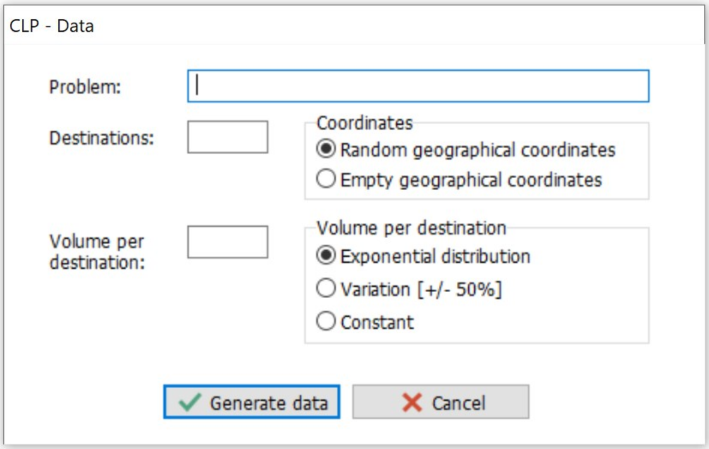


Figure 89: Creating a problem in LogisticsLab/CLP

The ***Problem*** tab (Figure 90) contains input fields for a *Comment* and an input field for the number of locations to be determined (*Sources*). Furthermore, the tab contains options for specifying the problem type of the optimisation calculation (*Medians* and *Centre of gravity*), a selection option for the distance function to be used (*Distance → Euclidean*, *Great Circle*, *Manhattan*) and yellow highlighted output fields for information on the solution. In addition, it is possible to specify whether the capacities of the locations should be considered (*Capacity constraint*), the demands of the receivers should be included in the objective function (*Demand weighted)* and only locations on existing demand nodes can be used to solve a discrete location problem (*discrete*). If a new value is entered in the *Sources* input field, either new potential locations without coordinates are added to the location list or surplus locations are deleted.

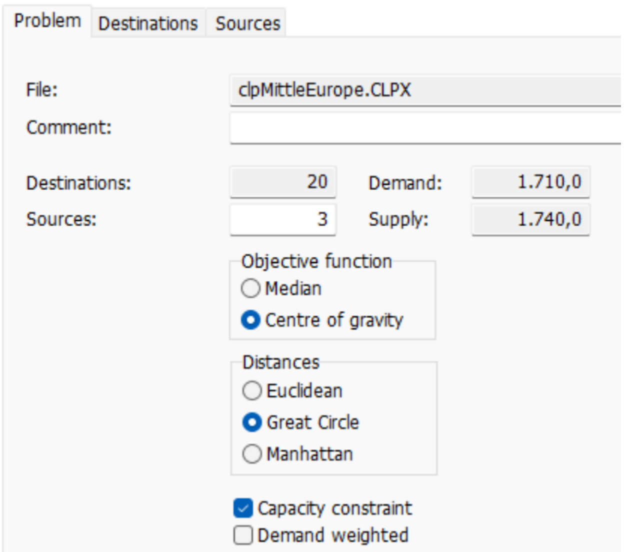


Figure 90: Problem tab in LogisticsLab/CLP

The ***Destinations*** tab (Figure 91) contains the information on the demand nodes. They are displayed after loading the problem data or can be entered and changed manually. Entering the number of demand nodes (*Destinations*) adjusts the size of the input sheet. If the number is reduced, surplus entries are deleted after confirmation.

For the destinations, the following information can be provided:

- *Fixed*: Fixing the destination to a location,
- *Name*: Name of the destination*,*
- *Lat., Long*: Coordinates of the location,
- Demand: Demand of the destination,
- Cost *factor*: Cost rate per kilometre and unit of the goods to be transported,
- *City, PostCode, Street, Country*: Address data.

If a user has entered valid address data, it is possible to retrieve the geographical coordinates of all nodes (*All coords*) or of the selected node (*Node coords*) via a Komoot/Photon server.

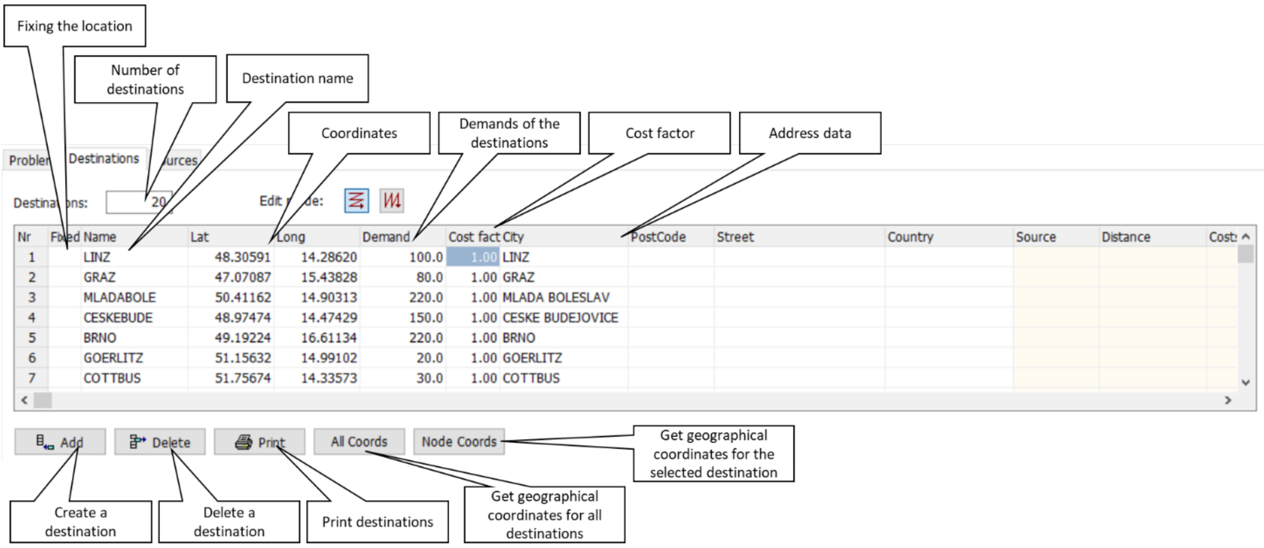


Figure 91: Destinations tab in LogisticsLab/CLP

After the optimisation, the *Destinations* tab displays the destination-relevant solution details.

In the *Source* column, LogisticsLab enters the name of the assigned location and in the columns *Distance* and *Costs* the corresponding information regarding the relation destination-location. These values cannot be changed manually.

It is possible to enter a different location identifier in the *Source* column and thus define a new customer-location assignment. After entering the new location, LogisticsLab/CLP calculates the costs and displays the changed values for the distances and costs depending on it in all tabs. Furthermore, the network graphic is updated.

A new destination can be added via the *Add* button. The *Delete* button deletes the selected destination. The destination list can be printed using the *Print* button.

With a click on a destination in the *Nr* column, it is marked with a red flag in the map. A mouse click on the upper left grey field *Nr* restores the normal display of all clients. Clicking on the *Fixed* column heading again deletes all fixed assignments. A double-click in the *Fixed* column of a customer line changes the fixation of this destination.

The **Locations** tab (Figure 92) contains the details of the locations whose positions are to be determined by the optimisation. It is also possible to specify fixed positions for certain locations, to fix them and thus exclude them from the optimisation. After loading the problem data, the location data is displayed. They can also be entered manually and changed interactively.

By entering the number of locations (*Sources*), the size of the input sheet is adjusted automatically. If the number of locations is reduced, excess entries are deleted after confirmation.

The following information can be entered for the individual locations:

- *Fixed*: Fixing the location,
- *Name*: Name of the site; If no name has been entered, the LogisticsLab/CLP automatically assigns default identifiers (S001, S002, ...),
- *Lat., Long*: The coordinates of the location can be pre-set and remain unchanged after the location has been fixed. By default, the coordinates are pre-set with zero and then determined by the algorithm.

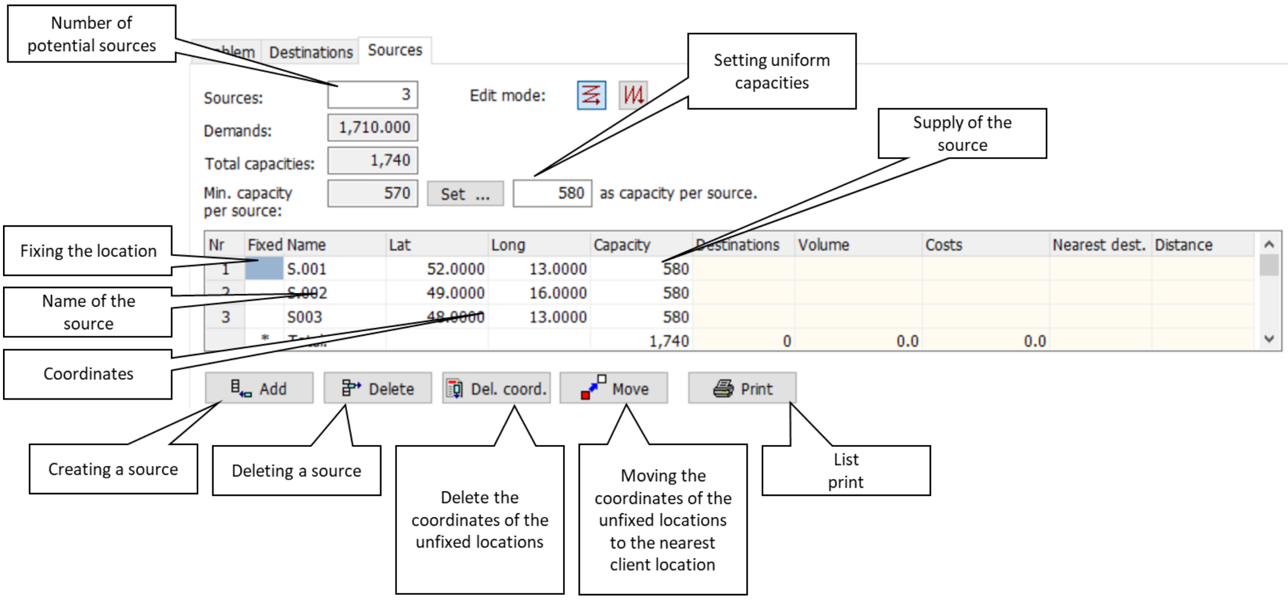


Figure 92: Sources tab in LogisticsLab/CLP

After the optimisation, the results for each location are entered in the following columns:

- *Destinations*: Number of assigned destinations,
- *Volume*: Delivery volume to the assigned destinations,
- *Costs*: total costs for delivery to the assigned destinations,
- *Nearest dest.:* Name of the nearest destination,
- *Distance*: Distance to the nearest destination.

These columns cannot be changed manually. If, however, the coordinates of a location are changed, the result values are recalculated and displayed.

A new location can be created via the *Add* button. The button *Delete* deletes the selected location. The *Del. coord.* button deletes the coordinates of all non-fixed locations, i.e. the location coordinates are set to zero. The *Move* button moves the non-fixed locations to the nearest destination location. Afterwards, all characteristic values are recalculated and the displays are updated. The *Print* button can be used to print the location list.

If one clicks on a location in the *Nr* column, it is marked with a blue flag in the map. A mouse click on the column header *Nr* restores the normal display of all locations.

A mouse click on the column header *Fixed* field fixes all locations. Clicking on it *again* removes all fixations. A double click in the *Fixed* column of a location row changes the fixation of this location.

After a mouse click on the column header *Name,* the standard names S001, S002 ... are entered for all locations that do not yet have a name. After entering the data, it should be saved with the menu item *Save Problem* or *Save Problem as*.

11.3 Optimisation and results

Once all the data has been entered, the problem can be solved. To do this, the problem type (*medians* and *centre of gravity*) and the distance function to be used (*Distance → Euclidean*, *Great Circle*, *Manhattan*) must be selected in the *Problem* data area. In addition, it can be specified whether the capacities of the locations should be considered (*Capacity constraint*) and the demands of the destinations should be included in the objective function (*Demand weighted)*.

Optimisation is started by selecting either the *Optimisation → Start Optimisation* menu or the *Optimise* button in the toolbar.

The solution is displayed in both the network and data areas (Figure 93). The key figures of the solution can be found in the *Problem* tab (Figure 94).

LogisticsLab uses heuristics to solve problems. Therefore, the solutions of different optimisation runs may differ due to the non-deterministic nature of the underlying heuristic.

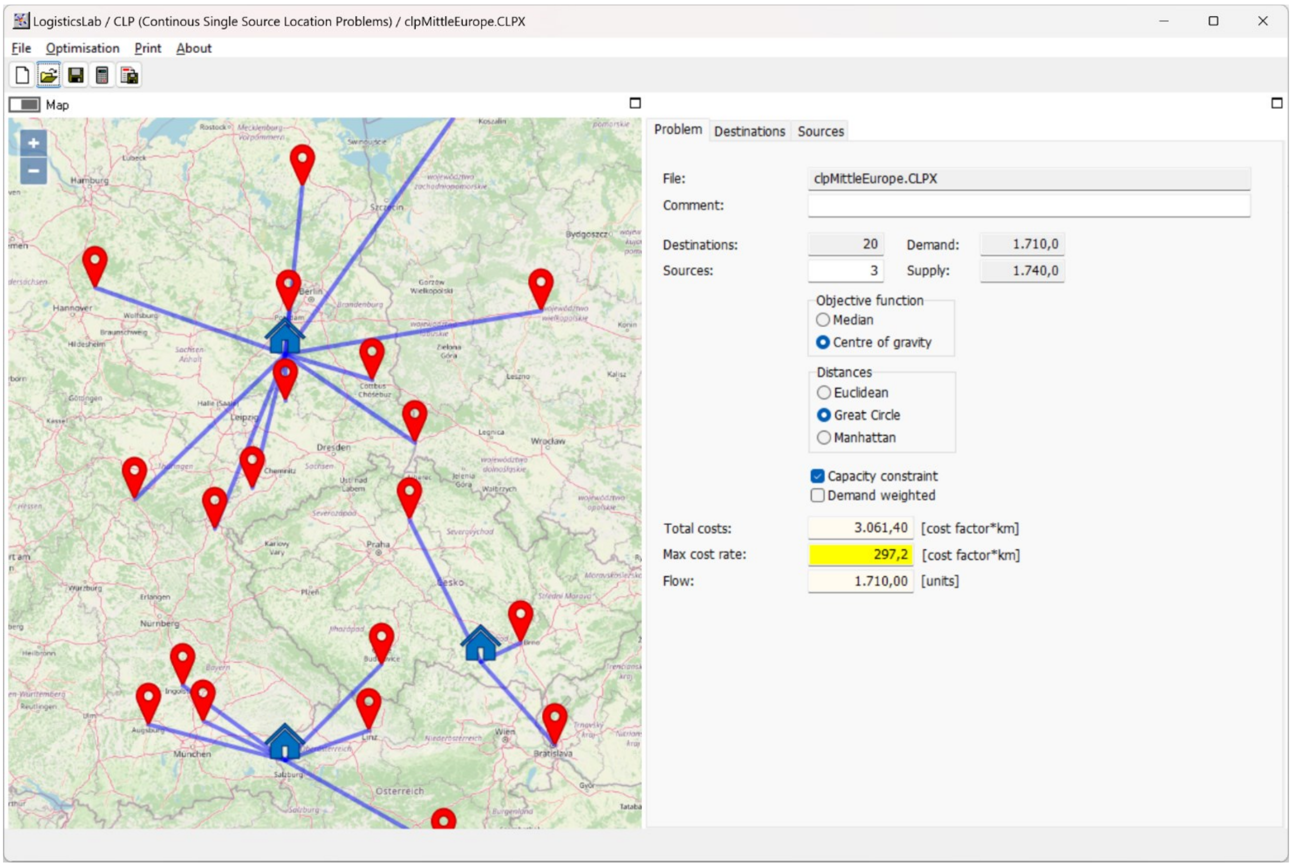


Figure 93: Representation of a solution in LogisticsLab/CLP

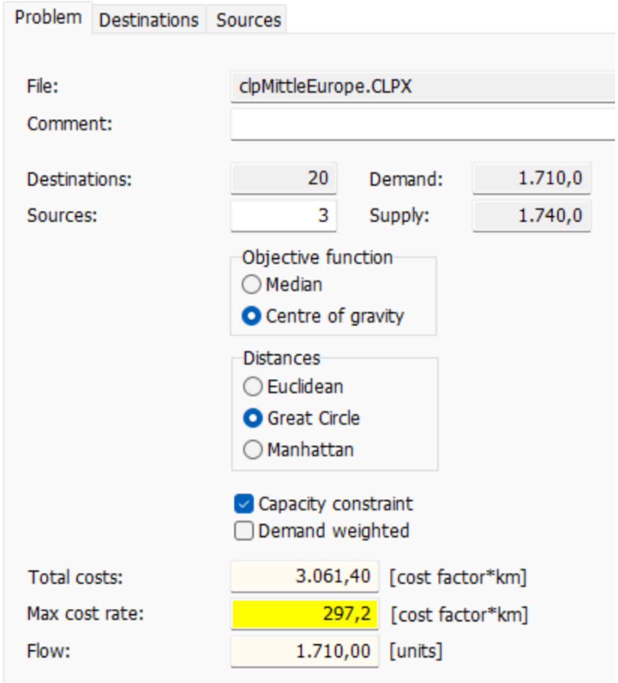
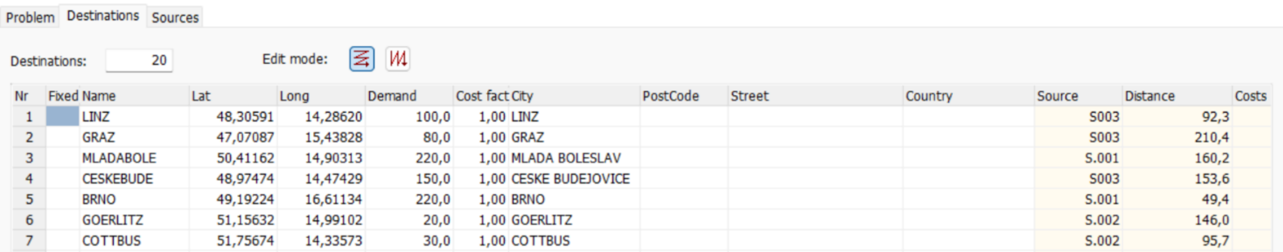


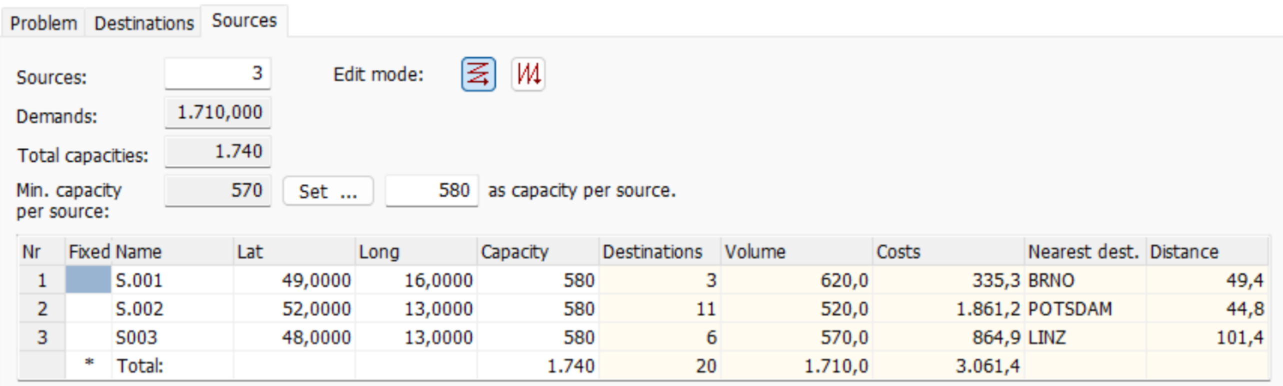
Figure 94: Display of the key figures of a solution in the data area Problem in LogisticsLab/CLP

In addition, the location coordinates can be viewed in the *Sources* tab (Figure 96) and the destination assignments in the *Destinations* tab (Figure 95).



Nr	Fixed	Name	Lat	Long	Demand	Cost fact	City	PostCode	Street	Country	Source	Distance	Costs
1		LINZ	48,30591	14,28620	100,0	1,00	LINZ				S003	92,3	
2		GRAZ	47,07087	15,43828	80,0	1,00	GRAZ				S003	210,4	
3		MLADABOLE	50,41162	14,90313	220,0	1,00	MLADA BOLESLAV				S.001	160,2	
4		CESKEBUDE	48,97474	14,47429	150,0	1,00	CESKE BUDEJOVICE				S003	153,6	
5		BRNO	49,19224	16,61134	220,0	1,00	BRNO				S.001	49,4	
6		GOERLITZ	51,15632	14,99102	20,0	1,00	GOERLITZ				S.002	146,0	
7		COTTBUS	51,75674	14,33573	30,0	1,00	COTTBUS				S.002	95,7	

Figure 95: Representation of the recipient assignments in the Destinations tab in LogisticsLab/CLP



Nr	Fixed	Name	Lat	Long	Capacity	Destinations	Volume	Costs	Nearest dest.	Distance
1		S.001	49,0000	16,0000	580	3	620,0	335,3	BRNO	49,4
2		S.002	52,0000	13,0000	580	11	520,0	1.861,2	POTSDAM	44,8
3		S003	48,0000	13,0000	580	6	570,0	864,9	LINZ	101,4
	*	Total:			1.740	20	1.710,0	3.061,4		

Figure 96: Display of the coordinates of the locations in the Sources tab in LogisticsLab/CLP

The results can be saved as a text file with the file extension *SOLX.*

12 Authors and contact

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