1982

A PROGRAMMABLE CALCULATOR APPLICATIONS NOTEBOOK FOR PRACTICING PLANNERS

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A PROGRAMMABLE CALCULATOR APPLICATIONS NOTEBOOK FOR PRACTICING PLANNERS

BY

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A RESEARCH PROJECT SUBMITTED IN

PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MASTER OF COMMUNITY PLANNING

UNIVERSITY OF RHODE ISLAND

1982

MASTER OF COMMUNITY PLANNING

RESEARCH PROJECT

OF

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CONTENTS

INTRODUCTION 2

QUANTITATIVE METHODS IN PLANNING PRACTICE 6

ECONOMICS OF PROBLEM SOLVING 10

HARDWARE 15

SOFTWARE 24

PROGRAMMING FOR PLANNERS 32

DATA MANAGEMENT 45

CONVERSION 50

ROWS AND COLUMNS 60

POPULATION PROJECTION 67

LIFE CYCLE COSTING 79

HYDROELECTRIC SITES 85

BIBLIOGRAPHY 101

INTRODUCTION

A practicing planner needs the capability to solve quantitative problems. No planning curriculum can prepare its students for every kind of quantitative problem they can conceivably encounter. In my own field, renewable energy planning, some of the most important problems have emerged within the past few years: shadow calculations for solar access, tax incentive calculations for small hydroelectric site redevelopment, etc. Planners in this field are turning to powerful programmable calculator/printer systems as a means of coping.

Electronics engineers have been using programmable calculators since these tools appeared in 1977. I first began using the TI-59/PC-100C system in late 1979, while working on passive solar design problems with architects at the Northeast Solar Energy Center. Since then I have done thousands of runs for a wide variety of problems, mostly energy-related. It has become increasingly apparent that most of the advantages of the system can be transferred to other kinds of public planning.

Given an introductory notebook, most students should be able to acquire competence in calculator programming and applications more efficiently than I did. And so I decided to write such a notebook.

Quantitative problem solving with the TI-59/PC-100C is a blend of many things, from mathematical theory to keeping your fingerprints off the magnetic program cards.

Writing a notebook that respects the utility of brand-name and housekeeping information is not accepted academic practice in graduate schools, nor is the required double-spaced format appropriate for communicating this kind of information in the most efficient way. I have entered this project with some trepidation, despite my complete confidence in the hardware/software system.

Many of you will probably be unfamiliar with the specific hardware system discussed in this notebook. The Texas Instruments TI-59 programmable calculator operates much like the inexpensive TI-57. You may know someone who has a TI-57, so I will note here that its instruction manual, MAKING TRACKS INTO PROGRAMMING, is the best possible introduction to the TI algebraic operating system (AOS) and programming in general.[1]

This notebook is based on several premises that should be discussed here. First, most planners will not have access to computers with the software they need. Furthermore, for problems with fewer than about 100 input data points, the TI-59 outperforms computers more often than not, simply because it is so easy to program, access and operate. I own a $4000 microcomputer with a multi-purpose spreadsheet program, and the TI-59 is the minimal block time choice for most of the complex calculations in my work. The microcomputer works well for word processing and data storage, but it cannot compete as a calculator.

Second, the calculator's small size is a real advantage. It fits on the corner of a desktop or in an attache case (with printer). Without the printer it operates on battery power for field applications. There is no substitute for this kind of close and constant utility.

Third, most planners will have at least a refreshable knowledge of algebra. Algebra is an important tool, good for understanding most of the quantitative problems you will face, and good for programming in an assembly language based on algebraic notation.

Fourth, consecutive, quick numerical solutions permit consideration of several values for variables that cannot be accurately determined or estimated. It is reassuring to know when improved accuracy of inputs adds little to the value of a solution, because then we can manage problem-solving resources more efficiently.

Fifth, the above process can be extended to provide broad understanding of the underlying dynamics of a problem, understanding that would otherwise be achieved only by more experienced or more analytical minds. It is difficult to appreciate this phenomenon without experiencing it once or twice. Trust me.

Sixth, the knowledge acquired from the process of quantitative problem solving is a commodity related to power. It can be used constructively to note specific options and consequences, thereby minimizing the latitude for politicizing decisions. Planners who cannot provide specific, accurate solutions to quantitative problems cannot expect to be trusted by elected government officials.

Finally, the programmable calculator has been underestimated because of its small size, even though its speed and capacity exceed that of a central processing unit sold by IBM for a quarter million dollars in 1960. In 1980, when the federal government required utilities to provide on-site energy audits for their residential customers, I worked with a small group that designed a complying audit procedure. It required more than a hundred data inputs, more than a thousand calculations, and a complete discussion of results on-site. While other states set up central computer systems to be accessed by portable modem terminals, we developed an incredibly compressed TI-59 program. The Rhode Island utilities' non-profit auditing firm uses twenty calculator/printer systems for more than 10,000 audits per year. These systems save some $300,000 per year in computer programming, leasing and operations costs. The good feeling of having worked on that project has sustained me through more than a few disappointing days since then.

NOTES

[1] Ralph Oliva et al, MAKING TRACKS INTO PROGRAMMING, (Lubbock: Texas Instruments, 1977).

QUANTITATIVE METHODS IN PLANNING PRACTICE

Because quantitative methods have emerged from so many substantive fields and mathematical techniques, planning schools can include only the most practical and understandable in a two-year curriculum. And even this basic approach presents problems.

The economist John Kain has commented that quantitative methods courses in planning schools are too often about methods.[1] Students complete degrees without gaining competence in methods as tools.

In 1974 Daniel Isserman surveyed AIP-recognized schools to find out what methods were being taught. He found almost no consensus: only population projection and economic base were widely taught beyond the introductory level. Isserman also surveyed practicing planners for recommendations on what they thought should be taught. Again he found almost no consensus, and practicing planners collectively had different priorities from those of schools.[2]

Practicing planners listed the methods in which they thought competence should be required, while schools listed methods in which a basic introduction was required. The following list is ranked according to the practicing planners' priorities:

	Planners	Schools
1. Population projection	67%	75%
2. Questionnaire surveys	66	51
3. Housing need	54	17

		Planners	Schools
4.	Economic base	50%	75%
5.	Market area	49	24
6.	Descriptive statistics	43	61
7.	Cost-benefit	41	37
8.	Cost-revenue	37	24
9.	Inferential statistics	27	51
10.	Gravity model	26	54
11.	Input-output	14	46
12.	Multiple regression	14	46

The schools were clearly not providing the training that the profession required, however farsighted they may have been in selected methods such as input-output. The surveys were inconsistent in several ways. Schools were questioned on the gravity model, while planners were questioned on land use and transportation models in general. This makes the planners' minimal interest all the more emphatic. Property development finance was not included, which may account for the practicing planners' response to the housing need methods.

Isserman accepted all responses at face value, despite misgivings. Terms such as "competence" and "introduction" are subjective. It would have been prohibitively expensive to monitor course offerings by questioning or testing students. It might have been even more disconcerting.

The Isserman survey raises some serious questions about the sources of "professional judgment" in planning. For the experienced planner a reputation for wisdom may be sufficient to secure support for a plan or program, but younger planners will be increasingly challenged by management and systems science techniques from tangential fields.

The Isserman survey also raises questions about the classification of quantitative methods. The survey did not discriminate between substantive field applications and mathematical techniques. This was most obvious in the case of inferential statistics. How much of inferential statistics are we discussing? Is probability included? What substantive field applications are we concerned with beyond questionnaire surveys?

Many planning schools offer statistics as an introductory techniques course, without attention to the mechanics of substantive field applications. This is particularly true when the course is taught outside the department. Students may concurrently be studying the mechanics of substantive field applications for other mathematical techniques they may not have learned before entering planning school. This double bind situation could be remedied with diagnostic tests and short tutorial courses that incorporate calculator programs. Business schools have done this within and parallel to their curricula.[3]

It would be helpful to classify commonly used planning methods in a two-way table that shows the intersections of mathematical techniques and substantive field applications. Each application method could be linked to at least one published source. For example, the PRACTITIONER'S GUIDE TO FISCAL IMPACT ANALYSIS is probably the most important published information source for that method, although sources for variations of the method could be noted.[4] The manual calculation method presented in the GUIDE has been enhanced in programmable calculator and microcomputer software, but nothing has been published to date.

NOTES

[1] John Kain, "Rampant Schizophrenia: The Case of City and Regional Planning," JOURNAL OF THE AMERICAN INSTITUTE OF PLANNERS, (July 1970), p. 221.

[2] Daniel Isserman, PLANNING PRACTICE AND PLANNING EDUCATION: THE CASE OF QUANTITATIVE METHODS, (Urbana: Illinois, 1975).

[3] LRN, (January 1982), p. 3.

[4] Robert Burchell and David Listokin, PRACTITIONER'S GUIDE TO FISCAL IMPACT ANALYSIS, (New Brunswick: Rutgers, 1980).

ECONOMICS OF PROBLEM SOLVING

Linear programming was developed in the USSR during the 1930's, but it became a practical operations research method in the United States during the 1950's. The number of man-hours required to perform thousands of arithmetic operations increased costs and limited the number of problems worth solving. High-speed computers simply decreased the costs of linear programming (and, of course, increased the speed for real time applications).

Although computation costs have decreased dramatically over the past thirty years, lower costs have not necessarily been directly accessible. Professionals with relatively infrequent quantitative problem solving requirements may find the first cost of a computer and appropriate software to be prohibitive. When consultants are hired to solve the problems, they absorb the difference between the cost of computation and the market value of the solution.

There are some adaptive methods for getting around the cost problem. Large computers may test the limits of error for less complex models that fit into programmable calculators or even nomographs. Screening methods developed from back-of-the-envelope calculations can eliminate alot of problem cases that are not even worth considering for the purpose at hand. This is a bit theoretical, but the bottom line conclusion is that we can often avoid being dependent on equipment we cannot afford.

Think for a moment about how problems are solved. I might begin with a pencil and some graph paper (non-repro blue, four squares to the inch). I generally try to assemble the graphic, numerical and verbal components I need: a stylized drawing, diagrams, some arrows, a few numbers, book citations, some equations, more arrows, and erasures of things that seemed germaine but turned out not to be. I understand some of the dynamics of the problem from related experiences. In other ways I feel very inadequate. These are the times that professionals hide. We all try to cheat our limitations and avoid defeat (the area under a curve equals the number of squares you count on the graph paper).

If the problem is quantitative, it eventually boils down to data, mathematical operations and a useful format. Then is when it would be nice to have an inexpensive programmable calculator capable of doing things that would otherwise require computer access. There is something very satisfying about accomplishing the apparently impossible with tools you can easily conceal. To the extent that the Texas Instruments TI-59/PC-100C system can do this, the practicing planner has significant new opportunities.

In a world of complex problems, there are a few natural laws working for those of us using small tools. First, big models are not necessarily more useful than small models. William Alonso's old article on sources of error in models remains a good source of consolation and advice.[1] He notes two kinds of error. Measurement errors are those acquired from inaccurate measurement. Specification errors come from deliberate (or mistaken) model simplification. Alonso's central point is that elaborate specification may in fact generate cumulative measurement errors beyond what a simpler model would have produced. There is, in almost every case, a point of diminishing return. His summary advice is to avoid the operations that generate cumulative error fastest, namely intercorrelated variables, subtraction and exponentiation. Add where possible, and multiply or divide if you cannot add.

Second, complex problems can often be broken down into relatively autonomous sub-problems. If we can represent a problem graphically, it is often possible to understand how component parts are connected before that connection is expressed mathematically. Dennis Meadows' world systems model appears on the following page; it shows in some detail which sectors are most directly related to which. If these linkages were expressed only mathematically, relatively few people would understand what is going on. And some strange things would happen as a result of that lack of understanding.

Results generated from mathematical models that have not been graphically represented may be counterintuitive (contrary to our intuitive understanding of how things work). This might be because we have underestimated the extent to which certain combinations of variables could affect outcomes (watch out for exponents between 0.9 and 1.1: they strike surprisingly quickly). Once you know how the game is played, KEY

1. IC. Industrial Capital
2. ICDR. Industrial Capital Depreciation Rate
3. ALIC. Average Lifetime of Industrial Capital
4. ICUF. Industrial Capital Utilisation Fraction
5. IO. Industrial Output
6. ICOR. Industrial Capital Output Ratio
7. ICIR. Industrial Capital Investment Rate
8. FIOAC. Fraction of Industrial Output Allocated to Consumption
11. IOPC. Industrial Output *Per Capita*
12. ISOPC. Indicated Service Output *Per Capita*
13. FIOAS. Fraction of Industrial Output Allocated to Services
18. SCIR. Service Capital Investment Rate
19. SC. Service Capital
20. SCDR. Service Capital Depreciation Rate
21. ALSC. Average Lifetime of Service Capital
22. SO. Service Output
23. SCOR. Service Capital Output Ratio
24. SOPC. Service Output *Per Capita*
25. F. Food
25.1. LFH. Land Fraction Harvested
25.2. PL. Processing Loss
26. PAL. Potentially Arable Land
27. AL. Arable Land
28. LFC. Land Fraction Cultivated
28.1. PALT. Potentially Arable Land Total
29. DCPH. Development Cost per Hectare
30. LDR. Land Development Rate
31. IFPC. Indicated Food *Per Capita*
34. TAI. Total Agricultural Investment
35. FIOAA. Fraction of Industrial Output Allocated to Agriculture
38. FPC. Food *Per Capita*
39. LY. Land Yield
40. LYF. Land Yield Factor
41. AIPH. Agricultural Inputs Per Hectare
42. LYMC. Land Yield Multiplier from Capital
43. CAI. Current Agricultural Inputs
44. AI. Agricultural Inputs
46. FIALD. Fraction of Investment Allocated to Land Development
47. MPLD. Marginal Productivity of Land Development

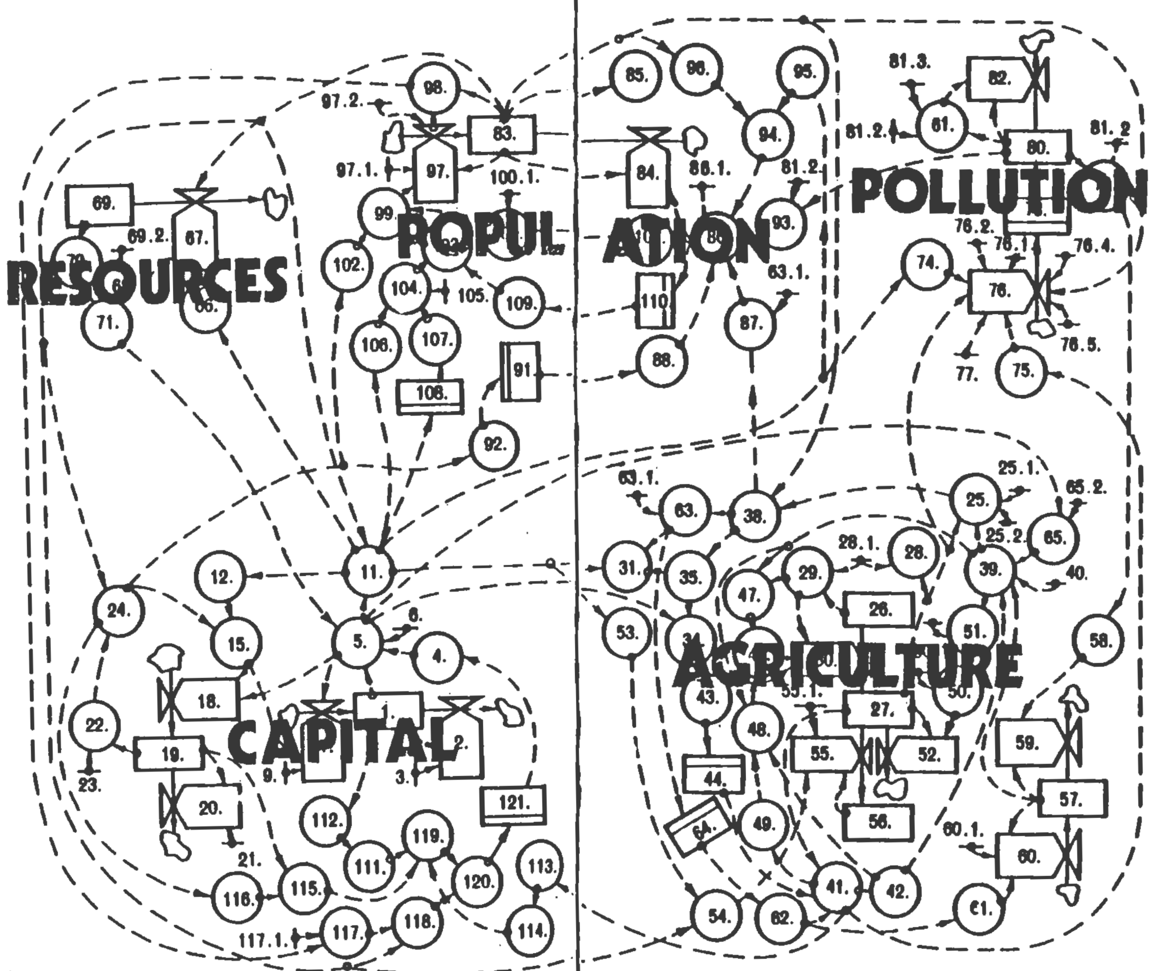


Figure 8. The complete World 3 model.

48. MPAI. Marginal Productivity of Agricultural Inputs
49. MLYMC. Marginal Land Yield Multiplier from Capital
50. ALL. Average Life of Land
50.1. ALLN. Average Life of Land Normal
51. LLMY. Land Life Multiplier from Yield
52. LER. Land Erosion Rate
53. UILPC. Urban-Industrial Land *Per Capita*
54. UILR. Urban-Industrial Land Required
55. LRUI. Land Removal for Urban-Industrial use
55.1. UILDT. Urban-Industrial Land Development Time
56. UIL. Urban-Industrial Land
57. LFERT. Land FERTility
58. LFDR. Land Fertility Degradation Rate
59. LFD. Land Fertility Degradation
60. LFR. Land Fertility Regeneration
60.1. ILF. Inherent Land Fertility
61. LFRT. Land Fertility Regeneration Time
62. FALM. Fraction Allocated to Land Maintenance
63. FR. Food Ratio
63.1. SFPC. Subsistence Food *Per Capita*
64. PFR. Perceived Food Ratio
65. LYMAP. Land Yield Multiplier from Air Pollution
65.2. IO70. Industrial Output in 1970
66. PCRUM. *Per Capita* Resource Usage Multiplier
67. NRUR. Nonrenewable Resource Usage Rate
68. NRUF. Nonrenewable Resource Usage Factor
69. NR. Nonrenewable Resources
69.2. NRI. Nonrenewable Resources Initial
70. NRFR. Nonrenewable Resources Fraction Remaining
71. FCAOR. Fraction of Capital Allocated to Obtaining Resources
74. PGMO. Pollution Generation Multiplier from Output
75. PGML. Pollution Generation Multiplier from Land
76. POLG. POLlution Generation
76.1. FPL. Fraction of Pollution from Land
76.2. FPO. Fraction of Pollution from Output
76.4. POP70. POPulation in 1970
76.5. AL70. Arable Land in 1970
77. POLGF. POLlution Generation Factor

keeping score is simple enough. Think graphically whenever you can. Drag the unknowns back to familiar ground. As one unimpressed reviewer wrote of a noted professor's mathematical model:

> Is it true, however, that the policy suggestions Forrester derives from his model are really surprising? The simplest way to answer these questions is to point out that one gets out of computer models what one puts in. If Forrester has defined a sick city in terms of a declining economy, increasing numbers of unemployed and high taxes, then it is obvious that a healthy city will simply manifest the reverse symptoms.
>
> Keeping the underemployed out of the city . . . would certainly lead industry to soak up available labor. Then the quality of urban life would improve, the demands on taxes diminish because of the decline in large numbers of demoralised, discontented workers and the economy would begin to recover.
>
> In fact there is nothing at all surprising in Forrester's conclusions given his assumptions. The model has only to be stood on its head for the solution to appear.[2]

NOTES

[1]William Alonso, "Predicting Best with Imperfect Data," JOURNAL OF THE AMERICAN INSTITUTE OF PLANNERS (July 1968), pp. 251-55.

[2]H. Cole et al, MODELS OF DOOM, (New York: Universe Books, 1973), p. 198.

HARDWARE

Texas Instruments and Hewlett-Packard manufacture the only magnetic-card-reading programmable calculators sold in the United States. From 1977-81 the Texas Instruments TI-59 dominated its market, essentially because it offered greater capacity and lower price than the Hewlett-Packard HP-67 and HP-97 calculators. The new HP-41CV is superior to the TI-59, but at more than double the price.

The most obvious difference between the TI and HP equipment is in the assembly language used for programming. TI uses an Algebraic Operating System (AOS) that permits anyone with an understanding of algebraic notation to program almost literally from an equation. The HP assembly language uses Reverse Polish Notation (RPN), a more efficient method for allocating program steps. Competent mathematicians tend to prefer RPN as the more efficient calculation logic. Algebraic notation was developed for concept assembly on paper. My preference for AOS is based on the ease with which it can be translated from program steps back to equations. The review and modification of available programs turns out to be an important activity.

TI and HP programmables also differ in physical design. The TI-59 uses a fast (60 characters per second) printer that runs on 120VAC only. The slower HP printer can run on battery power. The HP-41CV displays letters; the TI-59 does not.

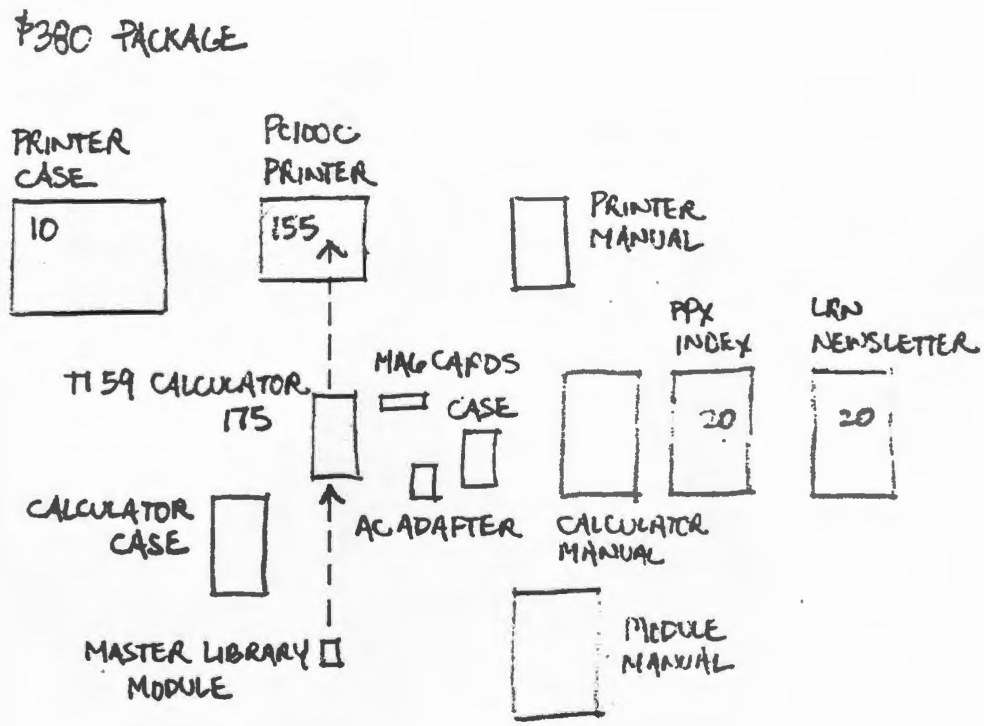
The HP calculators have superior card-reading tolerances; it is sometimes difficult for one TI-59 to read a card written on another. This has important implications for the way programs are marketed.

The TI-59 was designed as a multi-purpose calculation tool. None of its keys are dedicated to programs for specific substantive field applications. Instead, one program call key and ten user-defined keys access dedicated firmware contained in small modules that slide into the back of the calculator. These interchangeable modules contain up to 5000 program steps (typically a library of 20-25 programs). There are modules for business, investment, farming, etc., but none for community planning. The calculator comes with a master module designed for general use.

The TI-59/PC-100C system is both compact and modular. The diagram on the following page shows the relationship among parts. Note that the printer, calculator and modules each have their own instruction manuals. My entire system fits in a $10 Woolworth attache case lined with thin, rigid foam sheeting from a Xerox packing case. The system costs about $380 at discounted prices. Since repairs to the calculator are made on an exchange basis ($63 per exchange for a replacement after warranties expire), there are no service benefits to buying from a local retail dealer rather than a discount mail order firm. The equipment is remarkably reliable.

For those of you who have seen or used a TI-57, the

DIAGRAM OF COMPONENT RELATIONSHIPS



HARDWARE LIST (but not the best available prices)

Texas Instruments

TEXAS INSTRUMENTS CALCULATORS AND ACCESSORIES

CALCULATORS	DESCRIPTION	WEIGHT	PRICE
PROFESSIONAL CALCULATORS			
TI STUDENT BUSINESS ANALYST WITH BOOK		(3 LBS)	29.95
BUSINESS ANALYST II - SLIMLINE LCD BUS/FINAN W/STATISTICS		(3 LBS)	42.95
THE MBA	ADVANCED PROGRAMMABLE W/FINANCE & STATISTICS	(3 LBS)	59.95
SCIENTIFIC CALCULATORS			
TI-30 II	STUDENT SLIMLINE W/CONSTANT MEMORY FEATURE	(3 LBS)	18.95
TI-35 SP	SLIMLINE STUDENT SLIDE RULE W/CONSTANT MEM & BOOK	(3 LBS)	22.95
TI-40	TILT-TOP LCD W/CONSTANT MEMORY & BOOK	(3 LBS)	26.95
TI-55-II	ADVANCED SLIDE RULE PROGRAMMABLE LCD W/BOOK	(3 LBS)	44.95
TI-58C	480 STEPS - PLUG-IN SOLID STATE SOFTWARE	(5 LBS)	99.95
TI-59	960 STEPS - CARD PROGRAMMABLE	(6 LBS)	179.95
PC-100C	PRINTER/PLOTTER FOR TI-58/59	(8 LBS)	179.95
CARRYING CASE FOR PC-100C PRINTER WITH TI-59 MOUNTED		(4 LBS)	39.95
TI LCD PROGRAMMER	ADV TILT-TOP HEX/OCTAL CONVERTER	(4 LBS)	69.95
SOLID STATE SOFTWARE LIBRARIES			
STAT-5859	APPLIED STATISTICS	(2 LBS)	40.00
REI-5859	REAL ESTATE & INVESTMENT	(2 LBS)	40.00
AV-5859	AVIATION	(2 LBS)	40.00
NAV-5859	MARINE NAVIGATION	(2 LBS)	40.00
SURV-5859	SURVEYING	(2 LBS)	40.00
LEIS-5859	LEISURE LIBRARY	(2 LBS)	40.00
SEC-5859	SECURITIES LIBRARY	(2 LBS)	40.00
BUS-5859	BUSINESS DECISIONS	(2 LBS)	40.00
MATH-5859	MATH/UTILITIES	(2 LBS)	40.00
EE-5859	ELECTRICAL ENGINEERING	(2 LBS)	40.00
FARM-5859	FARMING	(2 LBS)	55.00
RPN-5859	RPN SIMULATOR	(2 LBS)	40.00
POOL-5859	POOL WATER ANALYSIS	(2 LBS)	45.00
SPECIALTY PAKETTES			
SP-SECUR	SECURITIES (TI-59 REQUIRED)	(2 LBS)	10.00
SP-STAT/TEST	STATISTICAL TESTING	(2 LBS)	10.00
SP-CIVIL/ENG	CIVIL ENGINEERING	(2 LBS)	10.00
SP-ELEC/ENG	ELECTRONIC ENGINEERING	(2 LBS)	10.00
SP-BLACKBODY	BLACKBODY	(2 LBS)	10.00
SP-OIL/GAS/ENG	OIL GAS ENERGY	(2 LBS)	10.00
SP-PROG/AIDS	PROGRAMMING AIDS (TI-59 W/PC-100C REQUIRED)	(2 LBS)	10.00
SP-PRINTR/UTIL	PRINTER UTILITY (TI-59 W/PC-100C REQUIRED)	(2 LBS)	10.00
SP-ASTROLOGY	ASTROLOGY	(2 LBS)	10.00
SP-59/FUN	59 FUN (TI-59 REQUIRED)	(2 LBS)	10.00
SP-3D/GRAPH	3D GRAPHICS	(2 LBS)	10.00
SP-MATH	MATH	(2 LBS)	10.00
SP-FLUID/DYN	FLUID DYNAMICS	(2 LBS)	10.00
SP-LAB/CHEM	LAB CHEMISTRY (TI-59 REQUIRED)	(2 LBS)	10.00
SP-PROD/PLAN	PRODUCTION PLANNING	(2 LBS)	10.00
SP-MKT/SALES	MARKETING/SALES	(2 LBS)	10.00
SP-QA1	QUALITY ASSURANCE I	(2 LBS)	10.00
SP-QA11	QUALITY ASSURANCE II	(2 LBS)	10.00
ACCESSORIES			
ADAPTERS/CHARGERS			
AC-9130A	SR-50/51/52/56/10/11/2550 111 (FOR BP-1A)	(2 LBS)	9.95
AC-9130SW	DUAL VOLTAGE 120/240V FOR BP-1 OR BP-1A	(2 LBS)	14.75
AC-9131	TI-59/58/51-11/1600/1650/58C	(2 LBS)	6.57
AC-9132	BA/MBA/57/55/PROGRAMMER/40 FOR BP-7 & BP-8	(2 LBS)	8.95
RK-2	TI-30/BA-1, INCLUDES AC-9132 & BP-8	(2 LBS)	12.00
BATTERY PACKS			
BP-1A	TI-59/58C/SR50/50A/52SA/51/51A	(1 LB)	10.00
BP-6	TI-51-11	(1 LB)	10.00
BP-7	MBA/TI-55/57	(1 LB)	8.95
BP-8	PROGRAMMER/SR-40/BA	(1 LB)	8.95
PAPER PRODUCTS			
TP-20225	TI-5135/5015/5040 (3 ROLLS PER PKG)	(3 LBS)	2.15
TP-27225	TI-5015/5040 (3 ROLLS PER PKG)	(3 LBS)	3.69
TP-30250	PC-100C (3 ROLLS PER PKG)	(3 LBS)	10.00
SP-3	2 1/4" STANDARD PAPER (3 ROLLS) TI-5142	(3 LBS)	1.90
MISCELLANEOUS			
PAD-58/59	PROGRAM RECORD FORMS PAD 58/59	(2 LBS)	2.95
BC-59	40 BLANK CARDS & CARD CASE FOR TI-59	(2 LBS)	20.00
BC-59A	120 BLANK CARDS & CARD CASE FOR TI-59	(3 LBS)	45.00

Free Software Offer

A dated copy of proof-of-purchase between February 1, 1982 and June 15, 1982. Items must be postmarked June 25, 1982.

☐ I've bought a TI-59, send me two free modules right away.

☐ I've bought a TI-58C, send me one free module right away.

I want these modules. ☐ Applied Statistics ☐ Business Decisions ☐ Real Estate/Investment ☐ Math/Utilities ☐ Aviation ☐ Electrical Engineering ☐ Marine Navigation ☐ Farming† ☐ Surveying ☐ RPN Simulator ☐ Leisure Activities ☐ Pool Water Analysis† ☐ Securities Analysis

Programmable TI 59

TI-59

$179.95

Programmable TI 58C

TI-58C

$99.95

PC100C PRINTER $179.95

CARRYING CASE $39.95

differences in the TI-59 can be described as capacity-related rather than format related:

	TI-57	TI-59
Program steps	50	460
Memory registers	8	60
Subroutines	6	72
Subroutine levels	6	6
Conditional branching	yes	yes
User-defined keys	0	10

The TI-59 has modifiable capacity: it can trade 60 program steps for 10 memory registers. Instead of a fixed 460/60 split, the range can be shifted from 160/100 to 960/0 in increments of 60/10.

The TI-57 has only 50 program steps, but these are functionally equivalent to about 80 steps on the TI-59, simply because more keystrokes are merged. For example, recalling a number from memory register 02 requires one step on a TI-57 and two on a TI-59. Of the minor differences in notation, only subroutine calls are worth mentioning here. The TI-57 calls numbered labels (eg, LBL 01), while the TI-59 calls key labels (eg, LBL x^2). You can set key/number equivalencies to keep track, so that programs for the TI-57 can be run or listed on the more expensive system.

The two instruction manuals are conceptually related, and the TI-57 uses the apt analogy of a model train layout to introduce programming concepts. The TI-59 manual, PERSONAL PROGRAMMING, uses flowcharting without analogies.[1]

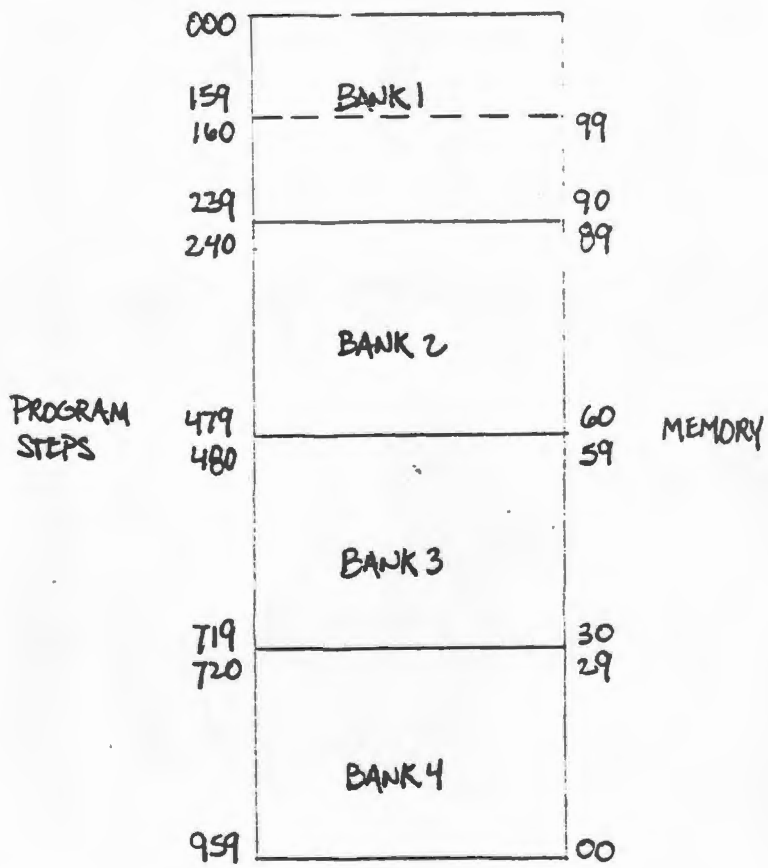
The most sensitive component in the TI-59 system is the magnetic card, but that card sets it apart as a professional tool. Each card has four banks (magnetic tracks), and each bank holds up to 240 program steps or 30 memory registers. Card numbers and bank numbers are not the same; they are simply equated by convention. The calculator can hold up to four banks of input at once. By convention the left side of the first card is called side one and uses bank one. The right side of that card is side two and uses bank two. The left side of the second card is called side three and uses bank three, etc. Respect the convention and save your mind for more important complications.

Although the instruction manual fails to mention erasure and rerecording, the magnetic cards can be used over again. Since each card side physically includes all four banks (or tracks), simply remember to overwrite the same bank you used before. This option is useful when data has to be stored on cards temporarily. Magnetic cards cost about $.40 each. When marking magnetic cards, use a black Flair pen that likes the surface (the ones that like the surface are great, but not all do). Let the ink dry thoroughly; it stays on until you wipe it off with soap and water.

Key definition cards that come with program library modules are black with gold lettering. Those that come with blank magnetic cards are gold and can be confused with magnetic cards. Throw them all away. The card case instruction manual is all you need for a program library module, and that is a good format to adopt for magnetic card programs as well.

BANK DIAGRAM

This diagram has been redrawn from PERSONAL PROGRAMMING, and it is a necessary reference for intial program/memory allocation. The following pages show the key codes as keys and as printed steps. The latter is a necessary reference



for interpreting other people's programs. Note that the keys and printed steps are not always easy to match. Not all codes are directly entered.

Key Codes In Numerical Order

Key Code	Key	Key Code	Key	Key Code	Key
00	0	39	2nd cos	72	STO 2nd Ind
↓	↓	40	2nd Ind	73	RCL 2nd Ind
09	9	42	STO	74	SUM 2nd Ind
10	2nd E'	43	RCL	75	−
11	A	44	SUM	76	2nd Lbl
12	B	45	y^x	77	2nd $x \geq t$
13	C	47	2nd CMs	78	2nd Σ+
14	D	48	2nd Exc	79	2nd $\bar{x}$
15	E	49	2nd Prd	80	2nd Grad
16	2nd A'	50	2nd $\|x\|$	81	RST
17	2nd B'	52	EE	*82	HIR
18	2nd C'	53	(	83	GTO 2nd Ind
19	2nd D'	54	)	84	2nd Op 2nd Ind
20	2nd CLR	55	÷	85	+
22	INV	57	2nd Eng	86	2nd St flg
23	$\ln x$	58	2nd Fix	87	2nd If flg
24	CE	59	2nd Int	88	2nd D.MS
25	CLR	60	2nd Deg	89	2nd π
27	2nd INV	61	GTO	90	2nd List
28	2nd log	62	2nd Pgm 2nd Ind	91	R/S
29	2nd CP	63	2nd Exc 2nd Ind	92	INV SBR
30	2nd tan	64	2nd Prd 2nd Ind	93	.
32	$x \rightleftarrows t$	65	×	94	+/−
33	x^2	66	2nd Pause	95	=
34	$\sqrt{x}$	67	2nd $x=t$	96	2nd Write
35	$1/x$	68	2nd Nop	**97	2nd Dsz
36	2nd Pgm	69	2nd Op	98	2nd Adv
37	2nd P→R	70	2nd Rad	99	2nd Prt
38	2nd sin	71	SBR		

NOTES

* This command cannot be directly keyed in, but may be written into a program by going into learn mode and pressing STO 82 and deleting the STO. There is a two-digit number XY which follows the 82 command. X stands for the hierarchy register operation, where 0 is STO, 1 is RCL, 3 is SUM, 4 is *Prd, 5 is INV SUM, and 6-9 are INC *Prd. Y stands for the hierarchy register to be accessed (1-8). XY may be entered in the same manner as code 82 if XY by itself is an invalid keyboard entry.

**The Dsz instruction on the TI-59 can be used with any register (except 40, which implies indirect). Registers 10-99 cannot be keyed in directly but may be generated as follows: LRN *Dsz STO nn BST BST *Del SST — LRN.

000	00	0
001	09	9
002	10	E'
003	11	A
004	12	B
005	13	C
006	14	D
007	15	E
008	16	A'
009	17	B'
010	18	C'
011	19	D'
012	20	CLR
013	22	INV
014	23	LNX
015	24	CE
016	25	CLR
017	27	INV
018	28	LOG
019	29	CP
020	30	TAN
021	32	X⇌T
022	33	X²
023	34	√X
024	35	1/X
025	36	PGM
026	00	00
027	37	P/R
028	38	SIN
029	39	COS
030	40	IND
031	42	STO
032	00	00
033	43	RCL
034	00	00
035	44	SUM
036	00	00
037	45	YX
038	47	CMS
039	48	EXC
040	00	00
041	49	PRD
042	00	0
043	50	I×I
044	52	EE
045	53	(
046	54	)
047	55	÷
048	57	ENG
049	58	FIX

050	00	00
051	59	INT
052	60	DEG
053	61	GTO
054	62	PG*
055	63	EX*
056	00	00
057	64	PD*
058	00	00
059	65	×
060	66	PAU
061	67	EQ
062	68	NOP
063	69	OP
064	00	00
065	70	RAD
066	71	SBR
067	00	00
068	00	00
069	72	ST*
070	00	00
071	73	RC*
072	00	00
073	74	SM*
074	00	00
075	75	-
076	76	LBL
077	77	GE
078	78	Σ+
079	79	x̄
080	80	GRD
081	81	RST
082	82	HIR
083	00	00
084	83	GO*
085	00	00
086	00	0
087	84	OP*
088	00	00
089	85	+
090	86	STF
091	00	00
092	87	IFF
093	00	00
094	00	00
095	00	00
096	88	DMS
097	89	π
098	90	LST
099	91	R/S

100	92	RTN
101	93	.
102	94	+/-
103	95	=
104	96	WRT
105	97	DSZ
106	00	00
107	98	ADV
108	99	PRT
109	00	0

133	21	2ND
134	26	2ND
135	31	LRN
136	41	SST
137	46	INS
138	51	BST
139	56	DEL
140	00	0

SOFTWARE

Many people simply purchase the software they need and avoid programming altogether. Program instructions can be treated like cookbook recipes, but there are risks involved. Even good programmers make mistakes that can embarrass you. Most programs can be modified to meet your needs more efficiently. The trick is to integrate review and modification.

TI-59 programs are available from several sources, but the largest and most important source is TI's own Personal Programming Exchange. PPX provides a quarterly newsletter and program catalog for $20 per year. Cataloged programs cost $4 each and are listed by six digit codes. The first two digits denote the subject area. A subject area classification table and sample abstract listings appear on the following pages.

PPX programs are also sold in related groups of 5-10 in books called Specialty Pakettes. The notation numbers are those used in the PPX catalog.

Texas Instruments does not pay for programs submitted to PPX, and there are people who write sophisticated programs worth more than $100 per copy. These are sold independently, often through appropriate professional journals. When they are sold as "protected" magnetic cards, the contents cannot be reproduced or analyzed. Be wary of these: if they have programming mistakes within them, you may never know. Your

TI-59 may have trouble reading cards written on another machine.

Texas Instruments offers program library modules that can be downlisted. Independent sources typically offer far more expensive modules that cannot be downlisted. If you trust the programmer, note that the modules present none of the reading problems posed by cards, nor do they wear out with extended use. If you do not trust the programmer, cards can at least be "unprotected" with a little effort.[1]

Most planners will probably want to purchase relevant PPX programs, review the listings, and modify them as necessary. The best source for information on modifications and utility routines is LRN, the newsletter of the Washington, D.C. area TI-59 users group. The $20 membership includes twelve issues (some of which are double issues) and at least a hundred directly useful programs, routines and insights.

Addresses for further information are:

PPX-59 P.O. Box 53 Lubbock, TX 79408	LRN 9213 Lanham Severn Road Lanham, MD 20801

NOTES

LRN, (march 1980), p. 2.

Professional Categories

BUSINESS
01 Management Accounting
02 Manufacturing Engineering
03 Inventory Control
04 Marketing/Sales
05 Personnel
06 Transportation
07 Insurance
08 Real Estate
09 Business (General)

FINANCE
10 Accounting
11 Auditing
12 Banking
13 Consumer Finance
14 Personal Finance
15 Economics
16 Leasing
17 Tax Planning/Preparation
18 Securities
19 Finance (General)

STATISTICS & PROBABILITY
20 Regression/Curve Fit
21 Analysis of Variance
22 Statistical Testing
23 Statistical Inference
24 Stochastic Processes
25 Probability Theory
26 Probability Distributions
27 Quality Assurance
28 Reliability/Maintainability
29 Statistics & Probability (General)

MATHEMATICS
30 Linear Algebra/Matrices
31 Complex Variables
32 Harmonic Analysis
33 Nonlinear Systems
34 Numerical Integration
35 Differential Equations
36 Number Systems
37 System Modeling
38 Operations Research
39 Mathematics (General)

NATURAL SCIENCES
40 Physics
41 Chemistry
42 Biology
43 Agriculture
44 Forestry
45 Ecology
46 Geology/Resources
47 Oceanography
48 Anthropology
49 Natural Sciences (Other)

LIFE SCIENCES
50 Clinical/Diagnostic
51 Virology/Immunology
52 Pathology
53 Biochemistry
54 Genetics
55 Physiology
56 Pharmacology
57 Ophthalmology/Optics
58 Nutrition/Food Science
59 Life Sciences (General)

ENGINEERING
60 Aeronautical Engineering
61 Chemical Engineering
62 Civil Engineering
63 Computer Science
64 Electrical Engineering
65 Electronic Engineering
66 Mechanical Engineering
67 Nuclear Engineering
68 System Engineering
69 Engineering (General)

TECHNICAL
70 Acoustics
71 Architecture
72 Ceramics
73 Heating, Air Conditioning, Cooling
74 Optics
75 Programming
76 Seismology
77 Surveying
78 Astronomy
79 Technical (Other)

SOCIAL & BEHAVIORAL SCIENCES
80 Political Science
81 Sociology
82 Psychology/Psychiatry
83 Law Enforcement
84 Social & Behavioral Sciences (Other)

NATURAL RESOURCES
85 Lumber/Forest Products
86 Oil/Gas/Energy
87 Food Resources
88 Water Resources
89 Natural Resources (Other)

GENERAL
90 Utility Programs
91 Demonstration/Games
92 Education
93 Air Navigation
94 Marine Navigation
95 Photography
96 Music
97 Astrology
98 Sports
99 Other

198060G INTERNAL RATE OF RETURN COMPUTATION

THIS PROGRAM CALCULATES THE IRR (INTERNAL RATE OF RETURN) FOR A WIDE CLASS OF PROBLEMS AND IS SIMILAR TO THE SECURITIES ANALYSIS PROGRAM 05 (SA-05). HOWEVER, THE RESTRICTION THAT EACH CASH FLOW BE IN A SUCCESSIVE SEQUENCE IS REMOVED. THIS ALLOWS ADDITIONAL FLEXIBILITY BUT DOES REQUIRE THE PERIOD OF EACH CASH FLOW TO BE ENTERED. THE PERIOD VALUE MAY ALSO BE A NONINTEGER. THE IRR OF 46 CASH FLOWS CAN BE COMPUTED.

USER BENEFITS: ALLOWS THE USER TO MAKE BETTER DECISIONS BY ANALYZING FINANCIAL TRANSACTIONS.

RANDALL E. STAPONSKI, TULSA, OK.
104 STEPS

198061G FINANCIAL STATEMENT ANALYSIS

USES 20 LINE ITEMS FROM COMPARATIVE B/S AND P/L TO PROVIDE 11 MAIN AND 5 SECONDARY ANALYTICAL DATA ITEMS AS FOLLOWS: WORKING CAPITAL, CURRENTS RATIO, QUICK RATIO, AVERAGE COLLECTION PERIOD, INVENTORY TURNS, DEBT/EQUITY %, GROSS MARGIN %, NET PROFIT TO SALES %, RETURN ON ASSETS %, RETURN ON EQUITY %, ALTMAN'S Z-SCORE, Z-SCORE "X" TERMS. PROVIDES FOR INDEPENDENT PRINTOUT OF: INPUT DATA, COMPUTED DATA, Z-SCORE "X" TERMS, AND RECOMPUTATION OF Z-SCORE. THIS PROGRAM IS AN EXPANSION AND REORGANIZATION OF PPX#198004 AND PROVIDES FOR THE USE OF THE PC-100C PRINTER.

USER BENEFITS: EASY TO USE.

JIM GAINSLEY, MINNEAPOLIS, MN.
718 STEPS, PC-100A

198062G PROFITABILITY MEASURES

GIVEN NET RECEIPTS OF A PROJECT, CALCULATES SOLOMON'S AVERAGE RATE OF RETURN, NET PRESENT VALUE, PROFITABILITY INDEX, AND NET FUTURE VALUE; ALL ON A DISCRETE OR CONTINUOUS BASIS.

USER BENEFITS: READY CALCULATION OF WEALTH GROWTH RATE AND OTHER PROFITABILITY MEASURES.

JORGE VALENCIA, LIMA, PERU
429 STEPS

198063G IRR WITH INCREASING CASH FLOWS

FINDS RATE OF RETURN OF AN INVESTMENT WHOSE NET RECEIPTS GROW AT A FIXED RATE PER PERIOD.

USER BENEFITS: SIMPIFIES CALCULATION.

JORGE VALENCIA, LIMA, PERU
169 STEPS

198064G PROJECT APPRAISAL UNDER RISK

FOR A PROJECT WITH SEVERAL PROBABLE CASH FLOWS PER PERIOD, CALCULATES STANDARD DEVIATION OF CASH FLOWS PER PERIOD, STANDARD DEVIATION AND EXPECTED VALUE (INCLUDING INVESTMENT) OF PROBABLE NET PRESENT VALUE OF PROJECT, AND PROBABILITY OF GIVEN NET PRESENT VALUE OR LESSER AMOUNT.

USER BENEFITS: CONSIDERABLE TIME SAVING AND ERROR PREVENTION.

JORGE VALENCIA, LIMA, PERU
239 STEPS, MOD 2

198065G VARIABLE CASH FLOWS - CONTINUOUS

GIVES PRESENT VALUE AND FUTURE VALUE OF A SERIES OF CASH FLOWS BEING DISBURSED CONTINUOUSLY, WITH INTEREST CONVERTED CONTINUOUSLY ALSO. UNLIKE PPX#198006 THIS PROGRAM HANDLES A SERIES OF CASH FLOWS.

USER BENEFITS: BETTER FOR INVESTMENT MODELS BECAUSE OF ITS MATHEMATICAL ANALYSIS APPROACH.

JORGE VALENCIA, LIMA, PERU
152 STEPS

208038G SIMPLE REGRESSION MODELING

COMPARES AND SELECTS THE BEST AMONG 4 COMMON SIMPLE REGRESSION MODELS. ALSO TIES IN WITH REGRESSION ANALYSIS AND MULTIVARIATE STATISTICAL METHODS PROGRAMMING SYSTEM FOR THE COMPARISON OF OTHER USER-DEFINED MODELS, ANALYSIS OF RESIDUALS, AND AUTOCORRELATION ANALYSIS.

USER BENEFITS: ELIMINATES DATA RE-ENTRY.

CHORMAN W. CHING, HAMILTON, CANADA
320 STEPS, PC-100A, MOD 3, REV B

STRUCTURAL PROGRAMS (Side A)

All programs (except Ft. - In. - Sixteenths) include a reproducible calculation sheet, program description, a design example and a preprogrammed magnetic card. Allow approximately 2-3 weeks for delivery. Ten (10) individual program combinations at 20% off; twenty (20) individual program combinations at 30% off; thirty (30) or more individual program combinations at 40% off of list price.

License Fee

	HP67/HP97	TI-59	HP-41C
VOLUME I - Programs 1 through 15			
1. Retaining Walls	@ $90.00	@ $115.00	@ $130.00
2. Footing-Axial Load	@ $40.00	@ $ 50.00	@ $ 60.00
3. Eccentrically Loaded Footing/Combined Loads	@ $90.00	@ $115.00	@ $130.00
4. Eccentrically Loaded Footing/Individual Loads	@ $90.00	@ $115.00	@ $130.00
5. Pole Foundation	@ $45.00	@ $ 50.00	@ $ 60.00
6. Bearing Plate/Base Plates	@ $20.00	@ $ 20.00	@ $ 25.00
7. Simple Span Beam/Uniform Load - Simple Span Beam/ Uniformly Varying Load	@ $30.00	@ $ 35.00	@ $ 40.00
8. Overhanging Beam	@ $30.00	@ $ 35.00	@ $ 40.00
9. Beam - Uniformly Distributed Load and Variable End Moment	@ $30.00	@ $ 35.00	@ $ 40.00
10. Plastic Design Continuous Beams	@ $30.00	@ $ 35.00	@ $ 40.00
11. Simple Span Concrete Tee Beam	@ $65.00	@ $ 70.00	@ $ 80.00
12. Section Properties	@ $30.00	@ $ 35.00	@ $ 40.00
13. Fink Truss	@ $30.00	@ $ 35.00	@ $ 40.00
14. Wood Column Design	@ $65.00	@ $ 70.00	@ $ 80.00
15. Feet - Inches - Sixteenths	@ $15.00	@ $ 15.00	@ $15.00
VOLUME II - Programs 16 through 30			
16. End Plate Moment Splices for Steel beams	@ $75.00	@ $ 75.00	@ $ 80.00
17. Wood studs, Rafters, or Truss Members	@ $75.00	@ $ 75.00	@ $ 80.00
18. Steel Beam - Biaxial Bending	@ $60.00	@ $ 60.00	@ $ 65.00
19. Simple Span beam with Moving Wheel Loads	@ $60.00	@ $ 60.00	@ $ 65.00
20. Rigid Frames	@ $100.0	@ $110.00	@ $125.00
21. Simple Span Beam Equal and Symmetrical Concentrated Loads	@ $40.00	@ $ 40.00	@ $ 40.00
22. Simple Span Beam: Concentrated Loads at any Point	@ $45.00	@ $ 50.00	@ $ 50.00
23. Simple Span Beam: Uniform and Triangular Loads	@ $45.00	@ $ 45.00	@ $ 45.00
24. Simple Span Beam: Partial Uniform Loads	@ $40.00	@ $ 40.00	@ $ 45.00
25. Beam - Fixed on Right End Concentrated Loads at any Point	@ $40.00	@ $ 40.00	@ $ 45.00
26. Beam - Fixed on Right End Partial Uniform Loads at any Location	@ $40.00	@ $ 40.00	@ $ 45.00
27. Beam - Fixed Both Ends with Concentrated Loads at any Point	@ $40.00	@ $ 40.00	@ $ 45.00
28. Beam - Fixed Both Ends with Partial Uniform Loads at any Location	@ $40.00	@ $ 40.00	@ $ 45.00
29. Cantilever Beam	@ $40.00	@ $ 40.00	@ $ 45.00
30. Payroll tabulation	@ $40.00	@ $ 40.00	@ $ 45.00
VOLUME III - Programs 31 through 45			
31. Steel Column - Combined Axial Load and Biaxial Bending	@ $70.00	@ $ 75.00	@ $ 80.00
32. Column Stiffeners	@ $65.00	@ $ 65.00	@ $ 70.00
33. Flange Plate Moment Splices for Steel beams	@ $65.00	@ $ 65.00	@ $ 70.00
34. Composite Interior Beams	@ $95.00	@ $ 95.00	@ $100.00
35. Composite Spandrel Beams	@ $95.00	@ $ 95.00	@ $100.00
36. Cover Plates	@ $60.00	@ $ 60.00	@ $ 65.00
37. Composite Interior Beams with Metal Deck	@ $90.00	@ $ 90.00	@ $100.00
38. Composite Spandrel Beams with Metal Deck	@ $90.00	@ $ 90.00	@ $100.00
39. Composite Beams General Design	@ $90.00	@ $ 90.00	@ $100.00
40. Beams Fixed at Both Ends - Uniformly Varying Loads	@ $40.00	@ $ 40.00	@ $ 40.00
41. Drilled Piers or Caissons	@ $55.00	@ $ 55.00	@ $ 60.00
42. Double Overhanging Beam	@ $40.00	@ $ 40.00	@ $ 45.00
43. Two Span Continuous Beam with Uniform and Concentrated Loads	@ $55.00	@ $ 60.00	@ $ 65.00
44. Three Span Continuous Beam with Uniform Loads	@ $40.00	@ $ 40.00	@ $ 45.00
45. Four Span Continuous Beam with Uniform Loads	@ $45.00	@ $ 45.00	@ $ 45.00
46/47. Continuous Beam (Rotations and Matrix) with Variable Spans, Moment of Inertia, Concentrated, Uniform and Partial Uniform Loads		@ $160.00	@ $175.00
48. Continuous Beam (Positive Moments, Shears, Deflections)		@ $ 80.00	@ $100.00
61. Suspended Cables	@ $40.00	@ $40.00	@ $45.00
62. Bolt and Pile Loads Circular and Rectangular Patterns with Biaxial Bending	@ $40.00	@ $40.00	@ $45.00
63. Base Plates with Moment and Axial Loads	@ $40.00	@ $40.00	@ $45.00
VOLUME VII (Programs 71-76) (For Fabricators and Detailers)			
71. Right and Oblique Triangles	@ $100.00	@ $100.00	@ $110.00
72. Stair Solutions for A&E's	@ $ 70.00	@ $ 70.00	@ $ 80.00
73. Stair Solutions	@ $ 60.00	@ $ 60.00	@ $ 65.00
74. Unsymmetrical Knee Bracing	@ $ 80.00	@ $ 80.00	@ $ 85.00
75. Curved Sectors	@ $ 80.00	@ $ 80.00	@ $ 85.00
76. Unsymmetrical Cross Bracing for Beams and Trusses	@ $100.00	@ $100.00	@ $110.00
77. Decimal Number Sorting Program			@ $100.00
78. Feet - Inches - Sixteenths Number Sorting Program			@ $100.00
79. Unsymmetrical Cross Bracing for Towers		@ $100.00	@ $110.00

Independently-produced, "protected" mag card programs.

HAND CALCULATOR PROGRAMS FOR PASSIVE SOLAR DESIGN

You are probably aware of the special architectural quality, and large energy savings, possible using Passive Solar techniques in buildings. In this context **PEGFIX/PEGFLOAT**, the first hand calculator solar design aids published by Princeton Energy Group, should be of special interest to you, and to all solar designers, builders, and educators. PEGFIX and PEGFLOAT model both the hourly and daylong performance of direct gain or 'sunspace' solar configurations, using **any of the four major card-programmable hand-held calculators.**

PEGFIX predicts auxiliary heat demand and excess heat available in a space with user-defined maximum and minimum temperature limits. The program is directly useful in sizing and specifying the system components, including the backup heating and ventilating equipment if needed. The results stored by PEGFIX are: total auxiliary heating load, excess heat available, maximum fan rate needed to vent excess heat, and maximum hourly auxiliary load.

PEGFLOAT predicts hourly temperatures of air and storage mass in a space without auxiliary heat input or removal of excess heat. Its purpose is to evaluate temperature excursions in a 100% solar operating mode. This program can examine non-south glazing orientations with user-specified hourly input values for insolation. PEGFLOAT automatically stores maximum and minimum storage and air temperatures of the system being modelled.

PEGFIX/PEGFLOAT are the first hand calculator programs which allow truly fast, low cost and accurate hour-by-hour analysis of direct gain systems, **by designers with little or no experience in building thermal analysis.** Both programs require only a few user-defined inputs regarding the building design and local weather: heat loss coefficients; effective thermal capacity and storage surface area; solar energy available, fraction to storage and fraction to air; average outdoor temperature and daily range. The programs automatically differentiate day and night heat loss values if desired, enabling you to evaluate night-deployed moveable insulation. If only a daylong insolation value is available, PEGFIX and PEGFLOAT will automatically proportion this input among the daylit hours. All inputs are expressed in familiar terms, and are clearly explained in the accompanying PEGFIX PEGFLOAT HANDBOOK. The programs can be run through a 24-hour day, without user interaction, in **only five to nine minutes.** You may also choose hourly display of air and storage temperatures, and of auxiliary or excess heat, without interrupting program execution. Optional hourly display does not affect the stored data.

Our attitude in design is reflected in the clarity and utility of these programs, which support rapid development of **design judgement on a sound technical base.** It is our experience that using programmable hand calculators in passive design analysis is inherently self-instructive. PEGFIX/PEGFLOAT employ the best available procedures suited to programmable hand calculators, refined in several years' use by PEG staff in all stages of our own design work. PEGFIX/PEGFLOAT combine fast and simple execution with sophisticated numerical methods including a new 'walking' solution of simultaneous equations. We introduced PEGFIX/PEGFLOAT at the Third National Passive Solar Conference in San Jose, where they were warmly received by leading specialist in performance simulation and testing from throughout North America. The programs are now used with confidence by other experienced designers, reducing the time and expense devoted to similar analyses on larger equipment. Less experienced designers gain a fine learning tool, as well as access to hourly simulation capability without costly computer time and programmer expertise which their present work can ill afford. Students and educators especially appreciate the speed with which results are obtained using PEGFIX/PEGFLOAT, allowing quick assessment of design options with very little preparation. (We've been told that from a teacher's standpoint, program results which aren't available until next week's class, might as well be unavailable until next term; not quite true, but we got the point!) The same advantage is important to any designer whose time is valuable.

PEGFIX/PEGFLOAT are available in Hewlett-Packard RPN and Texas Instruments AOS versions. An **HP-67**, **HP-97**, **HP-41C**, or **TI-59** card-programmable calculator is required. A printer is convenient but, because of the hourly display option, not needed. Either **English** or **Metric** programs are available; they must be ordered separately. Each program package includes **prerecorded card(s)**, printed **Worksheets**, and 70+ page instruction **HANDBOOK**. A **Library Package**, with cards for both English and Metric calculations on all four machines, is offered at a special price. The **PEGFIX PEGFLOAT HANDBOOK** and worksheets are thorough, clear, and well illustrated. Program use is presented in a way which allows any designer, **whether or not previously skilled in passive solar techniques**, to effectively apply—and to learn in the process of using—PEGFIX/PEGFLOAT. Extensive references provide ample documentation, and excellent resources for further study.

Although Passive Solar building principles are rapidly gaining acceptance due to proven performance at low cost, strong expertise is still limited to relatively few practicing architects and engineers. Among these, inexpensive and fast hourly simulation techniques have been in great demand. We at Princeton Energy Group believe our programs are the most significant step to date toward solving these problems.

Please take a close look at PEGFIX/PEGFLOAT, and see how valuable these programs can be in your work.

TI-59 SURV-CROM II

DIAGNOSTIC - Checks operation of the calculator and the SURV-CROM II module, partitions the calculator for maximum storage, insures that the calculator is in the degree mode, and prints tape heading.

COORDINATE GEOMETRY - The prime purpose of this program is the storing of coordinates for use in other programs. The bearing-distance, bearing-distance method of entry is used; and angles may be used instead of bearings. Other features include: up to 40 (20) points may be stored; previously stored bearings may be recalled as stored or 90, 180, or 270 degrees right of the stored bearing, unneeded points may be "unstored" to conserve storage space; coordinate may be stored or recalled by point number; horizontal or slope distances may be used, and temperature and grid factor corrections may be applied; you may traverse around a simple curve by arc distance; coordinates may be listed by point number; simple sideshots as well as branching are available.

TRAVERSE 1 - (Parts A, B, and C) (Part A is for traverses with 39 or fewer courses. Part B for those with more than 39 courses and Part C is for use in the field.)
The purpose of this program is closure with area (if a closed loop) to be followed by balancing in Program 06, if desired. It has most of the features of SC-02, and in addition, you may compute error of closure, precision, and area. You may force a closure back to the point of beginning at any time. Entry errors are corrected readily - you may "back out" several courses as easily as they were entered. And it may be used in the field without the printer... You may not recall bearings by number, traverse around a curve, or do sideshots or branching. When sideshots are necessary, after the main traverse has been entered and closure checked, you would go to Program 06 to balance the traverse, and then to Program 02, Step 11 to enter the sideshot(s), and finally to Program 07 to compute the final traverse.

TRAVERSE II - ANGLES - (Programs 04 and 05 are complementary.) When all the angles of a traverse have been entered, this program computes the angular error of closure: balances the angles with the error of closure being distributed equally to all angles, and computes balanced azimuths for use in SC 05. Or, you may use the program to balance angles and compute and print balanced bearings for use in SC-02 or SC-03.

TRAVERSE II-DISTANCES - This program must immediatley follow SC-04. Either horizontal or slope distances may be entered and temperature and grid factor corrections may be applied. After all distances have been entered, the error of closure is computed, followed by computation of unbalanced coordinates and area.

BALANCING THE TRAVERSE - This program balances the traverse by either the Transit Rule method or the Compass Rule method from coordinates stored in the calculator using SC-03 or SC-04/05 programs.

AREA FROM COORDINATES/INVERSE - This program computes area from selected coordinates by entering their point numbers and produces a printout of the finished traverse. Curved boundaries may be used. It also may be used for simple inverses from point selected coordinates by entering their point numbers and pre-number to point number, or coordinates may be entered from the keyboard.

ROTATION AND TRANSLATION - This program will translate stored coordinates from one grid system to another when a common point and the angle between systems are known.

STAKEOUT - This program computes the angles and distances from stored coordinates for field stakeout purposes.

LINE AVERAGING (LINEAR REGRESSION) - This program computes the line that bestfits any number of coordinates which may be entered by point number or from the keyboard.

INTERSECTIONS: BB1 - DD1 - BD1 - When the coordinates of two points and any two elements of two lines connecting them are entered, this program computes and prints all the other unknowns Coordinates may be entered by point number or from the keyboard.

PERPENDICULAR OFFSET TO A LINE - This program computes distances along a base line and offset distances to points on either side of the base line. All entries are by point number.

PREDETERMINED AREA - After the required area is entered, bearings and distances are entered until the calculator completes the figure that will produce the desired area.

SIMPLE CURVE DATA - When given the PC or PI station and the delta, and then either the degree, radius, tangent, length, or external, and the offset distances, this program computes all for the centerline curve and offset lines left and right of the the other curve data and deflections as well as the chord data centerline. Also, the length and radius may be entered instead of the delta and another element.

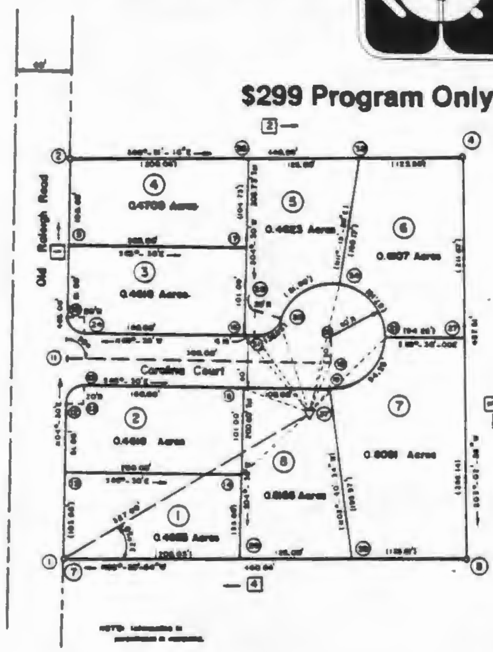
Program includes instruction manual and preprogrammed ROM Module

TI-59 SURV-CROM II......$299

Prices are subject to change without notice.
Merchandise is subject to availability from suppliers.

Surveyors Supply Co.

$299 Program Only



TI-59 SURVEYING

Combination TI-59, PC-100C and SURV-CROM Program

$659

Independently-produced program library module.
CROM = calculator read-only module

MANUAL PLOTTER-SCALER. *There are lots of automatic plotting programs which will plot f(x), provided you define f(x) somehow in program memory. But what if you have a list of data you would like to plot? You could use OP 07 manually, but you would still be faced with the task of manually scaling your data within the zero to twenty range of OP 07. After having experienced this problem a couple of times at the office, I finally settled on this short routine. It is short enough to be used even by TI-58 fans. The instructions are simple:*
Scan your data and spot the lowest point, enter it and press A.MIN printed.
Do the same for your maximum point, enter it and press B. MAX printed.
Now enter in succession all your data points either through key E or R/S.
If you enter a data point out of bounds, either upper or lower, a small e is printed.

```
LBL E  - RCL 00  = DIV  RCL 02  =.CP  INV  GE  083  X:T 20  X:T  GE  094  OP 07  R/S
GTO E  LBL A  STO 00 282429  OP 04  RCL 00  OP 06 RTN  LBL B  STO 01  281344  OP 04
RCL 01  OP 06  -  RCL 00  =  DIV  20  +  1  EE  9  +/-  INV  EE  =  STO 02  OP 00  ADV  R/S
GTO  E  54  EE  8  INV  EE  OP 01  GTO  098  54  OP 04  OP 05  OP 00  R/S  GTO  E
```

TWO-VARIABLE GRID-PLOT. *As the name implies, this short routine by Bill Skillman, will plot simultaneously two variables in the range 0 to 19. If out of bounds, a "?" is printed at the appropriate edge.The grid spacing is 5 printing spaces. The symbol for x is the asterisk (*) and for the y he used an "8". A cross-over is indicated with an "x". The instructions are: Write the definition of f(x) in user memory. Place x in the t-register, place y in the display, a call to E' will plot both.*

```
000:  LBL E'  INV STF 4  INV  STF 5  STO 04  2 OP 01 OP 02 OP 03  OP 04  X:T  NOP
SBR  137  EXC 04  SBR 137  OP 22  OP  23  X  49  +  RCL 02  X:T RCL 03  EQ  049  2  =
OP IND 02  RCL 04 X  58  X:T  9  =  EQ  064  NOP  +  2 =  OP IND 03  INV IFF 4  093  1
+  71  X  HIR  15  X:T  1  EE  4  +/-  GE  090  1 EE 6  +/-  =  HIR 35  INV IFF 5  134
1 EE  10  +/-  X:T  HIR  18  GE  123  X  50 =  EQ  123  71  X  X:T  GTO  129  69  EE  12
+/-  +  1  =  HIR 38  OP 05  RTN  INV EE CP  INV GE  174  X:T  20  X:T  GE  180  INT
+/-  +  (  CE  +/-  DIV  5  )  INT  X  EXC  02  STO  03  5  + 4  =  INV  LOG  X2  RTN
STF  4  CLR  GTO  183  STF 5  3 EXC 02  STO 03  CLR RTN
```

To demonstrate its abilities, I wrote this short sin-cos routine. Start with A.

```
LBL  A  RCL 11  SIN +  1 = X 9.9  =  INT  X:T  RCL 11  COS  + 1  =  X 9.9  =  E'  18
SUM 11 GTO  A
```

Bill's routine uses registers 2, 3 and 4 and flags 4 and 5.

Part on a single page in LRN. Note the density of information.

PROGRAMMING

PERSONAL PROGRAMMING provides a good introduction to everything Texas Instruments has chosen to document. The collected issues of LRN cover additional capabilities that are far too complex for general use. In this section we will concentrate on programming formats that planners will find useful.

Most people develop preferences for particular programming techniques. Some become adept at conditional looping; others prefer to set flags to achieve similar ends. My general suggestion is to work as simply and directly as possible using the techniques you prefer. There are benefits to be gained from optimization, but the TI-59 usually has more than enough capacity to get the job done with some inefficiencies. Direct logic runs fast enough. Once the program goes on the magnetic card, no one can tell how sophisticated you are.

Learn the techniques as you need them. Learn to translate from program steps back to algorithms and equations. Whatever the problem, it is usually possible to find a program nearly matched to your needs. Load it, record it, and then work on modifications to it. Always keep duplicates of cards, because oily fingerprints, accidental bending, etc. can destroy cards unexpectedly.

The easiest way to understand someone else's program is to isolate the alphanumeric labels first, equations second, and data shifting routines last. When in doubt about a step sequence, run the program from the nearest preceeding label with the printer on TRACE. This causes the calculator to explain what it is doing, step by step. Program labels can be listed by step location by entering RST OP 08 from the keyboard when the program is not running. Given these capabilities, most programs can be listed without annotation or flowcharting of the kind that would be required for a microcomputer written in BASIC.

The important issues for planners are input and output formatting. All of a programmer's work should follow the same format whenever possible. The user-defined keys A,B,C,D, E and their primes are like paragraph headings. The first number in the first data category should be entered through the A key, with each subsequent number in the same category entered through the R/S key (one key controls "run" and "stop"). The next category begins with B, and so on. The E key should always be reserved for starting the program run. The prime letters should be used reluctantly (for ergonomic reasons). The data sequences should feel right to users familiar with the problem being processed.

Alphanumeric labelling consumes significant amounts of program step capacity and should be minimized. Alphanumerics also slow program execution and consume printer paper. Three-letter margin labels and asterisks will generally suffice. Planners often need output that can be copied and distributed.

With this in mind, consider the following method of separating labelling from program processing.

The PC-100C prints 5.68 lines per inch, and the conventional advance moves more than a line (but less than two). We must therefore use a set of background numbers in place of a graph paper grid. The following page shows lines populated by digits 1-9 in reverse order, with blank space at two of the twenty locations. The program used to generate the digits and spaces is listed on the second following page. By laying the digit grid page underneath a clean sheet of white paper, we can fill in block letters for a label sheet. After copying the label sheet, we have paste-up sheets for the numerical outputs.

After establishing a final format, we can write labels from the printer using the print processor program. It appeared in LRN almost as it appears here, except for minor changes in instructions and program steps. Note that some copiers copy at more than 100% of original size, so you may want to generate the label directly from the printer for each paste-up. Any margin labels on the numerical output tapes can be cut off without affecting the numerical output itself. The hydroelectric site screening program uses this paste-up method. All the labels were right-justified (which is why the digits for the background numbers were in reverse order).

The most serious limitation I have encountered is the lack of a printed dollar sign. I have used D for dollar and DK for $ 000, but it should be interpreted in a key when you choose to use the label.

There is one other device planners should know about: direct address subroutines run faster than common label subroutines. PERSONAL PROGRAMMING explains the difference, but you should know it is easy to convert. If we use SBR STO, for example, the entry point is LBL STO. If we write the original program steps as SBR STO NOP, we can shift to SBR 01 75 (or whatever) for direct addressing without moving steps out of sequence. The entry point can then be NOP NOP instead of LBL STO. Most good programmers consider NOPs inelegant, but they work nicely.

Finally, documentation needs some attention. Always list the program steps and paste them up on a reference sheet. Pressing OP 08 gives you a list of common labels, so others can find the subroutines. Even after you convert to direct addressing, keep the common label version for documentation. It also helps to downlist the storage registers for future reference. Document the contents.

TRACE

This is a trace of operations for program steps 282-349 in the hydroelectric site screening program.

0.	RCL	10.000	
	24	1.	-
0.150		1.000	(
0.150	PRT	1.	+
0.15	+	1.	RCL
1.	=		25
1.150		0.150	
1.15	STO	0.15	)
	36	1.150	
1.150		1.15	Y^X
1.15	RCL	1.15	RCL
	25		26
0.150		20.000	
0.150	PRT	-20.	=
0.15	RCL	0.939	
	26	.9388997211	÷
20.000		.9388997211	RCL
20.000	PRT		25
20.	RCL	0.150	
	27	0.15	=
0.080		6.259	
0.080	PRT	6.259331474	1/X
0.08	+	0.160	
1.	=	.1597614704	×
1.080		.1597614704	RCL
1.08	STO		13
	34	2121.239	
1.080		2121.239035	=
1.08	RCL	338.892	
	28	338.892	PRT
0.060		338.8922673	STO
0.060	PRT		17
0.06	+	338.892	
1.	=	338.8922673	RCL
1.060			29
1.06	STO	10.000	
	35	10.	STO
1.060			2
1.06	RCL	10.000	
	29	10.	RCL
10.000			26
10.000	PRT	20.000	
10.	OP	20.	STO
	5		3
		20.000	

RUNNING THE PROGRAM

Clear and load mag card bank 1.

Press A to initialize the alphanumeric code and print one row of digits. (This is required for the first row only.)

Press B to list one row of digits (except for the initial row, which requires A).

Press C to advance one.

Press D to list five rows of digits.

Press E to run OP 06. Note that although it prints some digits, OP 06 in any program lacking labels will cause the printer to "advance" a distance equivalent to one printed line. This option is sometimes useful.

```
987654321 987654321
987654321 987654321

987654321 987654321
987654321 987654321
987654321 987654321
987654321 987654321
987654321 987654321

987654321 987654321
987654321 987654321
987654321 987654321
987654321 987654321
987654321 987654321
987654321 987654321

987654321 987654321
987654321 987654321
987654321 987654321
987654321 987654321
987654321 987654321
           0.     4321
987654321 987654321
987654321 987654321
```

000	76	LBL
001	11	A
002	08	8
003	00	0
004	01	1
005	02	2
006	01	1
007	01	1
008	01	1
009	00	0
010	08	8
011	07	7
012	69	OP
013	01	01
014	08	8
015	06	6
016	00	0
017	05	5
018	00	0
019	04	4
020	00	0
021	03	3
022	00	0
023	02	2
024	69	OP
025	02	02
026	08	8
027	00	0
028	01	1
029	02	2
030	01	1
031	01	1
032	01	1
033	00	0
034	08	8
035	07	7
036	69	OP
037	03	03
038	08	8
039	06	6
040	00	0
041	05	5
042	00	0
043	04	4
044	00	0
045	03	3
046	00	0
047	02	2
048	69	OP
049	04	04
050	69	OP
051	05	05
052	91	R/S
053	76	LBL
054	12	B
055	69	OP
056	05	05
057	91	R/S
058	76	LBL
059	13	C
060	98	ADV
061	91	R/S
062	76	LBL
063	14	D
064	69	OP
065	05	05
066	69	OP
067	05	05
068	69	OP
069	05	05
070	69	OP
071	05	05
072	69	OP
073	05	05
074	91	R/S
075	76	LBL
076	15	E
077	00	0
078	69	OP
079	06	06
080	91	R/S
081	00	0
082	00	0
083	00	0
084	00	0

001	11	A
054	12	B
059	13	C
063	14	D
076	15	E

RUNNING THE PROGRAM

Clear and enter mag card banks 1 and 2.
Note that the program runs in FIX 2, so you must key INV FIX before reading or writing data cards.

Press E' to clear all previously stored data. The 1.01 in display indicates that the "pointer" is located at the first character of the first line (L.nn).

To store print codes, enter up to five 2-digit codes and press A. The program will store the codes appropriately. The pointer is then automatically set to indicate the next available location. When a line is completed it is automatically printed (unless you turn off the printer).

To end and print a line before 20 characters have been entered, press A'. To relocate the pointer, specify the line and character position desired (L.nn), and press E.

To print only the line you want, relocate to the last character in that line (eg, 4.20), and press E followed by A'.

To print all the lines you want, from any given point on, specify the beginning line and character position (eg, 1.01), and press E followed by B.

To correct line errors, relocate to the line and character to be changed, press E, and proceed to enter as if for the first time.

Note that a blank space can be designated as 00 or 80, and the latter is always preferred if there is any question about whether the space will be "filled" in a given line.

Unlike the original program, pressing B does not advance the paper.

```
000  76  LBL
001  17  B'
002  22  INV
003  28  LOG
004  52  EE
005  54   )
006  92  RTN
007  76  LBL
008  18  C'
009  69  OP
010  22   22
011  69  OP
012  23   23
013  73  RC*
014  02   02
015  84  OP*
016  03   03
017  92  RTN
018  76  LBL
019  10  E'
020  47  CMS
021  01   1
022  76  LBL
023  15   E
024  88  DMS
025  59  INT
026  65   ×
027  04   4
028  54   )
029  42  STO
030  00   00
031  82  HIR
032  18   18
033  85   +
034  39  COS
035  59  INT
036  75   -
037  01   1
038  54   )
039  55   ÷
040  05   5
041  75   -
042  59  INT
043  44  SUM
044  00   00
045  54   )
046  65   ×
047  01   1
048  00   0
049  94  +/-
050  85   +
051  01   1
052  00   0
053  95   =
054  17  B'
055  42  STO
056  01   01
057  76  LBL
058  91  R/S
059  22  INV
060  86  STF
061  01   01
062  43  RCL
063  00   00
064  55   ÷
065  04   4
066  75   -
067  59  INT
068  42  STO
069  02   02
070  54   )
071  55   ÷
072  05   5
073  85   +
074  53   (
075  05   5
076  75   -
077  43  RCL
078  01   01
079  34  √X
080  28  LOG
081  85   +
082  01   1
083  54   )
084  55   ÷
085  02   2
086  17  B'
087  44  SUM
088  02   02
089  25  CLR
090  43  RCL
091  02   02
092  58  FIX
093  02   02
094  92  RTN
095  53   (
096  43  RCL
097  01   01
098  82  HIR
099  47   47
100  22  INV
101  64  PD*
102  00   00
103  63  EX*
104  00   00
105  75   -
106  59  INT
107  64  PD*
108  00   00
109  54   )
110  65   ×
111  92  RTN
112  76  LBL
113  11   A
114  22  INV
115  58  FIX
116  55   ÷
117  52  EE
118  53   (
119  53   (
120  52  EE
121  55   ÷
122  52  EE
123  00   0
124  01   1
125  94  +/-
126  54   )
127  65   ×
128  34  √X
129  22  INV
130  59  INT
131  69  OP
132  10   10
133  17  B'
134  82  HIR
135  06   06
136  54   )
137  82  HIR
138  07   07
139  71  SBR
140  00   00
141  95   95
142  82  HIR
143  16   16
144  75   -
145  59  INT
146  42  STO
147  03   03
148  54   )
149  65   ×
```

```
150  43 RCL
151  01  01
152  55  ÷
153  82 HIR
154  16  16
155  95  =
156  74 SM*
157  00  00
158  82 HIR
159  17  17
160  75  -
161  59 INT
162  74 SM*
163  00  00
164  54  )
165  29 CP
166  67  EQ
167  02  02
168  10  10
169  69 OP
170  20  20
171  65  ×
172  01  1
173  52 EE
174  01  1
175  00  0
176  82 HIR
177  08  08
178  22 INV
179  64 PD*
180  00  00
181  54  )
182  32 X⇌T
183  82 HIR
184  16  16
185  55  ÷
186  43 RCL
187  01  01
188  54  )
189  82 HIR
190  68  68
191  64 PD*
192  00  00
193  73 RC*
194  00  00
195  75  -
196  59 INT
197  44 SUM
198  03  03
199  95  =
200  65  ×
201  82 HIR
202  18  18
203  85  +
204  32 X⇌T
205  54  )
206  72 ST*
207  00  00
208  69 OP
209  30  30
210  43 RCL
211  01  01
212  55  ÷
213  02  2
214  32 X⇌T
215  82 HIR
216  16  16
217  95  =
218  77  GE
219  02  02
220  27  27
221  65  ×
222  69 OP
223  20  20
224  01  1
225  00  0
226  17 B'
227  42 STO
228  01  01
229  25 CLR
230  43 RCL
231  02  02
232  59 INT
233  32 X⇌T
234  43 RCL
235  00  00
236  55  ÷
237  04  4
238  95  =
239  59 INT
240  87 IFF
241  01  01
242  00  00
243  06  06
244  67  EQ
245  91 R/S
246  43 RCL
247  00  00
248  75  -
249  05  5
250  85  +
251  42 STO
252  02  02
253  04  4
254  95  =
255  61 GTO
256  02  02
257  67  67
258  76 LBL
259  12 B
260  68 NOP
261  03  3
262  42 STO
263  02  02
264  43 RCL
265  00  00
266  32 X⇌T
267  22 INV
268  58 FIX
269  25 CLR
270  42 STO
271  03  03
272  18 C'
273  18 C'
274  18 C'
275  18 C'
276  69 OP
277  05  05
278  43 RCL
279  02  02
280  22 INV
281  77  GE
282  02  02
283  69  69
284  61 GTO
285  91 R/S
286  76 LBL
287  16 A'
288  43 RCL
289  02  02
290  59 INT
291  82 HIR
292  04  04
293  65  ×
294  04  4
295  75  -
296  01  1
297  82 HIR
298  34  34
299  95  =
```

```
300  42  STO
301  02   02
302  43  RCL
303  00   00
304  32  X:T
305  71  SBR
306  02   02
307  67   67
308  82  HIR
309  14   14
310  61  GTO
311  15   E
312  76  LBL
313  13   C
314  86  STF
315  01   01
316  85   +
317  28  LOG
318  32  X:T
319  43  RCL
320  02   02
321  82  HIR
322  04   04
323  03   3
324  77   GE
325  03   03
326  46   46
327  00   0
328  95   =
329  11   A
330  29  CP
331  43  RCL
332  03   03
333  67   EQ
334  03   03
335  08   08
336  55   ÷
337  82  HIR
338  16   16
339  95   =
340  71  SBR
341  01   01
342  37   37
343  61  GTO
344  03   03
345  30   30
346  71  SBR
347  00   00
348  95   95
349  93   .
350  00   0
351  01   1
352  52  EE
353  82  HIR
354  41   41
355  95   =
356  65   ×
357  43  RCL
358  01   01
359  95   =
360  74  SM*
361  00   00
362  73  RC*
363  00   00
364  22  INV
365  59  INT
366  22  INV
367  74  SM*
368  00   00
369  29  CP
370  67   EQ
371  03   03
372  08   08
373  65   ×
374  01   1
375  02   2
376  17  B'
377  85   +
378  69  OP
379  20   20
380  73  RC*
381  00   00
382  95   =
383  55   ÷
384  02   2
385  17  B'
386  72  ST*
387  00   00
388  61  GTO
389  03   03
390  64   64
391  76  LBL
392  14   D
393  86  STF
394  01   01
395  42  STO
396  03   03
397  43  RCL
398  00   00
399  42  STO
400  02   02
401  71  SBR
402  00   00
403  95   95
404  02   2
405  17  B'
406  22  INV
407  59  INT
408  65   ×
409  43  RCL
410  01   01
411  95   =
412  74  SM*
413  00   00
414  69  OP
415  20   20
416  73  RC*
417  00   00
418  29  CP
419  67   EQ
420  04   04
421  46   46
422  55   ÷
423  01   1
424  52  EE
425  01   1
426  00   0
427  72  ST*
428  00   00
429  52  EE
430  08   8
431  75   -
432  22  INV
433  59  INT
434  64  PD*
435  00   00
436  69  OP
437  30   30
438  95   =
439  74  SM*
440  00   00
441  69  OP
442  20   20
443  61  GTO
444  04   04
445  14   14
446  43  RCL
447  02   02
448  42  STO
449  00   00
```

450	97	DSZ
451	03	03
452	04	04
453	01	01
454	61	GTO
455	91	R/S
456	76	LBL
457	19	D'
458	05	5
459	06	6
460	52	EE
461	01	1
462	02	2
463	55	÷
464	09	9
465	09	9
466	95	=
467	59	INT
468	82	HIR
469	05	05
470	82	HIR
471	06	06
472	82	HIR
473	07	07
474	82	HIR
475	08	08
476	69	OP
477	05	05
478	61	GTO
479	91	R/S

The following page is a copy of the print code chart published by LRN.

001	17	B'
008	18	C'
019	10	E'
023	15	E
058	91	R/S
113	11	A
259	12	B
287	16	A'
313	13	C
392	14	D
457	19	D'

 00	0 01	1 02	2 03	3 04	4 05	5 06	6 07
7 10	8 11	9 12	A 13	B 14	C 15	D 16	E 17
– 20	F 21	G 22	H 23	I 24	J 25	K 26	L 27
M 30	N 31	O 32	P 33	Q 34	R 35	S 36	T 37
• 40	U 41	V 42	W 43	X 44	Y 45	Z 46	+ 47
x 50	* 51	$\sqrt{\ }$ 52	π 53	$\underline{e}$ 54	(55	) 56	, 57
↑ 60	% 61	: 62	/ 63	= 64	$\underline{,}$ 65	x 66	$\bar{x}$ 67
$\underline{2}$ 70	? 71	÷ 72	! 73	II 74	Δ 75	Π 76	Σ 77

DATA MANAGEMENT

The cost of data acquisition can sometimes limit a planner's ability to solve a given quantitative problem. Budget restrictions may make it impossible to spend money on data acquisition, even though such expenditures would be cost effective.

The practicing planner may have to find alternative solutions that use less expensive or more readily available data. In some cases the process may reveal an approach that is more cost effective than the one originally considered. In other cases the process may be simply lead to a dead end.

The first question to ask about data is whether someone else has already collected it in a way that can be directly or indirectly useful. Talk to someone with experience in the field and search the literature in that field. Most professionals are willing to share information with people who ask thoughtful questions. It usually helps to explain what you want to do with the information.

Data sources, whether published or otherwise, may not agree. Estimates of population and resources are notably various. Sometimes differing sources are each correct in their own terms: read the fine print. Sometimes sources are in agreement because both have been copied from a common incorrect source. Planners have to search critically and learn to read between the lines.

Every profession has its peculiar sources that are difficult to find between the time of publication and ultimate entry into a formal indexing system. In New England energy planning the mother lode is the FINAL REPORT of the New England Energy Congress. This large, 454-page paperback costs $24 from the National Technical Information Service, but most of the planners who own a copy got it free when it was free, simply by requesting it. The book's many tables have some frustrating typographical errors, but an owner-annotated copy is a priceless reference.[1]

An almanac is often the least expensive single source for information. The PROVIDENCE JOURNAL publishes one for Rhode Island. Someone ought to edit a paperback almanac for planners, with the basics that one now searches for in various planning standards references, human factors design books, census publications, etc. For unit conversions the best tables I have seen are in THE NEW MATHEMATICS DICTIONARY, a paperback now out of print.[2] The tables are reproduced on the second following page.

When relevant data can be retrieved, we are faced with the storage limitations of the programmable calculator. The data storage capacity can be effectively doubled by "splitting" the storage register at the decimal point.

Suppose we want to store 53467 and 519 in the same register. Load it as 5367.519 into, say, register 01. The 519 can be recalled as the decimal value (INV INT) of register 01 and immediately multiplied by 1000 in the body of the program. Suppose the numbers to be stored are 53.46 and 51.97. They can be stored as 5346.5197 and retrieved as an integer value (INT) divided by 100 and a decimal value (INV INT) multiplied by 100. Data packing methods were not included in PERSONAL PROGRAMMING, although simple splitting is widely used, often just for the sake of making data entry more efficient. Programs exist for more complex forms of splitting and packing.

Another widely-used approach to data management is curve fitting. In many instances several hundred data points conform to a pattern that we can describe with a curve equation (eg, a fifth degree polynomial). If we find several equation variables with one program, we can then supply the main applications program with several variables instead of several hundred data points. There are programs for fitting data to 5-8 kinds of curves. The user simply instructs the calculator to list the solution that fits best.

NOTES

[1]New England Energy Congress, FINAL REPORT (Boston: NEEC, 1979).

[2]Robert Marks, THE NEW MATHEMATICS DICTIONARY (New York: Bantam Books, 1964).

Units of Volume

Units		Cubic inches	Cubic feet	Cubic yards	Cubic centimeters	Cubic decimeters	Cubic meters
1 cubic inch	=	**1**	0.000 578 704	0.000 021 433	**16.387 064**	0 016 387	0.000 016 387
1 cubic foot	=	**1728**	**1**	0.037 037 04	**28 316.846 592**	28 316 847	0.028 316 847
1 cubic yard	=	**46 656**	**27**	**1**	**764 554.857 984**	764.554 858	0.764 554 858
1 cubic cm.	=	0.061 023 74	0.000 035 315	0.000 001 308	**1**	**0.001**	**0.000 001**
1 cubic dm.	=	61.023 74	0.035 314 67	0.001 307 951	**1000**	**1**	**0.001**
1 cubic meter	=	61 023.74	35.314 67	1.307 951	**1 000 000**	**1000**	**1**

168

Units of Capacity (Liquid Measure)

Units		Minims	Fluid drams	Fluid ounces	Gills	Liquid pints
1 minim	=	**1**	0.016 666 7	0.002 083 33	0.000 520 833	0.000 130 208
1 fluid dram	=	**60**	**1**	**0.125**	**0.031 25**	**0.007 812 5**
1 fluid ounce	=	**480**	**8**	**1**	**0.25**	**0.062 5**
1 gill	=	**1920**	**32**	**4**	**1**	**0.25**
1 liquid pint	=	**7680**	**128**	**16**	**4**	**1**
1 liquid quart	=	**15 360**	**256**	**32**	**8**	**2**
1 gallon	=	**61 440**	**1024**	**128**	**32**	**8**
1 milliliter	=	16.231	0.270 519 8	0.033 814 97	0.008 453 742	0.002 113 436
1 liter	=	16 231.19	270.519 8	33.814 97	8.453 742	2.113 436
1 cubic inch	=	265.974	4.432 900	0.554 112 6	0.138 528 1	0.034 632 03
1 cubic foot	=	459 603.1	7660.052	957.506 5	239.376 6	59.844 16

Units of Capacity (Liquid Measure) Continued. Bold face type indicates exact values

Units		Liquid quarts	Gallons	Milliliters	Liters	Cubic inches	Cubic feet
1 minim	=	0.000 065 104	0.000 016 276	0.061 610	0.000 061 610	0.003 760	0.000 002 176
1 fluid dram	=	**0.003 906 25**	0.000 976 562	3.696 588	0.003 696 588	0.225 586	0.000 130 547
1 fluid ounce	=	**0.031 25**	**0.007 812 5**	29.572 70	0.029 572 7	1.804 687	0.001 044 379
1 gill	=	**0.125**	**0.031 25**	118.290 8	0.118 290 8	**7.218 75**	0.004 177 517
1 liquid pint	=	**0.5**	**0.125**	473.163 2	0.473 163 2	**28.875**	0.016 710 07
1 liquid quart	=	**1**	**0.25**	946.326 4	0.946 326 4	**57.75**	0.033 420 14
1 gallon	=	**4**	**1**	3785.306	3.785 306	**231**	0.133 680 6
1 milliliter	=	0.001 056 718	0.000 264 179	**1**	**0.001**	0.061 025	0.000 035 316
1 liter	=	1.056 718	0.264 179 4	**1000**	**1**	61.025 45	0.035 315 66
1 cubic inch	=	0.017 316 02	0.004 329 004	16.386 61	0.016 386 61	**1**	0.000 578 704
1 cubic foot	=	29.922 08	7.480 519	28 316.05	28 316 05	**1728**	**1**

169

Units of Capacity (Dry Measure)

Units		Dry pints	Dry quarts	Pecks	Bushels	Liters	Dekaliters	Cubic inches
1 dry pint	=	**1**	**0.5**	**0.062 5**	**0.015 625**	0.550 595	0.055 060	**33.600 312 5**
1 dry quart	=	**2**	**1**	**0.125**	**0.031 25**	1.101 190	0.110 119	**67.200 625**
1 peck	=	**16**	**8**	**1**	**0.25**	8.809 521	0.880 952	**537.605**
1 bushel	=	**64**	**32**	**4**	**1**	35.238 08	3.523 808	**2150.42**
1 liter	=	1.816 217	0.908 108	0.113 514	0.028 378	**1**	**0.1**	61 025 45
1 dekaliter	=	18.162 17	9.081 084	1.135 136	0.283 784	**10**	**1**	610.254 5
1 cubic inch	=	0.029 762	0.014 881	0.001 860	0.000 465	0.016 386	0.001 639	**1**

Units of Mass not Greater than Pounds and Kilograms

Units		Grains	Apothecaries' scruples	Pennyweights	Avoirdupois drams	Apothecaries' drams	Avoirdupois ounces
1 grain	=	1	0.05	0.041 666 67	0.036 571 43	0.016 666 67	0.002 285 71
1 scruple	=	20	1	0.833 333 3	0.731 428 6	0.333 333 3	0.045 714 29
1 pennyweight	=	24	1.2	1	0.877 714 3	0.4	0.054 857 14
1 dram avdp.	=	27.343 75	1.367 187 5	1.139 323	1	0.455 729 2	0.062 5
1 dram ap.	=	60	3	2.5	2.194 286	1	0.137 142 9
1 oz. avdp.	=	437.5	21.875	18.229 17	16	7.291 667	1
1 oz. ap. or t.	=	480	24	20	17.554 29	8	1.097 143
1 lb. ap. or t.	=	5760	288	240	210.651 4	96	13.165 71
1 lb. avdp.	=	7000	350	291.666 7	256	116.666 7	16
1 milligram	=	0.015 432	0.000 771 618	0.000 643 015	0.000 564 383	0.000 257 206	0.000 035 274
1 gram	=	15.432 36	0.771 617 9	0.643 014 9	0.564 383 4	0.257 206 0	0.035 273 96
1 kilogram	=	15 432.36	771.617 9	643.014 9	564.383 4	257.206 0	35.273 96

Units		Apothecaries' or troy ounces	Apothecaries' or troy pounds	Avoirdupois pounds	Milligrams	Grams	Kilograms
1 grain	=	0.002 083 33	0.000 173 611	0.000 142 857	64.798 91	0.064 798 91	0.000 064 799
1 scruple	=	0.041 666 67	0.003 472 222	0.002 857 143	1295.978 2	1.295 978 2	0.001 295 978
1 pennyweight	=	0.05	0.004 166 667	0.003 428 571	1555.173 84	1.555 173 84	0.001 555 174
1 dram avdp.	=	0.056 966 15	0.004 747 179	0.003 906 25	1771.845 195	1.771 845 195	0.001 771 845
1 dram ap.	=	0.125	0.010 416 67	0.008 571 429	3887.934 6	3.887 934 6	0.003 887 935
1 oz. avdp.	=	0.911 458 3	0.075 954 86	0.062 5	28 349.523 125	28.349 523 125	0.028 349 52
1 oz. ap. or t.	=	1	0.083 333 333	0.068 571 43	31 103.476 8	31.103 476 8	0.031 103 47
1 lb. ap. or t.	=	12	1	0.822 857 1	373 241.721 6	373.241 721 6	0.373 241 722
1 lb. avdp.	=	14.583 33	1.215 278	1	453 592.37	453.592 37	0.453 592 37
1 milligram	=	0.000 032 151	0.000 002 679	0.000 002 205	1	0.001	0.000 001
1 gram	=	0.032 150 75	0.002 679 229	0.002 204 623	1000	1	0.001
1 kilogram	=	32.150 75	2.679 229	2.204 623	1 000 000	1000	1

Units of Mass not Less than Avoirdupois Ounces

Units		Avoirdupois ounces	Avoirdupois pounds	Short hundredweights	Short tons	Long tons	Kilograms	Metric tons
1 oz. avdp.	=	1	0.0625	0.000 625	0.000 031 25	0.000 027 902	0.028 349 523	0.000 028 350
1 lb. avdp.	=	16	1	0.01	0.0005	0.000 446 429	0.453 592 37	0.000 453 592
1 short cwt.	=	1600	100	1	0.05	0.044 642 86	45.359 237	0.045 359 237
1 short ton	=	32 000	2000	20	1	0.892 857 1	907.184 74	0.907 184 74
1 long ton	=	35 840	2240	22.4	1.12	1	1016.046 908 8	1.016 046 909
1 kilogram	=	35.273 96	2.204 623	0.022 046 23	0.001 102 311	0.000 984 207	1	0.001
1 metric ton	=	35 273.96	2204.623	22.046 23	1.102 311	0.984 206 5	1000	1

CONVERSIONS

The program documented on the following pages provides an example of a modification strategy. The unit conversion program in the Master Library module converts units of length from English to SI measure and vice-versa. The program uses conversion factors for multiplications and divisions as required.

The conversion factors in the existing program use from four to nine program steps. In the modification the factors were replaced by recall instructions and inert "no operation" fillers for the leftover step spaces. The data storage registers recalled are 91 for A, 92 for B, 93 for C, 94 for D, and 95 for E.

Data stores 90-99 are in bank 1. By changing the partition to 159/99, the program steps and stored factors can reside in the same bank. If you want to change factors, simply store the new factors in the 91-95 registers and rewrite the magnetic card (or use a new card). Sometimes factors have to be changed periodically, as with fuel costs, for example.

Conversions seem trivial enough, but remember that planners do alot of converting. We convert assessed values to tax revenue, map measurements to actual distances, population numbers to standard service requirements, and so on. Even fiscal impact analysis consists mainly of conversions.

In my work I read energy and environmental research that use SI units of measurement. Practicing architects and land use planners in this country generally use English units of measurement, even in such recent technologies-of-interest as solar design and siting. The program documented on the following pages helped me translate between research and practice.

There are times when the user needs more conversion capacity. What if we borrowed the algorithm used in the Master Library program and kept rolling new numbers into storage registers 91-95? We would, of course, need to keep track of what sets of numbers we rolled in, but the technique would permit us to keep 85 conversions in one program.

Each row stores five conversions. When we want to change a row number, we reset the program (RST), choose the new row number (eg, 9), hit R/S, and we are ready to use a "new" unit conversion program. Any number from 0-17 constitutes a legitimate row call number, but keep a chart of what you have in each row (and cell).

We can modify the program by inserting SUM 00 R/S before what is now step 049, and SUM 01 R/S before what is now step 125. If we hit R/S after a conversion has been completed, the converted output sums into a register that we can then retrieve or zero out at will. Note that this adds more to the fiscal impact analysis capability, among other things.

The worked example demonstrates a recorded conversion from a 14.2 centimeter measurement on a 1:24000 map to an actual distance in feet. Two more centimeter measurements are then converted. The third conversion is further converted from feet to miles, and then from miles to kilometers. If this had to be done very often, you would provide a direct conversion or group sequential conversions on the same row. Grouping by utility is important, even though the same conversion may be available on more than one row.

000	76	LBL	000	76	LBL
001	11	A	001	11	A
002	53	(	002	53	(
003	24	CE	003	24	CE
004	65	×	004	55	÷
005	02	2	005	43	RCL
006	93	.	006	91	91
007	05	5	007	68	NOP
008	04	4	008	68	NOP
009	54	)	009	54	)
010	92	RTN	010	92	RTN
011	76	LBL	011	76	LBL
012	12	B	012	12	B
013	53	(	013	53	(
014	24	CE	014	24	CE
015	65	×	015	55	÷
016	93	.	016	43	RCL
017	03	3	017	92	92
018	00	0	018	68	NOP
019	04	4	019	68	NOP
020	08	8	020	68	NOP
021	54	)	021	54	)
022	92	RTN	022	92	RTN
023	76	LBL	023	76	LBL
024	13	C	024	13	C
025	53	(	025	53	(
026	24	CE	026	24	CE
027	65	×	027	55	÷
028	93	.	028	43	RCL
029	09	9	029	93	93
030	01	1	030	68	NOP
031	04	4	031	68	NOP
032	04	4	032	68	NOP
033	54	)	033	54	)
034	92	RTN	034	92	RTN
035	76	LBL	035	76	LBL
036	14	D	036	14	D
037	53	(	037	53	(
038	24	CE	038	24	CE
039	65	×	039	55	÷
040	01	1	040	43	RCL
041	93	.	041	94	94
042	06	6	042	68	NOP
043	00	0	043	68	NOP
044	09	9	044	68	NOP
045	03	3	045	68	NOP
046	04	4	046	68	NOP
047	04	4	047	68	NOP
048	54	)	048	54	)
049	92	RTN	049	92	RTN

Parallel listings of Master Library conversion program (#24) and an all-purpose variation.

```
050   76  LBL
051   15   E
052   53   (
053   24  CE
054   65   ×
055   93   .
056   08   8
057   06   6
058   08   8
059   09   9
060   07   7
061   06   6
062   02   2
063   04   4
064   54   )
065   92  RTN
066   76  LBL
067   16  A'
068   35  1/X
069   11   A
070   35  1/X
071   92  RTN
072   76  LBL
073   17  B'
074   35  1/X
075   12   B
076   35  1/X
077   92  RTN
078   76  LBL
079   18  C'
080   35  1/X
081   13   C
082   35  1/X
083   92  RTN
084   76  LBL
085   19  D'
086   35  1/X
087   14   D
088   35  1/X
089   92  RTN
090   76  LBL
091   10  E'
092   35  1/X
093   15   E
094   35  1/X
095   92  RTN
096   00   0
097   00   0
098   00   0
099   00   0
```

```
050   76  LBL
051   15   E
052   53   (
053   24  CE
054   55   ÷
055   43  RCL
056   95   95
057   68  NOP
058   68  NOP
059   68  NOP
060   68  NOP
061   68  NOP
062   68  NOP
063   68  NOP
064   54   )
065   92  RTN
066   76  LBL
067   16  A'
068   35  1/X
069   11   A
070   35  1/X
071   92  RTN
072   76  LBL
073   17  B'
074   35  1/X
075   12   B
076   35  1/X
077   92  RTN
078   76  LBL
079   18  C'
080   35  1/X
081   13   C
082   35  1/X
083   92  RTN
084   76  LBL
085   19  D'
086   35  1/X
087   14   D
088   35  1/X
089   92  RTN
090   76  LBL
091   10  E'
092   35  1/X
093   15   E
094   35  1/X
095   92  RTN
096   00   0
097   00   0
098   00   0
099   00   0
```

```
001   11   A
012   12   B
024   13   C
036   14   D
051   15   E
067   16  A'
073   17  B'
079   18  C'
085   19  D'
091   10  E'
```

```
          2.    ****
        14.2
 11181.10237    B
        12.1
 9527.559058    B
        56.8
 44724.40946    B
 44724.40946
 8.470532095    A

         12.    ****
       8.471
 13.63277918    E'
         55.
 88.51408983    E'
```

Printout record of conversions, with a TRACE for the first conversion to show how the program runs.

```
                RST
          2.    STO
                 90
          2.
          2.    RCL
                 94
5151515151.
5151515151.     OP
                  4
5151515151.
5151515151.     RCL
                 90
          2.
          2.    OP
                  6
          2.    ****
                R/S
```

```
       14.2     X:T
      1765.
         1.     SBR
                 13
         1.     STO
                 91
         1.
        95.     +
        95.     RCL
                 91
         1.
         1.     =
        96.
        96.     STO
                 93
        96.
        96.     RCL
                 91
         1.
         1.     +
         1.     RCL
                 90
         2.
         2.     ×
         5.     =
        11.
        11.     STO
                 92
        11.
        11.     RC*
                *93
                 96
  1400.1465
  1400.1465     OP
                  4
      1400.
      1400.     X:T
       14.2
       14.2     PRT
       14.2     ×
       14.2     RC*
                *92
                 11
 787.401575
 787.401575     =
11181.10237
11181.10237     OP
                  6
11181.10237     B
                R/S
```

CONVERSION RECORD SHEET FORMAT

The rows would normally be filled and listed sequentially. It can be handwritten on graph paper.

ROW 2

A (10)	B (11)	C (12)	D (13)	E(14)
Feet-Miles	Centimeters-Feet at 1:24000	Centimeters-Feet at 1:25000	1"=100' to 1:25000	1:25000 to 1:24000
.0001893939	787.401575	820.2099725	20.83333333	.96

ROW 12

A (60)	B (61)	C (62)	D (63)	E (64)
Centimeters-Inches	Meters-Feet	Meters-Yards	Nautical miles-Miles	Kilometers- Miles
.3937	3.28084	1.093613	1.151158237	.62137

ROW 15

A (75)	B (76)	C (77)	D (78)	E (79)
Acres-Square feet	Hectares-Acres	Square miles-Acres	Kilometers^2-Miles^2	Not used
43560	2.4710538	640	.386019	1.

000	42	STO
001	90	90
002	98	ADV
003	43	RCL
004	94	94
005	69	OP
006	04	04
007	43	RCL
008	90	90
009	69	OP
010	06	06
011	91	R/S
012	76	LBL
013	11	A
014	32	X⇌T
015	00	0
016	42	STO
017	91	91
018	09	9
019	05	5
020	85	+
021	43	RCL
022	91	91
023	95	=
024	42	STO
025	93	93
026	43	RCL
027	91	91
028	85	+
029	43	RCL
030	90	90
031	65	×
032	05	5
033	95	=
034	42	STO
035	92	92
036	73	RC*
037	93	93
038	69	OP
039	04	04
040	32	X⇌T
041	99	PRT
042	65	×
043	73	RC*
044	92	92
045	95	=
046	69	OP
047	06	06
048	91	R/S
049	76	LBL
050	12	B
051	32	X⇌T
052	01	1
053	71	SBR
054	00	00
055	16	16
056	76	LBL
057	13	C
058	32	X⇌T
059	02	2
060	71	SBR
061	00	00
062	16	16
063	76	LBL
064	14	D
065	32	X⇌T
066	03	3
067	71	SBR
068	00	00
069	16	16
070	76	LBL
071	15	E
072	32	X⇌T
073	04	4
074	71	SBR
075	00	00
076	16	16
077	68	NOP
078	68	NOP
079	68	NOP
080	76	LBL
081	16	A'
082	32	X⇌T
083	00	0
084	42	STO
085	91	91
086	09	9
087	05	5
088	85	+
089	43	RCL
090	91	91
091	95	=
092	42	STO
093	93	93
094	43	RCL
095	91	91
096	85	+
097	43	RCL
098	90	90
099	65	×
100	05	5
101	95	=
102	42	STO
103	92	92
104	73	RC*
105	93	93
106	22	INV
107	59	INT
108	65	×
109	01	1
110	00	0
111	00	0
112	33	X^2
113	95	=
114	69	OP
115	04	04
116	32	X⇌T
117	99	PRT
118	55	÷
119	73	RC*
120	92	92
121	95	=
122	69	OP
123	06	06
124	91	R/S
125	76	LBL
126	17	B'
127	32	X⇌T
128	01	1
129	71	SBR
130	00	00
131	84	84
132	76	LBL
133	18	C'
134	32	X⇌T
135	02	2
136	71	SBR
137	00	00
138	84	84
139	76	LBL
140	19	D'
141	32	X⇌T
142	03	3
143	71	SBR
144	00	00
145	84	84
146	76	LBL
147	10	E'
148	32	X⇌T
149	04	4

150	71	SBR
151	00	00
152	84	84
153	00	0
154	00	0
155	00	0
156	00	0
157	00	0
158	00	0
159	00	0

013	11	A
050	12	B
057	13	C
064	14	D
071	15	E
081	16	A'
126	17	B'
133	18	C'
140	19	D'
147	10	E'

0.	90
0.	91
0.	92
0.	93
5151515151.	94
1300.1365	95
1400.1465	96
1500.1565	97
1600.1665	98
1700.1765	99

0.	00	0.	50
0.	01	0.	51
0.	02	0.	52
0.	03	0.	53
0.	04	0.	54
3.1496063	05	0.	55
7.8740158	06	0.	56
15.748032	07	0.	57
2.5	08	0.	58
5.	09	0.	59
.0001893939	10	0.3937	60
787.401575	11	3.28084	61
820.2099725	12	1.093613	62
20.83333333	13	1.151158237	63
0.96	14	0.62137	64
1.201	15	0.1550003	65
0.2641794	16	10.76391	66
2.352583	17	1.19599	67
1.609	18	.0002471054	68
3.28084	19	1.	69
8.345172596	20	0.06102374	70
2150.42	21	35.31467	71
7.480519	22	1.307951	72
448.83114	23	7.480519	73
325851.4076	24	8.345172596	74
.9259259259	25	43560.	75
.9090909091	26	2.4710538	76
.8928571429	27	640.	77
.8695652174	28	0.386019	78
.8333333333	29	1.	79
0.	30	0.03527396	80
0.	31	0.0625	81
0.	32	2.204623	82
0.	33	0.001102311	83
0.	34	62.426	84
0.	35	3.96831	85
0.	36	3412.	86
0.	37	0.947813	87
0.	38	0.08805471	88
0.	39	316.98518	89
0.	40	12.	90
0.	41	4.	91
0.	42	64.	92
0.	43	99.	93
0.	44	5151515151.	94
0.	45	1300.1365	95
0.	46	1400.1465	96
0.	47	1500.1565	97
0.	48	1600.1665	98
0.	49	1700.1765	99

Data bank for the conversion program. The registers would normally be full.

ROWS AND COLUMNS

The administration of related grants requires creative budgeting. Suppose the agency budget is adequate, but program X has more than enough money and program Y has too little. The accounting for overhead and shared costs can be modified according to the relationships between the two programs. This means that we may have to run several trial budgets to allocate money effectively.

The following ten-row-by-nine-column program has many practical applications, but I have appreciated it most in the program budgeting process. It assigns entries to storage registers (equivalent to grid cells) for later column and row summations. The ability to keep printing out complete revisions makes it useful.

Surprisingly, no one had written such a program, probably because there are more efficient ways to sum rows and columns without assigning cells for inputs. I bought the PPX program nearest to what I needed. It could not relist modified columns, because operations were performed upon entry and only the results were assigned to (summation) cells. PPX 908109 handles any combination of rows and columns that total 79 (eg, 40x39, 50x29, etc.), far more rows and columns than I needed.

The 10x9 program can function in tandem for 20x9 or 10x18 problems. With two layer processing it might be used to assemble the totals of 12-90 of the 10x9 macro cells. In the worked example the seven columns are, from 1-7: personnel, fringe, travel, supplies, printing, contracts and other. Rows 1-6 are programs (make up your own names). The programs could have been labelled using the print processor method, so that columns can be pasted up, as on a typical budget sheet.

TRIAL BUDGET SHEET

1.
30140.
16412.
9080.
10410.
14520.
38200.
118762.

2.
7836.
4267.
2360.
2704.
3775.
9932.
30874.

3.
9410.
5820.
4562.
8320.
2540.
5240.
35892.

4.
2110.
1870.
2580.
3650.
2980.
1450.
14640.

5.
980.
690.
1450.
2100.
2540.
3000.
10760.

6.
1410.
1520.
2560.
2300.
1450.
3600.
12840.

7.
24112.
10870.
18470.
12040.
16500.
20450.
102442.

75998.
41449.
41062.
41524.
44305.
81872.
326210.

RUNNING THE PROGRAM

Partition the memory to 159.99 (10 OP 17). Fix the number of decimal places to be printed (usually FIX 0 or FIX 2). Clear and load mag card bank 1.

ENTER	KEY	DISPLAYS	PRINTS	COMMENTS
Number of columns: 7	A	7.		
Number of rows: 6	A'	6.		
Column number: 1	B	10.		
Value for cell 10: 30140	R/S	11.		
Value for cell 11: 16412	R/S	12.		

Enter remaining column values (up to 10 per column). In this case we would initialize column 2 after entering the seventh value in column 1. Continue until the chosen number of columns are completed.

Column number: 1	D	118762	Prints all entered values in that column, along with sum.
Row number: 0	D'	75998	Prints sum of entered values in that row.
No entry	E	402208	Total of completed row sums (only those sums processed by the D' routine)
No entry	E'	0	Prints and totals all columns; sums all rows and prints sums; prints total of row sums.

The user would normally enter values by column, go directly to E', enter modified values directly into cells (eg, 28450 STO 10), and use E' for another printout.

DATA REGISTERS

00 Sum of a row or column being processed
01 Stores column number being processed
02 Stores seed number for decrementing
03
04 Number of columns in use
05 Number of rows in use
06 Stores contents of register 04 for decrementing
07
08 Stores seed number for incrementing
09 Total of completed row sums
10 First of the series of usable storage cells for entries
99 Last of the series of usable storage cells for entries

Note that we can develop a 7x12 cell grid (for monthly accounts) by shifting the work of register 08 to 03, that of 09 to 99, and using registers 07-91 as the series of usable storage cells. Three control numbers in the program would have to be changed from 10 to 7.

```
000  76  LBL
001  12   B
002  65   ×
003  01   1
004  00   0
005  95   =
006  42  STO
007  01   01
008  91  R/S
009  72  ST*
010  01   01
011  69  OP
012  21   21
013  43  RCL
014  01   01
015  91  R/S
016  71  SBR
017  00   00
018  09   09
019  76  LBL
020  14   D
021  99  PRT
022  65   ×
023  01   1
024  00   0
025  95   =
026  42  STO
027  01   01
028  43  RCL
029  05   05
030  42  STO
031  02   02
032  73  RC*
033  01   01
034  99  PRT
035  44  SUM
036  00   00
037  69  OP
038  21   21
039  97  DSZ
040  02   02
041  00   00
042  32   32
043  43  RCL
044  00   00
045  99  PRT
046  00   0
047  42  STO
048  00   00
049  98  ADV
```

```
050  92  RTN
051  76  LBL
052  19  D'
053  68  NOP
054  85   +
055  01   1
056  00   0
057  95   =
058  42  STO
059  01   01
060  43  RCL
061  04   04
062  42  STO
063  02   02
064  73  RC*
065  01   01
066  68  NOP
067  44  SUM
068  00   00
069  01   1
070  00   0
071  44  SUM
072  01   01
073  97  DSZ
074  02   02
075  00   00
076  64   64
077  43  RCL
078  00   00
079  99  PRT
080  44  SUM
081  09   09
082  00   0
083  42  STO
084  00   00
085  92  RTN
086  76  LBL
087  11   A
088  42  STO
089  04   04
090  91  R/S
091  76  LBL
092  15   E
093  43  RCL
094  09   09
095  99  PRT
096  00   0
097  42  STO
098  09   09
099  98  ADV
```

```
100  91  R/S
101  76  LBL
102  16  A'
103  42  STO
104  05   05
105  91  R/S
106  43  RCL
107  00   00
108  99  PRT
109  00   0
110  42  STO
111  00   00
112  98  ADV
113  92  RTN
114  76  LBL
115  10  E'
116  43  RCL
117  04   04
118  42  STO
119  06   06
120  01   1
121  42  STO
122  08   08
123  43  RCL
124  08   08
125  14   D
126  69  OP
127  28   28
128  97  DSZ
129  06   06
130  01   01
131  23   23
132  43  RCL
133  05   05
134  42  STO
135  06   06
136  00   0
137  42  STO
138  08   08
139  43  RCL
140  08   08
141  19  D'
142  69  OP
143  28   28
144  97  DSZ
145  06   06
146  01   01
147  39   39
148  15   E
149  00   0
```

001	12	B
020	14	D
052	19	D'
087	11	A
092	15	E
102	16	A'
115	10	E'

0.	00	980.	50
85.	01	690.	51
0.	02	1450.	52
0.	03	2100.	53
7.	04	2540.	54
6.	05	3000.	55
0.	06	0.	56
0.	07	0.	57
6.	08	0.	58
0.	09	0.	59
30140.	10	1410.	60
16412.	11	1520.	61
9080.	12	2560.	62
10410.	13	2300.	63
14520.	14	1450.	64
38200.	15	3600.	65
0.	16	0.	66
0.	17	0.	67
0.	18	0.	68
0.	19	0.	69
7836.	20	24112.	70
4267.	21	10870.	71
2360.	22	18470.	72
2704.	23	12040.	73
3775.	24	16500.	74
9932.	25	20450.	75
0.	26	0.	76
0.	27	0.	77
0.	28	0.	78
0.	29	0.	79
9410.	30	0.	80
5820.	31	0.	81
4562.	32	0.	82
8320.	33	0.	83
2540.	34	0.	84
5240.	35	0.	85
0.	36	0.	86
0.	37	0.	87
0.	38	0.	88
0.	39	0.	89
2110.	40	0.	90
1870.	41	0.	91
2580.	42	0.	92
3650.	43	0.	93
2980.	44	0.	94
1450.	45	0.	95
0.	46	0.	96
0.	47	0.	97
0.	48	0.	98
0.	49	0.	99

POPULATION PROJECTIONS

Population projection methods ranked first with both practicing planners and planning schools in the Isserman survey. The location, number and age distribution of a community's population are data of critical importance to land use planning. Census publications make decennial population data inexpensive to the planner, but useful development of that data can be time-consuming and expensive.

In Rhode Island the Statewide Planning program provides projections of state population by sex, age and race, along with aggregated totals for cities and towns. Local government planners generally do not have access to cohort survival projections for their own census tracts.

Cohort survival population projection is relatively simple to understand when the operations are diagrammed. The calculations are tediously repetitive: multiplication after multiplication followed by additions. The calculations might even be worth suffering through if all the answers to our questions could be answered with one round of processing.

What do we really need to know? The planner might be interested in determining the different migration patterns of each cohort in a census tract. This can be an important indicator of relative stability in neighborhoods.

Assume that the town of Jefferson had a 1970 population of 18475, and a 1980 population of 19921. Given cohort survival rates and fertility rates, what kind of average net migration brings 18475 to 19921 in a decade? Once we know that, specific cohorts can be identified as having greater or lesser net migration rates. Within overall population growth there may be signs of serious problems.

This kind of analysis requires iterative runs with increasing or decreasing migration rates that eventually come close to generating the 19921 figure. For the town of Jefferson this may require thousands of arithmetic operations. With a TI-59 program the runs require 2-3 minutes of unattended operation once the data has been loaded and stored on a magnetic card. The printouts can be formatted and labelled for publication.

Our example begins with 1970 population data. Using statewide fertility and survival rates, we can project two sequential five-year periods, to 1980, using a migration factor of 1.0 (not enough to bring us to 19921). Maybe the women of Jefferson had higher fertility rates than we expected. That would show up in descrepancies in the 00-04 cohort in 1975 and 1980, as well as the 05-09 cohort in 1980. Maybe most cohorts had better survival rates than we expected. That can be isolated through death records. The point remains that we have control over the sometimes opaque set of relationships over time. This is not straight matrix multiplication. If it had been, the program would have been about 300 steps shorter.

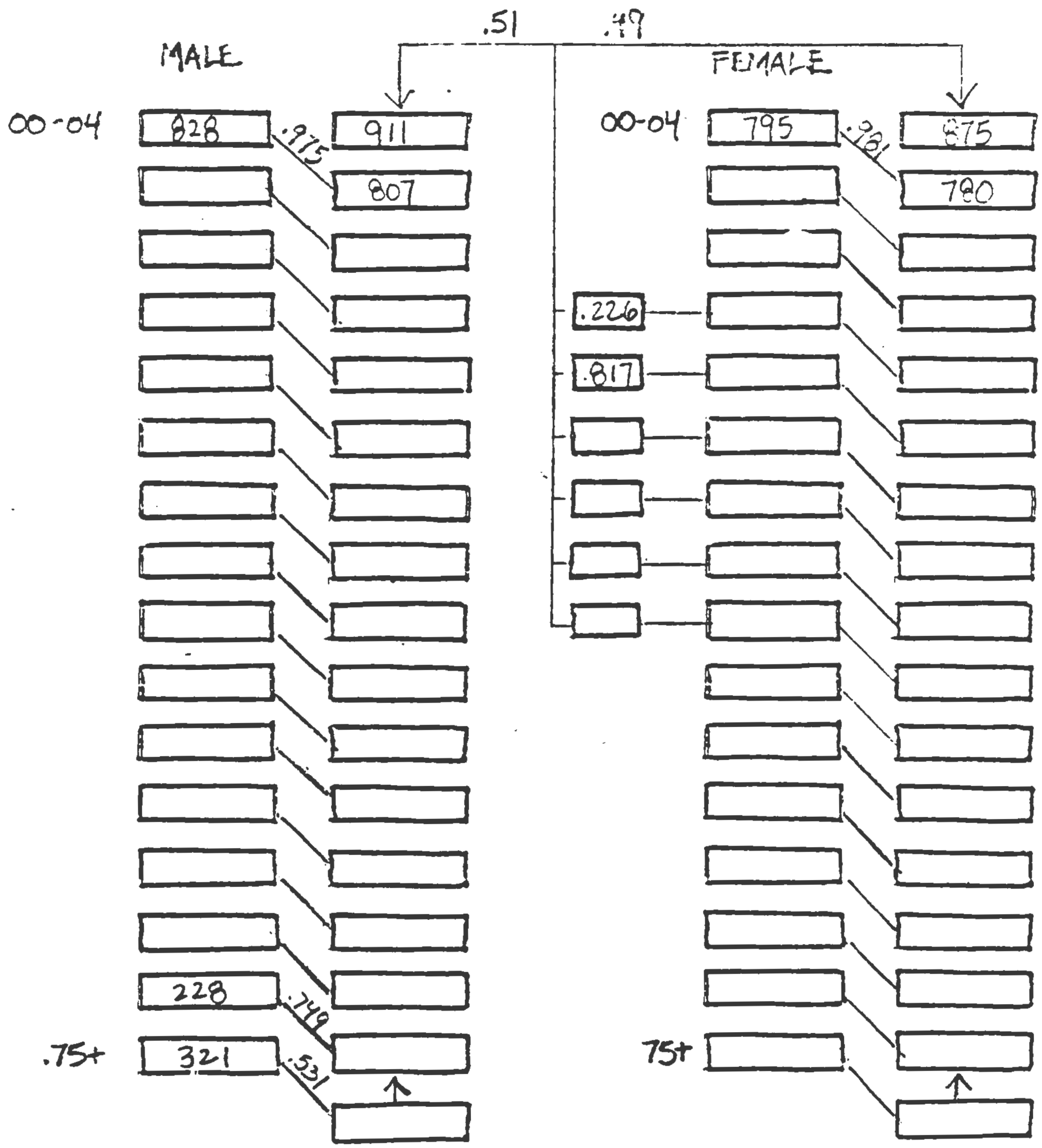
This problem is a good example of the possibilities for merging graphic and numerical approaches to problems. I found cohort survival projection difficult because the text I read explained it poorly. Krueckeberg and Silvers' URBAN PLANNING ANALYSIS explains it backwards, with 15 year projections.[1] How much more distant can a theoretical explanation stray from real world applications? David Winsor, a graduate student with remarkable graphic understanding, passed out copies of his diagram to anyone who needed one. That diagram has been redrawn, with several modifications, as the entry point to the calculator program.

NOTES

[1]Donald Kruekeberg and Arthur Silvers, URBAN PLANNING ANALYSIS: METHODS AND MODELS, (New York: John Wiley and Sons, 1974), pp. 276-81, and particularly p. 278.

DIAGRAM FOR COHORT SURVIVAL POPULATION PROJECTION

Note that the numbers used are the same as those on the formatted printout on the following page (1975, 1980).



	1975.	YR		1980.	YR
	117.	CT		117.	CT
00-04	795.		00-04	875.	
05-09	692.		05-09	780.	
10-14	780.		10-14	691.	
15-19	885.		15-19	779.	
20-24	771.		20-24	883.	
25-29	723.		25-29	769.	
30-34	682.		30-34	721.	
35-39	558.		35-39	679.	
40-44	448.		40-44	552.	
45-49	403.		45-49	443.	
50-54	505.		50-54	394.	
55-59	513.		55-59	493.	
60-64	533.		60-64	494.	
65-69	483.		65-69	496.	
70-74	333.		70-74	437.	
75-	489.		75-	535.	
	9593.			10021.	

00-04	828.	00-04	911.
05-09	716.	05-09	807.
10-14	792.	10-14	715.
15-19	875.	15-19	791.
20-24	813.	20-24	871.
25-29	673.	25-29	809.
30-34	555.	30-34	664.
35-39	560.	35-39	548.
40-44	397.	40-44	549.
45-49	373.	45-49	389.
50-54	451.	50-54	357.
55-59	487.	55-59	431.
60-64	439.	60-64	443.
65-69	374.	65-69	381.
70-74	228.	70-74	297.
75-	321.	75-	341.
	8882.		9304.

18475. 19325.

FORMATTED LABELS GENERATED WITH THE PRINT PROCESSOR

00-04
05-09
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-

00-04
05-09
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-

00-04
05-09
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-

00-04
05-09
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-

RUNNING THE PROGRAM

Clear and load mag card banks 1,2 and 4.

ENTER	KEY	DISPLAYS	PRINTS		COMMENTS
Year of input data: 1970	A	1970.	1970.	YR	
Census tract number: 117	R/S	117.	117.	CT	
Female 00-04 population and survival rate in the form P.S: 795.981	R/S	5.	795.981		Cue for next cohort
Female 05-09: 692.999	R/S	10.	692.999		

Continue entering all female cohorts. After last entry (75+) the total female population will be printed.

ENTER	KEY	DISPLAYS	PRINTS		COMMENTS
Male 00-04 population and survival rate in the form P.S: 828.975	B	5.	828.975		

Continue entering all male cohorts. After last entry (75+) the total male population will be printed.

ENTER	KEY	DISPLAYS	PRINTS		COMMENTS
Female 15-19 fertility rate: .226	C	.226	.226	FR	

Continue entering required female fertility rates.

ENTER	KEY	DISPLAYS	PRINTS		COMMENTS
Net migration rate: 1.0	D	1.0	1.0	MR	
Number of 5 year periods for projection: 2	E	Prints year, census tract, cohort projections and totals for females, then males. Prints total population.			

Note that before running the program at E, the user will generally want to save the data by writing banks 3 and 4 to a new card. This permits use of various migration rates without the need to repeatedly key in data.

DATA REGISTERS

00 Temporary storage of intermediate results
01 Pointer numbers for indirect recalls
02 Pointer numbers for indirect recalls
03 Counter for number of cohorts (decremented)
04 Total 00-04 generated
05 Female 00-04
06 Male 00-04
07 Alphanumeric code for YR
08 Alphanumeric code for CT
09 Counter for number of five year projections
10 Initial year (incremented by 5 after each run)
11 Census tract number
12 Migration rate
13 Merged population and survival rate for female 00-04 cohort. Subsequent cohorts follow in sequence through storage register 28
29 Total females
43 Merged population and survival rate for male 00-04 cohort. Subsequent cohorts follow in sequence through storage register 58
59 Total males

```
000  76  LBL
001  11   A
002  32  X:T
003  43  RCL
004  07   07
005  69  OP
006  04   04
007  32  X:T
008  42  STO
009  10   10
010  69  OP
011  06   06
012  91  R/S
013  32  X:T
014  43  RCL
015  08   08
016  69  OP
017  04   04
018  32  X:T
019  42  STO
020  11   11
021  69  OP
022  06   06
023  91  R/S
024  32  X:T
025  01   1
026  03   3
027  42  STO
028  01   01
029  02   2
030  09   9
031  42  STO
032  02   02
033  43  RCL
034  38   38
035  69  OP
036  04   04
037  71  SBR
038  42  STO
039  68  NOP
040  91  R/S
041  91  R/S
042  76  LBL
043  12   B
044  32  X:T
045  04   4
046  03   3
047  42  STO
048  01   01
049  02   2
050  09   9
051  42  STO
052  02   02
053  43  RCL
054  40   40
055  69  OP
056  04   04
057  71  SBR
058  42  STO
059  68  NOP
060  43  RCL
061  42   42
062  69  OP
063  04   04
064  43  RCL
065  29   29
066  85   +
067  43  RCL
068  59   59
069  95   =
070  69  OP
071  06   06
072  98  ADV
073  91  R/S
074  76  LBL
075  42  STO
076  01   1
077  06   6
078  42  STO
079  03   03
080  00   0
081  42  STO
082  04   04
083  72  ST*
084  02   02
085  32  X:T
086  58  FIX
087  03   03
088  69  OP
089  06   06
090  69  OP
091  00   00
092  72  ST*
093  01   01
094  59  INT
095  74  SM*
096  02   02
097  69  OP
098  21   21
099  97  DSZ
100  03   03
101  01   01
102  12   12
103  73  RC*
104  02   02
105  22  INV
106  58  FIX
107  99  PRT
108  98  ADV
109  92  RTN
110  68  NOP
111  68  NOP
112  43  RCL
113  04   04
114  85   +
115  05   5
116  95   =
117  22  INV
118  58  FIX
119  42  STO
120  04   04
121  91  R/S
122  61  GTO
123  00   00
124  86   86
125  76  LBL
126  13   C
127  32  X:T
128  02   2
129  01   1
130  03   3
131  05   5
132  00   0
133  00   0
134  69  OP
135  04   04
136  32  X:T
137  42  STO
138  30   30
139  69  OP
140  06   06
141  91  R/S
142  42  STO
143  31   31
144  99  PRT
145  91  R/S
146  42  STO
147  32   32
148  99  PRT
149  91  R/S
```

```
150  42  STO
151  33   33
152  99  PRT
153  91  R/S
154  42  STO
155  34   34
156  99  PRT
157  91  R/S
158  42  STO
159  35   35
160  99  PRT
161  98  ADV
162  91  R/S
163  91  R/S
164  68  NOP
165  68  NOP
166  68  NOP
167  68  NOP
168  68  NOP
169  68  NOP
170  68  NOP
171  68  NOP
172  76  LBL
173  14   D
174  32  X:T
175  03   3
176  00   0
177  03   3
178  05   5
179  00   0
180  00   0
181  69  OP
182  04   04
183  32  X:T
184  42  STO
185  12   12
186  69  OP
187  06   06
188  98  ADV
189  91  R/S
190  91  R/S
191  76  LBL
192  15   E
193  42  STO
194  09   09
195  71  SBR
196  10  E'
197  68  NOP
198  97  DSZ
199  09   09
```

```
200  10  E'
201  68  NOP
202  91  R/S
203  91  R/S
204  76  LBL
205  10  E'
206  43  RCL
207  10   10
208  85   +
209  05   5
210  95   =
211  42  STO
212  10   10
213  71  SBR
214  49  PRD
215  98  ADV
216  71  SBR
217  16  A'
218  71  SBR
219  17  B'
220  68  NOP
221  43  RCL
222  42   42
223  69  OP
224  04   04
225  43  RCL
226  29   29
227  85   +
228  43  RCL
229  59   59
230  95   =
231  69  OP
232  06   06
233  98  ADV
234  92  RTN
235  76  LBL
236  49  PRD
237  43  RCL
238  07   07
239  69  OP
240  04   04
241  43  RCL
242  10   10
243  69  OP
244  06   06
245  43  RCL
246  08   08
247  69  OP
248  04   04
249  43  RCL
```

```
250  11   11
251  69  OP
252  06   06
253  01   1
254  06   6
255  42  STO
256  01   01
257  03   3
258  00   0
259  42  STO
260  02   02
261  06   6
262  42  STO
263  03   03
264  00   0
265  42  STO
266  04   04
267  73  RC*
268  01   01
269  65   ×
270  73  RC*
271  02   02
272  95   =
273  44  SUM
274  04   04
275  69  OP
276  21   21
277  69  OP
278  22   22
279  97  DSZ
280  03   03
281  02   02
282  67   67
283  43  RCL
284  04   04
285  65   ×
286  93   .
287  04   4
288  09   9
289  95   =
290  58  FIX
291  00   00
292  52  EE
293  58  FIX
294  00   00
295  22  INV
296  52  EE
297  22  INV
298  58  FIX
299  42  STO
```

300	05	05	350	42	STO	400	00	00
301	75	-	351	01	01	401	52	EE
302	43	RCL	352	05	5	402	58	FIX
303	04	04	353	09	9	403	00	00
304	95	=	354	42	STO	404	22	INV
305	94	+/-	355	02	02	405	52	EE
306	58	FIX	356	43	RCL	406	22	INV
307	00	00	357	40	40	407	58	FIX
308	52	EE	358	69	OP	408	32	X↕T
309	58	FIX	359	04	04	409	43	RCL
310	00	00	360	43	RCL	410	00	00
311	22	INV	361	06	06	411	97	DSZ
312	52	EE	362	71	SBR	412	03	03
313	22	INV	363	48	EXC	413	04	04
314	58	FIX	364	32	X↕T	414	35	35
315	42	STO	365	43	RCL	415	85	+
316	06	06	366	41	41	416	73	RC*
317	92	RTN	367	69	OP	417	01	01
318	76	LBL	368	04	04	418	22	INV
319	16	A'	369	32	X↕T	419	59	INT
320	01	1	370	69	OP	420	95	=
321	02	2	371	06	06	421	72	ST*
322	42	STO	372	98	ADV	422	01	01
323	01	01	373	92	RTN	423	32	X↕T
324	02	2	374	76	LBL	424	74	SM*
325	09	9	375	48	EXC	425	01	01
326	42	STO	376	42	STO	426	73	RC*
327	02	02	377	00	00	427	01	01
328	43	RCL	378	00	0	428	59	INT
329	38	38	379	72	ST*	429	99	PRT
330	69	OP	380	02	02	430	74	SM*
331	04	04	381	01	1	431	02	02
332	43	RCL	382	06	6	432	73	RC*
333	05	05	383	42	STO	433	02	02
334	71	SBR	384	03	03	434	92	RTN
335	48	EXC	385	69	OP	435	74	SM*
336	32	X↕T	386	21	21	436	02	02
337	43	RCL	387	73	RC*	437	69	OP
338	39	39	388	01	01	438	06	06
339	69	OP	389	59	INT	439	69	OP
340	04	04	390	65	×	440	00	00
341	32	X↕T	391	73	RC*	441	85	+
342	69	OP	392	01	01	442	73	RC*
343	06	06	393	22	INV	443	01	01
344	98	ADV	394	59	INT	444	22	INV
345	92	RTN	395	65	×	445	59	INT
346	76	LBL	396	43	RCL	446	95	=
347	17	B'	397	12	12	447	72	ST*
348	04	4	398	95	=	448	01	01
349	02	2	399	58	FIX	449	32	X↕T

450	42	STO
451	00	00
452	61	GTO
453	03	03
454	85	85
455	00	0
456	00	0
457	00	0
458	00	0
459	00	0
460	00	0
461	00	0
462	00	0
463	00	0
464	00	0

001	11	A
043	12	B
075	42	STO
126	13	C
173	14	D
192	15	E
205	10	E'
236	49	PRD
319	16	A'
347	17	B'
375	48	EXC

140.	00
58.	01
59.	02
0.	03
1622.798647	04
795.	05
828.	06
45350000.	07
15370000.	08
0.	09
1975.	10
117.	11
1.	12
795.981	13
692.999	14
780.999	15
885.998	16
771.998	17
723.997	18
682.996	19
558.99	20
448.988	21
403.978	22
585.977	23
513.962	24
533.93	25
483.905	26
333.818	27
489.538	28
9593.	29
0.226	30
0.817	31
0.777	32
0.398	33
0.178	34
0.047	35
0.	36
0.	37
0.	38
0.	39
0.	40
0.	41
0.	42
828.975	43
716.998	44
792.999	45
875.995	46
813.995	47
673.987	48
555.987	49

560.981	50
397.981	51
373.956	52
451.956	53
487.909	54
439.868	55
374.793	56
228.749	57
321.531	58
8882.	59

LIFE CYCLE COSTING

The federal Office of Management and Budget defines life-cycle costing (LCC) as the "sum total of all the direct, indirect, recurring, non-recurring, and other related costs . . . in the design, development, production, operation, maintenance and support of a major system over its anticipated useful life."[1] Everything counts. Most of the costs in the lifetime of a system occur after the initial investment, so that choosing the system with the lowest first cost can be expensive. In LCC costs occurring after the initial investment are appropriately discounted to present value. Some discount rates are more appropriate than others.

Because planners typically assume some responsibility for capital budgeting, LCC falls within our domain. The federal government has developed standard methods for LCC, largely in response to the increased factor costs for energy. In most cases, lifetime savings on energy or maintenance will generally provide the justification for choosing a system with a higher first cost.

Suppose that the town of Jefferson needs a new public works verhicle, and we want to compare the lifetime costs of vehicle A (conventionally called the Defender) and vehicle B (the Challenger). The Defender costs less initially, but the Challenger uses less fuel. If we compare life cycle costs at a discount rate of 14%, the Challenger is the preferred investment.

Several questions emerge from the discussion. Should we assume everything has an inflation rate, or should we normalize costs and consider only relative inflation rates (higher or lower than the base rate)? If we normalize prices, the actual discount rate equals the stated discount rate <u>plus</u> the general inflation rate, even though that is not explicitly noted. The federal government specifies normalized prices. The FEDERAL REGISTER for November 18, 1981 contains the DOE method. Local government planners would do well to ignore it and use inflated costs explicitly, if only to make the argument understandable.

If inflation is handled explicitly, how do we know what the salvage value will be in 20 years? You have to inflate presently known values and <u>then</u> discount them. The salvage rates entered in the example were previously inflated. For overhauls and other kinds of non-recurring costs, use the same inflate-then-discount approach.

The results of successive program runs are net present costs. This is a quick and relatively clean system. It assumes that the Defender and Challenger both do the same required job, and that doing more of the job provides no additional benefit streams.

NOTES

[1]R. Winslow et al, LIFE-CYCLE COSTING FOR PROCUREMENT OF SMALL BUSES, (Washington, D.C.: DOT, 1980), p. 1. The method uses explicit inflation rates.

RUNNING THE PROGRAM

Clear and load mag card bank 1.

ENTER	KEY	DISPLAYS	PRINTS	COMMENTS
Initial cost: 20800	A	20800.	20800.	
Expected salvage value: 2400	R/S	2400.	2400.	
Economic life in years: 20	R/S	1.	20.	
Fuel cost per year: 2600	B	2600.	2600.	
Expected rate of escalation for fuel costs: 1.08	R/S	1.08	1.08	
Other costs per year: 1900	C	1900.	1900.	
Expected rate of escalation for other costs: 1.06	R/S	1.06	1.06	
Discount rate: 1.14	D	1.14	1.14	
No entry	E	Prints 20 years of cash flow, followed by salvage value.		
Year of non-recurring cost: 10	A'	10.	10.	
Amount of non-recurring cost: 4600	R/S	1240.82	1240.82	Discounted.
No entry	E'	0.	56372.20	Total present value of costs.

The user would normally run the program first for the Defender and then for the Challenger.

DATA REGISTERS

05 Years of economic life
06 Contents of register 05 stored here and decremented
17 Year of non-recurring cost
18 Amount of non-recurring cost
31 Total present value of costs
32 Fuel cost per year (base year)
33 Other costs per year (base year)
40 Expected salvage value
42 Expected rate of escalation for fuel costs
43 Expected rate of escalation for other costs
44 Discount rate
49 Initial cost

Note that the storage registers should be allocated in a sequential, logical fashion. What would happen if we wanted to list storage registers for this program? This program could have been designed with some attention to possible future expansion. For example, we might want to run three or more classes of costs with differing escalation rates.

000	76	LBL
001	11	A
002	42	STO
003	49	49
004	99	PRT
005	91	R/S
006	99	PRT
007	42	STO
008	40	40
009	22	INV
010	44	SUM
011	49	49
012	91	R/S
013	99	PRT
014	42	STO
015	06	06
016	42	STO
017	05	05
018	55	÷
019	43	RCL
020	49	49
021	95	=
022	35	1/X
023	42	STO
024	48	48
025	68	NOP
026	01	1
027	44	SUM
028	06	06
029	91	R/S
030	76	LBL
031	12	B
032	42	STO
033	32	32
034	99	PRT
035	91	R/S
036	42	STO
037	42	42
038	99	PRT
039	91	R/S
040	76	LBL
041	13	C
042	42	STO
043	33	33
044	99	PRT
045	91	R/S
046	42	STO
047	43	43
048	99	PRT
049	68	NOP
050	91	R/S
051	76	LBL
052	14	D
053	42	STO
054	44	44
055	99	PRT
056	91	R/S
057	76	LBL
058	15	E
059	98	ADV
060	58	FIX
061	02	02
062	68	NOP
063	69	OP
064	29	29
065	97	DSZ
066	06	06
067	00	00
068	85	85
069	43	RCL
070	40	40
071	65	×
072	43	RCL
073	44	44
074	35	1/X
075	45	YX
076	43	RCL
077	05	05
078	95	=
079	94	+/-
080	99	PRT
081	44	SUM
082	31	31
083	95	=
084	91	R/S
085	43	RCL
086	42	42
087	45	YX
088	43	RCL
089	09	09
090	65	×
091	43	RCL
092	32	32
093	95	=
094	68	NOP
095	85	+
096	53	(
097	43	RCL
098	43	43
099	45	YX
100	43	RCL
101	09	09
102	65	×
103	43	RCL
104	33	33
105	54	)
106	85	+
107	43	RCL
108	48	48
109	95	=
110	68	NOP
111	65	×
112	43	RCL
113	44	44
114	35	1/X
115	45	YX
116	43	RCL
117	09	09
118	95	=
119	99	PRT
120	44	SUM
121	31	31
122	61	GTO
123	00	00
124	63	63
125	76	LBL
126	16	A'
127	42	STO
128	17	17
129	91	R/S
130	42	STO
131	18	18
132	43	RCL
133	44	44
134	35	1/X
135	45	YX
136	43	RCL
137	17	17
138	95	=
139	65	×
140	43	RCL
141	18	18
142	95	=
143	99	PRT
144	44	SUM
145	31	31
146	91	R/S
147	76	LBL
148	10	E'
149	43	RCL

```
150   31   31
151   99  PRT
152   47  CMS
153   98  ADV
154   91  R/S
155   00   0
156   00   0
157   00   0
158   00   0
159   00   0
001   11   A
031   12   B
041   13   C
052   14   D
058   15   E
126   16   A'
148   10   E'
```

Defender	Challenger
20800.00	24300.00
2400.00	2400.00
20.00	20.00
2600.00	1780.00
1.08	1.08
1800.00	1900.00
1.06	1.06
1.14	1.14
4943.86	4413.51
4597.66	4082.82
4278.70	3779.99
3984.54	3502.38
3713.00	3247.63
3462.10	3013.62
3230.06	2798.46
3015.28	2600.44
2816.30	2418.01
2631.82	2249.80
2460.63	2094.56
2301.66	1951.16
2153.93	1818.60
2016.55	1695.95
1888.70	1582.38
1769.65	1477.14
1658.72	1379.55
1555.29	1288.98
1458.80	1204.87
1368.74	1126.72
-174.63	-174.63
1240.82	1456.62
56372.20	49008.54

Note that this program runs the way we would solve the problem on paper (non-recurring cost entered last). We could modify this program to print alot more and give us a presentation format similar to that designed for hydroelectric site analysis.

HYDROELECTRIC SITES

Many New England cities and towns have hydroelectric sites within their jurisdictions. The generating equipment at such sites has typically been shut down within the past fifty years. In some cases the existing turbine/generator sets can be rehabilitated; in most cases at least some major components need to be replaced.

Even when private parties own the physical site and/or water rights, the municipality retains development priority under existing federal law, and hence the ultimate responsibility for making certain the energy resource is prudently developed. If the cost of electricity produced at the site is equal to, or less than, the cost of electricity otherwise acquired, the site can almost certainly be leveraged for economic development.

Before thousands of dollars are committed to engineering design, environmental assessment and financial studies, we need to know whether the project is worth further study. Even if the municipality chooses to postpone development, it is important to know how changing energy and other factor costs would affect the economics of development. If the municipality permits investment by private parties, the economic information developed in a hydroelectric site review can be useful in any negotiation related to the project.

In 1980 the U.S. Department of Energy released a site screening software package for the Apple II microcomputer.[1] The documentation for this package provides the standard calculation reference in this field.

The screening package provides a conservative interpretation of the cash flow for a site (as opposed to investor cash flow or combined investor/site flow). DOE needed a standard method for comparing projects and determining that its loan funds for feasibility studies would not be misallocated. At the time DOE was forgiving 90% of the loan amount for hydro projects with negative feasibility study results.

We can look at the hydro screening problem as a set of problems. Each can be solved, but at different confidence levels. For example, the available energy at a site over the course of an average flow year can be calculated with reasonable precision, but the flow curves for the years of a project life can only be discussed in terms of probabilities based on the historical record. Recently negotiated power purchase contract rates are known, but we are less certain about the earnings impacts of contract escalator clauses.

Engineering firms face considerable difficulties in estimating the physical rehabilitation costs for a site, particularly when dam repairs may be required. At the screening level cost estimates are based on Army Corps of Engineers cost tables for 1978 and extrapolations of those tables. A general cost escalator can be derived for any later date. The programmable can recalculate bottom line results

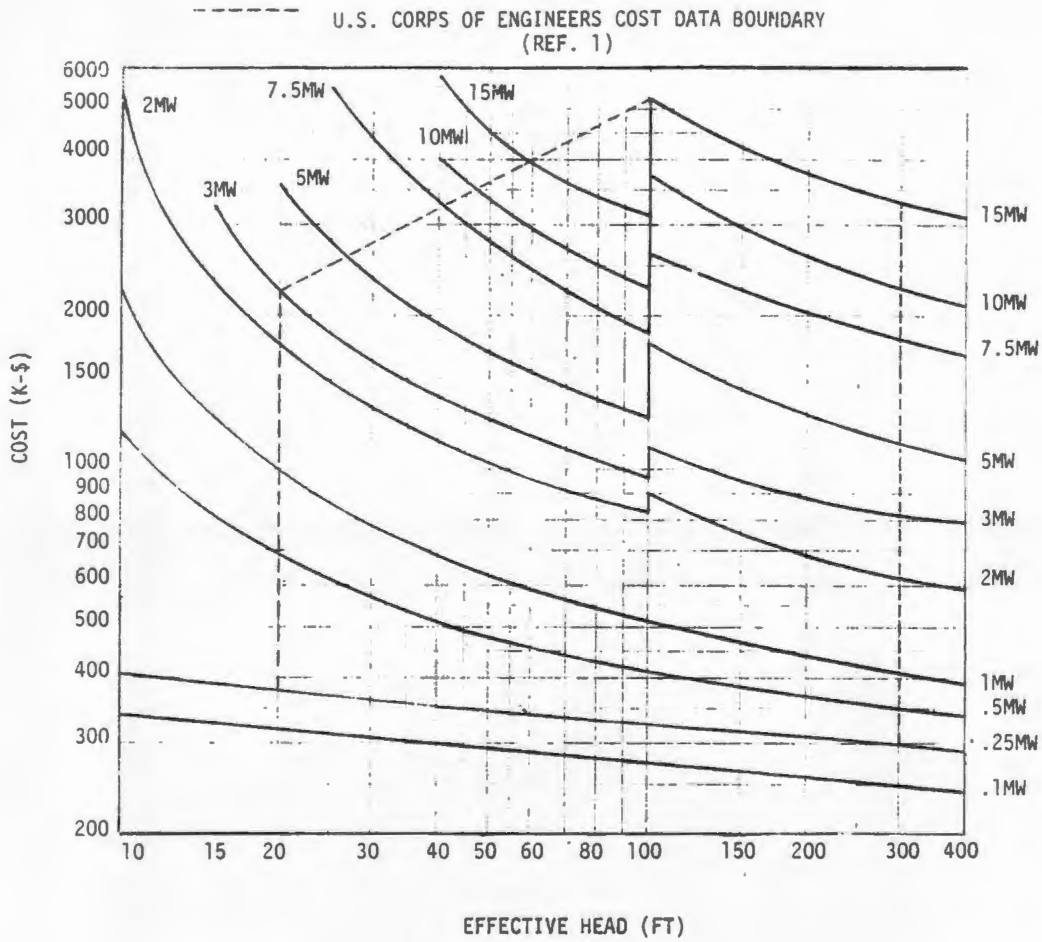


FIGURE 3-2. EXTRAPOLATED POWER GENERATION EQUIPMENT (SEE FIGURE 3-1)

TABLE 3-1

MISCELLANEOUS RECONNAISSANCE ESTIMATE COSTS*
(Cost Base July 1978)

PENSTOCK COST

Effective Head (Ft)	10	20	50	100	200	300
Cost Index (CI)	960	480	200	110	55	35

Installed cost = CI x Penstock Length (ft) x Installed Capacity (MW)
Minimum Penstock Cost is \$50 per linear foot.

TAILRACE COST
Construction Cost = \$15,000 fixed plus \$200 per linear foot

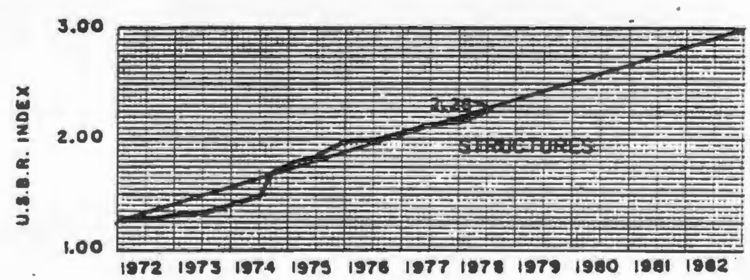
SWITCHYARD EQUIPMENT COST
(Thousand Dollars)

Plant	Transmission Voltage			
Capacity	13.8	34.5	69	115
1 MW	50	60	110	160
3 MW	85	100	120	175
5 MW	110	125	150	210
10 MW	150	170	210	280
15 MW	185	220	250	320

TRANSMISSION LINE COST
(Thousand Dollars)

Plant	Miles of transmission line				
Capacity	1	2	5	10	15
0.5 MW	30	60	150	–	–
5 MW	45	80	160	320	500
10 MW	60	100	180	380	600
15 MW	80	140	230	460	700

*TABLE 4-2 OF REF. 1



(Note: 2.28 represents July 1978)

FIGURE 3-3. ESCALATION OF SMALL HYDROELECTRIC PROJECT STRUCTURES (FIGURE 6-1 OF REF. 1, VOL. VI) quickly enough to permit efficient searching for the economic limits of capital investment. Successive numerical solutions begin to compensate for our analytical limitations.

A worked example will demonstrate the calculator version of the DOE screening program. Suppose that the town of Jefferson owns an existing hydro site. The dam provides 20 feet of usable head, and the nearest U.S. Geological Survey office informs us that the average flow rate near that site is 800 cubic feet per second. Given some knowledge of the flow duration curve for the river, we can assume a plant factor of about .7 (more on the derivation of this later). The program can then tell us the kilowatt capacity of the site at average flow, as well as the output in kilowatt hours per year. If we enter the value of a kilowatt hour the program tells us the yearly energy revenue, although not right away.

For costs the COE has provided graphs and tables, reproduced on the following two pages. With a ruler and some linear interpolation we can derive the appropriate numbers for entry. (The listed program actually includes interpolation and formula routines at A',B' and C', but we will not discuss them here.) After the costs have been entered we press control keys and let the economic calculations run.

The program includes built-in assumptions about project life, discount rate, etc. To change those assumptions, enter the new assumptions directly into the appropriate storage registers. For example, to change the interest rate from 15% to to 18%, simply key ".18 STO 25" (because the interest rate is stored in register 25). The instructions for running the program and the list of data register contents provide all the information required for running a series of calculations with changing variables. The instructions and list appear on the following two pages.

One of the more obvious questions one would ask is, "What happens if the value of electricity decreases?" If the purchasing utility offers $.042 per KWH rather than $.050, note the change in the number of years of negative cash flow. Some investors might be able to absorb that kind of negative flow, or compensate for it with the use of available tax incentives. For other investors that kind of change in the buyback rate would make the project infeasible.

The date of construction makes a difference in project feasibility. What would happen if the project is delayed until October 1983? We can determine that impact by changing the date (and hence the excalation factor for all costs). We might need to run the program 20-30 times with different values for selected variables before feeling confident about the dynamics of the project. But we could never feel confident about any one bottom line result, given the nature of the inputs.

No program is a final product, and this one has serious weaknesses that undermine its utility. We use it because it has assumed a life of its own as a DOE standard. It is not unusual for government-endorsed formulas to distort reality,

YEAR	ENERGY REVENUE	O+M	EXPENSES	EARNINGS
0.	358.073	62.453	379.508	-21.435
1.	386.719	66.200	383.255	3.464
2.	417.656	70.172	387.227	30.429
3.	451.069	74.383	391.437	59.631
4.	487.154	78.846	395.900	91.254
5.	526.127	83.577	400.631	125.496
6.	568.217	88.591	405.646	162.571
7.	613.674	93.907	410.961	202.713
8.	662.768	99.541	416.596	246.173
9.	715.790	105.513	422.568	293.222
10.	773.053	111.844	428.899	344.154

DATE	10.81
FT AVERAGE HEAD	20.000
CFS AVERAGE FLOW	800.000
KW CAPACITY	1167.883
PLANT FACTOR	0.700
KWH/YR OUTPUT	7161459.854
D/KWH ENERGY VALUE	0.050
GENERATING EQP DK	1100.000
SWITCHYARD EQP DK	50.000
TRANS LINES DK	34.000
OTHER DK	14.000
TAILRACE DK	18.000
PENSTOCK DK	11.000
COST ESC FACTOR	1.234
CONTINGENCY FACTOR	0.100
INDIRECTS FACTOR	0.250
O+M FACTOR	0.030
ESC GEN EQP DK	1357.310
ESC SWITCH EQP DK	61.696
ESC TRANS LINES DK	41.953
ESC OTHER DK	17.275
ESC TAILRACE DK	22.211
ESC PENSTOCK DK	13.573
ESC SUBTOTAL DK	1514.018
CONTINGENCY DK	151.402
CONST SUBTOTAL DK	1665.419
INDIRECTS DK	416.355
INVESTMENT DK	2081.774
BASE YR O+M DK	62.453
BASE YR REVENUE DK	358.073
DISCOUNT RATE	0.150
INTEREST RATE	0.150
YRS ECONOMIC LIFE	30.000
REVENUE ESC RATE	0.080
O+M ESC RATE	0.060
YRS ESCALATION	10.000
ANNUAL PAYMENT DK	317.055
PRESENT VALUE DK	3189.438
BENEFIT/COST	1.532

YEAR	ENERGY REVENUE	O-M	EXPENSES	EARNINGS
0.	300.781	62.453	379.508	-78.727
1.	324.844	66.200	383.255	-58.411
2.	350.831	70.172	387.227	-36.396
3.	378.898	74.383	391.437	-12.540
4.	409.210	78.846	395.900	13.309
5.	441.946	83.577	400.631	41.315
6.	477.302	88.591	405.646	71.656
7.	515.486	93.907	410.961	104.525
8.	556.725	99.541	416.596	140.130
9.	601.263	105.513	422.568	178.695
10.	649.364	111.844	428.899	220.465

DATE	10.81
FT AVERAGE HEAD	20.000
CFS AVERAGE FLOW	800.000
KW CAPACITY	1167.883
PLANT FACTOR	0.700
KWH/YR OUTPUT	7161459.854
D/KWH ENERGY VALUE	0.042
GENERATING EQP DK	1100.000
SWITCHYARD EQP DK	50.000
TRANS LINES DK	34.000
OTHER DK	14.000
TAILRACE DK	18.000
PENSTOCK DK	11.000
COST ESC FACTOR	1.234
CONTINGENCY FACTOR	0.100
INDIRECTS FACTOR	0.250
O+M FACTOR	0.030
ESC GEN EQP DK	1357.310
ESC SWITCH EQP DK	61.696
ESC TRANS LINES DK	41.953
ESC OTHER DK	17.275
ESC TAILRACE DK	22.211
ESC PENSTOCK DK	13.573
ESC SUBTOTAL DK	1514.018
CONTINGENCY DK	151.402
CONST SUBTOTAL DK	1665.419
INDIRECTS DK	416.355
INVESTMENT DK	2081.774
BASE YR O+M DK	62.453
BASE YR REVENUE DK	300.781
DISCOUNT RATE	0.150
INTEREST RATE	0.150
YRS ECONOMIC LIFE	30.000
REVENUE ESC RATE	0.080
O-M ESC RATE	0.060
YRS ESCALATION	10.000
ANNUAL PAYMENT DK	317.055
PRESENT VALUE DK	2585.848
BENEFIT/COST	1.242

so we will spend some time reviewing how it happened in this particular case.

The DOE method calculates full revenue, operating and maintenance costs, and loan payment for year zero, the capital investment year. The applicable convention of engineering economics is to show only interest on the unspent construction loan balance as year zero revenue. The flow in year zero in the DOE method would normally be assigned to year one. It appears that this quirk was a programming error. The TI-59 program was written for simple conversion to convention by changing seed numbers in one subroutine.

As previously stated, the DOE method focuses on the real cash flow from the project, without regard to the use of available investment tax credits, accelerated cost recovery methods or tax bracket effects. It is too rigid in the sense that it fixes the interest rate at the selected discount rate, even though there are many cases in which separate rates are required. The TI-59 program permits identical or different rates, so that one run can mimic the DOE method and another can reflect reality.

It should also be noted that the benefit/cost ratio is calculated against the required investment independent of mortgage consequences. When the interest rate changes, the payment changes, as does the cash flow, but not the BCR.

The DOE method calculates a site's kilowatt capacity by using average flow. The capacity is then multiplied by a plant factor to determine kilowatt hour output per year. It is possible to find the appropriate plant factor, but by means external to the DOE method. Rivers flow at varying rates from season to season and day to day. This variation is described by a flow exceddance curve. Turbines are typically matched to a flow rate exceeded only 15% of the time, and turbine efficiencies generally decline on either side of their rated flow. Determining yearly output from turbine efficiency curves and flow exceedance curves is an extremely complex problem. Suffice it to say that we can determine yearly output by the complex method and then divide by average flow KW rating to determine an accurate plant factor for the DOE method. This permits the merger of accurate design with COE costing.

In summary, we have a case in which no standard screening method existed before 1979. The DOE method became a standard by default. Because the microcomputer software was developed by a large engineering firm, few people questioned the method. David Thomas of Hoyle, Tanner and Associates developed reservations similar to mine while working with an HP-97. Similar conclusions from separate sources in different professions tend to reassure both sources.

NOTES

[1]Charles Broadus, HYDROPOWER COMPUTERIZED RECONNAISSANCE PACKAGE, Idaho Falls: DOE, 1980.

RUNNING THE PROGRAM

Partition the memory to 639.39 (4 OP 17) and clear.
Load mag card banks 1-4.

ENTER	KEY	DISPLAYS	PRINTS	COMMENTS
Date: 10.81	A	0.000	10.81	
Head in feet: 20	R/S	20.000	20.000	
Average flow in CFS: 800	R/S	7161459.854	800.000 1167.883 0.700 7161459.854	 KW capacity Plant factor KWH per year
Revenue per KWH in dollars	R/S	0.000	0.050	
Generating equipment costs in $ 000: 1100	B	1100.000	1100.000	
Switchyard equipment in $ 000: 50	R/S	50.000	50.000	
Transmission lines in $ 000: 34	R/S	34.000	34.000	
Other in $ 000: 14	R/S	14.000	14.000	
Tailrace costs in $ 000: 18	R/S	18.000	18.000	
Penstock costs in $ 000: 11	R/S	11.000	11.000	
No entry	C	Prints everything from "cost escalation factor" through "base year revenue"		
No entry	D	Prints everything from "discount rate" through "benefit/cost"		
No entry	E	Prints cash flow for years of revenue and O&M escalation		
No entry	E'	Prints everything in C,D,E without stopping		

DATA REGISTERS

00 Incremented exponent (revenue, O&M escalation factors)
01 Incremented exponent (discount factor)
02 Register 29 copied (decremented for present value calculation)
03 Register 26 copied (decremented for present value calculation)
04 Revenue in dollars per KWH
05 Tailrace costs in $ 000
06 Penstock costs in $ 000
07 Generating equipment costs in $ 000
08 Switchyard costs in $ 000
09 Transmission line costs in $ 000
10 Other costs in $ 000
11 Construction cost escalation rate
12 Plant factor
13 Investment total in $ 000
14
15 Operating and maintenance costs in $ 000
16 Energy revenue per year in $ 000
17 Annual payment, principal and interest, in $ 000
18 Present value of net revenue (ie, revenue - O&M)
19 Divisor in power formula
20 Hours in year
21 Contingency factor
22 Indirect costs factor
23 Operating and maintenance costs factor
24 Discount rate
25 Interest rate
26 Period of economic evaluation in years
27 Revenue escalation rate
28 O&M escalation rate
29 Years of escalation for revenue and O&M
30 Month and year (entered as MM.YY)
31 Net head in feet
32 Derived capacity in KW
33 KWH per year
34 Contents of register 27 +1
35 Contents of register 28 +1
36 Contents of register 24 +1
37
38 .00868567 (used in penstock cost formula)
39 -.959576 (used in penstock cost formula)

Input data is listed after the program step list.

```
000  76  LBL
001  11  A
002  58  FIX
003  02  02
004  99  PRT
005  42  STO
006  30  30
007  59  INT
008  55  ÷
009  01  1
010  02  2
011  85  +
012  53  (
013  43  RCL
014  30  30
015  22  INV
016  59  INT
017  65  ×
018  01  1
019  00  0
020  00  0
021  54  )
022  85  +
023  01  1
024  09  9
025  00  0
026  00  0
027  95  =
028  42  STO
029  30  30
030  00  0
031  58  FIX
032  03  03
033  91  R/S
034  99  PRT
035  42  STO
036  31  31
037  91  R/S
038  99  PRT
039  65  ×
040  43  RCL
041  31  31
042  55  ÷
043  43  RCL
044  19  19
045  68  NOP
046  68  NOP
047  95  =
048  99  PRT
049  42  STO
050  32  32
051  65  ×
052  43  RCL
053  12  12
054  99  PRT
055  65  ×
056  43  RCL
057  20  20
058  95  =
059  99  PRT
060  42  STO
061  33  33
062  91  R/S
063  99  PRT
064  42  STO
065  04  04
066  69  OP
067  05  05
068  91  R/S
069  76  LBL
070  17  B'
071  65  ×
072  93  .
073  02  2
074  85  +
075  01  1
076  05  5
077  95  =
078  68  NOP
079  91  R/S
080  76  LBL
081  18  C'
082  65  ×
083  43  RCL
084  31  31
085  45  Y^x
086  43  RCL
087  39  39
088  65  ×
089  43  RCL
090  38  38
091  65  ×
092  43  RCL
093  32  32
094  95  =
095  91  R/S
096  76  LBL
097  12  B
098  99  PRT
099  42  STO
100  07  07
101  91  R/S
102  99  PRT
103  42  STO
104  08  08
105  91  R/S
106  99  PRT
107  42  STO
108  09  09
109  91  R/S
110  99  PRT
111  42  STO
112  10  10
113  91  R/S
114  99  PRT
115  42  STO
116  05  05
117  91  R/S
118  99  PRT
119  42  STO
120  06  06
121  69  OP
122  05  05
123  91  R/S
124  76  LBL
125  13  C
126  43  RCL
127  30  30
128  65  ×
129  93  .
130  01  1
131  06  6
132  75  -
133  03  3
134  01  1
135  04  4
136  93  .
137  02  2
138  08  8
139  95  =
140  55  ÷
141  02  2
142  93  .
143  02  2
144  08  8
145  95  =
146  99  PRT
147  42  STO
148  11  11
149  43  RCL
```

150	21	21
151	99	PRT
152	43	RCL
153	22	22
154	99	PRT
155	43	RCL
156	23	23
157	99	PRT
158	69	OP
159	05	05
160	68	NOP
161	68	NOP
162	00	0
163	42	STO
164	13	13
165	43	RCL
166	07	07
167	71	SBR
168	02	02
169	62	62
170	43	RCL
171	08	08
172	71	SBR
173	02	02
174	62	62
175	43	RCL
176	09	09
177	71	SBR
178	02	02
179	62	62
180	43	RCL
181	10	10
182	71	SBR
183	02	02
184	62	62
185	43	RCL
186	05	05
187	71	SBR
188	02	02
189	62	62
190	43	RCL
191	06	06
192	71	SBR
193	02	02
194	62	62
195	69	OP
196	05	05
197	68	NOP
198	68	NOP
199	68	NOP

200	43	RCL
201	13	13
202	99	PRT
203	65	×
204	43	RCL
205	21	21
206	95	=
207	99	PRT
208	44	SUM
209	13	13
210	43	RCL
211	13	13
212	95	=
213	99	PRT
214	65	×
215	43	RCL
216	22	22
217	95	=
218	99	PRT
219	44	SUM
220	13	13
221	69	OP
222	05	05
223	43	RCL
224	13	13
225	95	=
226	99	PRT
227	68	NOP
228	68	NOP
229	65	×
230	43	RCL
231	23	23
232	95	=
233	99	PRT
234	42	STO
235	15	15
236	43	RCL
237	33	33
238	65	×
239	43	RCL
240	04	04
241	55	÷
242	01	1
243	00	0
244	00	0
245	00	0
246	95	=
247	99	PRT
248	42	STO
249	16	16

250	69	OP
251	05	05
252	92	RTN
253	68	NOP
254	68	NOP
255	68	NOP
256	68	NOP
257	68	NOP
258	68	NOP
259	68	NOP
260	68	NOP
261	68	NOP
262	68	NOP
263	68	NOP
264	65	×
265	43	RCL
266	11	11
267	95	=
268	99	PRT
269	44	SUM
270	13	13
271	92	RTN
272	76	LBL
273	10	E'
274	13	C
275	14	D
276	15	E
277	91	R/S
278	68	NOP
279	68	NOP
280	76	LBL
281	14	D
282	43	RCL
283	24	24
284	99	PRT
285	85	+
286	01	1
287	95	=
288	42	STO
289	36	36
290	43	RCL
291	25	25
292	99	PRT
293	43	RCL
294	26	26
295	99	PRT
296	43	RCL
297	27	27
298	99	PRT
299	85	+

```
300  01  1
301  95  =
302  42  STO
303  34  34
304  43  RCL
305  28  28
306  99  PRT
307  85  +
308  01  1
309  95  =
310  42  STO
311  35  35
312  43  RCL
313  29  29
314  99  PRT
315  69  OP
316  05  05
317  01  1
318  75  -
319  53  (
320  01  1
321  85  +
322  43  RCL
323  25  25
324  54  )
325  45  Y^X
326  43  RCL
327  26  26
328  94  +/-
329  95  =
330  55  ÷
331  43  RCL
332  25  25
333  95  =
334  35  1/X
335  65  ×
336  43  RCL
337  13  13
338  95  =
339  99  PRT
340  42  STO
341  17  17
342  43  RCL
343  29  29
344  42  STO
345  02  02
346  43  RCL
347  26  26
348  42  STO
349  03  03
350  01  1
351  42  STO
352  00  00
353  42  STO
354  01  01
355  00  0
356  42  STO
357  18  18
358  43  RCL
359  16  16
360  65  ×
361  43  RCL
362  34  34
363  45  Y^X
364  43  RCL
365  00  00
366  75  -
367  53  (
368  43  RCL
369  15  15
370  65  ×
371  43  RCL
372  35  35
373  45  Y^X
374  43  RCL
375  00  00
376  54  )
377  95  =
378  55  ÷
379  43  RCL
380  36  36
381  45  Y^X
382  43  RCL
383  01  01
384  95  =
385  68  NOP
386  44  SUM
387  18  18
388  97  DSZ
389  02  02
390  04  04
391  07  07
392  97  DSZ
393  03  03
394  04  04
395  13  13
396  43  RCL
397  18  18
398  99  PRT
399  55  ÷
400  43  RCL
401  13  13
402  95  =
403  99  PRT
404  69  OP
405  05  05
406  92  RTN
407  69  OP
408  20  20
409  61  GTO
410  03  03
411  92  92
412  68  NOP
413  69  OP
414  21  21
415  61  GTO
416  03  03
417  58  58
418  76  LBL
419  16  A'
420  42  STO
421  00  00
422  91  R/S
423  42  STO
424  01  01
425  91  R/S
426  42  STO
427  02  02
428  91  R/S
429  42  STO
430  03  03
431  91  R/S
432  42  STO
433  18  18
434  53  (
435  43  RCL
436  03  03
437  75  -
438  43  RCL
439  01  01
440  54  )
441  55  ÷
442  53  (
443  43  RCL
444  02  02
445  75  -
446  43  RCL
447  00  00
448  54  )
449  95  =
```

```
450   42 STO
451   14  14
452   53  (
453   43 RCL
454   18  18
455   75  -
456   43 RCL
457   00  00
458   54  )
459   65  ×
460   43 RCL
461   14  14
462   95  =
463   85  +
464   43 RCL
465   01  01
466   95  =
467   91 R/S
468   68 NOP
469   68 NOP
470   76 LBL
471   15  E
472   00  0
473   42 STO
474   00  00
475   43 RCL
476   29  29
477   85  +
478   01  1
479   95  =
480   42 STO
481   02  02
482   58 FIX
483   00  00
484   43 RCL
485   00  00
486   99 PRT
487   58 FIX
488   03  03
489   43 RCL
490   16  16
491   65  ×
492   43 RCL
493   34  34
494   45 Y×
495   43 RCL
496   00  00
497   95  =
498   99 PRT
499   42 STO
```

```
500   01  01
501   43 RCL
502   15  15
503   65  ×
504   43 RCL
505   35  35
506   45 Y×
507   43 RCL
508   00  00
509   95  =
510   99 PRT
511   85  +
512   43 RCL
513   17  17
514   95  =
515   99 PRT
516   75  -
517   43 RCL
518   01  01
519   95  =
520   94 +/-
521   99 PRT
522   97 DSZ
523   02  02
524   05  05
525   30  30
526   69 OP
527   05  05
528   91 R/S
529   68 NOP
530   69 OP
531   20  20
532   61 GTO
533   04  04
534   82  82
```

```
          0.          00
          0.          01
          0.          02
          0.          03
       0.05           04
          0.          05
          0.          06
          0.          07
          0.          08
          0.          09
          0.          10
          0.          11
        0.7           12
          0.          13
          0.          14
          0.          15
          0.          16
          0.          17
          0.          18
       13.7           19
      8760.           20
        0.1           21
       0.25           22
       0.03           23
       0.15           24
       0.15           25
        30.           26
       0.08           27
       0.06           28
        10.           29
          0.          30
          0.          31
          0.          32
          0.          33
       1.08           34
       1.06           35
       1.15           36
          0.          37
 0.00868567           38
  -0.959576           39
```

```
001   11   A
070   17  B'
081   18  C'
097   12   B
125   13   C
273   10  E'
281   14   D
419   16  A'
471   15   E
```

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