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User's Manual for FLP Spreadsheet Solver

Dr. Güneş Erdoğan

School of Management, University of Bath.

Download URL: <http://verolog.deis.unibo.it/flp-spreadsheet-solver>

Video tutorial: https://www.youtube.com/watch?v=_a7MbzzG9Hg

Developed by Dr. Güneş Erdoğan, 2016.
School of Management, University of Bath.

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1. INTRODUCTION

In the fall of 2013, I have developed and published a Microsoft Excel workbook named “VRP Spreadsheet Solver” on the VeRoLog website. The idea was to prove (to myself as much as the rest of the world) that it is possible to have a single unified platform on which Vehicle Routing Problems could be stated, solved, and visualized. As of the time of this writing, VRP Spreadsheet Solver has been used by a number of academics and graduate students, and a small number of companies. The video tutorial on YouTube attracts 30-60 viewers per day on the average. It has been an interesting experience to answer e-mails from complete strangers from the other side of the world, who ask questions and mostly do not offer any thanks for the answers. As I have been warned by a number of colleagues right from the start, the time I have invested into the VRP Spreadsheet Solver did not make a significant contribution to my academic career. One has to wonder what motivated me to write a second spreadsheet solver.

The common point of the scarce amount of feedback has shown me that the best use for spreadsheet solvers is in the education of management science and operational research (or as it is becoming increasingly popular, business analytics) practitioners. Going back to the fuzzy memories of my own education, I have uncovered a certain pattern. Every time I would learn about a new problem or a solution technique, I would realize that I would need specialized software to solve it in practice. My experience in my two internships has shown me that upper management of most companies would rather invest in physical resources than software. I have also realized that any “black box” software would need to be verified before being trusted. In short, there was (and there still is) a lack of educational software that would also be available after graduation.

In addition to this perceived need to open access educational solvers, there was the glaring fact that hardest part of the work was already done. The worksheet structure was in place, and the connection with the GIS was already established. It was a matter of modifying the code rather than developing it. The amount of time I needed to complete the FLP Spreadsheet Solver was a fraction of what I needed to develop the VRP Spreadsheet Solver. All the answers to the questions I had when I was developing the FLP Spreadsheet Solver were already answered on discussion boards on the Internet. Why not then, contribute a bit more?

As I have stated in the manual of the VRP Spreadsheet Solver, my research focuses on exact and approximate combinatorial optimization algorithms, and I am not an expert of software engineering (or Excel or VBA or GIS for that matter), and an expert could possibly build a much better solution. The resulting workbook is, all in all, a *proof of concept* for what can be done. I hereby advise you to go for a professional software solution if you have to routinely solve facility location problems that involve more than 200 locations. The readers are advised to keep the points made above in their minds as they progress through the rest of this document.

In the meanwhile, let me look into how I can develop a spreadsheet solver for the Bin Packing Problems...

2. HOW TO SOLVE A FACILITY LOCATION PROBLEM

FLP Spreadsheet Solver has been designed for simplicity above all. Using the menu item “FLP Spreadsheet Solver” in the tab “Add-ins”, you may issue the commands in their increasing numerical index, filling in data to each worksheet as it is generated. This menu is automatically generated when the file is opened, and deleted when it is closed. If the menu is not available for some reason, you can run the macro *SetupMenuItems* to refresh it. A step by step guide is given below. Note that GIS based functions are not available for Mac computers, due to the unavailability of certain VBA libraries.

- Enter all relevant data in the “FLP Solver Console” worksheet.
- Execute “1.1 Setup Locations Worksheet” and enter the names, demand, capacity, and setup cost of each location, and state if the location may be a facility, must be a facility, or cannot be a facility.
- Optionally, you may enter the addresses and execute “1.2 Optional – Populate Lat / Lon using addresses”. You need a Bing Maps key and an active internet connection to use this function.
- Optionally, you may execute “1.3 Optional – Sort locations alphabetically” for easier access through the solution worksheet (to be setup later).
- Execute “2.1 Setup Costs and Coverage Worksheet”, and fill in the distance data, either manually or by executing “2.2 Optional – Populate Distances Worksheet”. You need a Bing Maps key and an active internet connection to populate the distances using Bing Maps.
- Execute “3. Setup Solution Worksheet”.
- Optionally, you may execute “4. Optional – Setup Visualization Worksheet”. You need a Bing Maps key and an active internet connection to have a static map as the background.
- You may want to manually solve your FLP from this point on, by choosing locations from the drop down menus (the green cells under the columns “Location name”) in the solution worksheet. Alternatively, you can execute “5.1 Engage the FLP Spreadsheet Solver” and wait for the run to end.
- Check the solution and modify it to suit your objectives. Optionally, you can execute “5.2 Optional – Feasibility Check” function to see if the modified solution is still feasible.
- The “Send feedback / ask a question” command will bring up an e-mail addressed at me, in your default e-mail client. All (positive) feedback is welcome.
- The “About” command will display the current version of the workbook as well as my contact information. Please cite the software and this manual in all projects they have been used.

3. SCOPE AND LIMITATIONS

Among many others, FLP Spreadsheet Solver operates on the following assumptions:

- The number of locations is limited to 200. This limit can be increased by editing the code, but you are advised against it since the efficiency of VBA does not allow the FLP Spreadsheet Solver to handle instances of larger sizes.
- All locations are assigned to a single facility, and if a location is chosen to be a facility, it is assigned to itself. Multiple assignments (i.e. partial service) are not allowed.
- The distances are fixed and known beforehand.

- All facilities are assumed to belong to the decision maker, i.e. competitive location problems are not considered.
- Only three objectives have been implemented: Minimizing the total cost, maximizing the demand covered, and minimizing the maximum service distance. Only one objective can be selected per each run of the solver.
- Only the step coverage function and the linearly decreasing coverage function have been implemented.

4. STRUCTURE OF THE WORKSHEETS

FLP Spreadsheet Solver adopts an incremental flow of information, with subsets of data being kept in separate worksheets, as depicted in Figure 1. Initially, the workbook only contains the worksheet named FLP Solver Console. The remaining worksheets should be generated in the sequence denoted by their indices. The names of the worksheets are hardcoded within the code, so you are advised against renaming them. All cell references are absolute, so you are advised against inserting or deleting cells (or columns or rows) in the worksheets. With a few exceptions, if a worksheet is modified then the worksheets with a larger index will need to be generated again, and the previous information will be permanently overwritten. If you would like to do a what-if analysis on the parameters, you are strongly advised to make copies of the worksheets before doing so.

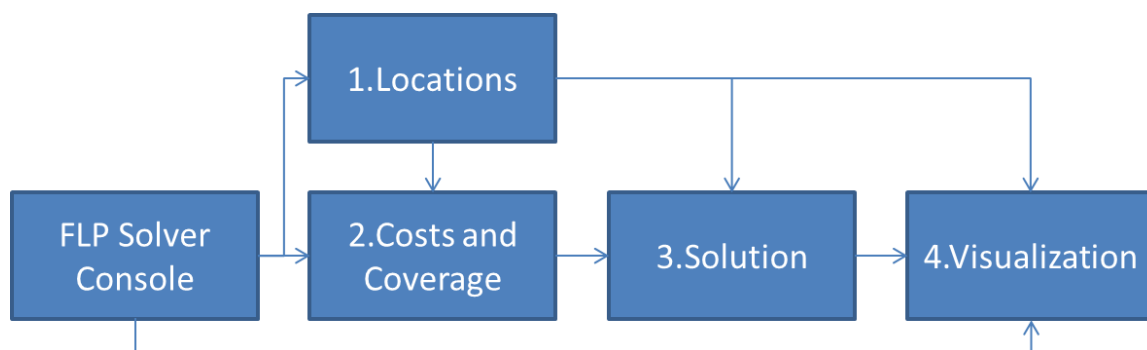


Figure 1: The flow of information between the worksheets.

The cells containing the data in the worksheets are colour-coded with the following scheme:

The cells with a black background are used by the worksheets and should not be modified.

The cells with a green background are parameters to be set by the user.

The cells with a yellow background are to be computed by the worksheets.

The cells with an orange background signal a warning.

The cells with a red background signal an error.

Note that some of the colour-coding features are not available for Excel 2007.

4.1 FLP Solver Console

This worksheet is central to the workbook, and **it should not be deleted**. If it is deleted, please run the macro *SetupConsoleWorksheet*, or close and reopen the workbook to generate it again. The parameters defined within the worksheet are described below.

Sequence: Instead of having a wizard interface, which is very easy to use but also very restrictive, the workbook numbers the worksheets in the order of progress. The parameters related to each worksheet are presented along with their sequence number. Please stick to the sequence unless you know what you are doing.

Bing Maps Key: Having a Bing Maps License is optional. You can still use the workbook without a Bing Maps License. A valid key is required for populating the Latitude / Longitude, the distances and duration, and for generating visualization of the locations and the routes on a map. You can generate a free key at <https://www.bingmapsportal.com/>. Just copy and paste your key into the cell.

Number of locations: Limited to the interval [10, 200]

Distance computation: This parameter describes how the distances should be populated, if they will be. The options are *Manual entry*, *Euclidian distances*, *Rounded Euclidian distances*, *Hamming (Manhattan) distances*, and *Bing Maps*. The option *Manual entry* disables the distance population function. The option *Euclidian distances* computes the distance between points (x_1, y_1) and (x_2, y_2) as $d_{12} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$, and the results of the formula are **not** in kilometres. The option *Rounded Euclidian distances* uses the Euclidian distance formula and rounds the result to the closest integer, and again the results of the formula are **not** in kilometres. The option *Rectilinear (Manhattan) distances* computes the distance between points (x_1, y_1) and (x_2, y_2) as $d_{12} = |x_1 - x_2| + |y_1 - y_2|$, and the results of the formula are **not** in kilometres. The option *Bird flight distances* uses a spherical approximation for the surface of the Earth, and the results of the formula are in kilometres. The option *Bing Maps driving distances* uses the web service of Bing Maps, and the results of the formula are in kilometres.

Bing Maps route type: This parameter describes the type of route returned by Bing Maps. The options are *Shortest*, *Fastest*, and *Fastest - Real Time Traffic*. *Shortest* option will find literally the shortest part, which usually goes through city centres, is subject to strict speed limits, and ends up with a very long duration. The recommended option is *Fastest*. The option *Fastest - Real Time Traffic* will give you estimates at the time the distances are populated, which may change drastically based on the traffic conditions at that instant.

Cost per unit distance: The distances are multiplied by this amount to determine the cost as assigning a location to a facility. This relationship is built into the Costs and Coverage worksheet as a formula.

Costs scaled by demand: Optionally, the assignment cost of a location to a facility may depend on the demand of the location. If the option *Yes* is selected, the cost formula also involves the demand of the location as a multiplier.

Service distance limit: Assigning a location to a facility at a distance more than the value of this parameter is prohibited, and a solution involving such an assignment is considered infeasible. This option may be used for solving FLP variants such as distance constrained p-median.

Coverage distance limit: Assigning a location to a facility at a distance more than the value of this parameter results in a coverage of 0.

Coverage type: If *Step function* is selected, 100% of the demand of a location is covered if it is assigned to a facility less than or equal to the *Coverage distance limit*, and none of the demand is covered otherwise. If *Linearly decreasing coverage* is selected, the percentage of the demand of a location covered by the facility it is assigned to is computed as $\max\{0, 1 - (\text{distance from the facility to the location} / \text{Coverage distance limit})\}$.

Number of facilities: This parameter denotes the maximum number of facilities to be located. The user may set this number to the *Number of locations* if the actual number of facilities located is to be determined by the solution algorithm.

Objective: The options are *Minimize total cost*, *Maximize demand covered*, and *Minimize maximum service distance*.

All facilities must be located? : If *Yes* is selected, the solver and the feasibility checker require the number of facilities located in a feasible solution to be *Number of facilities*. If *No* is selected, a feasible solution may have a smaller number of facilities located.

Visualization background: The options are *Bing Maps* and *Blank*. If *Bing Maps* is selected, the workbook will download the appropriate map containing the coordinates of the locations, and use it as the background image of the scatter chart depicting the routes.

Location labels: The options are *Blank*, *Location IDs*, and *Location names*. If *Location IDs* is selected, the ID number of the location will be displayed next to the location on the map. If *Location names* is selected, the name of the location will be displayed next to the location on the map.

Warm start: If “Yes” is selected, the solution algorithm will attempt to use the solution on the solution worksheet as a starting point.

Show progress on the status bar: If “Yes” is selected, the status bar (bottom left of the Excel screen) will display the result of the algorithm every 10 iterations. Every update takes a fraction of a second to display, which may steal away time from the optimization algorithm. This option is better suited to large instances with few iterations.

CPU time limit: This parameter denotes the runtime limit of the FLP Spreadsheet Solver. As a general rule, a longer run gives a higher probability of finding a good solution. The FLP Spreadsheet Solver will not stop before completing the first iteration, which may be longer than the time limit provided. The FLP Solver can be interrupted by pressing and holding down the ESC key.

4.2 1.Locations

The columns in this worksheet are explained below.

Location ID: This column is automatically generated, and must not be deleted or altered.

Name: The entries in this column must be unique. You may want to use the addresses in this column as well as the *Address* column.

Address: Please make sure that the address you provide is precise enough. For example the coordinates of “Cambridge” may resolve as those of “Cambridge, US” rather than those of “Cambridge, UK”.

Latitude (y) : The letter in the parenthesis refers to the axis on which these values correspond to.

Longitude (x): The letter in the parenthesis refers to the axis on which these values correspond to.

Demand: The entries in this column denote the amount of demand associated with a location. This value is expected to be smaller than the potential capacity of the location, which may not be true if the location does not allow for a facility.

May be a facility? : The options are *May be a facility*, *Must be a facility*, and *Cannot be a facility*.

Capacity: The entries in this column denote the potential capacity of a facility if it is located at a location. This parameter limits the total demand that can be assigned to a facility at this location. This value is expected to be larger than the demand of the location, which may not be true if the location does not allow for a facility.

Setup cost: The entries in this column give the cost of locating a facility at the associated location.

4.3 2.Costs and Coverage

The columns in this worksheet are explained below.

From: The origin for the arc.

To: The destination for the arc.

Distance: The unit of the distance is kilometres if it is computed using *Bird flight distances* or *Bing Maps driving distances*. There are no units for the other methods.

Cost: This column denotes the cost of serving location *To*, by a facility at *From*. It can be computed as a function of the *Distance*, the *Cost per unit distance* parameter, and optionally, the demand of the *To* location. The user can insert custom functions to this column as required, and the resulting cost figure will be used in the subsequent computations.

Coverage: This column can be computed as a function of the *Coverage distance limit* parameter and the *Coverage type* option, to denote the percentage of demand covered at *To* if it is assigned to a facility at *From*. The user can insert custom functions to this column as required, and the resulting coverage figure will be used to determine *Demand covered*.

Demand covered: This column is simply the result of the multiplication of *Coverage* with the demand of *To*. The user can insert custom functions to this column as required, and the resulting figure will be used in the subsequent computations.

4.4 3.Solution

For each facility a set of columns detailing the locations assigned to it will be generated. You may scroll right to see the routes of other facilities. Column A also contains the *List of detected infeasibilities*, below the locations assigned to the first facility. The columns in this worksheet are explained below.

Facility location: The name of location of the facility. Can be chosen from the drop down menu populated with the names of the locations.

Capacity: The capacity of the facility, based on its location. In a feasible solution, *Capacity* should be greater than or equal to the *Demand allocated*.

Location name: This column is composed of cells with drop down menus, populated with the names of the locations.

Distance: The distance from the facility to the location being served.

Demand: The demand of the location being served.

Covered: The amount of demand covered at the location being served.

Cost: The cost of serving the location from the facility.

The following values are computed based on the columns above.

Demand allocated: The sum of the column *Demand*. In a feasible solution, *Capacity* should be greater than or equal to the *Demand allocated*.

Demand covered: The sum of the column *Covered*.

Cost incurred: The sum of the column *Cost*.

4.5 4.Visualization

This worksheet is optional, and if generated, it contains a scatter chart showing the locations of the facilities and the assignments of the remaining locations to these facilities. The chart can be

formatted as any other Excel chart. The current design incorporates a “less ink” approach. You can add axes and gridlines, or remove labels as you see fit.

5. FUNCTIONS

5.1 Optional – Reset the workbook

This is a quick way of deleting the data worksheets and resetting the console worksheet. Be careful, it is irreversible. Corresponds to the macro *ResetWorkbook*.

5.2 Setup Locations Worksheet

Corresponds to the macro *SetupLocationsWorksheet*.

5.3 Optional - Populate Lat/Lon using addresses

An active internet connection and a Bing Maps key are required for this function. Please make sure that the limitations of your key match with the size of your problem instance. An instance with n locations will require n queries to populate the whole set of coordinates. Corresponds to the macro *PopulateLatitudeAndLongitude*.

5.4 Optional - Sort locations alphabetically

The drop down menus of the solution worksheet are populated by the list of locations. To have alphabetically ordered drop down menus, you need to sort the locations. Corresponds to the macro *SortLocations*.

5.5 Setup Costs and Coverage Worksheet

Corresponds to the macro *SetupCostsWorksheet*.

5.6 Optional - Populate Distances

An active internet connection and a Bing Maps Key are required for using the Bing Maps option of this function. Please make sure that the limitations of your key match with the size of your problem instance. An instance with n customers will require approximately $n * (n + 1) / 24$ queries to populate the whole set of distances. Corresponds to the macro *PopulateDistances*.

5.7 Setup Solution Worksheet

Corresponds to the macro *SetupSolutionWorksheet*.

5.8 Optional - Setup Visualization Worksheet

Corresponds to the macro *SetupVisualizationWorksheet*.

5.9 Engage FLP Spreadsheet Solver

Corresponds to the macro *FLP_Solver*.

5.10 Optional – Feasibility Check

This function is supplied for checking the feasibility of the data and the solution after manual alterations. Corresponds to the macro *FeasibilityCheckDataAndSolution*.

6. SOLUTION ALGORITHM

The field of FLP research mostly focuses on exact algorithm. The best known heuristic algorithm is arguably Tabu Search. The details of the literature would be beyond the scope of this document, and we do not claim that a single algorithm can successfully solve all variants of the FLP. Let it suffice to state that a variant of the Tabu Search is implemented within the FLP Spreadsheet Solver. An outline of the algorithm is given below.

Step 1 (Initialization): Initialize the incumbent solution, the best known solution, and the iteration counter $k = 1$. Initialize the Tabu list as an empty list. Read the solution on the Solution worksheet into the incumbent solution if a “warm start” is required.

Step 2 (Stopping condition): If the time limit is exceeded, stop and report the best known solution.

Step 3 (Select move): Explore all possible relocations of a single location and all possible exchanges of two locations between facilities. If the best move results in a solution better than the best known solution, execute it. Else, choose and execute the best move that does not involve any locations in the Tabu list. Add the location(s) in the move to the *Tabu list*.

Step 4 (Best solution update): If the incumbent solution is feasible and better than the best known solution, update the best known solution.

Step 5 (Tabu list update): Remove all locations with a tabu tenure larger than the *tabu tenure limit* from the Tabu list. Go to Step 2.

7. Conclusion

Despite its shortcomings, I hope that the FLP Spreadsheet Solver will be used as a minor decision support system for small and medium enterprises as well as for teaching and undergraduate and postgraduate levels. I am almost sure that academics will disagree with some design choices, but they can be corrected. I am also quite certain that practitioners will find features that do not completely fit their needs, but it can provide you starting points that lead to an actual solution. Please send bug reports, suggestions, and (not-too-harsh) comments to g.erdogan@bath.ac.uk.