# A NEW FRAMEWORK FOR ENGINEERING ECONOMICS

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**Abstract**
Students learning to solve engineering economics problems a century ago were instructed in the use of tools that reduced the time required for their solution. Today's widespread availability of financial calculators begs the question of whether it's time to replace the tools of the past.

Financial functions available in many calculators and incorporated into spreadsheet software ease the computational burden that gave rise to Tables of time-value of money ratios. Spreadsheets offer the additional benefit of a structured framework ideal for forecasting engineering project economics.

This paper continues the dialog, Peterson et al (2005), exploring the need for a new approach to engineering economics education. Two issues are addressed herein: 1. Building financial models with spreadsheets promotes financial literacy and 2. Factor Notation needs to be updated to utilize the capabilities built into today's ubiquitous financial functions.

**Keywords:** engineering economy, engineering education

**Background**
Engineering Management relies on the knowledge gained from engineering economics to evaluate prospective projects from a financial perspective. A project, in this context, can range from the relatively small, such as equipment replacement analysis, to as large as planning a new product line. In both cases, optimizing financial performance is a key responsibility of the engineer. The differences between these two project examples illuminate the debate about the content of engineering economics education. Planning a new product line arguably requires more financial sophistication than that required for equipment replacement analysis. The financial objectives, however, are the same. O'Neal and Kulonda (2004, 3247) observe "Most engineering curricula devote little time to the development of financial literacy among engineering students. Many civil and industrial engineers obtain some exposure in an undergraduate engineering economics course, but these courses generally focus primarily on the time value of money and the comparison of alternatives based upon discounted cash flow." They conclude that the requirement for engineering students to understand accrual accounting is essential. The importance of accounting knowledge is reinforced by Sullivan et al (2005, 71): "Engineers should make serious efforts to learn about a firm's accounting practice so they can better communicate with top management." The authors continue: "The fundamental accounting equation defines the format of the balance sheet which is one of the two most common accounting statements…"

Schmahl et al (2000, 6905) in counter point asks the question: "Where is the engineering in engineering economy?" The authors state that financial applications are emphasized at the expense of engineering applications. It appears that students may spend more time learning to analyze cash flow than engineering the project that produces the cash flow to be analyzed.

Peterson et al (2005, 9081) "…asks the question: should we drastically change the way we teach undergraduate engineering economics? With the widespread availability of spreadsheet software should we rethink the presentation of the material and concentrate on the creation of the cash flow and less on the mechanics of converting the cash flow into a decision variable?"

A survey of Master of Engineering Management students (Kauffman and Peterson, 2002) revealed engineering economy topics of importance to engineers in the workplace. Classroom topics given the highest ranking towards enhancing professional career development include simulation methods, equivalent worth, depreciation & taxes, and parametric cost estimation. Financial statement analysis was ranked in the category of least important topics. The topics of greatest value to these engineers are integral to financial modeling and require computer tools for their implementation.

Each of these authors is concerned that engineering economy education adequately prepares students to thrive in a management environment with an optimal balance of engineering and financial knowledge. Financial tools including spreadsheet software and financial functions are desirable to simplify the mechanics of cash flow analysis. Increased financial literacy is also desirable, but not at the expense of the engineering knowledge backing up the cash flow predictions. Student feedback appears to corroborate those topics The engineering economy content issues of today bear a striking similarity to those of the past.

JCL Fish (1915, 3), a railroad engineering professor at Stanford University, grappled with engineering economics content complicated by the same issues facing educators today. With respect to financial literacy, he wrote "It would appear that the principles of economic selection are an important part of the knowledge which is indispensable to owners or their executives, and to all others who hold responsible positions… And it may be confidently added that that by intelligently applying the principles of economic selection…a young [engineer] will establish a claim [to a position of increasing responsibility]." The importance of powerful financial tools was also apparent in his 1915 text introduction: "Understanding the methods of Part III and being supplied with all the pertinent numerical data ready formed for substitution in the formulas, the computer can without difficulty make all the computations required for the comparison of two or more [projects] proposed for a stated service." Of course, the computer that professor Fish was referring to was the engineering student! He then cautions that data used in the above referenced time-value formulas must be a result of judgment, training, and practice in the specific engineering field.

Professor Fish taught almost 100 years ago that 1. Increased financial literacy improves job advancement prospects for engineers; 2. Using modern financial tools reduces time required to analyze cash flow; and; 3. Engineering the project that creates the cash flow must be emphasized.

**Methodology**

Engineering economy is a required course at the University of Arizona for Systems Engineering, Industrial Engineering, and Engineering Management undergraduate majors. This course has been revised to require financial tools and software common in the workplace. Students construct a pro-forma financial framework in Microsoft Excel™ to model a hypothetical manufacturing company including income statements, cash flow statements, and balance sheets. Most textbooks address the construction of income and cash flow statements. Adding the balance sheet completes the trio of key financial statements. Inexpensive financial calculators (i.e. HP-10BII™ ≈$30) or calculators common to engineering students (i.e. TI -83Plus™) are required for the class including exams. All homework and project assignments are submitted electronically in Excel. The course is delivered via the web based learning management system *Desire to Learn*™ (D2L) which greatly simplifies disseminating class material and managing uploaded assignments. The textbook, *Contemporary Engineering Economics* (Park, 2002), has proven to be a good basis from which to contrast and compare problem solutions with alternate approaches. While it may appear that adding financial material would leave even less class time devoted to engineering issues, integrating a financial framework into the course results in more time available later in the semester to consider financial implications of, for example, manufacturing rate changes on company financials.

**Financial Modeling.** Constructing financial statements ensures students acquire financial literacy as they model a proposed manufacturing company by month for a year. The always dry subject of accounting becomes a much more interesting subject when it's presented in an entrepreneurial context. Accounting concepts become simulation rules necessary to model a new startup company. Accounting definitions are put to practice and the accounting equation is reinforced continuously as students work to balance assets with liabilities. As the manufacturing company assumptions grow assignment by assignment, simple cash based income and cash flow statements evolve into accrual accounting based pro-forma financials. Worksheets that feed into the financials include:

1. Sales and Manufacturing.

   This worksheet produces unit sales and manufacturing estimates, revenue, cost of goods sold, and the material balance necessary to calculate inventory.

2. Equipment Investment.

   Equipment is purchased, depreciated, and sold including taxable gain or loss. The common depreciation methods are included for financial statement accounting. MACRS is presented in the context of tax accounting.

3. Receivables and Payables.

   Cash flow and income may share the same symbol ($), however, students soon learn that income is not equal to cash because of accrual accounting principles.

4. Debt Amortization.

   The debt worksheet computes a loan amortization schedule including current and long term portions of debt.

5. Taxation.

   The tax worksheet is organized with flexibility to; tax the company as a new startup using the graduated tax tables; or tax the company at a flat rate assuming the company is a part of a larger enterprise; or include no tax for a before tax analysis.

6. Valuation.

After tax cash flow from the cash flow statement is the input to this worksheet that values the company using several methods including equivalent worth, periodic equivalence, internal rate of return and benefit-cost ratio analysis. This worksheet also includes a calculation of the capital required to finance the company.

As worksheets are added to the model, students gain an appreciation of each topic's impact on company financials as a whole. The pro-forma financial model students construct to simulate the manufacturing company becomes the framework, with accounting rules built in, that students then use to understand, organize, and solve other cash flow related problems. The time savings gained from using the model offsets the time required to teach the creation of the model. Students extend the model to five years in subsequent engineering management classes to analyze the economics of increasingly complex manufacturing scenarios.

**Factor Notation.** The need to borrow money to purchase equipment planned for acquisition by the hypothetical company introduces the subject of the time-value of money early in the semester. Factor notation is not presented in favor of organizing time-value problems in a format so they can be quickly and accurately solved both by calculator and Excel. Current textbook authors vary in their preferences of using factor notation versus the calculator. Park (2007, 74) writes that "Even with hand calculators, it is still often convenient to use such tables…"and "Because using the interest tables is often the easiest way to solve an equation, this factor notation is included…" Newnan et al (2005, 52) concur with: "The equation $F = P (1 + i)^N$ need not be solved with a hand calculator…" Blank and Tarquin (2005, 63) however, counter: "It is generally easier and faster to use formulas from a calculator or spreadsheet that has them pre-programmed."

The answer to whether calculators or tables are easier and faster to use for financial problems becomes apparent when financial problem variables don't align exactly with table values. Any problem where i or N don't match table entries or any problem where i or N are dependent variables requires using linear interpolation. Park (2007, 78) concedes that "This procedure (using tables) will be very tedious for fractional interest rates or where N is not a whole number, because you may have to approximate the solution by linear interpolation. …The most practical approach is to use either a financial calculator or an electronic spreadsheet." Blank and Tarquin (2005, 63) add: "Furthermore, the value obtained through linear interpolation is not exactly correct, since the equations are nonlinear." The following problem is straightforward with Excel or a calculator: *How much will I accumulate in 37 years if I start today with a $10,000 investment followed by yearly withdrawals of $1,000 from a fund that returns 19.00% annually?* A financial calculator quickly computes the answer in one function call returning $2,961,413. Solving this problem using tables (Park, 2002, 896) and linear interpolation produces an answer of $3,465,384. Considerable time is required to compute an answer using tables that differs by $503,971 or 17% from a financial calculator solution. There can be no question that using a calculator to solve financial problems is faster and more accurate than using tables for other than the most ideal of problems. Professor Fish promoted tables as a tool to accelerate problem solutions in 1915 when the alternative was solving these problems with log tables, slide rules and patience. Peterson et al (2005, 9083) opine: "…financial functions in the spreadsheet software makes the use of tables in the practice of engineering obsolete." Using built in financial functions today should be viewed no less favorably than using the square root or the $y^X$ functions available on most calculators.

Tables and factor notation aren't completely ignored in this class. The Fundamentals of Engineering (FE) exam allows only designated calculators (NCEES, 2006) to be used. A calculator like the HP 30S replete with statistical functions, powers, roots, physical constants, and quadratic solvers is approved for the FE exam. A simple financial calculator like the HP 10B that cannot store text nor communicate to the outside world is not allowed in the FE exam room. Until the FE exam calculator policy accommodating programmed financial functions is changed, students will be required to use tables for one important exam (Peterson et al, 2005) only to abandon tables in favor of calculators and spreadsheets for the rest of their professional careers. Consequently, the use of factor notation and affiliated tables is presented to interested students during FE exam review sessions.

One alternative to factor notation and tables is to organize time-value equations in the context of spreadsheet and calculator functions. Factor notation is based upon a three parameter construction like the following expression:

$$F/P = (F/P, i, N) \qquad (1)$$

Future-value divided by present-value (F/P) ratios (and many others) are published in tables for selected values of interest rate (i) and number of periods (N) to ease the tedium of time-value problems. Multiplying this ratio by a known present value (P) results in the sought after future value (F). Today, financial calculators greatly simplify time-value problems using a four parameter function.

$$F = f(i, N, A, P) \qquad (2)$$

This functional construct, including payment (A), accommodates the quick solution to the investment problem illustrated above. The future value function (2), including sign convention, is algebraically equivalent to:

$$F = -A\,((1 + i)^{N} - 1)/i - P\,(1+i)^{N} \qquad (3)$$

In similar fashion, functional construction and algebraic equivalents for P, A, and N are easily derived. Because there is no algebraic equivalent for i, built in trial and error algorithms offer fast financial calculator solutions to problems where interest rate is the dependent variable.

Calculator and spreadsheet software manufacturers developed four parameter (five if Begin/End mode is included) financial functions in response to the demands of the business marketplace. The conversion from three argument factor notation (1) to a four parameter functional construction (2) would align problem solution methodology with current financial tool capability.

**Conclusions and Recommendations**

Factor notation was designed to accelerate engineering economy problem solutions in an era of limited computational capability. Financial functions available to engineering students today greatly simplify and improve the accuracy of time-value of money computations. Use of these functions is so commonplace that they should be integrated into engineering economics education.

The structured framework provided by spreadsheet programs is ideal for implementing accounting rules to produce pro-forma financial statements. These statements are the common language of business to communicate financial implications of proposed projects. Simulating a manufacturing environment integrates engineering topics into the class and balances financial subject matter. Implementing accounting rules improves financial literacy and results in models students can use as a resource for the future.

Replacement analysis confirms that professor Fish's 1915 computer defender has lost the battle to today's technology challenger.

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