

About Excel's Solver: Marketing Engineering

Technical Note¹

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Introduction

You can use Excel as a platform to implement the Marketing Engineering response models, because spreadsheets are excellent tools for viewing data and for building models. Moreover, spreadsheets provide utilities—such as graphing capabilities—that facilitate analysis. And finally, and important to us, they offer links to other utilities that greatly expand the domain of an application. Excel's Solver add-in function (be sure your installation of Excel has this add-in feature) is such a utility, and it is used in many of the Excel software tools.

Solver is a program that solves linear and nonlinear optimization problems, with or without constraints. In English this means that

- If you can specify sales as a function of advertising spending, then Solver will tell you what level of advertising will maximize your profits. It will optimize the marketing mix.
- If you are looking for some model parameters that will make a function represent data best, Solver will determine which parameters minimize squared differences between actual values and predicted values (model calibration—via least squares regression).
- If you want to determine what level of marketing effort will help you meet a sales target, Solver will help you determine the value that will do it (market-mix target setting).

All of these problems (and optimization problems in general) have three

¹ This technical note is a supplement to Chapter 1 of Principles of Marketing Engineering, by Gary L. Lilien, Arvind Rangaswamy, and Arnaud De Bruyn (2007). © (All rights reserved) Gary L. Lilien, Arvind Rangaswamy, and Arnaud De Bruyn. Not to be re-produced without permission.

basic components: decision variables, constraints, and an objective function.

Decision variables are mathematical representations of the marketing-mix variables that we wish to set. An example variable is “Promotional spending (X) in Albuquerque (i) in July (t),” which we will represent below by X_{it} .

Constraints: All marketing problems have constraints. Promotional spending cannot be less than 0 (nonnegativity constraint). The number of sales calls in a period must be both nonnegative and an integer (integer constraint). The total promotional budget may be set at a fixed amount (equality constraint) or as a ceiling (inequality constraint).

Objectives: We must specify the objective as the (single) criterion that we wish to maximize (profit), minimize (sum of squared deviations), or set equal to a target (a specific target ROI, for example).

We can characterize an optimization problem mathematically as follows:

(Decision Variables)

Find

$\{X_{it}\}; X_{it} \geq 0$ for $i = 1, \dots$, number of markets and $t = 1, \dots$ end of planning period

(Objective)

To

Max (or Min) $Z(\{X_{it}\})$

(Constraints)

Subject to

$f_j \{X_{it}\} \geq b_j$ (or $\leq b_j$, or $= b_j$) for $j = 1, \dots$ number of constraints.

EXAMPLE

Find

X (the level of advertising spending—the decision variable)

(2A.1a)

To

(i.e., margin TIMES sales response to advertising LESS advertising expenditures)

Subject to

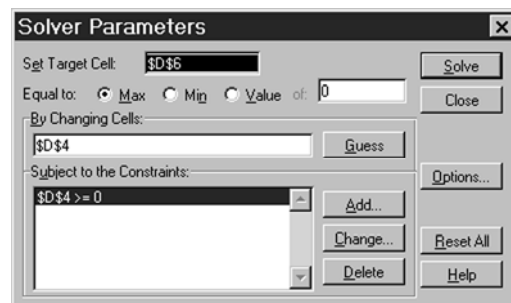
$$X \geq 0 \text{ (advertising must be nonnegative—constraint).} \quad (2A.1c)$$

This problem can be set up in a spreadsheet using Solver quite simply; the following spreadsheet implements the model:

Note that in this structure we

	A	B	C	D	E	F	G
1							
2							
3							
4		Advertising Level (X) =		\$7.25			
5							
6		Profit =		\$12.59			
7							
8							
9							
10				Advertising Profit			
11				\$0.00	\$3.50		
12				\$0.25	\$3.34		
13				\$0.50	\$3.34		
14				\$0.75	\$3.51		

By selecting solver from the **Tools** menu, we set up the optimization as



Set Cell: D6 (our profit objective)

Equal to Max

By Changing Cells: D4 (advertising spending)

Subject to the Constraints:

$$D_4 \geq 0.$$

Solver then finds the optimal value of advertising (\$7.25 in this case). See your Excel User's Guide or select Excel **Help** to obtain more details on setting up optimization problems using Solver.

How Solver Works

The Solver implemented in Excel (produced by a software firm called Frontline Systems) uses numerical methods to solve equations and to optimize linear and nonlinear functions with either continuous variables (as in advertising spending) or integer variables (number of account-visits in a quarter). The methods used are iterative; generally Solver calculates how small changes in the decision variables affect the value of the objective function. If the objective function improves (profit increases in our case), Solver moves the decision variables in that direction. If the objective function gets worse, Solver moves in the opposite direction. If the objective function cannot be improved by either an increase or a decrease in any of the decision variables, Solver stops, reporting at least a local solution.

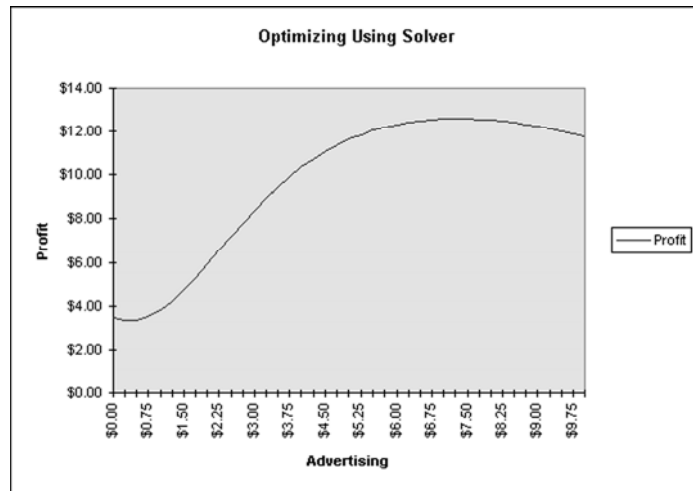
The field of nonlinear, constrained optimization (especially with integer variables) is quite complex and beyond the scope of this Appendix. Ragsdale (2006), and Winston, Albright, and Albright (2000) provide practical introductions to analyses and optimization with spreadsheets and www.optimization-online.org provides a wide variety of resources. However, you should be aware of some situations that can occur with nonlinear optimizers.

1. *Local optima*: While Solver may have found the top of a hill (the highest point in the region), there may be a higher peak elsewhere. Solver would have to go DOWN from the local peak and begin searching elsewhere to find it. In other words, Solver would need a new starting value (values in the "By Changing Variable" cells in the "Solver Parameter" box) to find the optimum.

EXAMPLE

Note the graph that follows of the advertising spending function that we optimized. Suppose that we started Solver with the level of advertising

= 0. Note that advertising spending cannot be negative and that profit initially decreases with increases in advertising spending because we have an advertising response model with a threshold. (The form of Eq. [2A.1b] has us subtracting advertising spending from the sales/profit response function. If the latter is flat, the profit function will be decreasing.) Hence Solver cannot decrease advertising spending to less than zero (because of the constraint) and it does not want to go up (as, locally, at least, that would decrease profitability), and so we are at a local maximum. However, if we start the problem with advertising at 1.0 or greater, Solver will correctly find the optimum value at \$7.25.



What this example illustrates is that when you are using market response functions that have threshold effects, you may need to try different starting values to be sure that you have reached a global optimal solution. Several of the software programs, like Syngen, have built-in options that permit you to, in effect, try a different starting value if Solver fails to converge or gives you a local solution.

2. *No feasible solution:* Suppose that we set two constraints: $X > 6$ and $X < 3$. Clearly both of these constraints cannot be satisfied at the same time, and Solver will fail to provide any solution. While the example here makes the lack of any feasible solution obvious, in larger problems this is often quite subtle.

3. *Other problems:* General nonlinear optimizers like Excel's Solver are remarkable technical additions to the analyst's toolkit. With their power and flexibility come a variety of other problems, however. The user who wants to use Solver directly in market analyses or who wants to adapt or adjust the operation of some of the software that uses Solver may run into a number of other questions or problems, many of which are addressed in Excel's Help and at www.frontsys.com.

Some of those problems are caused by the way the user formulates the specific problem and employs Solver's options. Other problems may be caused by bugs in your version of Excel and in Excel's link to your operating system (your version of Windows). If the results you are getting do not make sense, it may help to quit Windows or even to reboot your computer before trying to solve the problem again.

References

Ragsdale, Cliff T., 2006, Spreadsheet Modeling & Decision Analysis, (5th Edition), OH: South-Western Thomson Learning.

Winston, Wayne L.; Albright, S. Christian; and Albright, Christian , 2000, *Practical Management Science: Spreadsheet Modeling and Applications*, second edition, Duxbury Press, Pacific Grove.