Identifying environmentally friendly facility locations using eCOmpass

Instructions on how to use eCOmpass using IKEA as an example.

eCOmpass is available at: https://ecompass.se/

As we will use the expansion of the IKEA store network after the turn of the century as our example, the working paper Carling et al. (2024a) and its online supplemental material, which presents the analysis in more detail, are also downloadable from the decision support system (DSS) website:

Carling, K., Paidi, V. & Rudholm, N. (2024a) Minimizing travel distance and CO2 emissions when reconfiguring retail store networks. HFI working Paper No. 37.

Carling, K., Paidi, V. & Rudholm, N. (2024b) Minimizing travel distance and CO2 emissions when reconfiguring retail store networks. Online supplemental material.

The tool is set up so that the user can supply either addresses or coordinates in the format supplied by Google/Google Maps as input into the system. The address version is, however, sensitive to misspelling etc, and if this causes problems eCOmpass will report this in an error message and suggest using coordinates instead. Example csv-files of how to organize the input data are supplied within the tool, as are the csv-files with coordinates used in the analysis of the expansion of the IKEA store network in Sweden after the turn of the century. The name of these files are:

IKEA 1958 to 2000 coordinates.csv
IKEA 1958 to 2010 coordinates.csv
IKEA 1958 to 2020 coordinates.csv.

As the name suggest, the first file gives the locations of the 13 IKEA stores in Sweden before the 2004-2007 round of IKEA entries. The second file gives the locations of the 17 IKEA stores in Sweden before the 2013 to 2016 round of entries, and the last one gives the locations of the 20 stores currently in use by IKEA (ignoring the city-store in Stockholm).

As an exercise and to understand how to use eCOmpass, we are going to replicate some of the results presented in Table 2 from Carling et al. (2024):

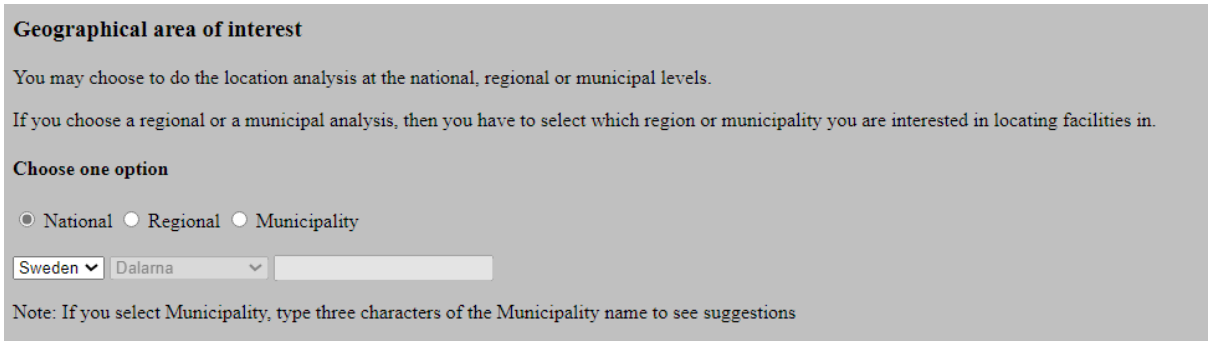
Table 2. IKEA store reconfiguration 2004-2016, real locations, optimal locations, reductions in average travel distance due to reconfiguration.

			Average distance to nearest IKEA store.		
Years of entry	Number of IKEA stores.	Distance to real IKEA locations	Reduction in distance in km (%)	Distance to optimal locations of new stores.	Reduction in distance in km (%)
1958-1993	13	87.0 km			
2004-2007	17	71.2 km	15.8 km (18.2%)	64.9 km	22.1 km (25.4%)
2013-2016	20	65.2 km	6.0 km (8.4%)	61.7 km	9.5 km (13.3%)

Note: 1 kilometer = 0.62 miles.

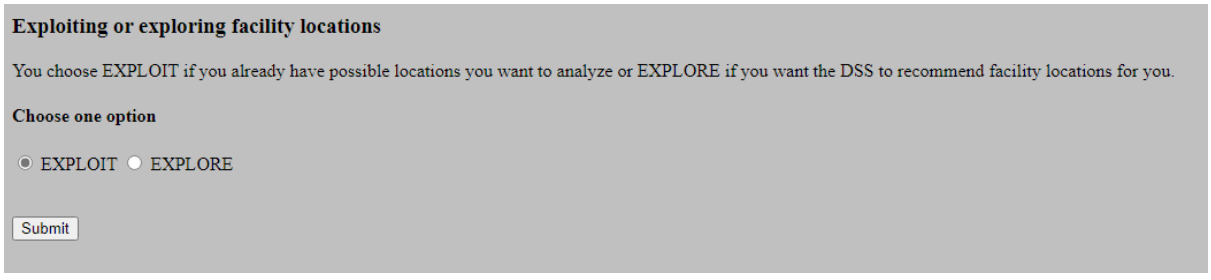
We will start with how to retrieve the distances to the actual locations in the different time periods, and then move on to the analysis of the optimal locations.

The first decision to be made in the DSS is on what geographical level the analysis is to be done. The alternatives are to do the analysis on the national, regional, or municipal level. For IKEA this will be at the national level as marked in the picture below, but for smaller retailers or other decision makers the other two alternatives might be more well-suited for the analysis. One could, for example, envision a school board using eCOmpass to place a new school in their municipality, or a region using it to locate a new emergency room within its health care system.



The second decision to be made is to choose between the DSSs two modes, “EXPLOIT” or “EXPLORE”. The “EXPLOIT” mode is used when the user knows the address or coordinates of the facilities they want to investigate, and these can then be either existing locations as in our IKEA example or potential new locations. The facility variable for existing locations are marked “1” in the csv-file, and potential new locations are marked “0”.

As we are investigating the distances and emissions of existing IKEA stores at different points in time, we will use the “EXPLOIT” mode and press submit.



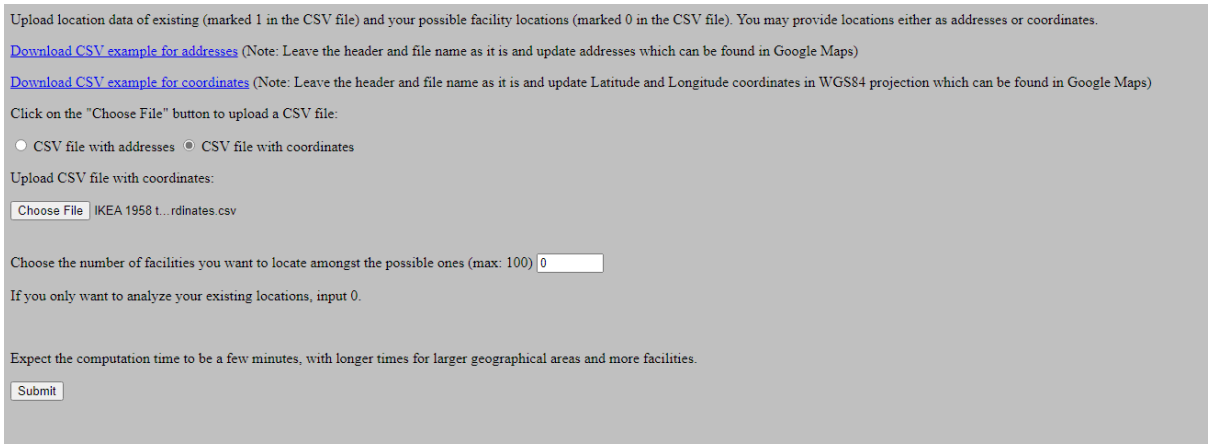
This takes us to the second page of the DSS, where we can download examples of how the csv-files should be created either using addresses or coordinates.

For our example, we will start by using the file “IKEA 1958 to 2000 coordinates.csv”, also supplied in the DSS, which gives the 13 IKEA locations before the 2004-2007 round of IKEA entries in Sweden, with the “facility” variable set to “1” since we are only dealing with existing locations.

Note that all information is given in one column, and using "," as the separator between Latitude, Longitude and facility.

Latitude,Longitude,facility
60.633759,16.993094,1
57.603742,12.048695,1
56.092249,12.762610,1
57.773762,14.203621,1
58.432467,15.586468,1
55.552489,12.989743,1
59.421108,17.859059,1
59.271002,17.916666,1
62.445176,17.334777,1
59.848242,17.694211,1
59.608244,16.456656,1
56.550128,14.162557,1
59.212934,15.134691,1

The tool cuts away some of the file name, but as stated above we are using the "IKEA 1958 to 2000 coordinates.csv". Since we are only studying existing locations, we are not trying to choose among possible locations, and the number of possible new locations should thus be set to "0". Then we again press "Submit", and when doing so, a map with the 13 existing IKEA store locations will appear. This is so that you can see if there are any obviously incorrect locations given in the csv-file. If, for example, one or more of the locations would be in Denmark rather than Sweden, you know that the csv-file is incorrect and need some attention.

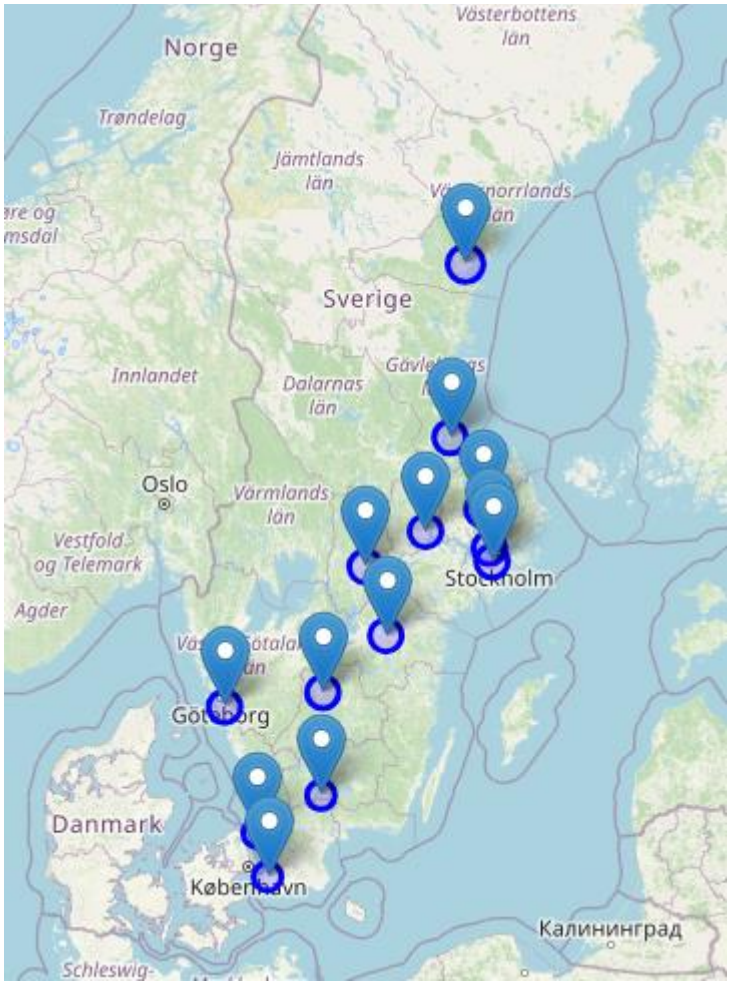


After a few minutes of work for the DSS, a results window will appear in eCOmpass. This window will include the following information:

Please find your results below
A total minimized weighted CO2 emissions of 135503675.7 Kg was observed.
A total minimized weighted distance of 903357838.0 Km was observed.

A mean kg/km CO2 emissions of 13.05 was observed
A mean distance of 87.0 km was observed
facility 0 serving 9.52% of customers;
facility 1 serving 8.64% of customers;
facility 2 serving 3.35% of customers;
facility 3 serving 9.88% of customers;
facility 4 serving 7.94% of customers;
facility 5 serving 2.29% of customers;
facility 6 serving 1.94% of customers;
facility 7 serving 4.59% of customers;
facility 8 serving 21.34% of customers;
facility 9 serving 3.35% of customers;
facility 10 serving 4.06% of customers;
facility 11 serving 11.46% of customers;
facility 12 serving 11.64% of customers;

Export Results

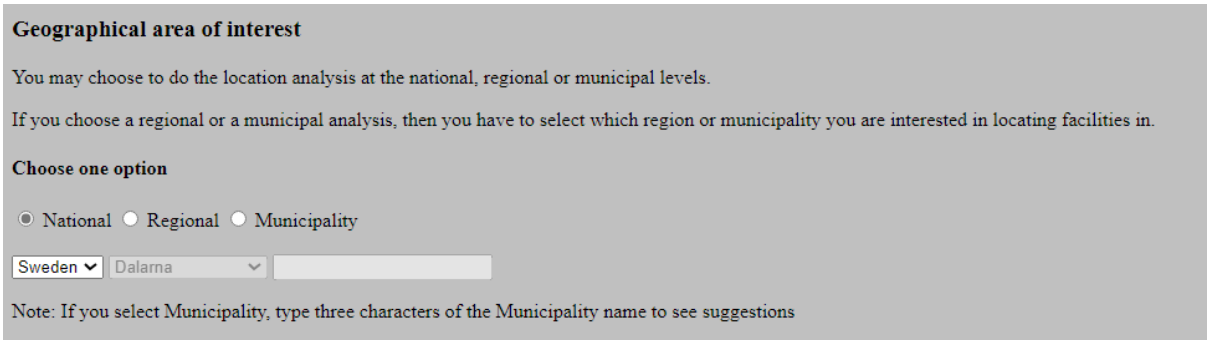


The map in the results window is also interactive so that you can get the coordinates of each location, zoom in and out, etc.

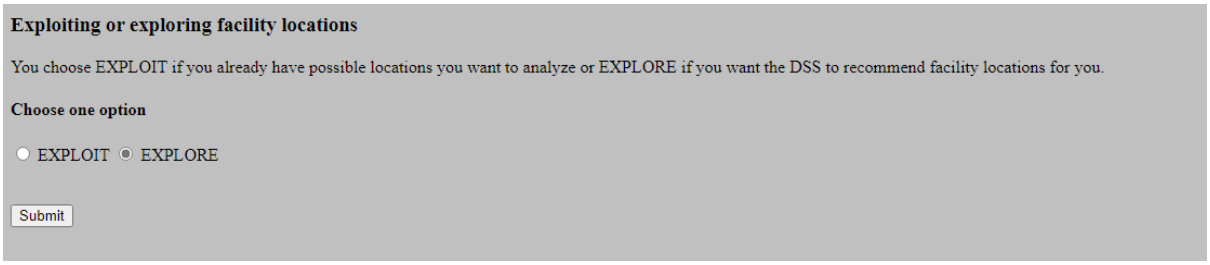
On the fourth row of the output text, we find “A mean distance of 87.0 km was observed” and if we compare it to Table 2 above, we see that we have been able to replicate the first important measure in the table.
To get the following two measures of the distances to the actual IKEA-stores, the procedure described above is repeated, but now using the csv-files “IKEA 1958 to 2010 coordinates.csv” and “IKEA 1958 to 2020 coordinates.csv” instead. This is left as an exercise in how to use eCOmpass!

Now we turn to a description of how to use eCOmpass to find the optimal locations from a travel distance and emissions perspective, i.e., we are now working to replicate the “Distance to optimal locations of new stores” column of Table 2.

As above, the analysis will be done at the national level (as in the picture below).

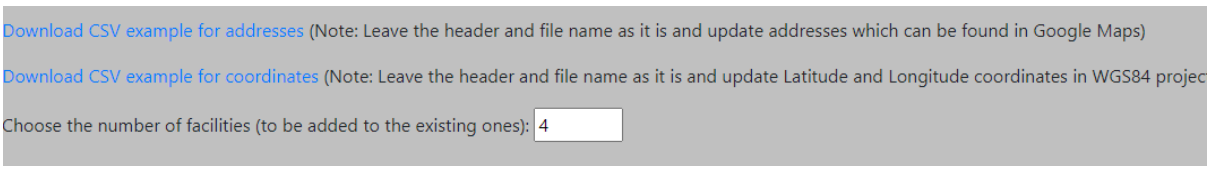


However, since we now want eCOmpass to provide the travel distance minimizing (optimal) location, we are now going to use the “EXPLORE” mode of the DSS.



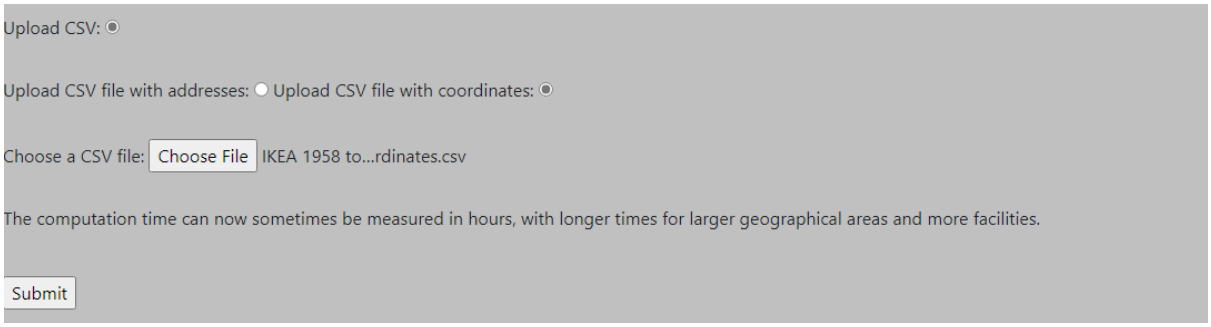
When pressing “Submit” the DSS takes us to the second page, and we are now first given the opportunity to download examples of the csv-files.

We are also asked to provide the number of new locations that we want to investigate. Since we know that IKEA located 4 new stores in the years 2004-2007 (Gothenburg, Kalmar, Karlstad and Haparanda), this is also the number we want to be able to compare how well IKEA could have done by using eCOmpass.



Then the DSS asks us to provide a csv-file with existing locations if there are any. The csv-file in the "EXPLORE" mode are in exactly the same format as in the "EXPLOIT" mode, but here we should never include any potential new stores marked zero, the files should only include already existing stores. In our IKEA example, the situation at the turn of the century is used as the baseline for the first round of entries, and we thus use the "IKEA 1958 to 2000 coordinates.csv" file.

NOTE 1: The full set of choices appears first after you have marked the "Upload CSV" here. The reason for this is that we might now not have any csv-file to provide, for example if there are no existing stores or facilities to consider.



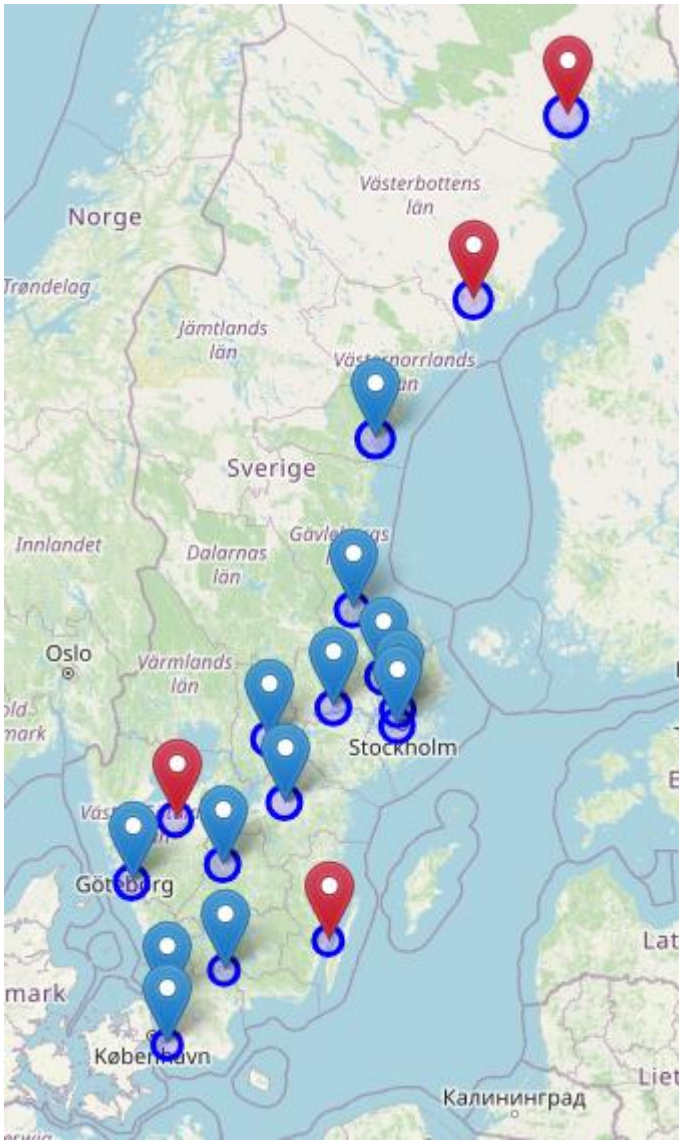
When clicking "Submit" a map of existing locations (if any) appears so that the user can check for irregularities.

NOTE 2: The computation time is considerably longer than in the "EXPLOIT" mode, and can often take several hours, or if trying to locate more than say 20-30 facilities, sometimes even days! Be patient!

When the optimization is done, a results window will appear, containing the same information as when using the "EXPLOIT" mode, but where the optimal locations suggested by eCOmpass are now marked in red rather than blue in the map provided by the DSS:

Please find your results below
A total minimized weighted CO2 emissions of 101094378.9 Kg was observed.
A total minimized weighted distance of 673962526.0 Km was observed.
A mean kg/km CO2 emissions of 9.74 was observed
A mean distance of 64.93 km was observed
facility 0 serving 2.47% of customers;
facility 2 serving 2.29% of customers;
facility 4 serving 1.94% of customers;
facility 6 serving 3.35% of customers;
facility 11 serving 3.35% of customers;
facility 14 serving 6.7% of customers;
facility 16 serving 6.53% of customers;
facility 18 serving 4.06% of customers;
facility 21 serving 4.41% of customers;
facility 24 serving 10.41% of customers;
facility 30 serving 9.7% of customers;

facility 47 serving 9.52% of customers;
facility 145 serving 7.41% of customers;
facility 161 serving 7.94% of customers;
facility 250 serving 6.0% of customers;
facility 286 serving 8.29% of customers;
facility 528 serving 5.64% of customers;



On the fourth row of the text, we find that “A mean distance of 64.93 km was observed”, and again we see that we have been able to replicate the analysis from Carling et al. (2024), Table 2.

As for the analysis of the optimal locations in the 2013 to 2016 round of entries, this is again left as an exercise in how to use the DSS. In this case, the csv-file named “IKEA 1958 to 2010 coordinates.csv” should be used for the baseline existing locations, and the number of stores to locate are now three. Good luck!

Now, an additional analysis is also included to show how to use potential locations in the “EXPLOIT” mode of the DSS. The result from this analysis is not presented in Table 2, only in the text in Carling

et al. (2024). The question we would like to answer is if IKEA, given that the 7 entries made after the turn of the century had to be in the chosen locations (Gothenburg, Kalmar, Karlstad, Haparanda, Uddevalla, Borlänge, Umeå), made them in the right order? Or could IKEA have reduced the distances to the nearest IKEA after the first set of entries more with some other configuration than Gothenburg, Kalmar, Karlstad and Haparanda?

Again, the analysis is done on the national level, and since we have potential locations supplied by IKEA, we use the "EXPLOIT" mode of eCOmpass. We input these choices and click "submit" to move on to the second page of the DSS.

We are now asked to supply a csv-file with existing and potential locations, and now we use the file "IKEA 1958 to 2010 coordinates.csv", but where we changed the facility variable for the last 7 locations to "0" since these are now the locations to choose from.

NOTE 3: You must make these changes in the csv-file supplied in the system yourself!

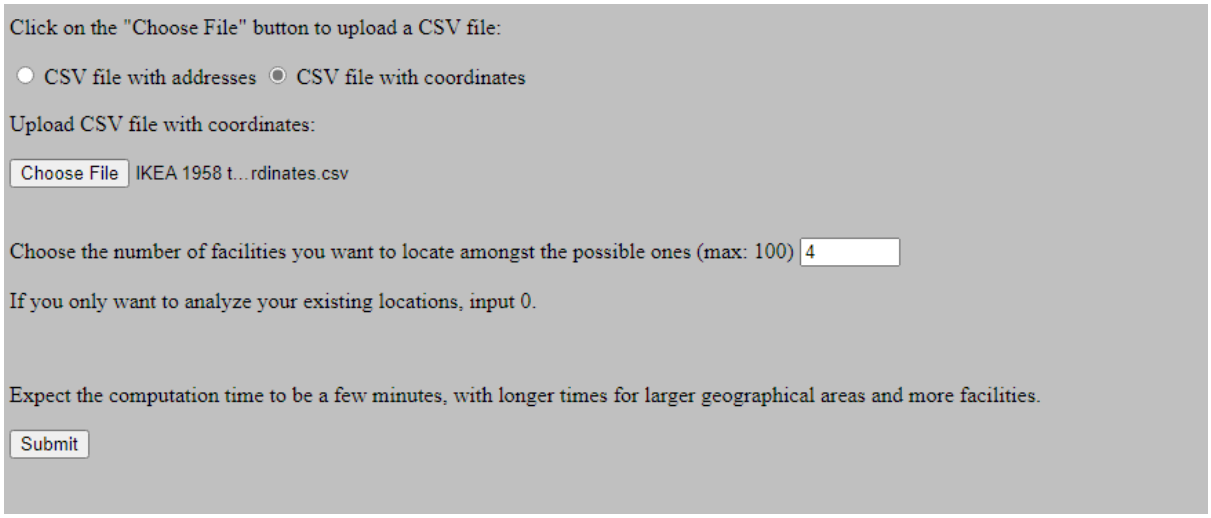
The file after the changes should look as follows:

Latitude,Longitude,facility
60.633759,16.993094,1
57.603742,12.048695,1
56.092249,12.762610,1
57.773762,14.203621,1
58.432467,15.586468,1
55.552489,12.989743,1
59.421108,17.859059,1
59.271002,17.916666,1
62.445176,17.334777,1
59.848242,17.694211,1
59.608244,16.456656,1
56.550128,14.162557,1
59.212934,15.134691,1
57.774386,12.001883,0
65.845223,24.126509,0
56.685677,16.320974,0
59.378745,13.419860,0
60.481601,15.421267,0
58.356521,11.818656,0
63.807555,20.254731,0

Here we see that the locations before 2004 are all marked "1" as existing store locations, and the following 7 are marked "0" as potential store locations.

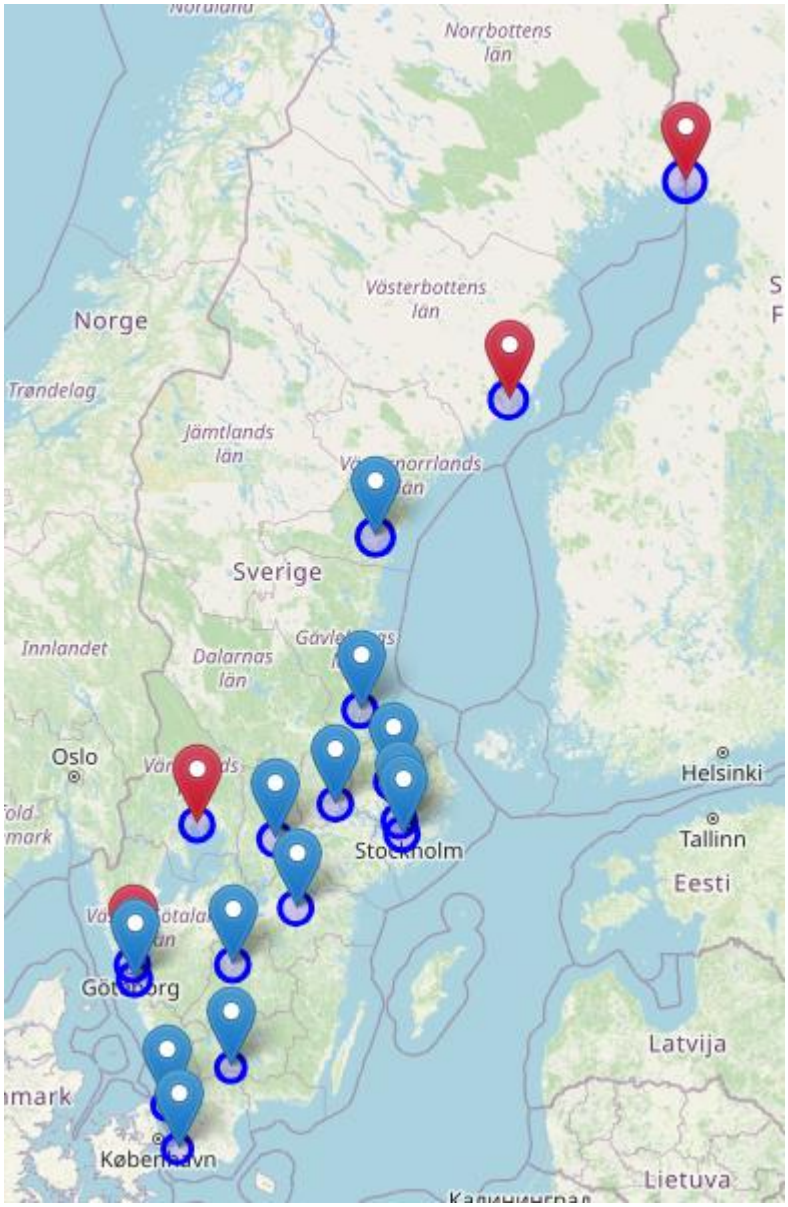
If we use this file and ask eCOmpass to choose 4 of the 7 potential store locations, we can see if these locations differ from the ones used by IKEA (i.e., Gothenburg, Kalmar, Karlstad and Haparanda). If they differ, we know that IKEA could have done better by doing this in a different order.

So, we input the above file and choose 4 locations:



After a few minutes the DSS delivers the results, and they are as follows:

Please find your results below
A total minimized weighted CO2 emissions of 108412593.75 Kg was observed.
A total minimized weighted distance of 722750625.0 Km was observed.
A mean kg/km CO2 emissions of 10.44 was observed
A mean distance of 69.6 km was observed
facility 0 serving 8.64% of customers;
facility 1 serving 2.65% of customers;
facility 2 serving 3.35% of customers;
facility 3 serving 8.82% of customers;
facility 4 serving 7.94% of customers;
facility 5 serving 2.29% of customers;
facility 6 serving 1.94% of customers;
facility 7 serving 4.59% of customers;
facility 8 serving 9.7% of customers;
facility 9 serving 3.35% of customers;
facility 10 serving 4.06% of customers;
facility 11 serving 11.46% of customers;
facility 12 serving 6.17% of customers;
facility 13 serving 6.17% of customers;
facility 14 serving 4.23% of customers;
facility 16 serving 7.23% of customers;
facility 19 serving 7.41% of customers;



The sharp-eyed viewer can see directly from the text results that something has changed. From Table 2, we know that after the first round of entries the average distance to the nearest IKEA was 71.2 kilometers, but here we are down to 69.6.

A look at the map shows that the four chosen locations are Gothenburg, Karlstad, Umeå and Haparanda. As such, it would have been better to leave the entry in Kalmar to the second round, while bringing up Umeå to the first round.

Finally, we turn to a description of how to use eCOmpass to find the optimal locations from a travel distance and emissions perspective when the network of stores is contracting. This is a rather unlikely scenario regarding IKEA Sweden, but it might be important for other retail chains. For example, several of the large consumer electronics retail chains in Sweden have contracted their store networks, and some of them have even declared bankruptcy during the last 15 years.

We will be using the “IKEA 1958 to 2020.csv” dataset in the example, but remember that this is a purely hypothetical exercise.

Now, when we are considering contracting networks we will know all current facility locations, in the hypothetical IKEA example all 20 store locations after 2016. As such, we are going to use the "EXPLOIT" mode of the DSS.

We also need to know how many stores are considered safe, i.e., not being considered for potential closure of the total network. In the hypothetical IKEA example considered here, let's say that the original 13 locations at the turn of the century are safe from closure (and thusly marked "1" in the facility variable in the csv-file").[1]

The csv-file should thus look as follows:

Latitude,Longitude,facility
60.633759,16.993094,1
57.603742,12.048695,1
56.092249,12.762610,1
57.773762,14.203621,1
58.432467,15.586468,1
55.552489,12.989743,1
59.421108,17.859059,1
59.271002,17.916666,1
62.445176,17.334777,1
59.848242,17.694211,1
59.608244,16.456656,1
56.550128,14.162557,1
59.212934,15.134691,1
57.774386,12.001883,0
65.845223,24.126509,0
56.685677,16.320974,0
59.378745,13.419860,0
60.481601,15.421267,0
58.356521,11.818656,0
63.807555,20.254731,0

After entering this into the DSS on page 2, we also need to know how many stores are to be kept open and how many are to be closed.

Of the 7 stores entered between 2004 and 2016 and marked "0" in the csv-file, let's assume that IKEA has decided that 3 stores are to be closed and that 4 are to be kept open.

So, in the box marked "Choose the number of facilities you want to locate amongst the possible ones (max: 100)", we now need to input the number of stores that <u>are to be kept open</u>. As such, we fil in:

Choose the number of facilities you want to locate amongst the possible ones (max: 100): 4

[1] If no stores are considered safe, they should all be marked "0" in the csv-file.

and press the “submit” button.

After a few minutes we get the results, and since we are technically doing the same analysis as in the previous example (but for another purpose), the results and the map will of course also be identical.

The stores to be kept open if one wants to minimize travel distance and emissions are Gothenburg, Karlstad, Umeå and Haparanda, and the stores to be closed are Uddevalla, Borlänge and Kalmar.

Hope that you now feel confident in using the DSS for your own purposes!