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Optimizing accounting decision making using goal programming

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Optimizing Accounting Decision Making Using Goal Programming

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Goal programming is a decision-making technique that seeks to help decision makers make decisions that satisfy competing goals to the best extent possible. This article provides a description of goal programming, demonstrates how it can be implemented on a spreadsheet, and illustrates its use through an example from management accounting.

Management accountants have a key role in supporting strategic decision making in an organization. They are often required to provide information, interpretations, and analysis of alternative courses of action that managers are contemplating, in areas including capital budgeting, outsourcing, product-mix, and the adding or dropping of specific product lines. To properly carry out these tasks, management accountants need broad knowledge of their organizations' activities and the ways those activities interact (Hilton, Mahar, & Selto, 2006). As the operating environment of organizations grows more complex, management accountants must increasingly rely on sophisticated analysis techniques to help them perform their tasks (ACCA, 2016). One such analysis technique is goal programming.

Simon (1955) suggests that modern decision makers work in complex environments and are often faced with competing objectives. In such decision environments, it is often impossible for decision makers to fulfill all objectives at the same time. Instead, decision makers must, in such settings, try to achieve a set of goals (or targets) as closely as possible. Rather than strive to achieve all goals, decision makers should consider how decisions involve possible trade-offs among competing goals, and aim to make decisions that allow them to achieve outcomes that come closest to satisfying the goals under consideration. In this respect, given that goal programming is a multiobjective programming technique that relies on the ethos of allowing decision makers to satisfy competing objectives to the best possible extent (Tamiz, Jones, & Romero, 1998), it represents an important analysis technique that management accountants can employ to improve decision making in the modern workplace.

The literature documents various applications of goal programming in accounting decision making (see Aouni, McGillis, and Abdulkarim, 2017 for a review). Charnes, Cooper, and Ijiri (1963) were the first to apply programming in accounting decision making, and examined how a goal programming model could be used to conduct breakeven analysis involving two products, a constant level of fixed costs and two machine capacity constraints. In addition, Merville

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and Petty (1978) used goal programming models in transfer pricing problems, examining how transfer prices between divisions within decentralized organizations could be established while making trade-offs among multiple conflicting objectives including differing tax rates (when operating internationally), profit requirements, and risk avoidance. Another application of goal programming that has been explored in the literature is in the evaluation of department performance. Specifically, Badran (1984) examined cost allocation decisions using goal programming models for departmental overhead allocation which addressed the conflicting objectives of the organizational desire to have full costing of departments and the departmental objectives to minimize the amount of indirect costs allocated to individual departments. More recently, Zamfirescu and Zamfirescu (2013) also employed goal programming in performance-based budgeting where they examined the optimization of the allocation of public funds across various programs in the public sector.

In this article, I will introduce the goal programming technique and highlight how management accountants can employ this technique. In particular, I will provide a description of goal programming, illustrate how goal programming can be implemented in a spreadsheet using a worked example from management accounting, and demonstrate how solver, the Excel add-in, can be used to help a management accountant arrive at decisions using goal programming.

ELEMENTS OF A GOAL PROGRAMMING MODEL

Goal programming was introduced by Charnes, Cooper, and Ferguson (1955), as a branch of multicriteria decision analysis. It has been applied for decision making in many areas, including in accounting, resource planning, energy forecasting, and many others (Tamiz, Jones, & El-Darzi, 1995). The key elements in a goal programming model include the following:

- **Decision variables:** The values of decision variables are often unknown at the start of the problem. These variables usually represent things that a manager can control, and his/her goal is to find values of the decision variables that best satisfy stated goals.
- **Goals:** These represent targets which a manager wishes to achieve. Goals are viewed as "soft constraints" (i.e., a constraint which is preferred but not required to be satisfied). A manager would often have to make trade-offs among different goals to determine an acceptable solution to a goal programming problem.
- **Goal constraints:** Constraints are mathematical functions that incorporate decision variables to express limits on possible solutions. Goal constraints are a particular type of constraint which allows a manager to determine how close a given solution comes to achieving stated goals. In stating goal constraints, deviational variables are introduced to represent the amount by which each goal deviates from its target value. In particular, negative deviational variables represent the amount by which each goal's target value is underachieved and positive deviational variables represent the amount by which each goal's target value is overachieved.
- **Hard constraints:** Not all constraints in a goal programming problem have to be goal constraints. Hard constraints set conditions for decision variables which must be satisfied.
- **Objective function:** The objective in a goal programming problem is to achieve all the goals as closely as possible. An objective function expresses a manager's corresponding goal of minimizing the weighted sum of percentage deviations from stated goals. Weights are assigned to deviational variables in an objective function to reflect the importance and desirability of deviations from the various goals.

IMPLEMENTING A GOAL PROGRAMMING MODEL IN A SPREADSHEET

In this section, I illustrate how goal programming can be implemented on a spreadsheet and used to solve decision problems using an example relevant to management accountants.

Atlas Co. is a manufacturer of metal casings for computers. The company has recently hired a consultant to advise it on its plan to purchase new machines to expand manufacturing capacity. Based on the space available in Atlas' manufacturing plant, the consultant suggests that Atlas should *ideally* purchase 5 small

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machines, 10 medium machines, and 15 large machines. Each small machine can produce 400 units of metal casings per day while each medium machine can produce 750 units of metal casings per day and each large machine can produce 1,050 units of metals casing per day. The company also learns that it would be ranked among the largest manufacturers of metal casings in the city if its new machines can produce 25,000 units of metal casings per day. This would be a key marketing point for the company and would be helpful when negotiating new contracts with customers. It will cost \$18,000 to purchase a small machine, \$33,000 to purchase a medium machine, and \$45,150 to purchase a large machine. Atlas has allocated a tentative budget of \$1,000,000 to purchasing these new machines. Atlas must decide how many small, medium, and large machines to purchase based on these facts.

Atlas can structure the above facts as a goal programming problem to help it make its purchasing decision. In this goal programming problem, Atlas has the following five goals:

1. The purchase should include *approximately* 5 small machines.
2. The purchase should include *approximately* 10 medium machines.
3. The purchase should include *approximately* 15 large machines.
4. Together, the new machines should produce *approximately* 25,000 units of metal casings per day.
5. The new purchases should cost *approximately* \$1,000,000.

Exhibit 1 presents the goal programming problem mathematically. The decision facing Atlas is the number of small, medium, and large machines to purchase. This is represented by the decision variables X_1, X_2, and X_3, respectively. The objective function in the problem seeks to minimize the weighted sum of percentage deviations from stated goals. Goal constraints utilize negative and positive deviational variables, represented by d_i^- and d_i^+, respectively, to allow a manager to determine how close a given solution comes to achieving his/her stated goals.

Next, I implement the mathematical goal programming model in an Excel spreadsheet. Exhibit 2 presents the spreadsheet model used while Exhibit 3 presents the formulas used in the spreadsheet.

X_1, X_2, and X_3 (in the mathematical model) represent our *decision variables* (i.e., how many of each machine to purchase) and are represented in cells B6, C6, and D6, respectively. The values of these decision variables are unknown at the start of the problem. There are five goals—related to the number of small, medium, and

Exhibit 1

Atlas' Goal Programming Model

Minimize:

$$\frac{1}{5}\left(w_1^- d_1^- + w_1^+ d_1^+\right) + \frac{1}{10}\left(w_2^- d_2^- + w_2^+ d_2^+\right) + \frac{1}{15}\left(w_3^- d_3^- + w_3^+ d_3^+\right) + \frac{1}{25000}\left(w_4^- d_4^- + w_4^+ d_4^+\right) + \frac{1}{1000000}\left(w_5^- d_5^- + w_5^+ d_5^+\right)$$ } Objective function

Subject to:

$X_1 + d_1^- + d_1^+ = 5$	} Small machine goal constraint
$X_2 + d_2^- + d_2^+ = 10$	} Medium machine goal constraint
$X_3 + d_3^- + d_3^+ = 15$	} Large machine goal constraint
$400X_1 + 750X_2 + 1050X_3 + d_4^- + d_4^+ = 25000$	} Total daily production goal constraint
$18000X_1 + 33000X_2 + 45150X_3 + d_5^- + d_5^+ = 1000000$	} Total budget goal constraint
d_i^- , $d_i^+ \geq 0$ for all i	} Deviational variables hard constraint
$X_i \geq 0$ for all i	} Decision variable hard constraint
X_i must be integers	

Where,
X_1 = number of small machines to purchase
X_2 = number of medium machines to purchase
X_1 = number of large machines to purchase

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Exhibit 2

Atlas' Goal Programming Problem Implemented on a Spreadsheet

	A	B	C	D	E	F
1	Problem Data	Small Machine	Medium Machine	Large Machine		
2	Production Quantity	400	750	1,050		
3	Purchase Cost	18,000	33,000	45,150		
4						
5	Constraints	Small Machine	Medium Machine	Large Machine	Production Quantity	Budget
6	Actual Amount				0	0
7	Under Achieve					
8	Over Achieve					
9	Goal	0	0	0	0	0
10	Target Value	5	10	15	25,000	1,000,000
11						
12	Percentage Deviation					
13	Under Achieve	0.00%	0.00%	0.00%	0.00%	0.00%
14	Over Achieve	0.00%	0.00%	0.00%	0.00%	0.00%
15						
16	Weights					
17	Under Achieve	1	1	1	1	1
18	Over Achieve	1	1	1	1	10
19						
20	Objective	0.000				
21						
22						
23	Decision variables					
24	Objective function					
25	LHS of constraints					

large machines to buy, to daily production quantity, and to the overall budget—which Atlas wants to achieve. These goals are represented in cells B10, C10, D10, E10, and F10, respectively. Atlas' stated goals also form part of the goal constraints in the goal programming problem. Specifically, the goals form the right-hand side of each corresponding goal constraint. The left-hand side of the goal constraints allows the manager to measure the extent to which specific goals are achieved, and are represented in the spreadsheet in cells B9, C9, D9, E9, and F9. In the spreadsheet, the objective function is represented in cell B20. The objective function seeks to minimize the weighted sum of percentage deviations from stated goals. Negative percentage deviations from each goal are represented in cells B13, C13, D13, E13, and F13 while positive percentage deviations from each goal are represented in cells B14, C14, D14, E14, and F14. Weights assigned to each negative deviational variable are represented in cells B17, C17, D17, E17, and F17 while weights assigned to each positive deviational variable are represented in cells B18, C18, D18, E18, and F18.[1]

Having implemented the goal programming model in a spreadsheet, we next proceed to use the Solver function in Excel to find a solution to the problem. Solver is an add-in function in Excel that must be installed separately before it can be installed.[2] The Solver perimeter inputs used in my example are presented in Exhibit 4. In Solver, we need to define three key components of our spreadsheet model. First, we need to define an objective cell (and whether its value should be maximized or minimized). This cell corresponds to the cell in the spreadsheet that represents the *objective function* in the mathematical model. Second, we need to define variable cells. These cells should correspond to cells in the spreadsheet that represent *decision variables or deviational variables* in the mathematical model. Third, we need to define constraints. These cells should correspond to cells in the spreadsheet that represent both goal constraints and hard constraints in the mathematical model. Given that the objective and constraint functions in our goal programming problem are linear in nature, we use the "Simplex LP" method as the solving method in Solver.

Once these input perimeters have been defined, I click

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Exhibit 3

Formulas Used in Excel Spreadsheet

Cell	*Formula*
E6	=SUMPRODUCT(B6:D6,B2:D2)
F6	=SUMPRODUCT(B6:D6,B3:D3)
B9	=B6+B7−B8
C9	=C6+C7−C8
D9	=D6+D7−D8
E9	=E6+E7−E8
F9	=F6+F7−F8
B13	=B7/B$10
C13	=C7/C$10
D13	=D7/D$10
E13	=E7/E$10
F13	=F7/F$10
B14	=B8/B$10
C14	=C8/C$10
D14	=D8/D$10
E14	=E8/E$10
F14	=F8/F$10
B20	=SUMPRODUCT(B13:F14,B17:F18)

"Solve" to instruct Solver to solve for a solution that minimizes the objective function. Exhibit 5 presents the Solver solution to my example. Solver solves for the number of small, medium, and large machines that Atlas should purchase by minimizing the objective function, given the set of weights assigned to the deviational variables in the problem. My spreadsheet indicates that Atlas should purchase 5 small machines, 10 medium machines, and 15 large machines.

Exhibit 4

Solver Parameter Inputs

Menu Field	*Input*
Set objective	$B$20, To: Min
By changing variable cells	$B$6:$D$6,$B$7:$F$8
Subject to the constraints	$B$9:$F$9 = $B$10:$F$10 $B6:$D$6 ≥ 0 $B$7:$F$8 ≥ 0 $B6:$D$6 = integer
Select a solving method	Simplex LP

REVISING THE GOAL PROGRAMMING MODEL

In goal programming, decision makers have to examine a given solution and evaluate if the extent to which individual goals are met or missed are acceptable. For example, the solution obtained in the previous section would lead to Atlas exactly meeting its goals of purchasing 5 small machines, 10 medium machines, and 15 large machines. However, it would, at the same time, lead to Atlas missing its goals of being able to produce 25,000 units of metal casings per day and keeping to a budget of $1,000,000. Specifically, the solution would lead to Atlas being able to produce 25,250 units of metal casings per day (exceeding its production quantity goal by 250 units per day) and requiring a budget of $1,097,250 (exceeding its budget goal by $97,250). If the decision maker is satisfied with the extent to which his/her goals are met or missed, he or she could then proceed to implement the solution obtained in the goal programming model in his/her decisions.

However, if the decision maker is not satisfied with the extent to which goals are met or missed, he or she could explore alternate solutions by assigning different weights to the individual deviational variables. In general, positive weights should be assigned

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Exhibit 5

Solution to Atlas' Goal Programming Problem

	A	B	C	D	E	F
1	Problem Data	Small Machine	Medium Machine	Large Machine		
2	Production Quantity	400	750	1,050		
3	Purchase Cost	18,000	33,000	45,150		
4						
5	Constraints	Small Machine	Medium Machine	Large Machine	Production Quantity	Budget
6	Actual Amount	5	10	15	25,250	1,097,250
7	Under Achieve	0	0	0	0	0
8	Over Achieve	0	0	0	250	97,250
9	Goal	5	10	15	25,000	1,000,000
10	Target Value	5	10	15	25,000	1,000,000
11						
12	Percentage Deviation					
13	Under Achieve	0.00%	0.00%	0.00%	0.00%	0.00%
14	Over Achieve	0.00%	0.00%	0.00%	1.00%	9.73%
15						
16	Weights					
17	Under Achieve	1	1	1	1	1
18	Over Achieve	1	1	1	1	1
19						
20	Objective	0.107				
21						
22						
23	Decision variables					
24	Objective function					
25	LHS of constraints					

to deviational variables that represent deviations that are undesirable, a weight of zero should be assigned to deviational variables that represent deviations that are neutral, and negative deviations should be assigned to deviational variables that represent deviations that are desirable. The magnitudes of positive/negative weights assigned to deviational variables should be increased as the undesirability/desirability of deviations increase.

For example, if the decision maker is not satisfied with the solution obtained in the previous section (perhaps he/she may feel that, given the initial budget goal of $1,000,000, the required budget of $1,097,250 in the solution is excessively high), he/she may decide to increase the magnitude of the weight assigned to the positive deviational variable for the budget goal from 1 to 10 (in cell F18). This would indicate an increase in the undesirability of exceeding the budget goal relative to other goals. Exhibit 6 presents the solution to the goal programming problem incorporating this change in assigned weight.

In this revised solution, Atlas would purchase 5 small machines, 10 medium machine, and 13 large machines. It would be able to produce 23,150 units of metal casings per day. The purchase would require a budget of $1,006,950. Using this set of weights would reduce the budget that Atlas would require from $1,097,250 (in the initial solution) to $1,006,950 (in the current solution). However, while Atlas would still be able to exactly meet its goal of purchasing 5 small machines and 10 medium machines, it would now only purchase 13 large machines (2 short of its goal of 15 machines). It would also only be able to produce 23,150 units of metal casings per day (1,850 short of its goal of 25,000 units of metal casings per day).

There is no standard procedure for assigning weights to deviational variables that will lead to optimal solutions. Instead, a decision maker follows an iterative procedure where he or she assigns a particular set of weights to deviation variables, solves the goal programming problem, analyses the solution obtained, refines the set of weights, and then solves the problem again. Often this process is repeated many times over before an acceptable solution is obtained. Indeed, goal programming does not provide a single best solution to a problem. Rather, the nature of

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Exhibit 6

Revised Solution to Atlas' Goal Programming Problem

	A	B	C	D	E	F
1	Problem Data	Small Machine	Medium Machine	Large Machine		
2	Production Quantity	400	750	1,050		
3	Purchase Cost	18,000	33,000	45,150		
4						
5	Constraints	Small Machine	Medium Machine	Large Machine	Production Quantity	Budget
6	Actual Amount	5	10	13	23,150	1,006,950
7	Under Achieve	0	0	2	1,850	0
8	Over Achieve	0	0	0	0	6,950
9	Goal	5	10	15	25,000	1,000,000
10	Target Value	5	10	15	25,000	1,000,000
11						
12	Percentage Deviation					
13	Under Achieve	0.00%	0.00%	13.33%	7.40%	0.00%
14	Over Achieve	0.00%	0.00%	0.00%	0.00%	0.70%
15						
16	Weights					
17	Under Achieve	1	1	1	1	1
18	Over Achieve	1	1	1	1	10
19						
20	Objective	0.277				
21						
22						
23	Decision variables					
24	Objective function					
25	LHS of constraints					

goal programming involves making trade-offs among the various goals until a solution that gives the decision maker the greatest level of satisfaction is found.

CONCLUSION

Goal programming is a tool that can be used for multi-criteria decision analysis. It is an especially important tool for management accountants who often have to make decisions that involve trade-offs among multiple goals. In this article, I introduce goal programming, demonstrate how it can be implemented using Excel's Solver feature, and illustrate its use through an example from management accounting. While this example is straightforward, it is representative of many decision-making problems faced by accountants in practice. In particular, it is reflective of many real-life scenarios which require accountants to make decisions while contenting with multiple business goals (often in addition to other constraints).

NOTES

1. In this example, I assign weights of 1 to all deviation variables. I examine the assigning of weights in further detail in the next section.
2. Once installed in Excel, go to Data → Analyze → Solver to run the Solver function.

REFERENCES

ACCA. (2016). *Drivers of change and future skills.* Retrieved from https://www.accaglobal.com/content/dam/members-beta/docs/ea-patf-drivers-of-change-and-future-skills.pdf

Aouni, B., McGillis, S., & Abdulkarim, M. E. (2017). Goal programming model for management accounting and auditing: A new typology. *Annals of Operations Research*, *251*, 41–54.

Badran, Y. (1984). Departmental full costing via goal programming models. *European Journal of Operational Research*, *17*(3), 331–337.

Charnes, A., Cooper, W. W., & Ferguson, R. (1955). Optimal estimation of executive compensation by linear programming. *Management Science*, *1*, 138–151.

Charnes, A., Cooper, W. W., & Ijiri, Y. (1963). Breakeven budgeting and programming to goals. *Journal of Accounting Research*, *1*(1), 16–43.

Hilton, R. W., Mahar, M. W., & Selto, F. H. (2006). *Cost management: Strategies for business decisions.* New York: McGraw-Hill.

Merville, L. J., & Petty, J. W. (1978). Transfer pricing for the multinational firm. *The Accounting Review*, *53*(4), 935–951.

Simon, H. A. (1955). *Models of men.* New York: Wiley.

DOI 10.1002jcaf

Tamiz, M., Jones, D., & Romero, C. (1998). Goal programming for decision making: An overview of the current state-of-the-art. *European Journal of Operational Research*, *111*, 569–581.

Tamiz, M., Jones, D. F., & El-Darzi, E. (1995). A review of goal programming and its applications. *Annals of Operations Research*, *58*, 39–53.

Zamfirescu, L., & Zamfirescu, C. (2013). Goal programming as a model for performance-based budgeting. *Procedia Computer Science*, *17*, 426–433.

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