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To What Extent Do Engineering Economy Textbooks Still Rely on the Factor Tables?

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Abstract

In 2011 *The Engineering Economist* published a proposition calling for engineering economy teaching to catch up with engineering practice by relying more on spreadsheets and financial calculators. Every example in 7 texts is analyzed for its use of tabulated factors, spreadsheets, or formulas. Our conclusion is that there has been progress in coverage of spreadsheets—but more progress is possible and needed. Moreover, the texts vary enough to suit many but not all instructors. The results will be useful to both teachers and authors, and most importantly to the students they serve. We include examples that instructors can use in a *text-independent* fashion. We also address the classroom and textbook challenges in shifting the balance between the engineering economy factors and the more modern tools of engineering economy practice.

Introduction

In 2011 *The Engineering Economist* published a proposition[1] on engineering economy teaching.

> "For nearly a century the teaching of engineering economy has relied on tabulated values of the engineering economy factors. However, for the last two decades the practice of engineering economy has relied on spreadsheets and financial calculators. We believe that it is time for the teaching of engineering economy to catch up with its practice.
>
> Thus, we ask textbook authors and classroom instructors to retain the pedagogical clarity of the tabulated engineering economy factors (e.g. (*P*/*A*, *i*, *N*)) but to rely more heavily on the analogous but more powerful calculator and spreadsheet functions (e.g. PV(*i*, *N*, *A*, *F*, type)). We believe the tabulated factors have their pedagogical place, but the financial arithmetic that permeates engineering economy instruction should be dramatically reduced. A heavier reliance on spreadsheets will allow students to solve more realistic problems, while developing their skills with the tools of engineering economy practice.
>
> We believe that engineering economy courses should spend less time on the basics of financial calculations and more on cash flow estimating, uncertainty, risk, inflation, replacement analysis, capital budgeting, etc. How well and how many topics are covered is currently constrained by time spent on interpolation, iterative solutions for *i* or *N*, arithmetic gradient factors, and financial arithmetic. All of these are of little value as soon as the tools of engineering practice are used."

The 39 signers included the authors of most popular texts, multiple editors of *TEE*, and other prominent engineering economists.

This paper analyzes current editions of 7 popular engineering economy texts in light of the proposition. This includes the presentation of data on each text's examples, as well as an analysis of the shift in topical coverage called for in the proposition. While this measures texts, not instructor classroom choices, it seems to be a good measure of how much more easily instructors could make the shift called for by the proposition.

In the opinion piece[2] that accompanied the proposition, the use of TVM calculators were recommended in addition to spreadsheets. These calculators (often referred to as financial calculators) use identical methods of calculation as spreadsheet annuity functions and can perform most of the same calculations, although without the accompanying electronic 'paper trail'. TVM calculators are mentioned in most texts, but explicit topical coverage is limited to Blank & Tarquin 7th (p. 569)[3], Blank & Tarquin Basics 2nd (pp. 54 – 56)[4], and Newnan et al. 12th (pp. 591 – 592)[5]. Thus the focus of our methodology is on the use of tabulated factors, spreadsheets, and formulas, and how they are presented in recent editions of our major textbooks.

As part of the analysis, we also address why publishers and authors may be slow to change their texts and why instructors may be slow to change how they teach their courses.

Methodology

We have chosen to focus on the most recent edition of 7 texts, because we believe it is much more important to assess where the field is now, than it is to estimate which texts have been the least or most responsive to the proposition. We know that most texts were initially written before spreadsheets were being widely used in engineering economy education, while one text is a first edition.

Five of the texts have been chosen based on their long and substantial history of use.

- Blank & Tarquin, 7th (2012)[3]
- Newnan, Lavelle, & Eschenbach, 12th (2014)[5]
- Park, 6th (2016)[6]
- Sullivan, Wicks, & Koelling, 16th (2015)[8]
- White, Case, & Pratt, 6th (2012)[9]

Three of the above texts have shortened versions that generally have a smaller market share than their "parent" edition. Two of these have been published more recently than their "parent" edition, and they have been included in our analysis. One of these is a first edition that was published after the proposition.

- Blank & Tarquin, 2nd (2014)[4]
- White, Grasman, Case, LaScola Needy, & Pratt (2014)[10]

The longer Park (2016) was published since Park (2013)[7], so the shorter book will not be included. Other titles in engineering economy have lower market shares than the included books. Note that reference #s are included here, but due to the large number of repetitive labels and references, the texts are simply referred to by author and edition.

We have chosen to focus on the content of formal examples that are presented as part of each chapter rather than homework problems for two reasons. First, it is much clearer which approach or approaches are being used. Second, since several texts have total problem sets ranging from nearly a 1000 to over 1500, using problems as a basis would be overwhelming.

In analyzing the examples, the first step was to classify the problem as time value of money (TVM) or not. For our purposes this meant the *calculation* of a present worth, future worth, etc. So a problem that stated a present worth, but had no calculation, was classified as *not* TVM. This paper is addressing which methods are being shown to students, not how frequently economic value is mentioned. In some cases, such as for depreciation or introductory chapters on economic decision-making, the classification was easy. Many were not quite so simple to classify.

The second step for each text was done a chapter at a time. Every example was listed by example number under every approach that was applicable. Thus, a TVM example would be listed as being solved using factors, spreadsheets, or formulas. Many examples contained more than one of these methods.

The third step was to calculate the number of examples solved by each method within each chapter. These were summed into totals for each text for the analysis that is presented in the results section.

While we have been as objective as possible, we highlight here some of the judgement calls that we had to make.

- We chose to classify examples as using factors because they used factor notation. Some of these examples also had a separate, clear use of spreadsheets. Whether tables, a calculator, or a spreadsheet was being used to solve the factor equation was often unclear, because not all texts show intermediate work, especially in more advanced chapters. However, we are pretty sure that some of these classifications used factor notation, but not tables. For example \$50(*F*/*A*, 0.826%, 120) = \$101,907.89 was clearly *not* solved with tables. Thus, the use of factors may be over-stated in some cases due to the notation used.
- We chose to classify using single (*P*/*F*) factors times irregular cash flows generated by a spreadsheet as not using the tabulated factors since the problem *clearly* was not solved with the (*P*/*F*) factors. Most of these were more advanced problems.
- Similarly, if only the calculated value from Excel was shown with no indication of its origin, this was not counted as an example of showing a TVM calculation.
- Spreadsheets may have been used to calculate the values for cash flow tables of some examples—or the values may have been done by calculators or factor tables from an earlier edition. Without an indication of how values were calculated these were classified as using factors or as non-TVM given the context of other examples in the chapter.
- Finally, the analysis of 7 texts has been a lengthy task with a new learning curve for each text. As much as possible we have tried to double or triple-check our work on earlier chapters and texts, but we cannot be sure that we have been absolutely consistent. We believe that the inconsistencies do not significantly impact our results.

Relative Factor, Formula, and Spreadsheet Use

The starting point is the number of examples in each category, as shown in Table 1. Percentages for each category are also shown. The TVM categories include examples where *how* the TVM was calculated could be determined and that would demonstrate that approach to students. As detailed in Table 1, spreadsheets and formulas can be applied to other types of examples where calculating the TVM is not the focus. Note that the percentages for each text sum to more than 100%, because many examples are solved more than one way.

Table 1. Tabulated Factors, Spreadsheets, Formulas, and Words for All Examples

	Book	TVM			not TVM			
Book	# Exp.	Factors	SSht	Formulas	SSht	Formulas	Words	# Exp.
B&T 7th	212	87	62	33	27	57	13	91
		41%	29%	16%	13%	27%	6%	
B&T Basic 2nd	127	61	26	22	1	32	10	42
		48%	20%	17%	1%	25%	8%	
Newnan 12th	211	96	82	34	3	39	15	55
		45%	39%	16%	1%	18%	7%	
Park 6th	169	91	43	28	9	50	19	70
		54%	25%	17%	5%	30%	11%	
Sullivan 16th	175	106	23	15	4	37	9	43
		61%	13%	9%	2%	21%	5%	
White 6th	290	107	129	14	20	39	76	127
		37%	44%	5%	7%	13%	26%	
White Fund.	110	58	61	9	8	13	21	36
		53%	55%	8%	7%	12%	19%	

Table 1 emphasizes that *all* of the texts include many numbered examples. Each of the texts also includes examples that are unnumbered or simply part of a table or figure.

Table 2 and Figure 1 consider only the subset of examples that included TVM calculations. We were somewhat surprised by the results shown in Table 2. As a group these texts have included more coverage of spreadsheets than we had expected. We have not done a detailed analysis of *pre-proposition* editions with the current editions, but we did see changes—sometimes very significant ones that represented using more spreadsheet functions or presenting them very differently.

Table 2. Methods for TVM Calculated Examples

	TVM	TVM		
Book	# Exp.	Factors	SSht	Formulas
B&T 7th	121	72%	51%	27%
B&T Basic 2nd	85	72%	31%	26%
Newnan 12th	156	62%	53%	22%
Park 6th	99	92%	43%	28%
Sullivan 16th	132	80%	17%	11%
White 6th	163	66%	79%	9%
White Fund.	74	78%	82%	12%

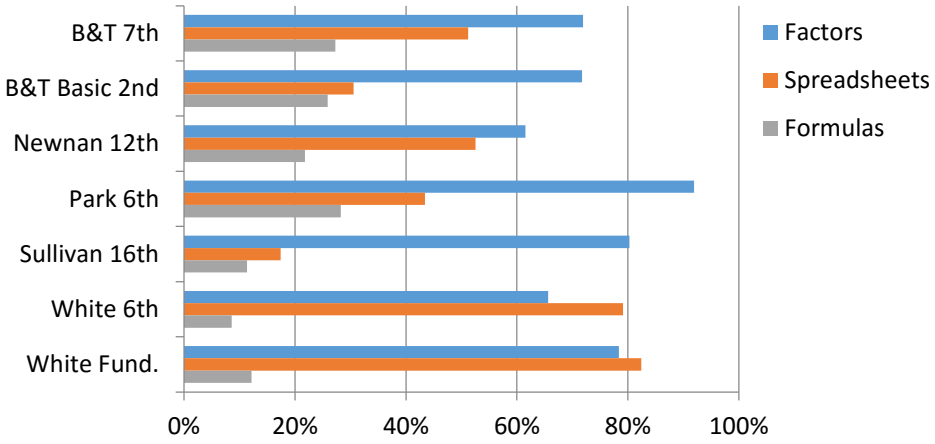

Figure 1. Barchart of Methods for TVM Calculations

Considering only the longer text for each author team, we have calculated the following averages (each text weighted equally). While factors are still the most frequently used tool, basically ½ of the examples are also solved with spreadsheets by the field's leading texts.

- 74% Factors
- 49% Spreadsheets
- 19% Formulas

If someone does attempt to measure the field's change as measured by the evolution of these texts, we suggest some caution in identifying which texts are pre-proposition. First, several and perhaps most or all publishers tend to state copyright dates that are at least a year later than the text's availability shown by Amazon. Second, the authors of these texts were aware of the proposition at least 6 months and some a year or more before it was published.

While these tables and figures measure texts, not instructor classroom choices, we believe this is a reasonably good measure of the material easily available to instructors who want to make the shift called for by the proposition.

Chapter Coverage of Basic Time Value of Money Calculations

Table 3 narrows the focus to the one or two chapter(s) where TVM calculations or approaches to TVM calculations are introduced. These chapters exert the most influence on how students approach the rest of the course—and later use of engineering economy in practice.

For each text the first row shows the number of examples for each method (like Table 1). Then the second row for each text shows the percentage for each method considering only the TVM examples (like Table 2).

Table 3. Methods for TVM Calculations in Introductory Chapter(s)

		TVM				not TVM			
Book	Chapters	# Exp.	Factors	SSht	Formulas	SSht	Formulas	Words	# Exp.
B&T 7th	Ch. 3	8	8	4	2	0	0	0	0
	TVM Total	8	100%	50%	25%				
B&T Basic 2nd	Ch. 2	13	11	3	3	0	0	0	0
	TVM Total	13	85%	23%	23%				
Newnan 12th	Ch. 3 & 4	33	18	16	14	0	0	2	2
	TVM Total	31	58%	52%	45%				
Park 6th	Ch. 3	29	21	13	12	0	0	0	0
	TVM Total	29	72%	45%	41%				
Sullivan 16th	Ch. 4	35	28	4	4	0	0	1	0
	TVM Total	35	80%	11%	11%				
White 6th	Ch. 2	44	29	27	5	1	4	4	8
	TVM Total	36	81%	75%	14%				
White Fund.	Ch. 2	22	18	18	2	0	0	1	1
	TVM Total	21	86%	86%	10%				

Some of the percentages shift between Tables 2 and 3 for some of the texts but the results as a whole are reasonably consistent. Newnan, White, and White Fundamentals use a balanced approach in introducing these concepts. In contrast Sullivan uses engineering economy factors as the dominant technique, with less use of spreadsheets or formulas. However, as will be described later Sullivan has an important and at least currently a distinctive use of spreadsheets.

Figure 2 is based on the values shown in Table 3. As a measure of each text's *relative* use of each TVM approach, the percentages of Table 3 are normalized to a total of 100%. Note that this is based on a simple count of examples for each approach. It does not consider whether 1 approach was allocated 1 line compared with 60 lines for another method.

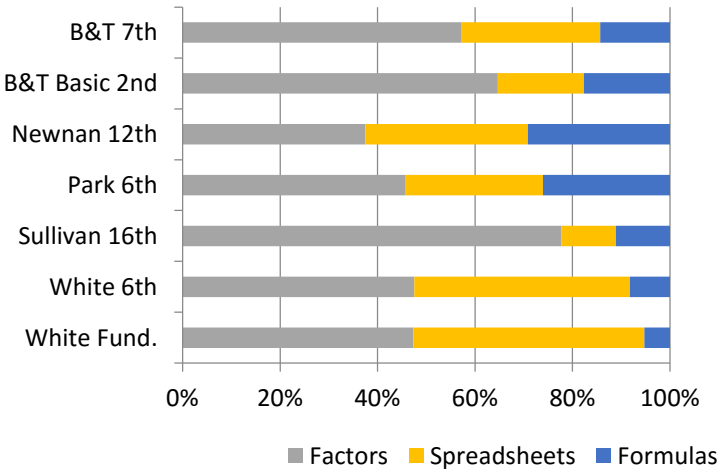

Figure 2. Approach Used (Normalized to 100%) in Introductory Chapter

Examples of Spreadsheet Use

These examples from different texts show different pedagogical and editorial approaches. Some of these approaches can be used by instructors in a *text-independent* fashion, even if their preferred text does not include that approach.

The Blank & Tarquin book contains spreadsheet functions and engineering factors inside the front cover, and both are given equal attention. Spreadsheet examples are integrated in the text along with factors, though factors are always discussed first. The use of calculators is detailed in the book's Appendix D. Blank & Tarquin 7th use a simple spreadsheet view with the cell formula clearly shown. Their use of data blocks is minimal, and variables are often hard coded in the cell's formula, as shown in Figure 3.

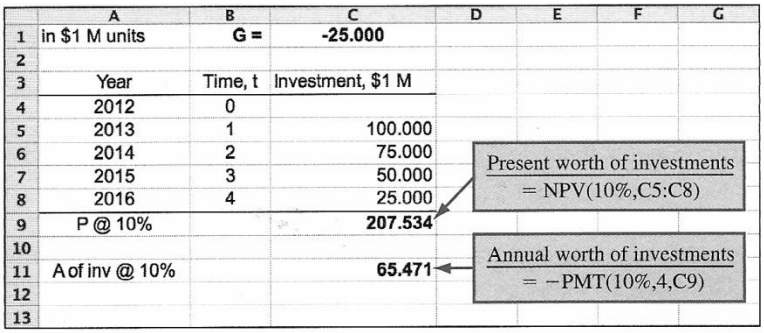

Figure 3. Blank & Tarquin 6th Example 2.10 p. 57

Newnan in its 12th edition introduced a visual spreadsheet view of the annuity functions that also supports financial calculators, as shown in Figure 4. Since its 8th edition Newnan has emphasized the use of data blocks when building cash flow tables. These data blocks define the values of all variables, and then the table is built with formulas that reference data block cells.

	A	B	C	D	E	F	G	H	I
1	Problem	*i*	*N*	*PMT*	*PV*	*FV*	Solve for	Answer	Formula
2	B-1	5.0%	2	0		110.25	PV	-$100.00	=PV(B2,C2,D2,F2)
3	B-2	7.0%	3	-3000	-5000		FV	$15,770	=FV(B3,C3,D3,E3)
4	B-3	3.5%	3		1500	200	PMT	-$599.79	=PMT(B4,C4,E4,F4)
5	B-4		5	-250	1000	100	RATE	5.15%	=RATE(C5,D5,E5,F5)
6	B-5	6.25%		450	-2000	0	N	5.37	=NPER(B6,D6,E6,F6)

Figure 4. Newnan Figure B-1, p. 589

Park 6th frequently included a graph of project balance/amount owed in introductory TVM spreadsheets (see Figure 5).

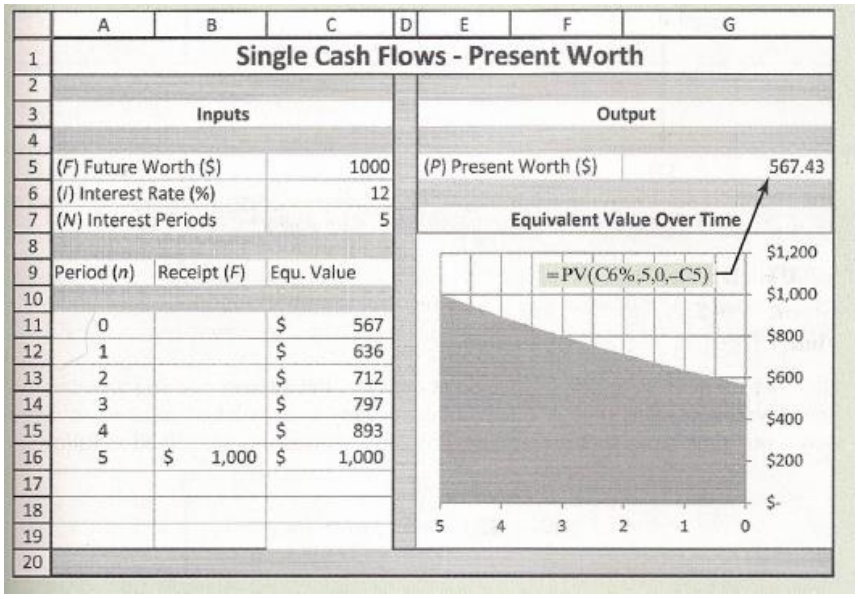

Figure 5. Park Example 3.8, p. 77

- White et al. 6th and White et al. Fundamentals include the highest percentage of spreadsheet inclusion. Both texts also make frequent use of SOLVER and GOAL SEEK, even in the very early chapters, as shown in Figure 6.

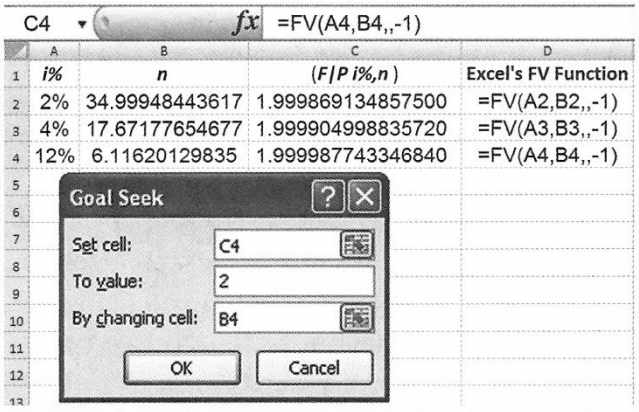

Figure 6. White Fundamentals Example 2.4 p. 32

Coverage of Financial Arithmetic

Quoting from the last paragraph of the proposition:

> "How well and how many topics are covered is currently constrained by time spent on interpolation, iterative solutions for *i* or *N*, arithmetic gradient factors, and financial arithmetic. All of these are of little value as soon as the tools of engineering practice are used."

While we were encouraged by the data on use of spreadsheets, we found the coverage of financial arithmetic to still be substantial. The amount of coverage may have decreased, but every text still has significant coverage of interpolation, iterative solutions, arithmetic gradients, and financial arithmetic.

Textbook users may wonder why authors who have stated the need for change—have not made more changes. Our perception is that publishers and authors are very protective of their adoption base. Because some instructors want a slow pace of change, that is what all instructors get. It is much easier to add coverage of spreadsheets than it is to drop existing material. The next section addresses some of the classroom and textbook challenges in shifting the balance between the engineering economy factors and the more modern tools of engineering economy practice.

Challenges in Matching Engineering Economy Teaching to Modern Practices

The previous section briefly described why authors and publishers may be slow at decreasing coverage of traditional tools. Basically some engineering economists and some (perhaps many) who teach the course as a "load filler" find the status quo methods acceptable and easier to teach. We know that adopters faced with more change than they are comfortable with are more likely to switch to another text—thus publishers and authors may be wary of change.

Change can be difficult, and certainly includes significant work. Restated for the publishers, it is instructor inertia and the desire to appeal to the majority of instructors that stands in the way of significant change. Fundamentally, the desire of publishers is to have each text be useable by as many potential adopters as possible.

So why are instructors reluctant to shift to modern computational tools?

- Large classes can be a challenge, since they cannot fit into teaching focused computer labs. While use of spreadsheets can be demonstrated in a lecture hall, only a limited number of universities require every student to have a laptop. Many but not all students own laptops, as some rely on the universities' computer labs. Thus student use of the tools can be inconsistent in the classroom.
- Use of computers can lead to difficulties in testing in classes of any size—but the problems are particularly acute in large classes. Computers need to be supplied by the school or students bring their own. If students bring their own computer, there is no control over what content is brought or what software may be used. Communication during a test via text or email can be an issue.
    - We know a number of instructors who encourage students to use spreadsheets for homework, but who nevertheless require the use of tabulated factors for testing.
    - We know of other instructors who move their class to a computer lab for testing.
    - There are others who have relocated the entire course to a computer lab, limiting the course enrollment by the availability of computers.
    - Unfortunately, our data base for each alternative is limited and broad conclusions cannot be drawn.
- Some instructors believe that the traditional tabulated factor approach is the best way to develop student understanding, and there is more than enough conceptual material to fill

the engineering economy course. The view of some might even be expressed as, "spreadsheets are easy to learn tools that can be left for the practicing engineer to learn."
- There is a strong inertia among overloaded faculty not to change, as they feel they cannot take the time to change how they teach.
- The FE exam continues to focus on a factor approach, as spreadsheets are not available. Two of the five accepted calculators can be programmed to act as a TVM calculator, however.
- Our conclusion is that for large classes, it is testing that stands in the way. For instructor inertia, it is the teaching and the testing.

As possible solutions to the testing problem, we note the following:
- There are a variety of hardware and software solutions that restrict students' access to email and the web for testing.
- The hardware solutions can work well and permit access to spreadsheets, but often they can only be used for smaller classes that fit in computer labs that can be reserved for teaching or testing.
- The software solutions even include the ability to have proctored exams using webcams and keystroke loggers for online students. However, the software solutions that we know of require that the student be restricted to a single software program that is the test environment—thus students cannot access spreadsheet programs.
- The Sullivan, Wicks, and Koelling 16th text is supported by Pearson's MyEngineeringLab, which is apparently the first publisher supported online system that includes "Assignable Spreadsheet Exercises that students can complete in an Excel-simulated environment." This does not seem to imply that students can use a spreadsheet for any problem, but it is certainly a step in that direction.

Conclusion

Our overall conclusion is that there has been progress in teaching with the tools of practice—but more progress is needed. Moreover, there is enough variety in the texts to suit many but probably not all instructors. This paper will be useful to both teachers and authors, and most importantly to the students they serve.

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