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A PROGRAMMABLE CALCULATOR APPLICATIONS NOTEBOOK FOR PRACTICING PLANNERS

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A PROGRAMMABLE CALCULATOR APPLICATIONS
NOTEBOOK FOR PRACTICING PLANNERS

BY

ROBERT M. ERICSON

A RESEARCH PROJECT SUBMITTED IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF COMMUNITY PLANNING

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1982

MASTER OF COMMUNITY PLANNING

RESEARCH PROJECT

OF

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DIRECTOR _____

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

¹Ralph 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

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

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

³LRN, (January 1982), p. 3.

⁴Robert 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 a lot 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 germane 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 Utilization 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. IDPC. Industrial Output Per Capita
 12. ISOPC. Indicated Service Output Per Capita
 18. 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. ALSCL. 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
 36. 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

48. MPAL. Marginal Productivity of Agricultural Inputs
49. MLYMC. Marginal Land Yield Multiplier from Capital
50. ALL. Average Life of Land
- 50.1. 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
- 56.1. UILD. Urban-Industrial Land Development Time
56. UIL. Urban-Industrial Land
57. LFERT. Land Fertility
58. LFD. Land Fertility Degradation Rate
59. LFR. Land Fertility Regeneration
- 60.1. ILF. Inherent Land Fertility
61. LFR. 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. PCRM. 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. PGM. Pollution Generation Multiplier from Output
75. PGM. 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

Figure 3. The complete World 3 model.

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

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

²H. 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

\$380 PACKAGE

HARDWARE LIST (but not the best available prices)

Texas Instruments

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CALCULATORS	DESCRIPTION	WEIGHT	PRICE
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TI-59	STUDENT BUSINESS ANALYST WITH BOOK	(3 LBS)	29.95
TI-59	BUSINESS ANALYST II - SLIMLINE LCD BUS/FINANCIAL W/STATISTICS	(3 LBS)	42.95
TI-59	THE MBA ADVANCED PROGRAMMABLE W/FINANCE & STATISTICS	(3 LBS)	59.95
SCIENTIFIC CALCULATORS			
TI-30	STUDENT SLIMLINE W/CONSTANT MEMORY FEATURE	(3 LBS)	18.95
TI-30	SLIMLINE STUDENT SLIDE RULE W/CONSTANT MEN & BOOK	(3 LBS)	22.95
TI-44	TILT-TOP LCD W/CONSTANT MEMORY & BOOK	(3 LBS)	26.95
TI-30-II	ADVANCED SLIDE RULE PROGRAMMABLE LCD W/BOOK	(3 LBS)	44.95
TI-58C	498 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
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STAT-5859	APPLIED STATISTICS	(2 LBS)	48.00
REI-5859	REAL ESTATE & INVESTMENT	(2 LBS)	48.00
AV-5859	AVIATION	(2 LBS)	48.00
NAV-5859	MARINE NAVIGATION	(2 LBS)	48.00
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POOL-5859	POOL WATER ANALYSIS	(2 LBS)	45.00
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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-PROD/AIDS	PROGRAMMING AIDS (TI-59 W/PC-100C REQUIRED)	(2 LBS)	10.00
SP-PRINTER/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
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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
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ADAPTERS/CHARGERS			
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AC-9132	BA/RMA/57/55/PROGRAMMER/40 FOR BP-7 & BP-8	(2 LBS)	8.75
RK-2	TI-30/BA-1, INCLUDES AC-9132 & BP-4	(2 LBS)	12.00
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BP-7	RMA/TI-55/57	(1 LB)	8.95
BP-8	PROGRAMMER/BA-40/BA	(1 LB)	8.95
PAPER PRODUCTS			
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TP-27225	TI-5015/5040 (3 ROLLS PER PKG)	(3 LBS)	3.69
TP-16250	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
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PAD-50/59	PROGRAM RECORD FORMS PAD 50/59	(2 LBS)	2.95
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TI-59

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- Print out memory contents.
- Tables, subroutines, calls and returns, conditional and unconditional branches and calls, conversions, etc.
- Easy-to-read alphanumeric printing.
- Makes checking and changing programs much easier, faster.
- Creates graphs, and value curves, etc.
- Automatically re-charges your programmable calculator.
- Efficient, highly reliable thermal printer prints over 40 characters per second. And it's whisper-quiet.
- Let's your programmable calculator at ease for added security.

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 initial 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
09	9	40	2nd Ind	73	RCL 2nd Ind
10	2nd E	42	STO	74	SUM 2nd Ind
11	A	43	RCL	75	-
12	B	44	SUM	76	2nd Lbl
13	C	45	y ^x	77	2nd x ^z
14	D	47	2nd CMs	78	2nd Σ+
15	E	48	2nd Exc	79	2nd x̄
16	2nd A'	49	2nd Prd	80	2nd Grad
17	2nd B'	50	2nd 1/x	81	RST
18	2nd C'	52	EE	82	HIR
19	2nd D'	53	(	83	GTO 2nd Ind
20	2nd CLR	54	)	84	2nd Op 2nd Ind
22	INV	55	÷	85	+
23	1/x	57	2nd Eng	86	2nd St ilg
24	CE	58	2nd Fix	87	2nd If ilg
25	CLR	59	2nd Int	88	2nd D.M.S
27	2nd INV	60	2nd Deg	89	2nd π
28	2nd log	61	GTO	90	2nd List
29	2nd CP	62	2nd Pgm 2nd Ind	91	R/S
30	2nd tan	63	2nd Exc 2nd Ind	92	INV SBR
32	x ^z	64	2nd Prd 2nd Ind	93	.
33	x ²	65	X	94	+/-
34	√x	66	2nd Pause	95	=
35	1/x	67	2nd x ^z	96	2nd Write
36	2nd Pgm	68	2nd Mop	**97	2nd Dsz
37	2nd P→R	69	2nd Op	98	2nd Adv
38	2nd sm	70	2nd Rad	99	2nd Prt
		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	050	00	00	100	92	RTN
001	09	9	051	59	INT	101	93	.
002	10	E*	052	60	DEG	102	94	+/-
003	11	A	053	61	GTO	103	95	=
004	12	B	054	62	PG*	104	96	MRT
005	13	C	055	63	EX*	105	97	DSZ
006	14	D	056	00	00	106	00	00
007	15	E	057	64	PD*	107	98	ADV
008	16	A*	058	00	00	108	99	PRT
009	17	B*	059	65	X	109	00	0
010	18	C*	060	66	PAU			
011	19	D*	061	67	EQ			
012	20	CLR	062	68	NOP			
013	22	INV	063	69	OP			
014	23	LNK	064	00	00			
015	24	CE	065	70	RAD			
016	25	CLR	066	71	SBR	133	21	2ND
017	27	INV	067	00	00	134	26	2ND
018	28	LDG	068	00	00	135	31	LRN
019	29	CP	069	72	ST*	136	41	SST
020	30	TAN	070	00	00	137	46	INS
021	32	X/T	071	73	RC*	138	51	BST
022	33	X²	072	00	00	139	56	DEL
023	34	FX	073	74	SM*	140	00	0
024	35	1/X	074	00	00			
025	36	PGM	075	75	-			
026	00	00	076	76	LBL			
027	37	P/R	077	77	GE			
028	38	SIN	078	78	Σ+			
029	39	CDS	079	79	Σ			
030	40	IND	080	80	GRD			
031	42	STD	081	81	RST			
032	00	00	082	82	HIR			
033	43	RCL	083	00	00			
034	00	00	084	83	GD*			
035	44	SUM	085	00	00			
036	00	00	086	00	0			
037	45	YX	087	84	DP*			
038	47	CMS	088	00	00			
039	48	EXC	089	85	+			
040	00	00	090	86	STF			
041	49	PRD	091	00	00			
042	00	0	092	87	IFF			
043	50	I×I	093	00	00			
044	52	EE	094	00	00			
045	53	(	095	00	00			
046	54	)	096	88	DMS			
047	55	÷	097	89	#			
048	57	ENG	098	90	LST			
049	58	FIX	099	91	R/S			

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	LRN
P.O. Box 53	9213 Lanham Severn Road
Lubbock, TX 79408	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

PPX PROGRAM ABSTRACTS

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 PPX0198004 AND PROVIDES FOR THE USE OF THE PC-100C PRINTER.

USER BENEFITS: EASY TO USE.

JIM GAINSLY, 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: SIMPLIFIES 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 PPX0198006 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	@ \$ 80.00
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	@ \$ 80.00
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	@ \$80.00	@ \$ 60.00	@ \$ 65.00
20. Rigid Frames	@ \$100.00	@ \$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 daylight 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 48 (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 sideshows as well as branching are available.

TRAVERSE I - (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 sideshows or branching. When sideshows 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 sideshow(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-01. If, 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 immediately 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 when 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 best fits any number of coordinates which may be entered by point number or from the keyboard.

INTERSECTIONS: BB1 - DD1 - DD1 - When the coordinates of two points and any two elements of the lines connecting them are entered, this program computes and prints all the other unknown 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 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

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Merchandise is subject to availability from suppliers.

**Surveyors
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\$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	STD	0.15	)
	36	1.150	
1.150		1.15	YX
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	x
1.080		.1597614704	RCL
1.08	STD		13
	34	2121.239	
1.080		2121.239035	=
1.08	RCL	338.892	
	28	338.892	PRT
0.060		338.8922673	STD
0.060	PRT		17
0.06	+	338.892	
1.	=	338.8922673	RCL
1.060			29
1.06	STD	10.000	
	35	10.	STD
1.060			2
1.06	RCL	10.000	
	29	10.	RCL
10.000			26
10.000	PRT	20.000	
10.	DP	20.	STD
	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	DP
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	DP
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	DP
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	DP
049	04	04

050	69	DP
051	05	05
052	91	R/S
053	76	LBL
054	12	B
055	69	DP
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	DP
065	05	05
066	69	DP
067	05	05
068	69	DP
069	05	05
070	69	DP
071	05	05
072	69	DP
073	05	05
074	91	R/S
075	76	LBL
076	15	E
077	00	0
078	69	DP
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	050	85	+	100	22	INV
001	17	B'	051	01	1	101	64	PD*
002	22	INV	052	00	0	102	00	00
003	28	LDG	053	95	=	103	63	EX*
004	52	EE	054	17	B'	104	00	00
005	54	)	055	42	STD	105	75	-
006	92	RTN	056	01	01	106	59	INT
007	76	LBL	057	76	LBL	107	64	PD*
008	18	C'	058	91	R/S	108	00	00
009	69	DP	059	22	INV	109	54	)
010	22	22	060	86	STF	110	65	x
011	69	DP	061	01	01	111	92	RTN
012	23	23	062	43	RCL	112	76	LBL
013	73	RC*	063	00	00	113	11	A
014	02	02	064	55	÷	114	22	INV
015	84	DP*	065	04	4	115	58	FIX
016	03	03	066	75	-	116	55	÷
017	92	RTN	067	59	INT	117	52	EE
018	76	LBL	068	42	STD	118	53	(
019	10	E'	069	02	02	119	53	(
020	47	CMS	070	54	)	120	52	EE
021	01	1	071	55	÷	121	55	÷
022	76	LBL	072	05	5	122	52	EE
023	15	E	073	85	+	123	00	0
024	88	DMS	074	53	(	124	01	1
025	59	INT	075	05	5	125	94	+/-
026	65	x	076	75	-	126	54	)
027	04	4	077	43	RCL	127	65	x
028	54	)	078	01	01	128	34	FX
029	42	STD	079	34	FX	129	22	INV
030	00	00	080	28	LDG	130	59	INT
031	82	HIR	081	85	+	131	69	DP
032	18	18	082	01	1	132	10	10
033	85	+	083	54	)	133	17	B'
034	39	CDS	084	55	÷	134	82	HIR
035	59	INT	085	02	2	135	06	06
036	75	-	086	17	B'	136	54	)
037	01	1	087	44	SUM	137	82	HIR
038	54	)	088	02	02	138	07	07
039	55	÷	089	25	CLR	139	71	SBR
040	05	5	090	43	RCL	140	00	00
041	75	-	091	02	02	141	95	95
042	59	INT	092	58	FIX	142	82	HIR
043	44	SUM	093	02	02	143	16	16
044	00	00	094	92	RTN	144	75	-
045	54	)	095	53	(	145	59	INT
046	65	x	096	43	RCL	146	42	STD
047	01	1	097	01	01	147	03	03
048	00	0	098	82	HIR	148	54	)
049	94	+/-	099	47	47	149	65	x

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

300	42	STD	350	00	0	400	02	02
301	02	02	351	01	1	401	71	SBR
302	43	RCL	352	52	EE	402	00	00
303	00	00	353	82	HIR	403	95	95
304	32	XIT	354	41	41	404	02	2
305	71	SBR	355	95	=	405	17	B'
306	02	02	356	65	x	406	22	INV
307	67	67	357	43	RCL	407	59	INT
308	82	HIR	358	01	01	408	65	x
309	14	14	359	95	=	409	43	RCL
310	61	GTD	360	74	SM*	410	01	01
311	15	E	361	00	00	411	95	=
312	76	LBL	362	73	RC*	412	74	SM*
313	13	C	363	00	00	413	00	00
314	86	STF	364	22	INV	414	69	OP
315	01	01	365	59	INT	415	20	20
316	85	+	366	22	INV	416	73	RC*
317	28	LDG	367	74	SM*	417	00	00
318	32	XIT	368	00	00	418	29	CP
319	43	RCL	369	29	CP	419	67	EQ
320	02	02	370	67	EQ	420	04	04
321	82	HIR	371	03	03	421	46	46
322	04	04	372	08	08	422	55	÷
323	03	3	373	65	x	423	01	1
324	77	GE	374	01	1	424	52	EE
325	03	03	375	02	2	425	01	1
326	46	46	376	17	B'	426	00	0
327	00	0	377	85	+	427	72	ST*
328	95	=	378	69	OP	428	00	00
329	11	A	379	20	20	429	52	EE
330	29	CP	380	73	RC*	430	08	8
331	43	RCL	381	00	00	431	75	-
332	03	03	382	95	=	432	22	INV
333	67	EQ	383	55	÷	433	59	INT
334	03	03	384	02	2	434	64	PD*
335	08	08	385	17	B'	435	00	00
336	55	÷	386	72	ST*	436	69	OP
337	82	HIR	387	00	00	437	30	30
338	16	16	388	61	GTD	438	95	=
339	95	=	389	03	03	439	74	SM*
340	71	SBR	390	64	64	440	00	00
341	01	01	391	76	LBL	441	69	OP
342	37	37	392	14	D	442	20	20
343	61	GTD	393	86	STF	443	61	GTD
344	03	03	394	01	01	444	04	04
345	30	30	395	42	STD	445	14	14
346	71	SBR	396	03	03	446	43	RCL
347	00	00	397	43	RCL	447	02	02
348	95	95	398	00	00	448	42	STD
349	93	.	399	42	STD	449	00	00

450	97	DSZ
451	03	03
452	04	04
453	01	01
454	61	GTD
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	DP
477	05	05
478	61	GTD
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'

	0	1	2	3	4	5	6
00	01	02	03	04	05	06	07
7	8	9	A	B	C	D	E
10	11	12	13	14	15	16	17
-	F	G	H	I	J	K	L
20	21	22	23	24	25	26	27
M	N	O	P	Q	R	S	T
30	31	32	33	34	35	36	37
•	U	V	W	X	Y	Z	+
40	41	42	43	44	45	46	47
x	*	√	π	e	(	)	,
50	51	52	53	54	55	56	57
↑	%	:	/	=	'	x	$\bar{x}$
60	61	62	63	64	65	66	67
$\underline{2}$	?	÷	!	∏	Δ	Π	Σ
70	71	72	73	74	75	76	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 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

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

²Robert 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

Units of Capacity (Liquid Measure)

891

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

691

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	1000	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

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	116.866 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. =	0.056 968 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	0.000 002 879	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 hundred-weights	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	0.000 094 207	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	x	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	x	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	x	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	x	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	050	76	LBL
051	15	E	051	15	E
052	53	(	052	53	(
053	24	CE	053	24	CE
054	65	X	054	55	+
055	93	.	055	43	RCL
056	08	8	056	95	95
057	06	6	057	68	NDF
058	08	8	058	68	NDF
059	09	9	059	68	NDF
060	07	7	060	68	NDF
061	06	6	061	68	NDF
062	02	2	062	68	NDF
063	04	4	063	68	NDF
064	54	)	064	54	)
065	92	RTN	065	92	RTN
066	76	LBL	066	76	LBL
067	16	A [*]	067	16	A [*]
068	35	1/X	068	35	1/X
069	11	A	069	11	A
070	35	1/X	070	35	1/X
071	92	RTN	071	92	RTN
072	76	LBL	072	76	LBL
073	17	B [*]	073	17	B [*]
074	35	1/X	074	35	1/X
075	12	B	075	12	B
076	35	1/X	076	35	1/X
077	92	RTN	077	92	RTN
078	76	LBL	078	76	LBL
079	18	C [*]	079	18	C [*]
080	35	1/X	080	35	1/X
081	13	C	081	13	C
082	35	1/X	082	35	1/X
083	92	RTN	083	92	RTN
084	76	LBL	084	76	LBL
085	19	D [*]	085	19	D [*]
086	35	1/X	086	35	1/X
087	14	D	087	14	D
088	35	1/X	088	35	1/X
089	92	RTN	089	92	RTN
090	76	LBL	090	76	LBL
091	10	E [*]	091	10	E [*]
092	35	1/X	092	35	1/X
093	15	E	093	15	E
094	35	1/X	094	35	1/X
095	92	RTN	095	92	RTN
096	00	0	096	00	0
097	00	0	097	00	0
098	00	0	098	00	0
099	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	XIT
14.2		1765.	
11181.10237	B	1.	SBR
12.1			13
9527.559058	B	1.	STD
56.8			91
44724.40946	B	1.	
44724.40946		95.	+
8.470532095	A	95.	RCL
			91

12.	****	1.	
8.471		1.	=
13.63277918	E'	96.	
55.		96.	STD
88.51408983	E'		93
		96.	
		96.	RCL
			91

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

1.	
1.	+
1.	RCL
	90
2.	
2.	x
5.	=
11.	
11.	STD
	92
11.	
11.	RC+
	*93
	96

	RST	1400.1465	
2.	STD	1400.1465	DP
	90		4
2.		1400.	
		1400.	XIT
2.	RCL	14.2	
	94	14.2	PRT
5151515151.		14.2	x
5151515151.	DP	14.2	RC+
	4		*92
5151515151.			11
5151515151.	RCL	787.401575	
	90	787.401575	=
2.		11181.10237	
2.	DP	11181.10237	DP
	6		5
2.	****	11181.10237	B
	R/3		R/3

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.

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

000	42	STD	050	12	B	100	05	5
001	90	90	051	32	XIT	101	95	=
002	98	ADV	052	01	1	102	42	STD
003	43	RCL	053	71	SBR	103	92	92
004	94	94	054	00	00	104	73	RC*
005	69	DP	055	16	16	105	93	93
006	04	04	056	76	LBL	106	22	INV
007	43	RCL	057	13	C	107	59	INT
008	90	90	058	32	XIT	108	65	X
009	69	DP	059	02	2	109	01	1
010	06	06	060	71	SBR	110	00	0
011	91	R/S	061	00	00	111	00	0
012	76	LBL	062	16	16	112	33	X²
013	11	A	063	76	LBL	113	95	=
014	32	XIT	064	14	D	114	69	DP
015	00	0	065	32	XIT	115	04	04
016	42	STD	066	03	3	116	32	XIT
017	91	91	067	71	SBR	117	99	PRT
018	09	9	068	00	00	118	55	+
019	05	5	069	16	16	119	73	RC*
020	85	+	070	76	LBL	120	92	92
021	43	RCL	071	15	E	121	95	=
022	91	91	072	32	XIT	122	69	DP
023	95	=	073	04	4	123	06	06
024	42	STD	074	71	SBR	124	91	R/S
025	93	93	075	00	00	125	76	LBL
026	43	RCL	076	16	16	126	17	B'
027	91	91	077	68	NOP	127	32	XIT
028	85	+	078	68	NOP	128	01	1
029	43	RCL	079	68	NOP	129	71	SBR
030	90	90	080	76	LBL	130	00	00
031	65	X	081	16	A'	131	84	84
032	05	5	082	32	XIT	132	76	LBL
033	95	=	083	00	0	133	18	C'
034	42	STD	084	42	STD	134	32	XIT
035	92	92	085	91	91	135	02	2
036	73	RC*	086	09	9	136	71	SBR
037	93	93	087	05	5	137	00	00
038	69	DP	088	85	+	138	84	84
039	04	04	089	43	RCL	139	76	LBL
040	32	XIT	090	91	91	140	19	D'
041	99	PRT	091	95	=	141	32	XIT
042	65	X	092	42	STD	142	03	3
043	73	RC*	093	93	93	143	71	SBR
044	92	92	094	43	RCL	144	00	00
045	95	=	095	91	91	145	84	84
046	69	DP	096	85	+	146	76	LBL
047	06	06	097	43	RCL	147	10	E'
048	91	R/S	098	90	90	148	32	XIT
049	76	LBL	099	65	X	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
Data bank for	32	2.204623	82
the conversion	33	0.001102311	83
program. The	34	62.426	84
registers would	35	3.96831	85
normally be full.	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

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.	5.
30140.	980.
16412.	690.
9080.	1450.
10410.	2100.
14520.	2540.
38200.	3000.
118762.	10760.
2.	6.
7836.	1410.
4267.	1520.
2360.	2560.
2704.	2300.
3775.	1450.
9932.	3600.
30874.	12840.
3.	7.
9410.	24112.
5820.	10870.
4562.	18470.
8320.	12040.
2540.	16500.
5240.	20450.
35892.	102442.
4.	75998.
2110.	41449.
1870.	41062.
2580.	41524.
3650.	44305.
2980.	81872.
1450.	326210.
14640.	

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	050	92	RTN	100	91	R/S
001	12	B	051	76	LBL	101	76	LBL
002	65	X	052	19	D*	102	16	A*
003	01	1	053	68	NOP	103	42	STD
004	00	0	054	85	+	104	05	05
005	95	=	055	01	1	105	91	R/S
006	42	STD	056	00	0	106	43	RCL
007	01	01	057	95	=	107	00	00
008	91	R/S	058	42	STD	108	99	PRT
009	72	ST*	059	01	01	109	00	0
010	01	01	060	43	RCL	110	42	STD
011	69	DP	061	04	04	111	00	00
012	21	21	062	42	STD	112	98	ADV
013	43	RCL	063	02	02	113	92	RTN
014	01	01	064	73	RC*	114	76	LBL
015	91	R/S	065	01	01	115	10	E*
016	71	SBR	066	68	NOP	116	43	RCL
017	00	00	067	44	SUM	117	04	04
018	09	09	068	00	00	118	42	STD
019	76	LBL	069	01	1	119	06	06
020	14	D	070	00	0	120	01	1
021	99	PRT	071	44	SUM	121	42	STD
022	65	X	072	01	01	122	08	08
023	01	1	073	97	DSZ	123	43	RCL
024	00	0	074	02	02	124	08	08
025	95	=	075	00	00	125	14	D
026	42	STD	076	64	64	126	69	DP
027	01	01	077	43	RCL	127	28	28
028	43	RCL	078	00	00	128	97	DSZ
029	05	05	079	99	PRT	129	06	06
030	42	STD	080	44	SUM	130	01	01
031	02	02	081	09	09	131	23	23
032	73	RC*	082	00	0	132	43	RCL
033	01	01	083	42	STD	133	05	05
034	99	PRT	084	00	00	134	42	STD
035	44	SUM	085	92	RTN	135	06	06
036	00	00	086	76	LBL	136	00	0
037	69	DP	087	11	A	137	42	STD
038	21	21	088	42	STD	138	08	08
039	97	DSZ	089	04	04	139	43	RCL
040	02	02	090	91	R/S	140	08	08
041	00	00	091	76	LBL	141	19	D*
042	32	32	092	15	E	142	69	DP
043	43	RCL	093	43	RCL	143	28	28
044	00	00	094	09	09	144	97	DSZ
045	99	PRT	095	99	PRT	145	06	06
046	00	0	096	00	0	146	01	01
047	42	STD	097	42	STD	147	39	39
048	00	00	098	09	09	148	15	E
049	98	ADV	099	98	ADV	149	00	0

001	12	B	0.	00	980.	50
020	14	D	85.	01	690.	51
052	19	D'	0.	02	1450.	52
087	11	A	0.	03	2100.	53
092	15	E	7.	04	2540.	54
102	16	A'	6.	05	3000.	55
115	10	E'	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 discrepancies 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

¹Donald Krueckeberg 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.

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.

Female 15-19 fertility rate: .226	C	.226	.226 FR	
---	---	------	---------	--

Continue entering required female fertility rates.

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

150	42	STD	200	10	E*	250	11	11
151	33	33	201	68	NOP	251	69	DP
152	99	PRT	202	91	R/S	252	06	06
153	91	R/S	203	91	R/S	253	01	1
154	42	STD	204	76	LBL	254	06	6
155	34	34	205	10	E*	255	42	STD
156	99	PRT	206	43	RCL	256	01	01
157	91	R/S	207	10	10	257	03	3
158	42	STD	208	85	+	258	00	0
159	35	35	209	05	5	259	42	STD
160	99	PRT	210	95	=	260	02	02
161	98	ADV	211	42	STD	261	06	6
162	91	R/S	212	10	10	262	42	STD
163	91	R/S	213	71	SBR	263	03	03
164	68	NOP	214	49	PRD	264	00	0
165	68	NOP	215	98	ADV	265	42	STD
166	68	NOP	216	71	SBR	266	04	04
167	68	NOP	217	16	A*	267	73	RC*
168	68	NOP	218	71	SBR	268	01	01
169	68	NOP	219	17	B*	269	65	*
170	68	NOP	220	68	NOP	270	73	RC*
171	68	NOP	221	43	RCL	271	02	02
172	76	LBL	222	42	42	272	95	=
173	14	D	223	69	DP	273	44	SUM
174	32	X/T	224	04	04	274	04	04
175	03	3	225	43	RCL	275	69	DP
176	00	0	226	29	29	276	21	21
177	03	3	227	85	+	277	69	DP
178	05	5	228	43	RCL	278	22	22
179	00	0	229	59	59	279	97	DSZ
180	00	0	230	95	=	280	03	03
181	69	DP	231	69	DP	281	02	02
182	04	04	232	06	06	282	67	67
183	32	X/T	233	98	ADV	283	43	RCL
184	42	STD	234	92	RTH	284	04	04
185	12	12	235	76	LBL	285	65	*
186	69	DP	236	49	PRD	286	93	.
187	06	06	237	43	RCL	287	04	4
188	98	ADV	238	07	07	288	09	9
189	91	R/S	239	69	DP	289	95	=
190	91	R/S	240	04	04	290	58	FIX
191	76	LBL	241	43	RCL	291	00	00
192	15	E	242	10	10	292	52	EE
193	42	STD	243	69	DP	293	58	FIX
194	09	09	244	06	06	294	00	00
195	71	SBR	245	43	RCL	295	22	INV
196	10	E*	246	08	08	296	52	EE
197	68	NOP	247	69	DP	297	22	INV
198	97	DSZ	248	04	04	298	58	FIX
199	09	09	249	43	RCL	299	42	STD

300	05	05	350	42	STD	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	STD	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	DP	408	32	XIT
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	D8Z
312	52	EE	362	71	SBR	412	03	03
313	22	INV	363	48	EXC	413	04	04
314	58	FIX	364	32	XIT	414	35	35
315	42	STD	365	43	RCL	415	85	+
316	06	06	366	41	41	416	73	RC*
317	92	RTN	367	69	DP	417	01	01
318	76	LBL	368	04	04	418	22	INV
319	16	A'	369	32	XIT	419	59	INT
320	01	1	370	69	DP	420	95	=
321	02	2	371	06	06	421	72	ST*
322	42	STD	372	98	ADV	422	01	01
323	01	01	373	92	RTN	423	32	XIT
324	02	2	374	76	LBL	424	74	SM*
325	09	9	375	48	EXC	425	01	01
326	42	STD	376	42	STD	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	DP	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	STD	433	02	02
334	71	SBR	384	03	03	434	92	RTN
335	48	EXC	385	69	DP	435	74	SM*
336	32	XIT	386	21	21	436	02	02
337	43	RCL	387	73	RC*	437	69	DP
338	39	39	388	01	01	438	06	06
339	69	DP	389	59	INT	439	69	DP
340	04	04	390	65	X	440	00	00
341	32	XIT	391	73	RC*	441	85	+
342	69	DP	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	X	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	XIT

450	42	STD	140.	00	560.981	50
451	00	00	58.	01	397.981	51
452	61	GTD	59.	02	373.956	52
453	03	03	0.	03	451.956	53
454	85	85	1622.798647	04	487.909	54
455	00	0	795.	05	439.868	55
456	00	0	828.	06	374.793	56
457	00	0	45350000.	07	228.749	57
458	00	0	15370000.	08	321.531	58
459	00	0	0.	09	8882.	59
460	00	0	1975.	10		
461	00	0	117.	11		
462	00	0	1.	12		
463	00	0	795.981	13		
464	00	0	692.999	14		
			780.999	15		
			885.998	16		
			771.998	17		
			723.997	18		
001	11	A	682.996	19		
043	12	B	558.99	20		
075	42	STD	448.988	21		
126	13	C	403.978	22		
173	14	D	505.977	23		
192	15	E	513.962	24		
205	10	E'	533.93	25		
236	49	PRD	483.905	26		
319	16	A'	333.818	27		
347	17	B'	489.538	28		
375	48	EXC	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		

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 vehicle, 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 plus 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 then 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

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

150	31	31	20800.00	24300.00
151	99	PRT	2400.00	2400.00
152	47	CMS	20.00	20.00
153	98	ADV	2600.00	1780.00
154	91	R/S	1.08	1.08
155	00	0	1800.00	1900.00
156	00	0	1.06	1.06
157	00	0	1.14	1.14
158	00	0		
159	00	0		
001	11	A	4943.86	4413.51
031	12	B	4597.66	4082.82
041	13	C	4278.70	3779.99
052	14	D	3984.54	3502.38
058	15	E	3713.00	3247.63
126	16	A*	3462.10	3013.62
148	10	E*	3230.08	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

Defender

Challenger

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 Capacity	Transmission Voltage			
	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 Capacity	Miles of transmission line				
	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 escalation 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	0.
ENERGY REVENUE		358.073
O+M		62.453
EXPENSES		379.508
EARNINGS		-21.435
	1.	
		386.719
		66.200
		383.255
		3.464
DATE	10.81	2.
FT AVERAGE HEAD	20.000	417.656
CFS AVERAGE FLOW	800.000	70.172
KW CAPACITY	1167.883	387.227
PLANT FACTOR	0.700	30.429
KWH/YR OUTPUT	7161459.854	3.
D/KWH ENERGY VALUE	0.050	451.069
		74.383
GENERATING EQP DK	1100.000	391.437
SWITCHYARD EQP DK	50.000	59.631
TRANS LINES DK	34.000	4.
OTHER DK	14.000	487.154
TAILRACE DK	18.000	78.846
PENSTOCK DK	11.000	395.900
		91.254
COST ESC FACTOR	1.234	5.
CONTINGENCY FACTOR	0.100	526.127
INDIRECTS FACTOR	0.250	83.577
O+M FACTOR	0.030	400.631
		125.496
ESC GEN EQP DK	1357.310	6.
ESC SWITCH EQP DK	61.696	568.217
ESC TRANS LINES DK	41.953	88.591
ESC OTHER DK	17.275	405.646
ESC TAILRACE DK	22.211	162.571
ESC PENSTOCK DK	13.573	7.
		613.674
ESC SUBTOTAL DK	1514.018	93.907
CONTINGENCY DK	151.402	410.961
CONST SUBTOTAL DK	1665.419	202.713
INDIRECTS DK	416.355	8.
		662.768
INVESTMENT DK	2081.774	99.541
BASE YR O+M DK	62.453	416.596
BASE YR REVENUE DK	358.073	246.173
		9.
DISCOUNT RATE	0.150	715.790
INTEREST RATE	0.150	105.513
YRS ECONOMIC LIFE	30.000	422.568
REVENUE ESC RATE	0.080	293.222
O+M ESC RATE	0.060	10.
YRS ESCALATION	10.000	773.053
		111.844
ANNUAL PAYMENT DK	317.055	428.899
PRESENT VALUE DK	3189.438	344.154
BENEFIT/COST	1.532	

	YEAR	0.
	ENERGY REVENUE	300.781
	O-M	62.453
	EXPENSES	379.508
	EARNINGS	-78.727
		1.
		324.844
		66.200
		383.255
		-58.411
		2.
	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
		378.898
		74.383
	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
		391.437
		-12.540
		4.
		409.210
		78.846
		395.900
		13.309
	COST ESC FACTOR	1.234
	CONTINGENCY FACTOR	0.100
	INDIRECTS FACTOR	0.250
	O+M FACTOR	0.030
		441.946
		83.577
		400.631
		41.315
	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
		477.302
		88.591
		405.646
		71.656
		7.
		515.486
	ESC SUBTOTAL DK	1514.013
	CONTINGENCY DK	151.402
	CONST SUBTOTAL DK	1665.419
	INDIRECTS DK	416.355
		8.
		556.725
	INVESTMENT DK	2081.774
	BASE YR O+M DK	62.453
	BASE YR REVENUE DK	300.781
		99.541
		416.596
		140.130
		9.
	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
		601.263
		105.513
		422.568
		178.695
		10.
		648.364
		111.844
	ANNUAL PAYMENT DK	317.055
	PRESSENT VALUE DK	2585.848
	BENEFIT/COST	1.242
		428.899
		220.465

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 exceedance 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

¹Charles 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	300.000 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 equip- ment costs in \$ 000: 1100	B	1100.000	1100.000	
Switchyard equip- ment 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 esca- lation 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	050	32	32	100	07	07
001	11	A.	051	65	x	101	91	R/S
002	58	FIX	052	43	RCL	102	99	PRT
003	02	02	053	12	12	103	42	STD
004	99	PRT	054	99	PRT	104	08	08
005	42	STD	055	65	x	105	91	R/S
006	30	30	056	43	RCL	106	99	PRT
007	59	INT	057	20	20	107	42	STD
008	55	÷	058	95	=	108	09	09
009	01	1	059	99	PRT	109	91	R/S
010	02	2	060	42	STD	110	99	PRT
011	85	+	061	33	33	111	42	STD
012	53	(	062	91	R/S	112	10	10
013	43	RCL	063	99	PRT	113	91	R/S
014	30	30	064	42	STD	114	99	PRT
015	22	INV	065	04	04	115	42	STD
016	59	INT	066	69	DP	116	05	05
017	65	x	067	05	05	117	91	R/S
018	01	1	068	91	R/S	118	99	PRT
019	00	0	069	76	LBL	119	42	STD
020	00	0	070	17	B'	120	06	06
021	54	)	071	65	x	121	69	DP
022	85	+	072	93	.	122	05	05
023	01	1	073	02	2	123	91	R/S
024	09	9	074	85	+	124	76	LBL
025	00	0	075	01	1	125	13	C
026	00	0	076	05	5	126	43	RCL
027	95	=	077	95	=	127	30	30
028	42	STD	078	68	NDP	128	65	x
029	30	30	079	91	R/S	129	93	.
030	00	0	080	76	LBL	130	01	1
031	58	FIX	081	18	C'	131	06	6
032	03	03	082	65	x	132	75	-
033	91	R/S	083	43	RCL	133	03	3
034	99	PRT	084	31	31	134	01	1
035	42	STD	085	45	Yx	135	04	4
036	31	31	086	43	RCL	136	93	.
037	91	R/S	087	39	39	137	02	2
038	99	PRT	088	65	x	138	08	8
039	65	x	089	43	RCL	139	95	=
040	43	RCL	090	38	38	140	55	÷
041	31	31	091	65	x	141	02	2
042	55	÷	092	43	RCL	142	93	.
043	43	RCL	093	32	32	143	02	2
044	19	19	094	95	=	144	08	8
045	68	NDP	095	91	R/S	145	95	=
046	68	NDP	096	76	LBL	146	99	PRT
047	95	=	097	12	B	147	42	STD
048	99	PRT	098	99	PRT	148	11	11
049	42	STD	099	42	STD	149	43	RCL

150	21	21	200	43	RCL	250	69	DP
151	99	PRT	201	13	13	251	05	05
152	43	RCL	202	99	PRT	252	9C	RTN
153	22	22	203	65	X	253	68	NOP
154	99	PRT	204	43	RCL	254	68	NOP
155	43	RCL	205	21	21	255	68	NOP
156	23	23	206	95	=	256	68	NOP
157	99	PRT	207	99	PRT	257	68	NOP
158	69	DP	208	44	SUM	258	68	NOP
159	05	05	209	13	13	259	68	NOP
160	68	NOP	210	43	RCL	260	68	NOP
161	68	NOP	211	13	13	261	68	NOP
162	00	0	212	95	=	262	68	NOP
163	42	STD	213	99	PRT	263	68	NOP
164	13	13	214	65	X	264	65	X
165	43	RCL	215	43	RCL	265	43	RCL
166	07	07	216	22	22	266	11	11
167	71	SBR	217	95	=	267	95	=
168	02	02	218	99	PRT	268	99	PRT
169	62	62	219	44	SUM	269	44	SUM
170	43	RCL	220	13	13	270	13	13
171	08	08	221	69	DP	271	92	RTN
172	71	SBR	222	05	05	272	76	LBL
173	02	02	223	43	RCL	273	10	E'
174	62	62	224	13	13	274	13	C
175	43	RCL	225	95	=	275	14	D
176	09	09	226	99	PRT	276	15	E
177	71	SBR	227	68	NOP	277	91	R/S
178	02	02	228	68	NOP	278	68	NOP
179	62	62	229	65	X	279	68	NOP
180	43	RCL	230	43	RCL	280	76	LBL
181	10	10	231	23	23	281	14	D
182	71	SBR	232	95	=	282	43	RCL
183	02	02	233	99	PRT	283	24	24
184	62	62	234	43	STD	284	99	PRT
185	43	RCL	235	15	15	285	85	+
186	05	05	236	43	RCL	286	01	1
187	71	SBR	237	33	33	287	95	=
188	02	02	238	65	X	288	42	STD
189	62	62	239	43	RCL	289	36	36
190	43	RCL	240	04	04	290	43	RCL
191	06	06	241	55	÷	291	25	25
192	71	SBR	242	01	1	292	99	PRT
193	02	02	243	00	0	293	43	RCL
194	62	62	244	00	0	294	26	26
195	69	DP	245	00	0	295	99	PRT
196	05	05	246	95	=	296	43	RCL
197	68	NOP	247	99	PRT	297	27	27
198	68	NOP	248	42	STD	298	99	PRT
199	68	NOP	249	16	16	299	85	+

300	01	1		350	01	1		400	40	RCL
301	95	=		351	42	STD		401	13	13
302	42	STD		352	00	00		402	95	=
303	34	34		353	42	STD		403	99	PRT
304	43	RCL		354	01	01		404	69	DP
305	28	28		355	00	0		405	05	05
306	99	PRT		356	42	STD		406	92	RTN
307	85	+		357	18	18		407	69	DP
308	01	1		358	43	RCL		408	20	20
309	95	=		359	16	16		409	61	GTD
310	42	STD		360	65	X		410	03	03
311	35	35		361	43	RCL		411	92	92
312	43	RCL		362	34	34		412	68	NOP
313	29	29		363	45	YX		413	69	DP
314	99	PRT		364	43	RCL		414	21	21
315	69	DP		365	00	00		415	61	GTD
316	05	05		366	75	-		416	03	03
317	01	1		367	53	(		417	58	58
318	75	-		368	43	RCL		418	76	LBL
319	53	(		369	15	15		419	16	A'
320	01	1		370	65	X		420	42	STD
321	85	+		371	43	RCL		421	00	00
322	43	RCL		372	35	35		422	91	R/S
323	25	25		373	45	YX		423	42	STD
324	54	)		374	43	RCL		424	01	01
325	45	YX		375	00	00		425	91	R/S
326	43	RCL		376	54	)		426	42	STD
327	26	26		377	95	=		427	02	02
328	94	+/-		378	55	+		428	91	R/S
329	95	=		379	43	RCL		429	42	STD
330	55	+		380	36	36		430	03	03
331	43	RCL		381	45	YX		431	91	R/S
332	25	25		382	43	RCL		432	42	STD
333	95	=		383	01	01		433	18	18
334	35	1/Y		384	95	=		434	53	(
335	65	X		385	68	NOP		435	43	RCL
336	43	RCL		386	44	SUM		436	03	03
337	13	13		387	18	18		437	75	-
338	95	=		388	97	DSZ		438	43	RCL
339	99	PRT		389	02	02		439	01	01
340	42	STD		390	04	04		440	54	)
341	17	17		391	07	07		441	55	+
342	43	RCL		392	97	DSZ		442	53	(
343	29	29		393	03	03		443	43	RCL
344	42	STD		394	04	04		444	02	02
345	02	02		395	13	13		445	75	-
346	43	RCL		396	43	RCL		446	43	RCL
347	26	26		397	18	18		447	00	00
348	42	STD		398	99	PRT		448	54	)
349	03	03		399	55	-		449	95	=

450	42	STD	500	01	01			
451	14	14	501	43	RCL	0.		00
452	53	(	502	15	15	0.		01
453	43	RCL	503	65	X	0.		02
454	18	18	504	43	RCL	0.		03
455	75	-	505	35	35	0.05		04
456	43	RCL	506	45	YX	0.		05
457	00	00	507	43	RCL	0.		06
458	54	)	508	00	00	0.		07
459	65	X	509	95	=	0.		08
460	43	RCL	510	99	PRT	0.		09
461	14	14	511	85	+	0.		10
462	95	=	512	43	RCL	0.		11
463	85	+	513	17	17	0.7		12
464	43	RCL	514	95	=	0.		13
465	01	01	515	99	PRT	0.		14
466	95	=	516	75	-	0.		15
467	91	R/S	517	43	RCL	0.		16
468	68	NOP	518	01	01	0.		17
469	68	NOP	519	95	=	0.		18
470	76	LBL	520	94	+/-	13.7		19
471	15	E	521	99	PRT	8760.		20
472	00	0	522	97	DSZ	0.1		21
473	42	STD	523	02	02	0.25		22
474	00	00	524	05	05	0.03		23
475	43	RCL	525	30	30	0.15		24
476	29	29	526	69	DP	0.15		25
477	85	+	527	05	05	30.		26
478	01	1	528	91	R/S	0.08		27
479	95	=	529	68	NOP	0.06		28
480	42	STD	530	69	DP	10.		29
481	02	02	531	20	20	0.		30
482	58	FIX	532	61	GTD	0.		31
483	00	00	533	04	04	0.		32
484	43	RCL	534	82	82	0.		33
485	00	00				1.08		34
486	99	PRT				1.06		35
487	58	FIX				1.15		36
488	03	03				0.		37
489	43	RCL				0.00868567		38
490	16	16				-0.959576		39
491	65	X				001	11	A
492	43	RCL				070	17	B'
493	34	34				081	18	C'
494	45	YX				097	12	B
495	43	RCL				125	13	C
496	00	00				273	10	E'
497	95	=				281	14	D
498	99	PRT				419	16	A'
499	42	STD				471	15	E

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