DOCUMENT RESUME

ED 193 395 UD 020 934

AUTHOR Dickey, John W.

TITLE Policy/Program Analysis and Evaluation Techniques. Module 4, Long Range Forecasting. Instructors' Manual (Including Student Manual). Package VI.

INSTITUTION Virginia Polytechnic Inst. and State Univ., Blacksburg. Div. of Environmental and Urban Systems.

SPONS AGENCY Department of Housing and Urban Development, Washington, D.C. Office of Policy Development and Research.: National Training and Development Service for State and Local Government, Washington, D.C.

PUB DATE [78]

NOTE 111p.: For related documents see UD 020 926-937. Prepared by the Center for Urban and Regional Studies. Some pages in the Appendix may be marginally legible due to broken print.

EDRS PRICE MF01/PC05 Plus Postage.

DESCRIPTORS Case Studies: Government (Administrative Body): Government Employees: Inservice Education: Instructional Materials: Learning Modules: *Long Range Planning: *Management Development: Management Systems: Postsecondary Education: Prediction: Professional Continuing Education: *Public Administration: *Public Administration Education: Public Agencies: *Public Policy: Systems Development

ABSTRACT

This packet contains the materials necessary for presentation of the fourth of ten modules that comprise a portion of the National Training and Development Service Urban Management Curriculum Development Project. This module focuses on long range or technical forecasting techniques which are designed to reduce predictive uncertainty in regard to unique or cataclysmic events. The packet includes a combined instructor's and student/participant manual which describes the management, objectives, and presentation of the module and cases used to study forecasting concepts. (Author/MK)

POLICY/PROGRAM ANALYSIS AND EVALUATION TECHNIQUES

Module 4
Long Range Forecasting
Instructors' Manual
(including Student Manual)

Developed by:

John W. Dickey

CENTER FOR URBAN AND REGIONAL STUDIES

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

DR. A. W. STEISS, PRINCIPAL INVESTIGATOR

Under Contract to:

THE URBAN MANAGEMENT CURRICULUM DEVELOPMENT PROJECT

THE NATIONAL TRAINING AND DEVELOPMENT SERVICE

5020 Wisconsin Avenue, N. W.

Washington, D. C. 20016

Funded by:

The Office of the Assistant Secretary for Policy Development and Research, U. S. Department of Housing and Urban Development

Package VI

TABLE OF CONTENTS

INSTRUCTORS' MANUAL (INCLUDING STUDENT MANUAL)

LIST OF TABLES AND FIGURES

INSTRUCTORS' MANUAL (INCLUDING STUDENT MANUAL)

LIST OF TABLES AND FIGURES

INSTRUCTORS' MANUAL (INCLUDING STUDENT MANUAL)

(CONTINUED)

Introduction: Objectives and Required Background

The purpose of this manual is to provide guidance to the person or persons who will be helping a small group of public officials from urban localities understand the principal techniques of long range forecasting. Note that many statistical and econometrics techniques traditionally employed in forecasting are not covered in this module.[a]

The objectives to be accomplished by the student are to:

1. Increase familiarity with the tools of long range(technological) forecasting.
2. Increase awareness of the conditions in which different tools can be employed.
3. Become more aware of the advantages and disadvantages of the various tools.
4. Increase awareness of the manner in which the tools can be applied to individual situations.

It is assumed here that the instructor:

1. Has been exposed to at least some of these techniques before, although probably not to the extent of applying them in a real-world situation (few people actually have done so).[b]
2. Has had an introductory course in statistics, including regression, within the last few years.
3. Has had some forecasting experience, at least to the point where he or she recognizes some of the inherent difficulties in making any type of forecast.

No background is assumed on the part of the (student) participant, although it would be helpful if he or she is at least able to perform independently the kind of calculations exemplified in Table 1 of "The Stone Gulch Saga" found in the attached Student Manual.[c] If participants

---

[a]This is not from lack of appreciation of the techniques but because the contract was limited to those coming under the heading of "technological" forecasting.

[b]Note well that few of the techniques discussed in this Manual have been applied broadly (if at all) in the local government domain. So relevant, in-depth examples are difficult to find (thus one reason for the hypothetical case study in this Manual).

[c]For simplicity, "The Stone Gulch Saga," will be referenced as TSGS.

cannot do this, it will mean that the instructor will have to allocate more effort to basic arithmetic when the time come^ to explain and undertake regression.

It is further assumed here that the participants will be able to complet this "course" on technological forecasting with about 20 hours of work. Not all of this time needs to be spent in group meetings. Much of the work can, if desired by the instructor, be assigned as individual homework exercises. These parts of the course are designated by an asterisk(*) in this mannual. This does not preclude, however, the full 20 hours being spent in a formal classroom.

Finally, it is suggested that class size range from 5 to 20. A smaller size would not allow for sufficient statistical analysis of responses, while a larger size would not allow for sufficient within group interaction.

Instructor Preparation

The task before you, the instructor, is not an easy one, primarily because of the nature of the techniques being demonstrated. Perhaps the most outstanding characteristic of technological forecasting methods is their emphasis on uncovering influential factors that usually cannot be identified through, for example, highly structured statistical techniques. As a result, your task is to guide people through uncharted waters using relatively unstructured methods. This is a tough job even for an experienced teacher. To make matters worse, in many cases you will have to reduce and perhaps oversimplify some of the results of the applications so that the main features of the techniques become apparent to the participant.

While these problems are difficult, they certainly are not insurmountable. We suggest the following steps in preparation for presenting the course:

1. Read "The Stone Gulch Saga" (TSGS) several times. As you do, pay particular attention to the way in which each technique has been (a) simplified and (b) interrelated to the other techniques.

2. Try to get a copy of the books by Martino; Ayres; Shyrock, Siegel, and Associates; Rosen; and Barton and read them to give further background on each technique.[a]

3. Thoroughly familiarize yourself with the scenario on Rurbania (in the Student's Manual). Anticipate and write down those approaches you would consider for each technique for Rurbania. This is needed particularly with respect to the discussions in tasks 4, 11, and 17 (see Table 1 and the task descriptions and tables).

[a]A forthcoming book also will cover these techniques, with applications to urban problems: J. W. Dickey and T. M. Watts, Analytic Techniques for Urban and Regional Planning, (New York: McGraw-Hill, forthcoming).

4. Read the Overview Manual to see where long range forecasting fits into the overall policy analysis process.

5. Talk to someone else who already has taught this course and find out his/her experiences, problem areas, emphases, etc.

If you follow these five steps faithfully, you should be able to provide a suitable course, avoiding most of the pitfalls of an unstructured situation.

More detailed preparation for the actual operation of the course include arrangements for:

1. Up to seven (7) separate rooms or small spaces (5 seats) in the meeting building for the first day (only two (2) spaces will be needed thereafter).

2. Course participant access to a library. This is desirable although not necessary. You should at least have a set of encyclopedias and a copy of the Statistical Abstract of the United States (any year after 1971) available for the analogy exercise (task 11, to be described).

3. Instructor (and possibly participant) access to a computer. While not mandatory, it would be instructive to use the computer for the regression, Probe, and Cross Impact exercises (tasks 7, 12, and 13, to be described), in which case the programs listed in the Appendix of this manual should be set up and running on your computer. Also, it should be possible to access the computer during the time of the course.

4. A large blackboard (plus chalk and erasers), or at least large rolls of paper (plus markers and tape). Several large diagrams need to be made (and remade) during the course.

5. A copying machine and possibly a secretary on an "on-call" basis to make copies of various lists, charts, etc. for the participants.

6. The usual name tags, pads of papers, pens, etc. for participants.

Course Structure

The course, as noted, has been set up for twenty hours of participant contact. This effort is divided into seventeen tasks (along with needed breaks) as shown in Table 1, which is set up to demonstrate scheduling over the expected 2½ course days. This time period can be compressed by meeting at night on the first day, in which case you will have to be ready to do your work (task 9 and 14) rather rapidly during meal breaks. After you have seen the size and makeup of the class, you should set up a schedule for tasks 5 and present this to the students after task 4.

Each task now will be described in turn. In some descriptions a rationale will be offered to let you know why a particular task is being done a certain way. In addition, for many tasks we have listed possible ideas, directions, etc. that may be of value to you in guiding classroom efforts and discussion.

*Task 1. Present Scenario

(a) Give each participant a copy of (only) the Rurbania scenario when he or she comes in.

(b) Give every participant a number as he or she comes in.

(c) Do not have participants introduce themselves at this point.

(d) Ask each to read the Rurbania Scenario.

(e) Ask for questions of clarification (only) on the scenario.

Rationale: The upcoming Delphi exercise requires anonymity. While this cannot be accomplished completely, if the participants do not know each other initially, it will help. The numbers are to be used in Delphi panel and committee member selection in Task 2.

*Task 2. "Genius" Forecasting Exercise

(a) Tell participants not to talk to each other during this effort.

(b) Before starting on the forecast, select five people at random and take them individually and quietly to five separate rooms or areas. Take other groups of five (or the remainder) to separate spaces for each group. Spread the group members out around the space so that they cannot see the others' writing. Remind them not to talk to each other (see rationale).

(c) Give each a copy of Form 1 (found in the Student Manual) and ask him or her to put down a forecast of the 1975 population of Rurbania and three main reasons for forecasting thus.[a] Indicate that he or she can consider events they know happened between 1960 and 1975. The forecast is for the city, not the metropolitan area. Note also that the university students residing in Rurbania were not included in the population in 1960 and before, but were in 1970 and 1975.

(d) Collect the individual ("Genius") forecast of each participant after fifteen minutes have elapsed.

[a]There is an instructional tradeoff here. Obviously, if we were making a forecast for 15 years from now, we would also have to forecast intervening events. However, our purpose here is to check the forecast against the actual result and, since many people will be knowledgable of events in the period from 1960 to 1975, we have decided to allow them to make full use of this knowledge.

TABLE 1. Sample Schedule of Technological Forecasting Course

TASK	TIME	DESCRIPTION
DAY 1		
	8:00-8:15	Wait for Everyone to Show Up/Announcements
1	8:15-8:30	Present Rurbania Scenario
2	8:30-8:45	"Genius" Forecasting Exercise
3	8:45-10:15	Committee/Delphi Exercise
	10:15-10:30	Break
4	10:30-11:00	Results/Discussion
5	11:00-12:00	"The Stone Gulch Saga" and Course Objectives
	12:00-1:00	Lunch
6	1:00-2:00	Gaming -- Round 1 Exercise
7	2:00-3:00	Regression, Gompertz Exercise
	3:00-3:15	Break
8	3:15-5:00	Relevance Tree Exercise
9		Instructor Work
DAY 2		
	8:00-8:15	Wait for Everyone to Show Up/Announcements
10	8:15-9:15	Gaming -- Round 2 Exercise
11	9:15-12:00	Analogy Exercise
	12:00-1:00	Lunch
12	1:00-3:15	Probe Exercise
	3:15-3:45	Break
13	3:45-5:00	Cross Impact Analysis Exercise
14		Instructor Work
DAY 3		
	9:00-9:15	Wait for Everyone to Show Up/Announcements
15	9:15-10:15	Morphological Analysis Exercise
	10:15-10:30	Break
16	10:30-11:00	Results of Gaming, Probe, and CIA Exercise
17	11:00-12:00	Comparison of Techniques

FORM 1. Individual Population Forecast

NAME NUMBER

FORECASTED POPULATION LEVEL FOR RURBANIA IN 1975:

REASONS FOR FORECASTED LEVEL (Please try to keep to three or less).

1.

2.

3.

OTHER

11

Rationale: The separated individuals later will comprise the Delphi panel. All other participants will be divided into committees of five people (except for the last) so that a comparison can be made to the Delphi panel results. If there are only 5 (or fewer) participants, they should comprise the Delphi panel, to be followed later by a committee exercise.

Task 3. Committee/Delphi Exercise

(a) Average the forecast of the five individuals (Delphi panel) and also compute the range. Summarize the reasons for their forecast. Where two or more reasons are essentially the same, restate them in common terms and put in parentheses after the statement the number of people giving that reason. The result of this effort should be a chart like that for Delphi round one in Table 3 of TSGS.

(b) Reproduce a copy of the resultant chart for each Delphi panelist and give it to him or her with the instructions to prepare a revised forecast and list any additional reasons for his new forecast. Give him or her another copy of Form 1 for this purpose.

(c) Pick up the forecast (Form 1) from the other participants.

(d) Tell them to meet together as a committee of five (or less) and come to a group decision for a revised forecast. They will have an hour and fifteen minutes for this purpose and may want to use a library or other facilities as needed and available.

(e) After about half an hour, repeat the process in (a) and (b) with the five Delphi panelists.

(f) After one hour, collect the Delphi panelists' forecasts and perform the calculations as in (a). Produce an overall chart as in Table 3 of TSGS.

(g) Ask each committee for its group forecast. Then separate the individuals in each committee and ask them to give a private, individual forecast (on Form 1, for use in task 4(b) below).

(h) Excuse everyone for a break.

Rationale: After this exercise is complete, you will be able to compare five sets of forecasts: for individuals before grouping, Delphi panelists (two additional rounds), each committee, and individuals in committees.

Task 4. Results/Discussion

(a) Have each person introduce himself or herself.

(b) In class, tabulate the results for each individual (by number, not name) and for each panel or committee. Make a chart showing each individual's starting and final forecasts (as in Form 2).

(c) Ask for discussion regarding the reasons for changes in individual forecasts and for differences between individual, Delphi, and committee forecasts. Ask for advantages/disadvantages of each technique. Possible items to stress (and agree or disagree with) relative to each technique are presented in Table 2.

Rationale: The discussion should help emphasize the advantage of a Delphi approach but also that <u>some</u> individuals still may be closer to the true figure (which <u>will</u> not be disclosed until the last day).

<u>*Task 5. Present "The Stone Gulch Saga" (TSGS) and the Overview</u>

(a) Let the participants spend about forty-five minutes reading the case study. Then allow fifteen minutes for clarification and further explanation of selected techniques.

(b) Present the Overview, Objectives, and Schedule for the rest of the course.

Rationale: Students now (1) can see how Delphi fits into the overall set of techniques and (2) will get a vision of efforts to come, the specific objectives of the course as a whole, and the schedule for accomplishing each task aimed at accomplishing these objectives.

<u>*Task 6. Gaming -- Round 1 Exercise</u>

(a) Have everyone reread the part of TSGS dealing with gaming (pages 16 to 18).

(b) Divide the whole group randomly into four teams -- "higher educationalists," "state legislators" (budget committee), "local (wealthy) historical preservationists," and "local developers."

(c) Have each team meet in a separate space to develop a written list of programs (specific tactics), as exemplified by the different teams in Table 4 of TSGS. The time period here will be 1960 to 1967. Their purpose is to simulate the goals and strategies of the particular group in <u>that time period</u>. Have them return their list in an hour's time.

Rationale: The first gaming round should be done at this time so that during the evening you, acting as judge, can develop a set of resultant outcomes (for 1967) for tomorrow's round two.

FORM 2. Individual and Group Population Forecasts

INDIVIDUAL				
INDIVIDUAL NO.	"GENIUS" FORECAST	DELPHI ROUND 2	DELPHI ROUND 3	"AFTER COMMITTEE" FORECAST
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

GROUP					
GROUP	"GENIUS" FORECAST	DELPHI ROUND 2	DELPHI ROUND 3	COMMITTEE	"AFTER COMMITTEE" FORECAST
Delphi Panel Mean				-	-
Range				-	
Committee 1 Mean		-	-		-
Range		-	-	-	
Committee 2 Mean		-	-		-
Range		-	-	-	
Committee 3 Mean		-	-		-
Range		-	-	-	

TABLE 2.[a] Comparison of "Genius" Traditional Committee, and Delphi Forecasting Techniques

Dimension	"Genius"	Traditional Committee	Delphi
1. Overall Methodology	Unstructured "guesstimate"	Unstructured meeting	Structured questionnaires and feedback
2. Role Orientation	Task-instrumental and emotional	Social-emotional	Task-instrumental
3. Search Behavior	Reactive & Intuitive; varied Problem Focus; Task Centeredness; new task knowledge	Relatively short problem focus; task avoidance tendency; new social knowledge	Proactive; controlled problem focus; high task centeredness; new task knowledge
4. Conforming Behavior	Possibly high but quite varied	High	Freedom not to conform
5. Equality of Participation	N/A	Member dominance	Equality
6. Committee Size and Composition	Only 1. Limited composition	Small, varied.	Fairly large, varied
7. Method of Conflict Resolution	Personal Anxiety	Person-centered; smoothing over and withdrawal	Problem-centered; majority rule of pooled independent judgements
8. Closure to Discussions	Direct; high feld accomplishment	Lack of closure; medium felt accomplishment	High closure; felt accomplishment
9. Utilization of Resources	Low	Low to medium	Low to medium
10. Relative Quantity of Forecast Ideas	Low medium; highly varied	Medium	Medium to high
11. Relative Quality and Specificity of Forecast Ideas	Medium; but highly varied	Medium; focused "rut" effect	High

[a]Table 3 of the Student Manual.

TABLE 2.[a] (continued)

Descriptions of Dimensions
1) Overall Methodology - the overall structure of the decision-making process (e.g., if members are present together, they are allowed to converse in an unstructured way, etc.).
2) Role Orientation - the tendency for committees to direct attention toward social roles (e.g., friendship acts or congeniality) or task-oriented roles (e.g., giving ideas or judgment sharing).
3) Search Behavior - the style used by a committee to generate task-relevant information, and the amount of effort directed to identifying problems.
4) Normative Behavior - the felt freedom to express ideas in discussions, and the level of conforming behavior in the process.
5) Equality of Participation - the number of individuals in the committee who contribute to search, evaluation, and choice of the product or output.
6) Committee Composition and Size - the homogeneity or heterogeneity of personnel as well as the number of individuals involved in the committee decision-making process.
7) Method of Conflict Resolution - the procedure used to resolve disagreements and conflicts.
8) Closure to Decision Process - the extent to which the committee arrives at a clear termination point, providing an agreed-upon decision and a sense of accomplishment.
9) Utilization of Resources - the time, cost, and effort involved for administrators and participants in the process.
10) Relative Quantity of Forecast Ideas - the number of factors identified related to that entity being forecast.
11) Relative Quality and Specificity of Forecast Ideas - the general relevance and detail of the factors identified as being related to the entity being forecast.

[a]Adapted in part from A. L. Delbecq, A. H. Van deVen, and D. H. Gustafson, Group Techniques for Program Planning (Glenview, Ill.: Scott, Foresman and Co., 1975)

*Task 7. Regression/Gompertz Exercise

(a) Given the Census population data for Rurbania in the scenario statement, have the participants develop a regression equation of population versus time (year or year from 1900) in the same fashion as in Table 1 of TSGS (see Table 3 of this Manual, which can be handed out thereafter).

(b) Have the class calculate the associated correlation coefficient (as in Table 1 of TSGS).

(c) Have the class calculate the expected 1975 population in Rurbania using the derived regression equation (as in Table 1 of TSGS).

(d) Hand out the diagram showing population versus time and the derived regression equation (Fig. 1 on p. 13).

(e) Discuss with the class possible forms for a Gompertz type (S) curve (several examples are shown in Fig. 2, copies of which should be handed out). Discuss specifically the top population level (if any) and the time needed to reach that level.

Possibility: In the Rurbania Scenario it is suggested that similar "filled in" cities in the same state have a density of 4000 people/sq. mile. So if Rurbania has 25 sq. miles, it will have a limit of 4000(25) = 100,000 people, as shown in Fig. 2.

Note: It is difficult (and really not worthwhile) to fit (statistically) a Gompertz (or similar S-type curve) to the data in Fig. 2. So emphasize the general shape of the curve rather than the technique of curve-fitting. (You still may want to fit the curve statistically, following the instructions in the Appendix).

(f) Discuss advantages/disadvantages of the linear regression and Gompertz-type equations.

(g) If a computer is available, you may want to demonstrate the use of the regression program in the Appendix.

Rationale: Rurbania probably will not show a large leap in population, as is expected for Stone Gulch. Hence linear regression might be more suitable for forecasting in the former area since past trends may continue in force.

*Task 8. Relevance Tree Exercise

With the class, develop a relevance tree for Rurbania. Include for each factor a relevance number (RN), and then compute a RN product for each factor.

Possibilities: Some factors you might want to consider in developing this tree are:

TABLE 3.[a] Computations To Develop Linear Regression Relating Population to Time in Rurbania

Column	(1)	(2)	(3)	(4)	(5)
	Year (since 1900)	Population (thousands)			
Symbol	(x)	(y)	(x^2)	(y^2)	(xy)
	0	35	0	1225	0
	10	37	100	1369	360
	20	37	400	1369	720
	30	42	900	1764	1260
	40	44	1600	1936	1760
	50	53	2500	2809	2650
	60	60	3600	3600	3600
Total	210	308	9,100	14,072	10,350

[a]For the requisite equations, see Table 1 of TSGS. This is Table 4 of the Student Manual.

$$\text{Slope} = \frac{7(10{,}350) - (210)(308)}{7(9100) - (210)^2} = \frac{72{,}450 - 64{,}680}{63{,}700 - 44{,}100} = \frac{7770}{19{,}600} = 0.396$$

$$\text{Intercept} = \frac{308 - (0.396)(210)}{7} = 32.12$$

$$\text{Correlation} = \frac{7770}{\sqrt{[19{,}600]\ [7(14{,}072) - (308)^2]}} = \frac{7700}{\sqrt{71.34 \times 10^6}} = \frac{7700}{8446} = 0.912$$

Population (thousands) in 1975 = 0.396(75) + 32.12 = 61.82
(75 years since 1900)
= 61,820 people

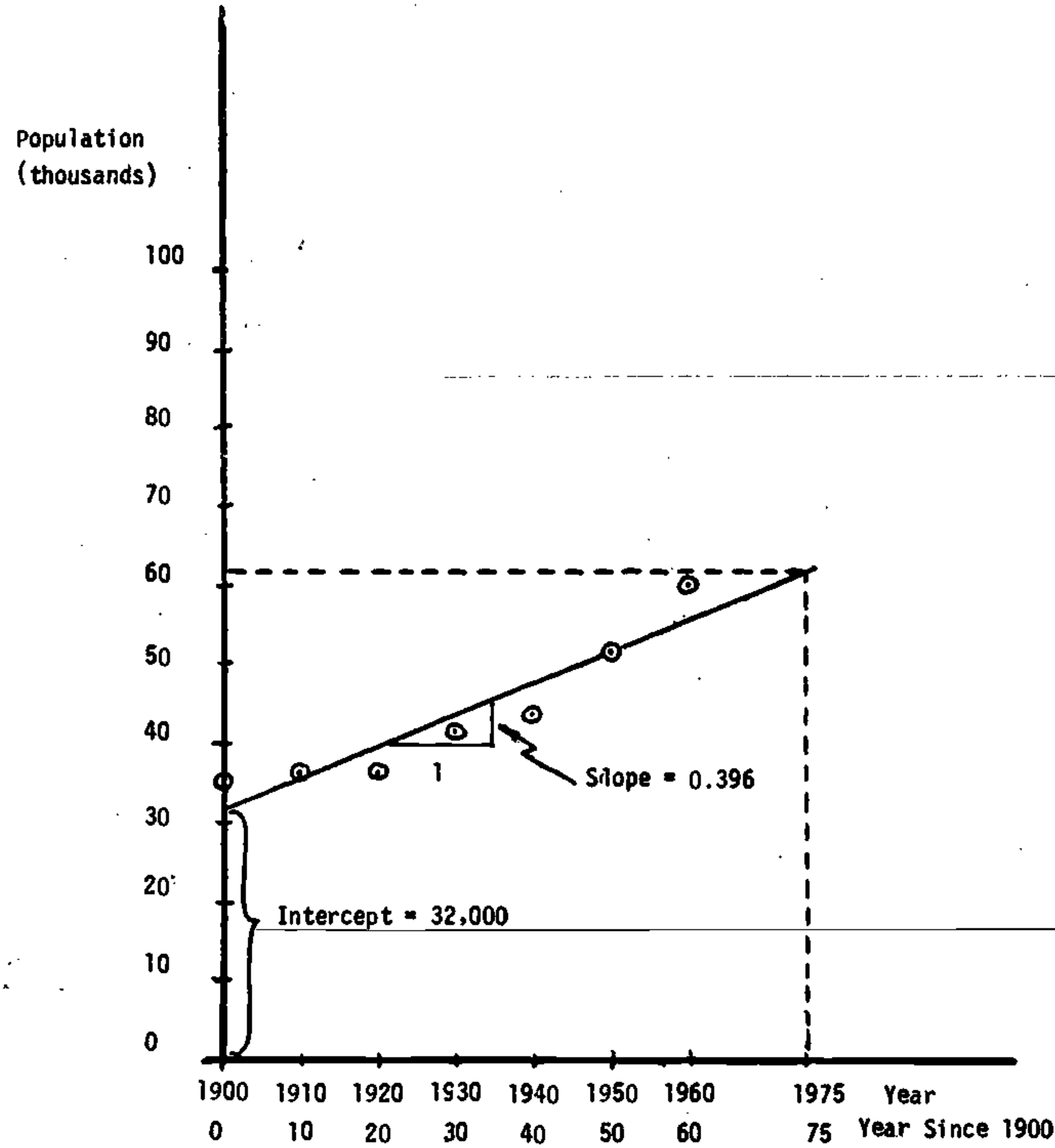

FIGURE 1. Linear Regression Relation Population To Time: Rurbania

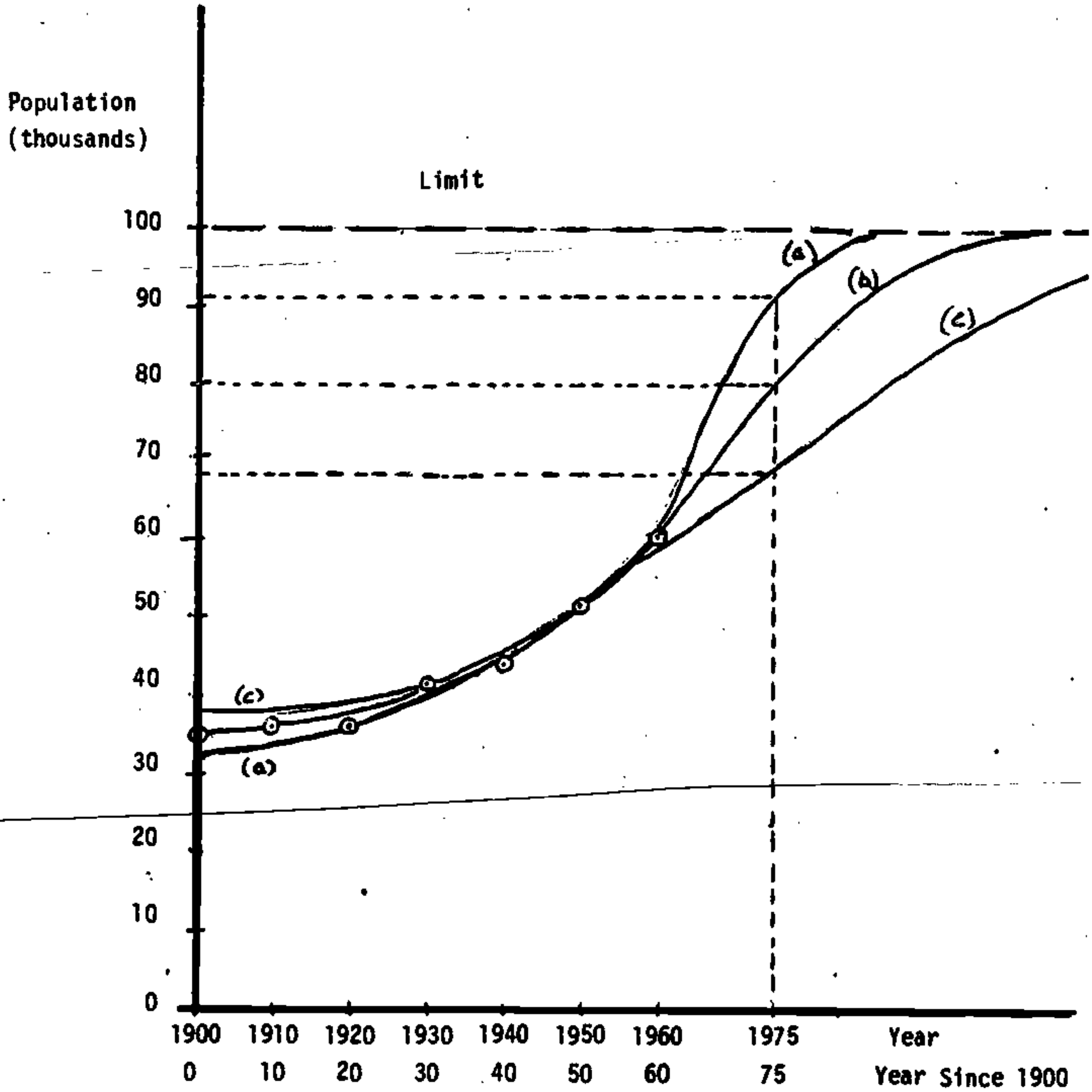

FIGURE 2. Sample Gompertz - Type Curves Relating Population To Time: Rurbania

(1) Growth of the state population
(2) Increase in number of college age people
(3) Low inflation and unemployment in the early 1960's; higher levels in 1970's.
(4) Increased tendency for the state to borrow funds for capital projects.
(5) Inclination by university officials not to increase student body rapidly, so as to insure "quality" education.
(6) Nearness to Washington, D. C.
(7) Historical preservation carried out by wealthy, "old guard" and environmental landowners in area.

Hint: You should not include too many factors or else the tree will be overly complicated and the example will lose its meaning.

(b) Have the class make a population forecast based on the information generated from this exercise.

*Task 9. Instructor Work

(a) Taking into account the strategies created by the four teams in round 1 of the gaming exercise (task 6), make a judgement as to the relative effectiveness of the strategies and develop resultant additions to the Rurbania scenario to bring it up to 1967. (See Table 4 of TSGS for an example). Make a copy of your scenario addition for each student.

Rationale: This is the first of two rounds in the gaming exercise. The strategies suggested in this round will be judged as part of the instructor work in task 14 in time for the comparative analysis in task 17.

*Task 10. Gaming-Round 2 Exercise

(a) Present the four teams formed in task 6 with the resultant scenario addition for 1960-1967 developed by you, as judge, in task 9. Have the teams create new strategies for the 1968-1975 period.

*Task 11. Analogy Exercise

(a) Have the class as a whole develop an analogy similar to that in Table 2 of TSGS. Use the characteristics shown on the left side of that table as a basis.

Possibilities: If no one does his work in this task, you could use the comparison shown on the next two pages or in Table 5.

CITY COMPARISON: RURBANIA VS. GREENVILLE, S. C.[a]

Both cities are located in the South, in or near the Appalachian Mountains. Both also are along major Interstate highways. Each appears to be a regional commercial center with a major university within its city limits. Greenville, however, is more industrialized and experienced a much higher growth rate between 1900 and 1950 than Rurbania. This probably is related to textile manufacturing, which grew rapidly in the area.

The population of Greenville in 1950 was 58,161 as compared to 52,631 for Rurbania. Both cities experienced growth rates between 1950 and 1960 of about 12%. Rurbania had a dwelling unit increase during this same time period of 14.7% as compared to an 18.4% rise in the number of households in Greenville.

Greenville differs from Rurbania in that it has more females than males and also about double the 1960 Black population percentage (30% vs. 16.7%). Further, the former area has experienced a steady increase in the Black population through 1960 as compared to a fluctuating rate for the latter.

The actual number of farms was not obtained from the Census. In 1950, however, Greenville had only 35 persons listed as farmers or farm managers as compared to 1,957 farms for Rurbania. Moreover, while wage and salary workers were grouped together in the Census figures, indications are that because of the generally rapid growth in Greenville and a steady rise in low income people, there probably is a much larger wage-earner labor force in that city than in Rurbania.

The 1970 Census reveals that the total population of Greenville decreased by 7.5% from 1960. This was comprised of an 11% drop in the White population and a 3.7% decrease in the Black. The number of households, however, increased fairly substantially during this period, perhaps indicating that a large group of unrelated persons had been added to the city's population. This may have been due to the addition of students to Census counts, a change in city boundaries, and concurrence with the national trend toward smaller families.

Greenville appears to have suffered from its dominance by textiles as the main component of its economic base during the 1960s. Rurbania's diversity and rather slow overall growth indicates a more diverse and flexible economy. On the other hand the settings still have many similarities and, based on the figures in Table 4, Rurbania may have grown only from 66,000 to 68,000 by 1975. The reason for the increase as compared to Greenville's decrease is that, unlike Greenville, most Southern cities reversed their decreasing population trends in the late 1960s and early 1970s. Rurbania's more diverse economy probably also forced change in that direction.

---

[a]This analogy was drawn by John Harvin, a graduate student in Urban and Regional Planning at Virginia Tech.

TABLE 4.[a] Selected Census Data For Greenville, South Carolina

Characteristics	Year 1900	1910	1920	1930	1940	1950	1960	1970
Population	11,860	15,741	23,127	29,154	34,734	58,161	66,188	61,208
Males						27,311	30,544	27,955
Females						30,850	35,639	33,253
Blacks						16,095	19,717	19,145
Households						16,466	15,980	19,886
Farmers and Farm Managers						35		
Wage & Salary Earners						30,820	28,045	

[a]Table 5 of the Student Manual.

Sources: U. S. Bureau of the Census, Census of Population, South Carolina, Washington, D. C. (Various years).

TABLE 5.[b] Population and Land Area For Selected Cities

City	1960 Land Area (sq. mi.)	Year 1900	1910	1920	1930	1940	1950	1960	1970
Berkeley, CA	9.7	13,214	40,434	56,036	82,109	85,547	113,805	111,000	117,000
Columbia, SC	106.2	21,108	26,319	37,524	51,581	62,396	87,000	97,000	114,000
Durham, NC	NA	6,679	18,241	21,719	52,037	60,195	71,311	78,302	95,438
Jackson, MS.	46.5	7,816	21,262	22,817	48,282	62,107	98,000	144,000	154,000
Lansing, MI.	21.2	16,485	31,229	57,327	78,397	78,753	92,000	108,000	132,000
Raleigh, NC	44.9	13,643	19,218	24,418	37,379	46,896	66,000	94,000	122,000
South Bend, IN	23.8	35,999	53,684	70,983	104,193	101,268	116,000	132,000	126,000
Chapel Hill, NC	NA	1,099	1,149	1,483	2,699	3,654	9,177	12,573	25,535
Athens, GA	NA	10,245	14,913	16,748	18,192	20,650	28,180	31,355	44,342

[b]Table 6 of Student Manual.

Sources: U.S. Bureau of the Census, Statistical Abstract of the United States Washington, D. C. (various years).
U.S. Bureau of the Census, 1970 Census of Population, (North Carolina and Georgia), Washington, D. C., 1970.

(b) Break the class into study teams that initially can work independently to brainstorm the analogy. If a library is available, have teams go there to hunt up Census figures and historical descriptions of the cities under study. If no library is available, you might at least get some relevant information from an Encyclopedia and the Statistical Abstract of the U.S. (for a year after 1971). In any case, most of the information probably will have to come from participant knowledge. Although not desirable from a scientific standpoint, it would be difficult to ignore the history of the analogous city from 1960 to 1975. So, allow this to be considered.

(c) Have the class develop a population forecast based on the analogy created in (a) and (b).

Task 12. Probe Exercise

(a) Have the class develop a list of "events" for Rurbania, starting in 1900 and proceeding to 1975. Then for each event specify a date (year) at which there is a 50% chance of occurrence. The last event should be a prespecified population level in 1975.

Hint: Keep the list of events below, say 20; otherwise this exercise will become overly complicated.

(b) Put the events on a chart in the form of Fig. 5 in TSGS. For each, check to see if it is a necessary predecessor to any other event. If so, draw an arrow to the successor and estimate the time required between the events.

(c) Readjust the types of, and times between, events based on the experiences in (a) and (b). You might also have to readjust the expected 1975 population level.

(d) If possible in class, find the maximum time path in the Probe network. If not, and a computer is available, use the PERT program in the Appendix of this Manual (this can be employed as a check in any case). Also if possible, find the second longest time path and determine how much the time on any link on the longest (but not on the second) path can be reduced before the second path becomes most critical.

(e) Determine if there is any change between the initially-expected date (1975) for the specified population level and that found from the Probe analysis. Discuss the reasons for any difference.

*Task 13. Cross Impact Analysis Exercise

(a) Using a subset (8 to 12) of the events from the Probe exercise in Task 12, develop with the class a cross impact matrix. For each pair of events determine:

(1) The mode of interaction: (+) enhancing or (-) inhibiting.

(2) The strength of interaction: on a scale from 0 (no strength) to 9 (the strongest possible).

(3) The predecessor relationship: 0 (immaterial), 1 (likely), or 2 (necessary).

Then set up a matrix like that in Fig. 6 of TSGS.

(b) If a computer is available, find the final probabilities (as in Fig. 6 of TSGS) using the computer program in the Appendix. (This can be done in task 14).

(c) If a computer is not available, you can only speculate with the participants on the final prabability. You might do this on the basis of the modes and strengths of the strongest relationships.

*Task 14. Instructor Work

(a) Develop a set of ajudged results from the second round of the gaming exercise in task 10. As one result give a value for the 1975 population level. Make a copy of the resultant scenario for each participant.

(b) If needed, use the PERT program in the Appendix to find the maximum path for the Probe chart from task 12.

(c) If a computer is available, find the final probabilities for the cross impact matrix formulated in task 13.

(d) Develop for each participant a summary chart of the population forecasts from the techniques tried so far. Leave space to write in the results of the morphological analysis (task 15, upcoming).

(e) (optional) Have the participants run the appropriate computer programs in (b) and (c) above.

*Task 15. Morphological Analysis Exercise

(a) Identify with the class three or four population growth-related factors in Rurbania which can be divided into a set of unique or discrete forms, parts, or subprocesses.

Possibilities:

Changes in Student Enrollment

Undergraduate - graduate split

New types of colleges within the university

Development of other higher educational institutions within the state.

Other land use law/tax incentives for "agricultural" (gentleman farmer) preservation

Racial integration policies, court decisions

(b) Identify each discrete form, etc. for each factor, and place these in a chart as in Fig. 3 of TSGS.

(c) Identify all the combinations of factor forms which make sense. Then decide which combination(s) is most likely for 1975 and the resulting population level(s).

(d) Include the results from (c) on the list of forecasts prepared in task 14(d).

*Task 16. Results of Gaming, Probe, and Cross Impact Analysis (CIA) Exercises

(a) Present the results of the gaming, Probe, and CIA exercises from task 14 (a), (b), and (c) along with the list of forecasts prepared in task 14(d). Clarify any discrepancies or misunderstandings.

*Task 17. Comparison of Techniques

(a) Tell the class the real 1975 population figure (87,000, which actually is an estimate). The 1970 population was 77,000. Give them Table 6 (Table 7 of Student Manual) showing interim events that transpired.

(b) Discuss with the class the forecasts from each technique. Elaborate on the advantages/disadvantages of each procedure. Tables 7 and 8 present some possible points for discussion and agreement or disagreement.

TABLE 6.[a] Pertinent Events and Facts and Associated With Rurbania (1961 to 1976)

Date	Event or Fact Description
1962	$13.6 million in construction. Retail sales up 14% per year at suburban shopping center; 3% elsewhere in city.
1963	2,514 acres of county annexed, including shopping center.
1963-73	Economy of nation (and State) doing well (low unemployment, inflation)
1965	University has 6,600 students, 4,190 undergraduate and 2,410 graduate.
1967	General Assembly approves $81 million bond issue for higher education.
1968	51 acres of county annexed.
1969	New city hall completed.
1970	University has 9,735 students, 5,769 undergraduate and 3,966 graduate. City population is 76,660, with 1,500 more males than females. Two-thirds of residents native to state. Maintenance of farms as estates; increases in horses as farm animals. Women enter university on undergraduate level.
1971	Local community college opens - 1,500 students. Some student protests over Viet Nam War.
1972	7,540 people in manufacturing (triple from 1950). Mostly small, clean industries. 2,130 people in health services.
1973	$42 million spent by tourists; 322 firms employ 1,929 people catering to tourists. 21 motels with 1,260 rooms. 47,765 air departures; 525,000 visit Monticello. 6,000 faculty and staff at university. $53 million in wages. Students spend $19.1 million.
1974	University finishes $34.5 million in 14 construction projects. $3.5 million downtown mall constructed. Open land (agricultural, recreation, etc.) taxed at less than market value.
1975	University has 14,382 students, 9,358 undergraduate and 5,024 graduate. Population reaches 87,000.

[a] Table 7 of the Student Manual.

Sources:

J. H. Moore, Albemarle: Jefferson's County, University Press of Virginia, Charlottesville, 1976.

E. Woods, The History of Albemarle County, C. J. Carrier, Bridgewater, Virginia, 1964.

TABLE 7.[a] A Rough Comparison of Technological Forecasting Techniques

Technique	COMPARISON FEATURE							
	1. Accuracy	2. Quality of Ideas	3. Cost	4. Time Period Required	5. Data Requirements	6. Individual Knowledge Needed	7. Group Knowledge Needed	8. Participant Benefits
1. Regression	High if past factors operative	Very Low	Low	Very Low	Very Low	High	NA	None
2. Gompertz	High if past factors operative	Very Low	Low	Very Low	Very Low	Very Low	NA	None
3. "Genius"	Varied	Medium	Medium	Low	Low	Very High	NA	None
4. Committee	Medium	Medium	Medium	Medium Low	Low	Medium	High	Fairly High
5. Analogy	Fair	Above Average	Medium	Medium	Fairly High	Medium	NA	None
6. Delphi	Fairly High	Fairly High	Medium	Medium	Low	Fairly High	High	Fairly High
7. Gaming	Fair	Fairly High	Medium	Medium	Medium	Fairly High	High	High
8. Morphological Analysis	Medium	Medium	Low	Low	Fairly Low	Very High	NA	None
9. Relevance Tree	Varied	Very High	Medium	Medium	Fairly High	Very High	NA	None
10. Probe	Fairly high if factors "discrete"	Below Average	Medium	Medium	Medium	Very High	NA	None
11. Cross Impact	High if factors "discrete"	Low	Above Average	Low	Fairly	Very High	NA	None

[a]Table 8 of the Student Manual.

TABLE 8.[a] Major Points to Consider in the Forecasting Process

(1) Do not forecast unless you have to. Forecasting is hazardous at best, yet is almost a necessity.

(2) Make several forecasts and compare results.

(3) Decide which factors need to be forecasted, which ones will seriously affect these, and which ones are under your (i.e., your agency's) control.

(4) Decide which groups of people will be impacted by, and which groups will affect, the factor being forecasted.

(5) Decide on the geographic area (and possibly subareas) for which forecasts are needed.

(6) Choose measures for each factor (some of which will be qualitative in nature).

(7) Decide on the time period(s), remembering that the longer the period, the less the certainty.

(8) Choose an allowable level of uncertainty.

(9) Decide which forecasting technique(s) or model(s) is most appropriate.

(10) Develop several scenarios, including the "most likely" (base case).

(11) Do a post-evaluation (several years later).

Use good theories, where tested and available.

[a] Table 9 of the Student Manual.

POLICY/PROGRAM ANALYSIS AND EVALUATION TECHNIQUES

Module 4
Long Range Forecasting
Student Manual

Developed by:

John W. Dickey

CENTER FOR URBAN AND REGIONAL STUDIES

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

DR. A. W. STEISS, PRINCIPAL INVESTIGATOR

Und
Under Contract to:

THE URBAN MANAGEMENT CURRICULUM DEVELOPMENT PROJECT

THE NATIONAL TRAINING AND DEVELOPMENT SERVICE

5028 Wisconsin Avenue, N. W.

Washington, D. C. 20016

Funded by:

The Office of the Assistant Secretary for Policy Development and Research, U. S. Department of Housing and Urban Development

TABLE OF CONTENTS

STUDENT MANUAL

33

LIST OF TABLES AND FIGURES

STUDENT MANUAL

SCENARIO

DEVELOPMENT OF THE CITY OF RURBANIA[a] (1744 to 1960)

Rurbania is an emerging metropolitan center (having reached the 50,000 level of population in 1950) in the South, with a fairly diverse economic base (light manufacturing and fabrication, regional retailing and wholesaling, services), serving as a regional center for various insurance companies and as the site of a major four-year university with significant law and medical schools. Its population is largely middle to upper-middle income families, whose heads of households work in the white-collar industries or are associated with the university. Rurbania is located beyond the immediate influence of other metropolitan centers and serves as a regional trade center for the surrounding rural areas. Most suburban residential areas have been annexed to the city as they emerged, although there are some scattered residential areas in the surrounding rural hinterland. In short, Rurbania is a "free-standing" metropolitan center (albeit relatively small). Yet there still is considerable undeveloped (mainly agricultural) land within the city limits.

Looking briefly at its past history, we find that Rurbania was established close to a beautifully mountainous area in 1744. The university came into existence in 1817, with an emphasis on the arts, law, and medicine. In the years before the Civil War the railroad came to Rurbania, and the city increasingly became a major center for transport of locally grown agricultural products like applies, peaches, and livestock. This process continued after the war.

The development of the streetcar in the early 1900's quickly altered the pattern of Rurbania's growth. For the first time it made suburban development possible and in addition served to tie the university to the city. Real estate values in areas served by the streetcars quickly increased and development soon followed.

At a broader scale, the train was the vital means of communications with the outside world and served as the artery for both commerce and industry. However, in 1897 the main rail company moved its shops to another city and thus the local economy suffered greatly. Yet this setback was soon to be overcome.

[a]This scenario was developed with the help of Curtis Jones, a graduate student in Urban Affairs at Virginia Tech.

Although a lot could be said for the area's streets, roads, and highways in the early 1900's, they actually were in terrible condition. Within the next twenty years this situation was to improve somewhat - at least in the central part of the city. The rural areas, on the other hand, were still to experience the inadequacies of these services. Gradually, however, improvements in this area would take place - largely as a result of the automobile. More and more real estate development, agriculture, commerce, and even the tourist trade of the area were dependent upon the auto and therefore good streets and roads. People realized that without these improvements progress would pass them by.

As the city became eager to adopt city ways, real estate developers increased their efforts to attract heavy industry into the area. Yet, the fact was that Rurbania could not really compete with her larger rivals in the deeper south. The area simply had no single staple waiting to be processed, nor did it have a ready supply of cheap labor. By the early 1920's, despite the growth of service companies, agricultural product processing firms, and a lawbook publisher, the largest employers were a woolen mill and two firms producing lumber products. The only local "industry" (if you can call it that) experiencing growth was real estate. Development companies flourished as the farmland on the outskirts of Rurbania was purchased, parcelled into lots, and sold at great profits. At first this speculation was concentrated largely to the eastern and southeastern sections of the city. However, after 1900, thanks to the streetcar, the expansion of the university, and the street system, development was focused upon the northern and western fringes. By 1920 most of the choice property within or near the center city had been converted to business or residential purposes and real estate interests turned even more attention to outlying areas.

It can be said that at the beginning of the 1920's Rurbania was a growing business, financial, and distribution center. The area was able to boast of a relatively stable economy, a good streetcar system, adequate rail service, and substantial urban growth. The university also was growing, and in 1919 women were admitted to the graduate and professional schools. In addition, the amenities of city life attracted many from the more rural county as was the national trend at that time.

Surprisingly, the Great Depression was relatively kind to Rurbania. During this period the university enrollment actually increased slightly. Enough construction was available to provide for many jobs, and it was during this time that the stadium, the art museum, new engineering school, dormitories, additions to the university hospital, a nearby national park and scenic drive, and various other school and highway projects were undertaken.

Probably the most unexpected result of the Depression was the change in attitude of bankers and local businessmen with respect to industrial development. Suddenly they were against having heavy manufacturing. They saw what had happened to localities dependent upon large industrial complexes for their economic well-being. As a result, they concluded that a well-balanced economy, dependent upon no single enterprise, was preferable. Also during this period a great stateman's home was dedicated as a public shrine. This aroused a considerable interest in tourism and the economic potential of the area's historical past.

In 1940 nearly half of Rurbania's labor force was still involved in some form of agricultural production, and within the city center, business and professional services along with retail and wholesale activities provided the bulk of employment. Yet, despite the growth of the university and an improving economic situation, international concerns obviously were becoming increasingly important.

The community's most vital contribution to the war effort, aside from manpower, came from its textiles, lumbering and quarrying, welding, rubber processing, and frozen food activities. Retail businesses were concentrated in the center city area. Because of labor shortages and good wages, submarginal farm operations were abandoned. Nevertheless the area remained closely tied to its rural, service-oriented heritage. Neither large defense installations nor sprawling factories were left after the war's end.

Following the war the community, which was an outlet for agricultural produce and a trading center, would become an urban industrial-technical complex. Field after field was to become either residential property or pastureland and the people were to become commuters. During the 1950's one issue tended to dominate local life: segregation. Until August, 1955 only limited token integration, especially in the schools, had been achieved. However, defeats in the Federal Courts, and President Johnson's Civil Rights Act, eventually paved the way for integration.

In conclusion, the growth of Rurbania appears to be the result of its natural beauty, early history, and the university and activities associated with it. Tables 1 and 2 summarize relevant events, facts, and statistics on Rurbania in the period from 1900 to 1960.

TABLE 1. Other Pertinent Events and Facts and Associated Dates for Rurbania (1922 to 1960)

Date	Event or Fact Description
1922	First radio station in area.
1924	Rebuilt home of one of America's most prominent forefather's opened to tourists.
1926	High school for Negroes opened. No need to go elsewhere for this level education.
	Opening of major historical tourist site only 150 miles away.
1927	Major country club opens.
1928	City almost chosen as site for Democratic National Convention.
	Only 60% of eligible school-aged children enrolled.
	One of largest bequests ever made to a university: $5 million.
	Switch to city manager form of government.
1930	First air flights to/from city.
	1000 "free lodgers" in jail.
1933	End of prohibition. Many bars open downtown.
1936	Opening of nearby national park and scenic drive.
1938	Annexation of 2200 county residents.
1940	Labor force divided as: 3500 business and professional services; 1778 manufacturing; 2302 wholesale and retail trade; 957 construction; 618 trans., comm. and utilities; 92 mining; 3839 agriculture.
1942	Tremendous labor shortage during World War II.
	Lumber and rubber production big industries as well as food processing.
1946	Temporary rent controls because of housing shortage.
1949	Large city-county high school completed for Negroes.
1950	Fraternal groups are important.
	First Negro admitted to university law school.
1954	New airport; 3540 outboarding per year.
1954-9	Integration of schools.
1956	Segregation of buses/trains ceases.
	Six story department store opens downtown.
1959-	Some private schools established; gerrymandering of public school districts.
1959	Major shopping center opens in county on edge of city.

TABLE 2. Relevant Data on Rurbania
(1900 to 1960)

Factor	Year 1900	1910	1920	1930	1940	1950	1960
Population							
Total	34,922	36,636	36,693	42,226	44,052	52,631	60,396
Male	16,980	17,814	18,056	20,941	21,603	26,997	30,485
Female	17,942	18,822	18,637	21,285	22,449	25,634	29,901
White	21,969	24,434	26,177	31,905	34,236	42,962	50,193
Negro	12,950	12,197	10,516	10,315	9,812	9,658	10,106
Dwellings	6,510	7,155	7,456	9,105	11,461	13,427	17,380
Farms							
Number	2,649	2,743	3,174	2,537	2,591	1,957	1,272
Size (Acres)	151	141	123	137	130	164	217
Value ($/Acre) (of land only)	10.52	21.82	40.19	38.84	26.98	98.86	182.84
Manufacturing							
Number of Establishments	151		99	61	48	62	78
Number of Wage Earners	917		1,440	2,297	2,709	2,853	4,278
Value of Products ($ millions)	1.3		3.8	5.4	5.3	16.3	48.3
University							
Total Students					3,062	4,964	4,761
Undergraduate					2,061	3,621	3,062
Graduate					1,001	1,343	1,699

FORM 1. Individual Population Forecast

NAME NUMBER

FORECASTED POPULATION LEVEL FOR RURBANIA IN 1975:

REASONS FOR FORECASTED LEVEL (Please try to keep to three or less).

1.

2.

3.

OTHER

FORM 1. Individual Population Forecast

NAME NUMBER

FORECASTED POPULATION LEVEL FOR RURBANIA IN 1975:

REASONS FOR FORECASTED LEVEL (Please try to keep to three or less).

1.

2.

3.

OTHER

FORM 1. Individual Population Forecast

NAME NUMBER

FORECASTED POPULATION LEVEL FOR RURBANIA IN 1975:

REASONS FOR FORECASTED LEVEL (Please try to keep to three or less).

1.

2.

3.

OTHER

TABLE 3. Comparison of "Genius" Traditional Committee, and Delphi Forecasting Techniques

Dimension	"Genius"	Traditional Committee	Delphi
1. Overall Methodology	Unstructured "guesstimate"	Unstructured meeting	Structured questionnaires and feedback
2. Role Orientation	Task-instrumental and emotional	Social-emotional	Task-instrumental
3. Search Behavior	Reactive & Intuitive; varied Problem Focus; Task Centeredness; new task knowledge	Relatively short problem focus; task avoidance tendency; new social knowledge	Proactive; controlled problem focus; high task centeredness; new task knowledge
4. Conforming Behavior	Possibly high but quite varied	High	Freedom not to conform
5. Equality of Participation	N/A	Member dominance	Equality
6. Committee Size and Composition	Only 1. Limited composition	Small, varied.	Fairly large, varied
7. Method of Conflict Resolution	Personal Anxiety	Person-centered; smoothing over and withdrawal	Problem-centered; majority rule of pooled independent judgements
8. Closure to Discussions	Direct; high feld accomplishment	Lack of closure; medium felt accomplishment	High closure; felt accomplishment
9. Utilization of Resources	Low	Low to medium	Low to medium
10. Relative Quantity of Forecast Ideas	Low medium; highly varied	Medium	Medium to high
11. Relative Quality and Specificity of Forecast Ideas	Medium; but highly varied	Medium; focused "rut" effect	High

TABLE 3.[a] (continued)

Descriptions of Dimensions
1) Overall Methodology - the overall structure of the decision-making process (e.g., if members are present together, they are allowed to converse in an unstructured way, etc.).
2) Role Orientation - the tendency for committees to direct attention toward social roles (e.g., friendship acts or congeniality) or task-oriented roles (e.g., giving ideas or judgment sharing).
3) Search Behavior - the style used by a committee to generate task-relevant information, and the amount of effort directed to identifying problems.
4) Normative Behavior - the felt freedom to express ideas in discussions, and the level of conforming behavior in the process.
5) Equality of Participation - the number of individuals in the committee who contribute to search, evaluation, and choice of the product or output.
6) Committee Composition and Size - the homogeneity or heterogeneity of personnel as well as the number of individuals involved in the committee decision-making process.
7) Method of Conflict Resolution - the procedure used to resolve disagreements and conflicts.
8) Closure to Decision Process - the extent to which the committee arrives at a clear termination point, providing an agreed-upon decision and a sense of accomplishment.
9) Utilization of Resources - the time, cost, and effort involved for administrators and participants in the process.
10) Relative Quantity of Forecast Ideas - the number of factors identified related to that entity being forecast
11) Relative Quality and Specificity of Forecast Ideas - the general relevance and detail of the factors identified as being related to the entity being forecast.

[a]Adapted in part from A. L. Delbecq, A. H. Van deVen, and D. H. Gustafson, Group Techniques for Program Planning (Glenview, Ill.: Scott, Foresman and Co., 1975)

OVERVIEW

LONG RANGE FORECASTING*

This decade is fast becoming known as the "Age of Uncertainty." Primarily because of rapid changes in oil availability and prices, but also for a whole variety of economic, environmental, and political reasons, it seems as if it is becoming more difficult to feel confident in a smooth transition into the future. Planning ahead for 10 to 15 years, which is often required for extensive (and capital intensive) public works projects, seems to be an increasingly hazardous task. And many local officials complain that they cannot even predict revenues and expenditures a month ahead of time, much less 10 to 15 years.

Part of the problem has to do with our techniques for making such forecasts. In the past it had been a relatively easy and accurate task simply to extrapolate historical trends. If revenues went up 5% a year for the past 10 years, then they surely would go up another 5% next year and for every year thereafter. But the energy crisis disturbed this complacency by bringing out a set of rather unique factors that had not had a significant impact on past events. No one gave much thought, for example, to the price of gasoline as a factor in highway revenues until it took a quantum jump in 1974. Then local officials quickly realized that many of their desired highway and transit projects could not be funded, at least until the distant future, because of state and federal revenue shortfalls.

The types of techniques demonstrated in this module have been developed to help reduce some of the uncertainties surrounding unique events like that described above. While making forecasts, even on a very short term basis, is a difficult occupation at best, and while these techniques certainly cannot be viewed as dispelling all or even a large part of the mystery enshrouding the future, they do have their benefits. The primary advantage is that the experience and intuition of a group of people with a broad range of expertise can be employed to identify the unique events that otherwise might not be considered. Another advantage lies in the use of mathematics to help trace these experienced forecasts to their logical (and sometimes illogical) ends. In these ways, long range forecasting derives the best benefits from two worlds--the intuition of experienced practitioners and the rigor of mathematical deduction. The result hopefully is a much more informed view of the future (and its uncertainties) than might otherwise be available.

---

*Portions of this presentation have been adopted, with permission of the author, by Gregory A. Daneke and Alan Walter Steiss in "Planning and Policy Analysis for Public Administrators," Management Handbook for Public Administrators, edited by John Sutherland (New York: von Nostrad-Reinhold, 1978).

This module really is concerned with "Technological Forecasting", a name which is something of a misnomer in the context of this effort. The title comes from a history of applications, to a great extent in the military, in which researchers were trying to track the evolution of various technologies and use their findings to make forecasts of future developments. Yet the techniques associated with Technological Forecasting have a much wider range of applicability than technology. They currently are being employed in a very broad spectrum of economic, social, environmental, and even political contexts. They also are being utilized to supplement an array of statistical estimation tools which traditionally have been used by, say, economists, to help make predictions.[a]

Some of the techniques described here are as old as mankind, but most were developed within the last 5 to 15 years and have been applied to urban problems only recently. Thus while there has been a considerable number of successful military and private sector trials, there have been relatively few in public, civil applications. Hence we must view most of the techniques as somewhat untested fro- our orientation. On the other hand, urban trials are proceeding rapidly, and it will not be long before the more useful tools get included in the standard packages of available techniques. Our purpose here consequently is to highlight these methods so that the practitioner will be aware of many of their advantages and disadvantages when faced with the opportunity to use one or more of them.

The most common tools falling under the heading of Technological Forecasting number about 11. These are:

1. Regression: a statistical technique for finding straight line relationships between a pair (or more) of variables.

2. S-Curves: relationships of the form of an S-curve over time, that is, when growth is slow initially, then rapid, then tapering off quickly as limit is reached.

3. "Genius" Forecasting: that done by an individual without interaction with any other people.

4. Committee Forecasting: that done by a typically unstructured group of people.

[a]These tools are not described in this module. The interested reader is referred to standard statistical and/or econometric texts and to J. W. Dickey and T. M. Watts, Analytic Techniques For Urban and Regional Planning, (New York: McGraw-Hill, forthcoming).

5. Analogy: prediction in which characteristics or events similar to that in a known entity are assumed to hold for the unknown entity.
6. Delphi: a structured committee in which feedback is anonymous and statistical.
7. Gaming: competitive actions between groups to generate simulated future outcomes.
8. Morphological Analysis: a search for unique forms or combinations of characteristics or events which may evolve.
9. Relevance Trees: a hierarchy of goals and functions indicating the most productive (relevant) parts for future developments.
10. Probe: a "critical path" arrangement of future events showing which ones are needed for a particular event to occur.
11. Cross Impact: a process for taking into account simultaneously the strength and direction of interaction between expected events.

The range of problem areas to which these techniques can be applied is very wide. In fact, for some techniques it is not even necessary to have "hard" data as input. The techniques therefore can be employed for both short and long term horizons for helping to make forecasts of factors such as population, employment, revenues, expenditures, racial tensions, public attitudes toward particular issues, and the like. Of course, the techniques also can be utilized for forecasting technological developments in such areas as solid waste disposal, transportation equipment, and energy generation. The usefulness of such forecasts naturally will vary with the item being considered, but generally will be of higher quality for technical rather than social factors (as is true for most other forecasting techniques).

The objectives to be accomplished by the student are to:

1. Increase familiarity with the tools of long range(technological) forecasting.

2. Increase awareness of the conditions in which different tools can be employed.

3. Become more aware of the advantages and disadvantages of the various tools.

4. Increase awareness of the manner in which the tools can be applied to individual situations.

THE STONE GULCH SAGA: A TALE OF TECHNOLOGICAL FORECASTING

Stan Slaviwicz mused over how he had gotten himself into this predicament. After all, it was somewhat unusual to have a Pollock in Stone Gulch. He had spent most of his life as a city manager in various small towns in New Jersey. He always liked hunting and fishing, so when his wife died right before he was ready to retire, he looked around for a place where he could concentrate on his hobbies while still earning a little money -- at least up to the Social Security maximum. As fortune would have it, the town of Stone Gulch, Wyoming needed a part time manager and was more than willing to let him take his time off during hunting and fishing seasons. After all, everyone else in town took off, too.

But now there were lots of major changes in the air. The black diamond--coal--had been discovered in some quantity about 15 miles from Stone Gulch. What with the "energy crisis," there undoubtedly would be a "coal rush" similar to that which occurred for gold a hundred years ago.

Stan had a rough vision of what it might be like. This small town of 10,000, which had been slowly losing its young people over the years, would suddenly find itself growing by leaps and bounds. First would come the coal company engineers and construction supervisors. They wouldn't be bad neighbors certainly, but he knew they would demand a lot of high quality services -- water, sewer, school buildings and teachers, and the like. Stan wasn't sure of the source of money or employees for these services.

Then the hundreds, maybe thousands, of workers to dig coal would appear on the scene. Maybe it would be like the Alaskan pipeline situation -- a lot of high paying jobs, but a lot more people looking for them. That would be a real shock to Stone Gulch, where welfare was almost unknown except for a small percentage of drunken Indians and a few senile old uranium prospectors. But then, maybe things would calm down somewhat after the word got around that jobs were scarce. Who really wanted to live in Stone Gulch anyway, especially without a job or some unique hobby like Stan's. The area had dusty hot summers where the temperature sometimes hit 110° F. In the winter it would get to -30° F, with lots of snow. Fall was pleasant but short, and spring was almost nonexistent, being a continuation of winter. In addition, there wasn't a city of any significant size within 150 miles. This made shopping a real chore, especially if you had a young family. On the other hand, coal company officials were estimating there was only enough coal for five to ten years of digging. After that most people probably would move on to the next mining location anyway.

"Yes," Stan continued to muse, "some big changes were in store for Stone Gulch." Most of the people were like him: older and happy to be unincumbered by a lot of heavy responsibilities. There were a few wealthy people around who had made their money years earlier in uranium and one or two in cattle ranching, but for the most part families made just enough to get by plus a little extra to buy a new gun or horse or pickup truck. The money that would go to the farmers and the other property owners (some absentee) for their coal-rich land was certainly going to turn some of their heads, perhaps make them different people. Of course, some of the more stubborn farmers didn't plan to sell, but most would eventually give out. Then they'd either build themselves a big mansion nearby or move to, say, California.

Stan then thought of the new shopping centers that would pop up, of the new motels, bars, and X-rated movie joints. Stone Gulch would become like many towns he had known, and not particularly liked, in rapidly developing parts of New Jersey near New York City. Well, there might be a good side to it all. Many of the Indians on nearby reservations would find employment, especially since they were used to the climate, and this would help them economically, and perhaps socially.

But then another, less desirable facet came to mind -- crime. Stone Gulch's population hardly knew the meaning of the word now. Oh sure, some cowhands would come into town every so often and get themselves drunked up, but that was minor. Stan could see real trouble on the horizon, with a lot more money and a lot more young, possibly unemployed men in town. It could turn out somewhat like the old west. And Stone Gulch had only three policemen, two part-time.

Stan left for last the two worst features of the whole situation, at least to him personally. First, with all the new people in town, the hunting and fishing were going to be ruined. He saw lines of hunters crossing the best grounds, and hundreds of noisy motor boats disturbing the whole reach of the nearby reservoir in the national park. This certainly was not what he had in mind when he came here.

"But what difference did it make, anyway," Stan thought, "I'm not going to have any time left to hunt or fish given my second problem: the big work load that was going to be imposed on him by the hordes of new citizens, coal company executives, and government, mostly Federal, officials and politicians." The Feds were particularly difficult to deal with. They had so many rules and regulations, mostly conflicting, it was almost impossible to make any sense of them. But, fortunately or unfortunately, Stone Gulch would need Federal financial help through "impact" funds if it was to be able to provide services to a population that probably would be around for no more than 10 years to pay for them.

This brought Stan back to his most immediate problem. He had to come up with some population projections as a basis not only for Federal "impact" funding but also for estimating the demand for the whole spectrum of town services. These estimates were critical since if they were too high, there might be overbuilding and overprovision of services, which would be expensive even with the Feds supplying a better portion of the funds. But then he certainly didn't want to underestimate and get caught short. That would mean lots of complaints, harrassment from politicians and government agency people on all levels, and, worse yet, probably more work and headaches in the end for himself.

"Too bad there weren't any other people around to help him with his task," thought Stan. In New Jersey he had had planners on his staff or else he could go to regional or state agencies for some help, but these were not to be found in Wyoming. Yet some things were coming back to him, mainly from various short courses he had taken in the past. He remembered one of the simplest techniques for population projection, known as regression or more specifically as linear regression.[1] Stan sorted through a bunch of old manuals he had received at one course until he came across the chart that somehow always stuck in his mind. It showed the population figures for a city at different Census years. Most cities, he remembered, grew or declined fairly steadily, barring annexations, catastrophes, and the like. Hence if you went to the local library and got the Census population figures back to, say, 1920, and plotted them versus either year or years since 1920, you usually got a fairly straight line (Fig. 1). The slope and intercept of this line were established using a couple of fairly simple equations.

So Stan took an hour off and went down to the local library to get the Census population figures. When plotted for each decade, they came out as those in Fig. 1. The result wasn't exactly a straight line, especially since there had been a slight decline since the uranium and copper heydays of the 1940's, but it was close enough. Stan then went ahead to find the slope and intercept of the line using the calculations shown in Table 1. The "6" in the equations represented the 6 cases or Census years for which he had data.

The next step was to find how closely the line "fit" the points. This "closeness" is usually represented by the correlation coefficient (r), which runs from plus or minus 1.0 when all the points fall right on the line to 0.0 when there is complete scatter about the line. A "plus" value indicates a positive sloping line (up to the right), a "minus" a negative slope (down to the right).[2] When Stan followed the computations in his manual (he actually was enjoying himself a little now since he had a chance to try out his new calculator), he came up with a correlation of +0.207. This indicated that population was rising over time, but that the relationship really was not that strong.

---

[1] This overly simple approach and many other more sophisticated techniques are discussed in H.S. Shyrock, Jacob S. Siegel, and Associates, The Methods and Materials of Demography, (2 Vols.), (Washington, D.C.: U.S. Government Printing Office, May, 1973).

[2] A simple explanation is given in J. P. Guilford, Fundamentals of Statistics in Psychology and Education (Fourth Edition) (New York: McGraw-Hill, 1965).

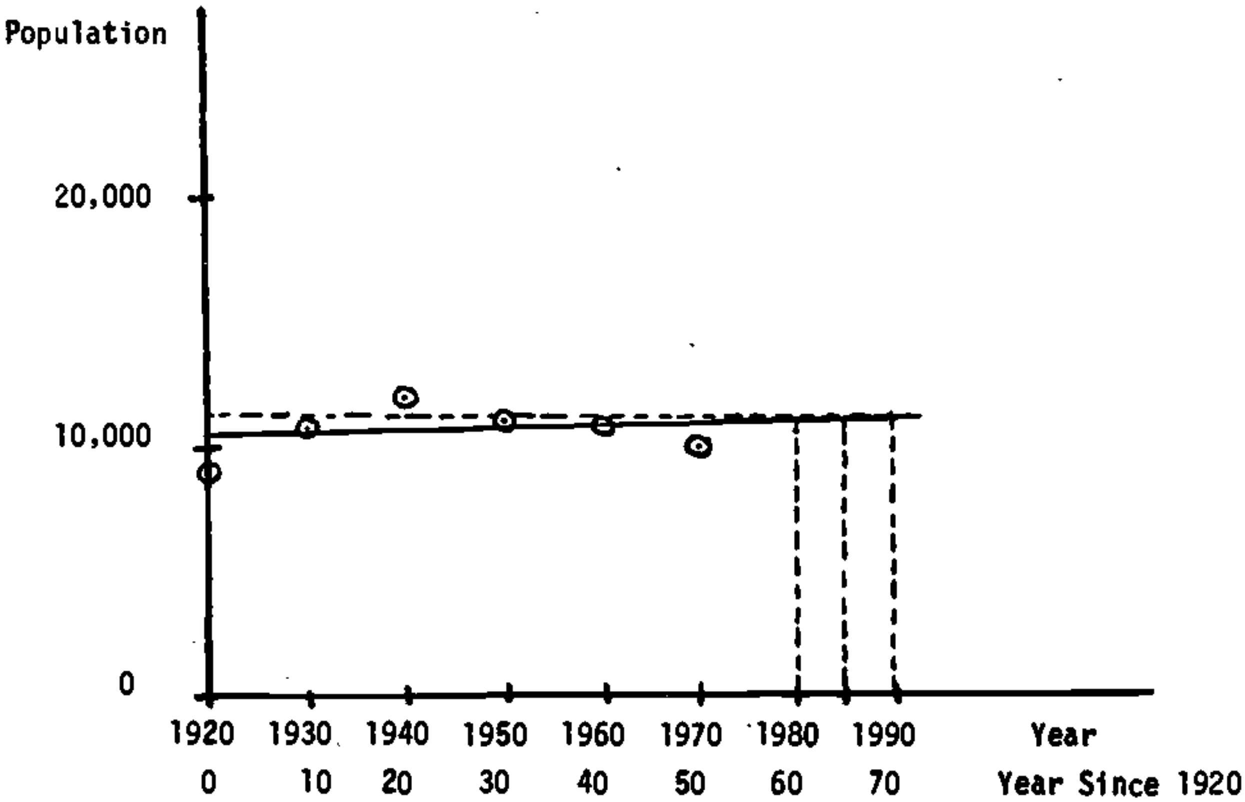

FIGURE 1. Linear Regression Relating Population To Time.

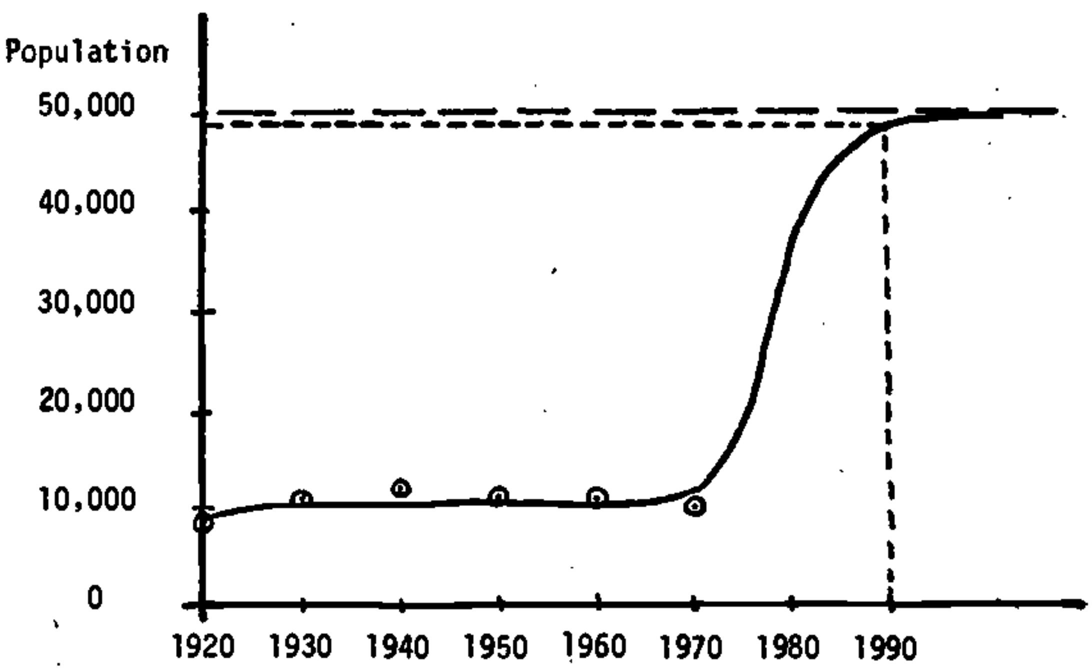

FIGURE 2. Hand-Drawn Facsimile of Gompertz Curve Relating Population To Time.

TABLE 1. Computations To Develop Linear Regression Relating Population To Time

Column	(1)	(2)	(3)	(4)	(5)
Variable	Year (since 1920)	Population (thousands)	x^2	y^2	xy
Symbol	(x)	(y)			
	0	9	0	81	0
	10	11	100	121	110
	20	12	400	144	240
	30	11	900	121	330
	40	11	1600	121	440
	50	10	2500	100	500
Total	150	64	5500	688	1620

$$\text{Slope} = \frac{6(\text{col. } 5) - (\text{col. } 1)(\text{col. } 2)}{6(\text{col. } 3) - (\text{col. } 1)^2} = \frac{6(1620) - (150)(64)}{6(5500) - (150)^2} = 0.0114$$

$$\text{Intercept} = \frac{(\text{col. } 2) - (\text{Slope})\ (\text{col. } 1)}{6} = \frac{64 - (0.0114)(150)}{6} = 10.38$$

$$\text{Correlation} = \frac{6(\text{col. } 5) - (\text{col. } 1)\ (\text{col. } 2)}{\sqrt{\left[6\ (\text{col. } 3) - (\text{col. } 1)^2\right]\left[6(\text{col. } 4) - (\text{col. } 2)^2\right]}}$$

$$= \frac{6(1620) - (150)(64)}{\sqrt{\left[6(5500) - (150)^2\right]\left[6(688) - (64)^2\right]}} = +0.207$$

Population (thousands) in 1990 = 0.0114 (70) + 10.38 = 11.178 or 11,178 people.
(70 years since 1920)

"To make a population forecast," Stan read from the manual, "you must insert the year (or year from 1920) of the forecast into the regression equation and solve for the corresponding population. Stan did this, as at the bottom of Table 1, and came out with 11,178 people for 1990 (70 years after 1920).

Stan was pleased to still be able to work with numbers but was somewhat dismayed by the actual results. The correlation coefficient showed the regression line as not fitting very closely, but worse yet, the 1990 population figure was much lower than he expected -- maybe by as much as 30 to 40,000 people. Certainly past population levels in Stone Gulch were not very indictive of its future, given the anticipated "coal rush." And the regression procedure only mirrored the past.

Perplexed, Stan thumbed through his manual to see if he could find a better technique. A second one that always stuck in his mind had something to do with the propagation of fruit flies -- the dirty buggers -- in a closed environment, say a big bottle.[3] Seems that in small numbers they didn't get that excited about continuing the species, but as the population grew, the interrelationships increased rapidly, mainly becuase there were more of the opposite sex to interrelate with, so that the overall family grew quickly. Fortunately, there seemed to be a limit. As the fruit fly population came close to filling up the bottle, they somehow could sense the crowding and subsequently decreased the rate at which they propagated. Eventually the population stabilized at a level approaching the capacity of the bottle environment to support it. In graphical terms, the fruit fly population level over time took the form of an S-shaped curve (Fig. 2).

"Boy, there certainly is an analogy here," Stan chuckled to himself. "We will have a lot of fruity people moving in during the next ten years, but maybe they will stop coming here and reproducing once the general congestion in the city reached its capacity." "But seriously, what is Stone Gulch's capacity?" Stan wondered. One possibility is the population that could fit on all the available residential land.[4] Stan got out the recently completed and approved zoning map, along with the calculations prepared by the consultant and the local planning commission when they developed the map. He noted that 720 acres of the presently undeveloped land was zoned MF-10 for multifamily units and the remainding residential area, zoned SF-3 for single family units, comprised about 2000 acres. If there were a density of, say, 25 people per gross acre of multifamily units and 11 people per gross acre of single family units, that would give a total population, including the existing (1970) of 10,000, of: 720 acres (25 people/acre) + 2000 acres (11 people/acre) + 10,000 = 50,000 people.

---

[3]For further explanation see W. Isard, Methods of Regional Analysis, (Cambridge, Mass.: MIT Press, 1960).

[4]For an explanation of land use holding capacity, see F. S. Chapin, Urban Land Use Planning (Second Edition), (Champaign-Urbana, Ill.: University of Illinois Press, 1970).

From these calculations it seemed that Stone Gulch would not grow to more than 50,000 people. Of course, this figure was based on the assumptions that (1) the town would not expand its territory through, say, annexation, (2) the zoning ordinance would not change, and (3) Stan's guesses on the average densities were nearly correct. Stan felt particularly uneasy about the second assumption because his experiences in New Jersey had shown him that when an area is growing fast, land developers can exert a lot of pressure on planning commissions and town councils to change zoning to suit their purposes. In fact, developers often <u>were</u> the planning commission or council.[5]

Ignoring his qualms for the moment, Stan pressed on reading his manual to find out how to fit an S-shaped curve to his data. It was then that he ran into two difficulties:

(1) The equation for the curve, known as a Gompertz curve, was quite complex and much more difficult to manipulate than the linear regression equation.[6]

(2) From the past population figures there was no indication of where Stone Gulch currently stood on the curve.

Stan subsequently decided to "eyeball" the curve into place, figuring that population was already (in 1975) starting to rise rapidly in Stone Gulch and that it would be fairly close to "capacity" by 1990, 15 years hence. This thinking led him to draw the curve shown in Fig. 2. He scaled off the 1990 population as 48,000 people.

At this point it dawned on Stan that if the coal reserves were all to be depleted by 1980 to 1985, as the coal company executives suggested, the population in 1990 actually would be less than in 1985, maybe considerably so. Stan then decided that he would need some more help in making his forecasts.

Knowing how tight the city elders were with a buck, Stan thought it best not to ask for a consultant at this time, but to use the services of the 7 member planning commission. After all, they represented a variety of business and professional concerns in the community and it seemed like they had been on the commission forever. Of course, they met only about twice a year since there really hadn't been that much for them to do.

So Stan called a Commission meeting for the succeeding week. As it turned out, only 6 of the 7 members showed up, but that was enough to get some opinions anyway, Stan felt. But he knew he made a mistake as soon as he gave them the charge to come up with population projections for 1980, 85, and 90. On one side of the small room was Jethro Kettle, a retired, conservative, and very stubbon land owner who didn't want to see anything change.

[5] Some evidence to this effect can be found in Marion Clawson, <u>Suburban Land Conversion in the United States</u>, (Baltimore: The Johns Hopkins Press, 1971).

[6] For procedures on how to fit Gompertz and related equations, see Shyrock, Siegel, and Associates, <u>op.cit</u>.

And on the other side, his arch antagonist, the brash young head of the local Chamber of Commerce, Jim Ward, who would try to make a quick buck on anything.

As Stan now expected, Kettle and Ward came up with estimates that were about as far apart as might be possible. Kettle claimed staunchly that neither he nor any of the other landowners had any interest in selling their property to the coal companies. He liked the area just as it was and didn't want any more people fouling it up and getting in the way. Ward, perhaps as a political ploy predicated to gin up more local business and to aggrevate Kettle (whom he despised), foresaw Stone Gulch turning into a major commercial-industrial complex of 100,000 people by 1990. The other members present, apparently depending on their feelings toward Ward or Kettle, arrayed their predictions along the continuum separating the two extremes. About the only consolation to Stan was that the average (mean) of the five forecasts for 1990 was about 50,000, close to that of his estimated capacity. But certainly the range between the top and bottom forecasts was excessive.[7]

What to do next? Stan felt he had to get some expert help despite the anticipated expense. So, after reporting to the council that he had been unable to obtain a reasonable forecast, he requested funds to hire a consultant, hopefully a cheap one, maybe from a university. The council, after a typical two hour debate, reluctantly agreed to spend $300 for the effort.

The next day Stan called up the university and, after being switched between five or six different departments, finally located a faculty member who seemed to have the proper credentials. Professor Plum, in Sociology, had spent about 20 years in demographic studies and currently was interested in the impacts of technology on development. Stan set up an appointment to see him, which also gave him an opportunity to get away from the growing chaos in his office.

The following week Stan drove the 200 miles to the university. Prof. Plum turned out to be 5 feet tall, chubby, and goateed. His office looked like it was located over the San Andreas fault. He greeted Stan by telling him in no uncertain terms that Stone Gulch was indeed going to boom by 1990, but for none of the reasons Stan had thought of or heard. The coal deposits were important, but technology was now being developed that would require almost no manpower for extraction and transport of coal. Huge "pans" would scrape off the top layers of soil to expose the coal seams. The coal then would be shattered with an intense burst of elections created by an advanced particle accelerator. The pulverized material subsequently would be transported via movable slurry pipelines to Seattle, where it would be shipped via super tanker to Japan. There it would be used in conjunction with iron

[7]The advantages and disadvantages of the traditional committee approach are discussed in J. P. Martino, Technological Forecasting for Decisionmaking, (New York: Elsevier, 1972) and in A. L. Delbecq, A. H. Van de Ven, and D. H. Gustafson, Group Techniques for Program Planning, (Glenview, Ill.: Scott, Foresman, and Co., 1975).

ore from Australia to make steel for India and other southeast Asian countries.[8,9] "The points are, however," said Prof. Plum, "first, that few hands will be involved in the coal excavation operation and, second, that the coal won't be used as an energy source."

Almost before Stan had a change to wonder what came next, Prof. Plum continued to explain that the real source of energy in 1990 will be via satellite from the sun. That is where Stone Gulch comes in. High intensity solar rays would be beamed to earth by the satellites. Yet they must be focused on a large (about 70 square miles) receptor on the earth. Since the area around Stone Gulch is relatively flat and uninhabited, and since the coal stripping is going to make an already desolate area more so, the natural thing to do would be to turn the stripped area into the needed solar collector. Moreover, the region around Stone Gulch was one of the few places in the country where this could be done.

Since Stone Gulch itself was going to be so close to this huge energy source, the costs of power would be minimal. Prof. Plum then envisioned a great migration to the region because of this low cost energy and the proximity to many of the nation's national parks, where the other half of the 3½ day working week in 1990 could be spent in recreation. He further imagined the whole city (which actually would be a region under a regional government in 1990) covered by a geodesic dome made out of new, high strength laminated carboard (from local forrests) and acrylic plastic. This would make the climate of the area acceptable year round. Perhaps a new Disney World then would be built in Stone Gulch. Based on all these factors, Prof. Plum conservatively set the 1990 population of the city (region) at 250,000 people, but rising rapidly.

Stan's head was in a whirl as he drove back to Stone Gulch. Everything Prof. Plum said had a ring of authenticity and authority to it, but Stan couldn't imagine himself telling the council about it much less putting it on paper for the Feds. Then too, he was bothered by the fact that after Prof. Plum expanded so positively about the radical changes coming to Stone Gulch, he indicated that the check for his consultant's fee was going to go directly to the Wyoming Historical Preservation Society. "The beauty of an 'expert' is his fantastic experience and ability to generalize on it," Stan thought to himself, "but the bane is that he is generalizing on few or no actual observations."[10]

---

[8]Many of the technological changes suggested here and in succeeding paragraphs are forecast by Stephen Rosen in his book, Future Facts, (New York: Simon and Schuster, 1976).

[9]The Japanese already use a large amount of Appalachian coal for steelmaking, and much in the future will be employed in conjunction with the plentiful Australian iron ore. See National Geographic, February, 1975.

[10]Further beauties and banes of experts are discussed in W.J.J. Gordon, Synectics (London: Collier-Macmillan, 1961) and their good and bad forecasts in R. U. Ayres, Technological Forecasting and Long Range Planning, (New York: McGraw Hill, 1969).

Stan continued to ponder his problem, which seemed to be getting worse the more he got into it. If only there were some other city of town that had gone through the same experience as that being faced by Stone Gulch. Then he could call them up, find out what happened, and make the direct analogy back to his place.

Just then Stan's thoughts were interrupted as he noticed he was approaching home. The day had been a hot one and his town-owned car had no air conditioning in it. After he got to his house, he went directly down the street to the local bar for a beer. As he sat in his accustomed seat, he remembered that he missed old Reginald MacKenzie. Reggie was an Australian who had come to the States in about 1960. Two months ago he had returned to his home in the northwestern part of the country to visit a few remaining, but fading relatives. He would be back next week.

Then it dawned on Stan. From what he had heard of northwestern Australia from Reggie, it had many of the characteristics of the region around Stone Gulch. In fact, that was the main reason why Reggie had chosen to come here in the first place. Stan quickly started to jot down on his napkin some of the analogous features.

The next week when Reggie returned he was able to verify and add to the similarities and differences Stan had recorded (Table 2). Probably the region in Australia closest in nature to that around Stone Gulch is the Pilbara, located in the northwest part of the state of Western Australia. One of the main cities is Dampier, with a 1971 population of about 3500. The small size of Dampier is indicative of the region, which is one of the sparseliest populated in the world. This is due in large measure to the climate and terrain, which perhaps are most like those of the Mojave Desert in the United States.

The strongest analogy with the area around Stone Gulch is in the mineral resources characteristics. In the Pilbara iron ore is the greatest resource while in Stone Gulch it obviously is the recently found coal. Great efforts already have been made in the Pilbara to start to get the iron ore out. In fact, Dampier actually was constructed by, and is composed almost entirely of, personnel from one iron ore mining company.

If the experience in Dampier is indicative of that which might occur in Stone Gulch, there would not be much growth. People generally do not like to go to Dampier. Besides the inhospitable climate, there are difficulties in finding variety in shopping, schools, social interaction, and jobs. A survey showed that 58% of the people there found the overall environment unfavorable, which may be the reason why the average stay is only about 1½ years. On the other hand, the Government of Western Australia is anticipating building a new town for about 130,000 people near Dampier. This figure is based on the expected rapid increase in iron ore mining in the region.[11]

---

[11] Sources for these analogies are: T. B. Brealey, Living in Remote Communities In Tropical Australia, Vol. 1, Exploratory Study (Highett, Australia: CSIRO, 1972).
and Government of Western Australia, Dept. of Development and Decentralization, The Pilbara: A Development Concept (Perth, Australia, no date).

TABLE 2. Analogous Characteristics[a] of Stone Gulch and Dampier

Characteristics	Stone Gulch	Dampier
I. Social Population	10,000	3,500
Distribution	Mostly older couples who have lived in the area for a long time.	Mostly young, single men or couples without children who stay for 1 to 2 years.
Institutions	A variety of social and church groups, with the latter dominating.	A company town, but has usual social and church groups.
II. Economic Base	Minerals--originally gold and uranium, now coal, some ranching.	Minerals--originally gold, but now almost entirely iron ore, some ranching.
Income	Somewhat low, but many people with valuable land holdings.	About average, but with lots of "extras" such as subsidized air fares, electricity, etc.
Market	Somewhat removed from large shopping complexes, etc.	Isolated from major shopping. Has a company store.
III. Cultural Values	Conservative, but with great emphasis on self-dependence.	Varied, but oriented to hard work and equally hard beer drinking.
IV. Ecological Climate	Relatively harsh. Over 100° F in summer, below 0° F in winter.	Harsh. Little rainfall, temperatures above 100° F for 1/3 of the year.
Terrain	Flat, open, little vegetation, but near mountains and national parks.	Flat, open, little vegetation, but near coast and ocean.
V. Technological Transportation	Near Interstate, railroad. Has small airport.	Dirt-gravel road only, railroad, and small airport (but with good service).
Housing	Old, in need of repair.	Recently built, concrete, maintenance by company.
Power	Readily available hydroelectric.	Provided over a long distance (but free) by company.

VI.4.S11

TABLE 2. Analogous Characteristics[a] of Stone Gulch and Dampier (Continued)

Characteristics	Stone Gulch	Dampier
Water	Available in quantity from nearby reservoir and from wells.	Provided free by company, but from a long distance; low capacity.
VI. Managerial	Varies with industrial/commercial establishment.	Entirely under company control.
VII. Political Type of System	Election by common ballot.	Election by common ballot.
Power/Control	Major control rests with "old-time" conservatives, mostly businessmen.	Major control rests with company managers, although company itself is not involved directly.
Taxation	Usual (but low) local property taxes and state and federal income taxes.	Company pays for all service improvements. Employees eligible for Federal tax deductions.
VIII. Intellectual	"Old guard" provides intellectual leadership.	Company managers provide intellectual leadership.
IX. Religious/ Ethical	-	-

[a]The characteristic dimensions listed in this table come from J. P. Martino, Technological Forecasting for Decisionmaking, (New York: Elsevier, 1972) and from T. O'Conner, A Methodology for Analogies, (Springfield, Va.: National Technical Information Service, June, 1970).

The reader is also referred to these for further examples of analogies and their use in forecasting.

Stan and Reggie agreed that the analogy between Dampier and Stone Gulch was as close as could be found, especially since people and government in the United States and Australia are also very similar. But still there are major differences. Stone Gulch, while somewhat distant from a major city, is nowhere near as isolated as Dampier. Nor is Stone Gulch a company town located in an overly harsh environmental area. Moreover, the analogy is confused by the apparent anomaly of the Western Australian Government in wanting to build a large new town when only a small one seems to be "making it" now. Did the Government see some great change that no one else did? With some hesitancy Stan and Reggie agreed that, on the basis of the analogy,[12] the population of Stone Gulch might grow to about 20,000.

The somewhat futile effort to develop an analogy left Stan greatly discouraged, if for no other reason than he had run out of techniques by which to make the needed population projection. And right now he didn't have much to show the Feds on the town's application for impact funds. He decided to take a couple of days off to go fishing. Maybe something brilliant would come to him.

Unfortunately, no bright ideas occurred to Stan, but he did get a long nap. When he got back to the office the following week, he found a rather odd message for him to call a Dr. Wolfgang Schmidtler of Sentinel Computer Research and Planning, Inc. Stan was intriqued to find out why someone from SCRAP, a nationally famous (and sometimes infamous) Department of Defense "think tank," would want to contact him. He quickly dialed the number. Dr. Schmidtler, as betrayed by his Germanic name, got right to the point. SCRAP was now working with ERDA and FEA to provide PPBS assistance to SCICT's. Would Stone Gulch be interested?

Stan, not knowing what all these initials stood for, felt like a real backwoods hick in asking for further elaboration. He found out that ERDA was the Energy Research and Development Administration, FEA was the Federal Energy Administration, PPBS was Planning, Programming, and Budgeting Systems, and SCICT's were Small Communities Impacted by Coal Technologies. After a longer conversation Stan also found out that some of the assistance being offered as part of the planning effort in PPBS was in population projections. He couldn't have been happier. Here was an advanced, sophisticated research firm wanting to come and do his population forecasts and at the same time provide a lot more city service and financial planning and budgeting aid. What could be more timely?

Dr. Schmidtler indicated he would be bringing his staff of six policy analysts to Stone Gulch the following week. They would start immediately on the population projections, using such techniques as Delphi, gaming, relevance trees, morphological analysis, PROBE, and breakthroughs. Stan didn't have the foggiest notion what these were about, but he was sure they would do the job and look really good on the Federal application form. Best yet, the whole effort didn't cost the town a penny.

---

[12] For more information on analogies as a means of forecasting, see the references in the footnote of Table 2.

Stan drove out to the airport to meet Dr. Schmidtler and his staff. They came on the daily air commuter plane from Denver, and they certainly were an impressive bunch. Dr. Schmidtler was followed by his six men, all about in their mid-forties, dressed in dark suits, and having crew cuts. They looked deadly efficient, and certainly way out of context with Wyoming.

After reaching Stan's office, Dr. Schmidtler quickly divided his crew into two teams of three each. He then requested that Stan help him find six other "typical" Stone Gulchers to augment these teams. In about an hour Stan had rounded up two housewives, a teenage high school student, a service station manager, a local farmer/landowner, and a newly-arrived coal company official to help that evening.

Before the 7 o'clock meeting Dr. Schmidtler divided the six town's people into two groups of three, to be combined with the SCRAP teams. One group was to undertake a Delphi exercise, the other a free form game. In Delphi it is important that the team members not know each other's identity, so Schmidtler had it arranged with Stan that three of the locals would be escorted individually to separate rooms in the old hotel. Also, the three in Schmidtler's part of the group, selected anonymously, were to be taken to different rooms. In this way each of the six group members would be unaware of the others' identities. Meanwhile, the remaining locals and SCRAP personnel would be working together on the free form game.

After the six Delphi group members were settled comfortably in their rooms they were given a short written background statement on Stone Gulch's situation as well as the charge to come up with a forecast of the 1990 population level. In doing this they were asked to write down the major reasons why they selected that particular level. This effort would comprise the first round of the Delphi exercise. On the second and succeeding rounds each member would be given a statistical summary of the forecasts of all six people in addition to a verbal summary of the suggested reasons. At no point would a member know who else was involved.[13]

After the Delphi exercise was over, Dr. Schmidtler explained the results to Stan (Table 3). On the first round the six respondees had given forecasts varying from 10 to 50 thousand people, for a range of 40 (thousand). The mean (average) was 25.8. One of the reasons given for the lowest estimate (by one of Schmidtler's people) was that environmental suits against stripping would prevent any mining, and hence Stone Gulch would not grow at all. But one of the local people foresaw the use of as yet untapped hot water geysers, which could create a major energy source for the town and its environs. As a consequence, he saw Stone Gulch growing to 50,000 people in 1990.

On the second and third rounds both these extreme expectations were tempered somewhat by comments of other members. It was suggested by one local person that the land containing the coal really was very marginal,

[13] The Delphi method and some of its applications are described in J. P. Martino, op.cit. and in H. A. Linestone and M. A. Turoff (Eds.), The Delphi Method: Techniques and Applications, (Reading, Mass.: Addison-Wesley, 1975).

TABLE 3. Delphi Exercise Results

Round 1

1. Environmental suits against strip mining will prevent any digging of coal.
2. People will not stay in Stone Gulch after mining ceases. Also, some wealthier land owners will move on.
3. A new "energy crisis", caused by severe OPEC[a] price rises in 1982, will cause heightened demand (and prices) for coal, so that even more marginal seams around Stone Gulch will be dug.
4. More hot water geysers will be found for thermal energy for Stone Gulch.

Round 2

1. Much of the land really does not have much "environmental" value, so many of the court suits will be dismissed quickly.
2. The geysers will produce such hot water that expensive equipment will be needed to cool it for home, commercial, and industrial delivery.

	Person							
Round	1	2	3	4	5	6	Mean	Range
1	25	30	10	15	15	50	25.8	10 to 50 = 40
2	35	30	15	15	20	40	25.0	15 to 40 = 25
3	35	30	20	15	20	30	25.0	15 to 35 = 20

[a]Organization of Petroleum Exporting Countries.

with no significant environmental value. So the court suits probably would not be that important. On the other side, one of Dr. Schmidtler's men, apparently well-read in thermal energy, amended the comment about geysers by mentioning that experience elsewhere indicated the great expense needed to cool the hot water or steam before delivery. The expected cost thus would not be as low as was thought. The attraction of cheap energy in Stone Gulch therefore would not be as much as anticipated.

After three rounds, the mean forecast remained at 25 (thousand) and the range seemed to be settling down at 20, so Dr. Schmidtler stopped the exercise there. Stan thought the results were great, but he had an agonizing feeling that the efforts were not completely anonymous. After all, Dr. Schmidtler's people had probably done this many times before and knew each other's thoughts, even though no names were given. And the local people surely knew that they would be quizzing each other afterwards, so they could not be completely candid in what they wrote down. Furthermore, Stan felt there was no sense of responsibility attached to the forecasts, that is, people might vote somewhat differently if they actually had to live in the highly competitive world that differed markedly from their relatively unfettered state when making the forecasts.

"Perhaps the gaming exercise would be more responsive to this latter part," Stan thought, as Dr. Schmidtler began debriefing (as he called it) him on that effort. The six "players" had been divided into two teams of three each, with local and SCRAP representatives on both. One team was supposed to represent environmental interests, the other those of the coal companies. Dr. Schmidtler had acted as "judge." He first submitted to each team a scenario describing Stone Gulch's situation up to the present and the anticipated future issues. The competing teams then were asked to develop strategies for the next five year time period. After that, Dr. Schmidtler presented his adjudged results from the conflict and also set the stage for the succeeding five year round. This continued through three rounds (until 1990).

Dr. Schmidtler showed Stan a summary of the strategies and results from the exercise (Table 4). The "environmentalists" (meant to represent a widely divergent set of people, clubs, local action groups, and the like) had started out immediately by bringing suit in court. Meanwhile the "coal company officials" were buying up land before it got more expensive. Their activity was slowed, however, by the "result" that the local court had granted a delay injunction for further study of environmental impacts.

In round two (1980-85), the strategies developed in response to the round one results again pointed to a turbulent situation. The environmentalists found an endangered species on the land, but the coal companies also found a cheap way to return the stripmined areas to their "natural" state. Despite the former finding, the court gave approval for mining. But at the same time a series of external events forseen by the "judge" resulted in a much decreased

TABLE 4. Round-by-Round Strategies and Results of The Gaming Exercise

Round 1 1975-80

"Environmentalists"

Got Sierra Club to help bring suit against stripmining. Got national television coverage of area's environmental "problems."

Coal Company Officials

Bought needed property. Undertook advertising campaign to highlight economic benefits. Undertook environmental impact statement (EIS) preparation.

Result: Court granted delay injunction for further study of environmental impacts.

Round 2 1980-85

"Environmentalists"

Organized protest demonstrations at coal company headquarters. Found that the Stone Gulch area is main breeding ground for jackalope (combination of jack rabbit and antelope), which is on the endangered species list.

Coal Company Officials

Hired world-renowned environmental expert, who declared area "environmentally nonproductive." Developed low-cost method to replace stripped area to "natural" form. Promised to dedicate renewed area to national park system.

Result: Court gave approval for mining. New oil discoveries on continental shelf showed vast reservoirs. Japanese found way to make steel without coke (coal).

Round 3 1985-90

"Environmentalists"

Campaigned for new governor, whose slogan was "leave Wyoming alone." Requested higher court review of mining approval decision.

Coal Company Officials

Decided not to mine coal near Stone Gulch because of recent low demand and protracted court fights.

Results: Court cases dropped. Stone Gulch grew slightly (to 15,000) because of notoriety, nearby recreational areas, and Governor's request to "leave Wyoming alone."

demand for coal. In the third round (1985) the coal company therefore decided to drop the whole effort. Still, Stone Gulch did grow to a population of 15,000, mainly because many families felt there must be something worthwhile there if the governor wanted people to "leave it alone."

Stan thought the outcome of the gaming exercise was interesting, if not unique.[14] But he had the feeling that another exercise with a different group of people could possibly produce completely opposite results. For all he knew, environmentalists and coal companies might not even be competing in 1990, and there certainly would be other groups trying to make their importance felt on the scene by then. On the other hand, maybe these are part of the problem of any forecasting effort. There are so many external factors and so many divisive decision making situations that could impinge on the future of Stone Gulch that it was nearly impossible for any techniques to foresee all the relevant and unique outcomes. But Stan was still waiting patiently to see what other "tricks" Dr. Schmidtler was going to pull out of his kitbag of tools.

Well, Dr. Schmidtler certainly did have some other "tricks." The next one he called "morphological analysis," a phrase coming from the Greek "morphy" and standing for "form." Stan vaguely remembered this when he recalled someone referring to his somewhat rotund body as a mesomorphy ("big middle form"). In any case, as Schmidtler described it, his team was looking for new combinations of "forms" that might point to unique factors that could affect Stone Gulch's 1990 population. They concentrated on the coal industry, since that obviously was going to have the biggest impact on the town.

The team divided the coal production and distribution process into four stages (Fig. 3)--excavation, processing, storage, and transport. They then identified all the ways in which each stage could be accomplished, both now and in the future.[15] Excavation, for example, was divided into:

1. Shovelling
2. Drilling
3. Blasting (Jetcord)
4. Melting
5. Shattering With Electrons

The "Blasting with Jetcord" method referred to an "explosive," created in 1961 to separate the stages of the Gemini launch vehicle, which actually cuts through, rather than blows up, massive formations or structures. The "Shattering With Elections" method Stan remembered as that suggested by Prof. Plum.

The next step by the SCRAP group was to try different combinations (forms) of items from each of the four stages. For instance, a common current technique is to shovel out the coal from the surface (stripmining), pile it up, and then truck it away. This combination would be denoted as (I1, II1, III1, IV1), corresponding to the respective items in Fig. 3. "If this technique were still

---

[14] For a further explanation of gaming and its uses, see R. S. Barton, A Primer On Simulation and Gaming, (Englewood Cliffs, N.J.: Prentice Hall, 1970), and for urban applications see Environmetrics, Inc., The State-of-the-Art in Urban Gaming Models, (Springfield, Va., National Technical Information Service, July, 1971), PB-201 944.

[15] Ideas for this chart were taken from S. Rosen, op.cit.and from S. L. Soo, et al, The Coal Future: Coal Transportation; Unit Trains - Slurry and Pneumatric Pipelines, (Springfield, Va.: National Technical Information Service, May, 1975), PB-248 652.

I. Excavation	1. Shovelling	2. Drilling	3. Blasting (Jetcord)	4. Melting	5. Shattering With Electrons		
II. Processing	1. None	2. Crushing	3. Burning	4. Melting/ Separating	5. Premixing With Inert Material		
III. Storage	1. Pile	2. Natural Gas	3. Fuel Cell	4. Lead-Aid Battery	5. Flywheel	6. Pump Storage Reservoir	7. Liquid Hydrogen
IV. Transport	1. Truck	2. Rail	3. Barge	4. Deep Freeze Cable	5. Slurry Pipeline	6. Pneumatic Pipeline	

FIGURE 3. Morphological Analysis of The Future Coal Production and Distribution Process.

in use in 1990, we would expect a large demand for local truck drivers," explained Dr. Schmidtler, "which might mean a relatively great but probably only temporary population increase for Stone Gulch." "On the other hand," he continued, "if some new combination, say (I3, II5, III2, IV6), which actually is the coal degasification process, were common in 1990, we might conclude that there would be less demand for personnel, but these would have to be highly skilled to handle the sophisticated equipment. In this case the population increase, while small, would be comprised of many higher income people."

Dr. Schmidtler then told Stan that his SCRAP team had concluded from their analysis of the many combinations of possibilities in Fig. 3 that the apparently unlikely combination of (I4, II3, III6, IV4) had the highest chance of being in use in 1990 around Stone Gulch. Rock melting equipment already has been developed by the Atomic Energy Commission. Since the resulting material already is hot, it can be readily burned on site to power steam generators to pump water from the nearby reservoir uphill to a second reservoir. During times of peak demand the upper reservoir water would run down to the other one through turbines. The power thus generated would be transmitted by means of underground (and therefore aesthetically pleasing), super cooled cables to distant population centers. Given this situation, Dr. Schmidtler predicted a need for many skilled people on-site near Stone Gulch, with a resultant population level of about 35,000.

Stan was very impressed by this type of analysis. It seemed to take into account many of the technological factors that would have a significant effect on the future of coal and hence of Stone Gulch. But Stan was also confused as to how the SCRAP team managed to (1) analyse the great number of combinations (5 x 5 x 7 x 6 = 1050) in such a short time, and (2) determine which one of these was most likely. He was particularly perplexed that some of the combinations, for instance (I5, II2, III7 and IV4), didn't make any sense. Then there also was the question of how Dr. Schmidtler translated the coal technology forecast into a population forecast.[16] Still, Stan had confidence some answers to these uncertainties would be forthcoming as the SCRAP team tried yet other techniques.

---

[16] More information on morphological analysis can be found in R. U. Ayres, op.cit. and in J. P. Martino, op.cit.

The next method Dr. Schmidtler's team had employed was referred to as the "Relevance Tree" technique.[17] He explained to Stan that this was aimed more at achieving a perspective than for direct forecasting. "But," he added," relevance trees also provide a valuable input for the Probe and Cross Impact methods performed later." With that statement, Schmidtler unravelled a wall chart that had on it a set of boxes arranged somewhat like an organizational diagram (Fig. 4). Stan didn't see why it was called a "tree" until he turned it upside down, but then it really looked more like a candelabra. "Why shouldn't this technique be referred to as the "Relevance Candelabra Technique? Stan suggested. Schmidtler wasn't amused. He hung the wall chart up and continued his explanation.

"Efforts were again concentrated on the employment sector in Stone Gulch, since that is the most important sector relative to population growth. Employment was divided into its basic components -- coal and agriculture. To each was assigned a relevance number (RN), which gated the importance or relevance of that industry to Stone Gulch. The RN's were specified so as to total to 1.0. Coal received a value of 0.8 and agriculture 0.2, corresponding roughly to be employment, productivity, and so forth created be each industry, respectively. For the series of boxes at the next level down the hierarchy, a more detailed identification was made of the industry or function. Coal for example, was divided into stripmined and deepmined, with the former having an RN of 0.8 and the latter 0.2, to bring the total to 1.0 on that "branch." A RN product then was calculated for each box (factor) by multiplying the RN's up to the top of the chart. Stripmining, for instance, had a RN product of 0.8 (0.8) = 0.64." Schmidtler paused for a breath, then went on.

"If we stop at this level we see that the RN products across a whole level total to one (0.64 + 0.16 + 0.12 + 0.02 + 0.06 = 1.00). As a result, each value indicates the fraction of relevance of the corresponding item. Stripmining in this case has be far the greatest relevance (0.64)."

"On the next level, each box represents a factor which could impact on the element above it. To illustrate: the pending environmental suit against stripmining certainly will affect its relevance to Stone Gulch's employment (RN = 0.6). But so will the national conservation measures, off-shore oil discoveries, and the coal slurry pipeline (given RN's of 0.1, 0.1, and 0.2 respectively). Yet these latter three will affect deepmining as well. Hence in this part of the relevance tree there are two connections into these three factors, with the RN for stripmining shown on the left connection and for deep mining on the right. The RN product for three is calculated by adding those from both connections. For national conservation, for instance, we have (0.8) (0.8) (0.1) = 0.064 for the stripmine side + (0.8) (0.2) (0.4) = 0.048 for the deep mine side. The total is 0.112."

---

[17] This technique is discussed in J.P. Martino, op. cit. and in M.E. Esch, "Honeywell's PATTERN: Planning Assistance Through Technical Evaluation of Relevance Numbers," in J. R. Bright and M.E.F. Schoeman (Eds.) A Guide to Practical Technological Forecasting, (Englewood Cliffs, N.J.: Prentice Hall, 1973).

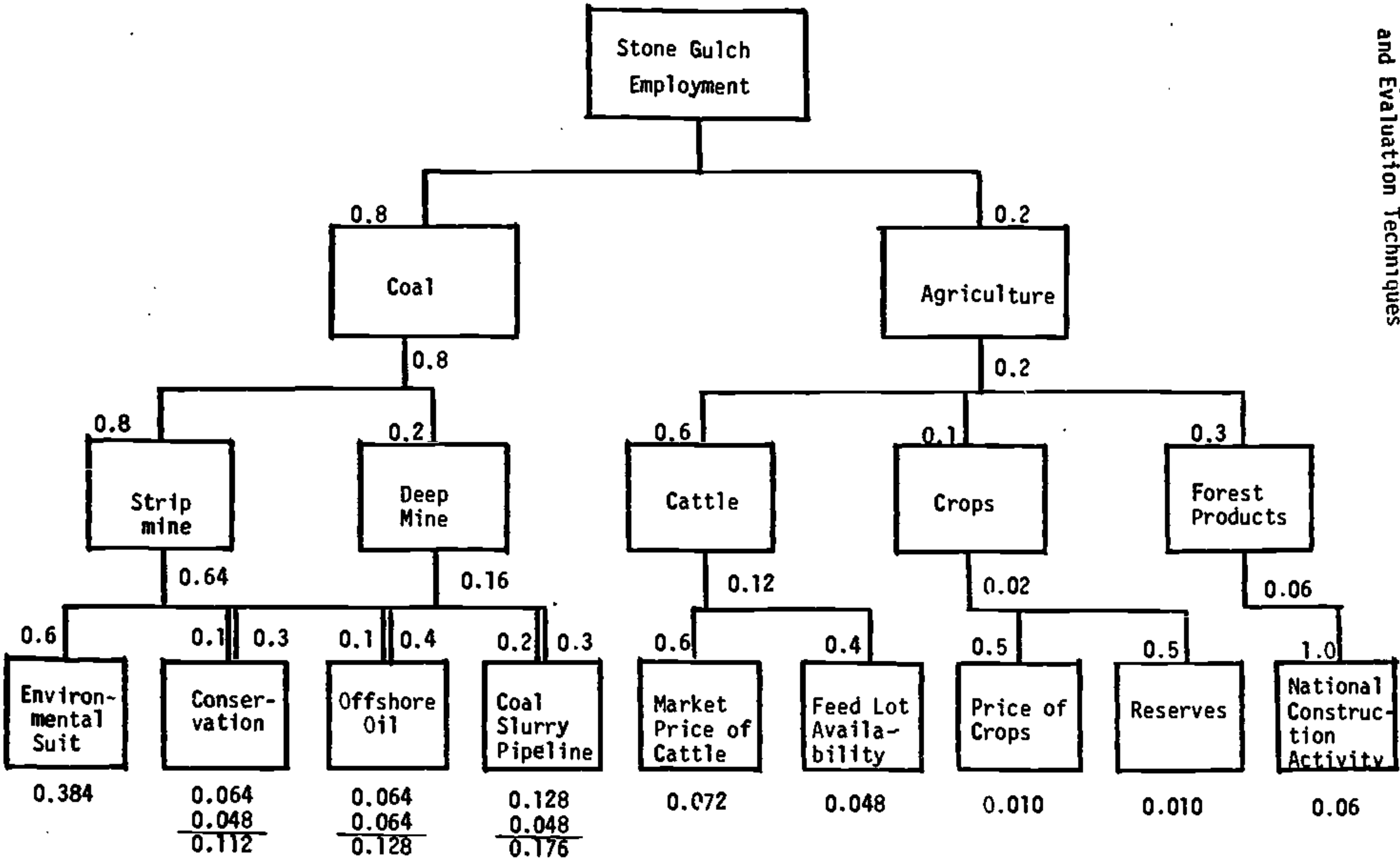

FIGURE 4. Relevance Tree for Employment in Stone Gulch

"The point is," concluded Dr. Schmidtler very auspiciously," that the relevance tree technique has verified our approach to population forecasting since those factors on the bottom level with the greatest relevance (RN products) were the same ones that have been considered in previous analyses. We therefore are on the right track." Stan, still somewhat groggy from trying to follow some of the calculations, nodded his head approvingly. He agreed in principle with Schmidtler, but was concerned with the amount of effort required just to get conformation. Besides, the relevance numbers were based on a very vague definition of "relevance." And Stan wasn't sure if he would come out with the same factors and levels, much less the same RN's, as had Schmidtler's men, if he tried the relevance tree approach.

Dr. Schmidtler seemed to sense his suspicion, because he jumped immediately into a description of the next technique, called Probe.[18] He quickly pointed out how the outputs from the relevance tree could be employed to set up a time-sequenced chart (Fig. 5). Each factor was described in detail (see Fig. 6) and placed on the chart at the year at which members of the SCRAP team felt there was half a chance (0.5 probability) that the particular factor level (or event) would occur. Connections then were drawn between the various events. These were supposed to indicate the linkages which <u>had</u> to occur before the succeeding event could take place.

Schmidtler illustrated this approach by pointing to another wall chart. Stan felt like he was a Pentagon general being briefed on a new tactical strategy. He was especially intrigued by the battery operated, retractable penlight pointer that Dr. Schmidtler used. It lent a very mechanical, systematic air to the whole affair. In any case, Schmidtler's men had assigned levels to most of the factors (see the chart in Fig. 6 for a listing). "Jobs" were set at 15,000, total net migration at 40,000 people, population at 50,000, and so on. The team subsequently guessed the year at which each level (event) had a 0.5 probability of occurrence. For example, they predicted that the pending environmental suit against stripmining (event 2, Fig. 5) would be settled in 1982 in favor of continued stripping (with lots of controls and penalities, however). Finally, they linked each event to its necessary successor and assigned a likely time to that linkage. To illustrate: the population in Stone Gulch could not reach 50,000 (event 8) until the total migration (in) reached 40,000 (event 5), and this transition would take 1 year to occur.

The resultant Probe chart then was employed for two purposes:

(1) To test for inconsistencies in the estimates of the timing of events, and

(2) To find the longest (and thus most critical) time path.

As an example of the first, the national demand for coal will not drop to the 1975 level (event 3) until offshore oil is discovered and is being extracted (event 4). But it will take 8 years (from the start at 1975) for that to happen and another 4 years to affect the coal demand. Thus, from 1975 it will take 4 + 8 = 12 years for event 3 to occur, which will bring it up to 1987 (1975 + 12), not 1984, as thought earlier by the team as they recorded it on the chart. A significant inconsistency thus has been found and corrected.

---

[18] Described in H. Q. North and D. L. Pyke, "'Probes' of the Technological Future," <u>Harvard Business Review</u>, May-June, 1969.

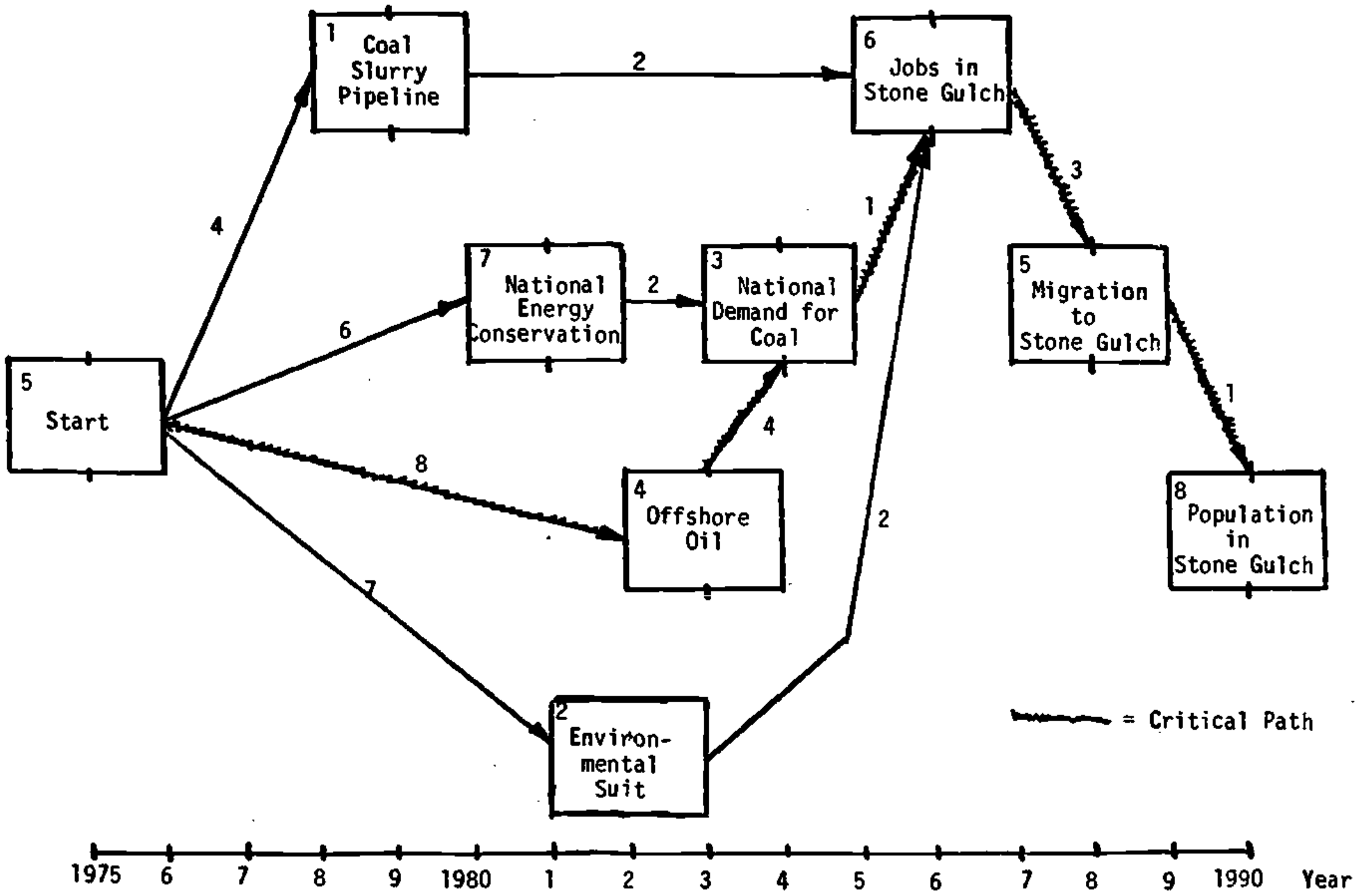

FIGURE 5. Probe Chart of Events Leading Up to Population Increase of 50,000 in Stone Gulch.

Affecting Event No.	Description	Year	Initial Prob.	Affected Event No. 1	2	3	4	5	6	7	8	Final Prob.
1	Coal Slurry Pipeline Used in Stone Gulch	1979	0.5	--	+30			+40	+50		+40	0.48
2	Environmental Suit Settled in Favor of Stripmining	1982	0.5	+72	--			+42	+82		+82	0.51
3	National Demand for Coal = 1975 Level	1984	0.5	-61	-60	--		-20	-20	+71	-20	0.59
4	Offshore Oil Discovered and Being Extracted	1983	0.5	-20	-30	+41	--	-20	-30	+41	-20	0.51
5	Total Net Migration Into Stone Gulch = 40,000 People	1987	0.5		+10			--	+72		+92	0.52
6	Total Work force in Stone Gulch = 15,000 Jobs	1985	0.5		+10			+82	--		+92	0.52
7	National Energy Consumption = 90% of 1975 Level	1982	0.5	-50	-50	+92	-20	-30	-30	--	-40	0.50
8	Population in Stone Gulch = 50,000 People	1990	0.5					+20	+41		--	0.55

Mode: + Enhancing
- Inhibiting

Strength: 0 Unconnected to 9 Very Strong

Predecessor: 0 Immaterial
1 Likely
2 Necessary

FIGURE 6. Cross Impact Matrix and Resultant Probabilities for Population Growth in Stone Gulch

"The second purpose is exemplified by the overhatched line on the chart," Dr. Schmidtler continued, pointing with his electric wand to the heavier, more jagged connections. "Since each link must be followed, that set with the largest sum of times will dictate the year when the population of Stone Gulch will reach 50,000 people (event 8). Since the longest (or critical) path[19] has 8 + 4 + 1 + 3 + 1 = 17 years, the 50,000 population level will not be reached until 1975 + 17 = 1992, instead of 1990 as anticipated earlier."

Now this was interesting, thought Stan. He had always felt it was important to check his own ideas from several different viewpoints. Moreover, he could see how it would be possible to keep a running record of potential changes in the various factors and if, say, off-shore oil were discovered and being extracted two years earlier then expected, this would also move up by two years the date at which Stone Gulch's population would reach 50,000.

But Stan, who now was feeling more confident in his ability to understand the various techniques being utilized by the SCRAP group, saw some difficulties in Probe. First, and perhaps foremost, the entities have to be discrete events. So you can predict only the time at which one level of, say, population (e. g., 50,000 people) will occur and not, as Stan needed, the population in a given year (1990). Second, the connections in Probe represent situations where the preceding event must take place before the succeeding one can. This type of relationship obviously does not fit every case since, for example, the availability of offshore oil (event 4) does not necessarily mean the national demand for coal will recede to 1975 levels (event 3). If the past were any indicator, people would consume more and more of each.

Stan felt he finally was one up on the SCRAP team as he confronted Schmidtler with his arguments. But Schmidtler would not be denied. He pulled his last trick out of the bag -- the Cross Impact Analysis (CIA) technique. He pointed out curtly to Stan that while there was some truth to his first point, the second was more than overcome by CIA because the analyst had a choice of what he (Schmidtler) called necessary, likely, or immaterial "predecessor" events. As Stan understood these, you could specify for each pair of events whether the first one is definitely necessary before the second can occur or, alternately, whether it is just likely or even unnecessary. "Moreov_r," continued Dr. Schmidtler, "the CIA is more useful because you also can specify a mode of relationship (enhancing (+) or inhibiting (-)) between each pair of events as well as a strength (measured on a scale from a low of 0 to a high of 9) of interaction."

With that, Schmidtler pulled out another wall chart (Fig. 6) and preceded to show Stan how to develop a CIA. "You start by listing each event along with the date at which it had half a chance of occurring (initial probability = 0.5). You then look at every pair of events and decide on a

---

[19] Techniques for finding critical paths in more complicated networks can be found in I. D. Wiest and F. K. Levy, A Management Guide to PERT/CPM, (Englewood Cliffs, N. J.: Prentice - Hall, 1969).

mode, strength, and predecessor relationship." He pointed to the row containing the first event (coal slurry pipeline) and to the column for event 2 (environmental suit settled). "The numbers at this intersection show that the SCRAP team felt that the presence of the coal slurry pipeline will enhance (+) the likelihood of the suit being settled in favor of stripping but that the influence will only be mild (3) and that the pipeline is immaterial as a predecessor (0) to the settlement.

Dr. Schmidtler then went on to try to tell Stan a little about the theory behind CIA.[20] The concept, as Stan found out after many agonizing questions, was that the stronger the relationship between a pair of events and the longer the time period between the preceding event and its successor, the greater the change in the probability of the succeeding event occurring at some prespecified future year (1990 in this case). The mathematics were somewhat complicated, but after the SCRAP team had filled in the matrix in Fig. 5, Dr. Schmidtler had hooked in his portable computer terminal to a computer back in his Washington, D. C. office and had it calculate the final probabilities.

"The results shown in this chart (right side of Fig. 6) again verify our previous efforts," Dr. Schmidtler told Stan in a commanding voice. "The cross impact estimates of the final (1990) probabilities of each factor varied little from the initial estimates. For example, the probability of the population level being 50,000 in 1990 changed only from 0.5 to 0.55. This means we have identified the correct factors influencing population and their interactions. So the 1990 population should be taken as 50,000."

Stan also was pleased with the results, but certainly was not willing to make such resounding conclusions. After all, there still was the problem of having to select a future population level ahead of time. Furthermore, Stan didn't know how the SCRAP team arrived at the numbers in the matrix nor was he sure of the theory. It wasn't necessarily true that one event would cause a greater change in another simply because there was a long time gap between them. "Besides," thought Stan, "there is no room on the Fed's application form for a probability figure."

Stan was about to question Schmidtler on these points when the Doctor announced he had to take his team right back to Washington for an important Defense Department strategy meeting. He quickly gathered his wall charts and tables together and almost ran to his waiting rental car to get to the airport.

Stan was left with a distinct impression of emptiness. He really didn't feel he was any better prepared to put a number on the application form than when he started this whole exercise. But as he thought over his experiences during the next two days he decided he really had learned something. First, he learned what he should have known from all his years as a city manager: there are no firm answers to anything, no approaches that were best all of the time. Second, he learned that there are a great many factors

[20]References for the Cross Impact Analysis approach are T. Gordon and H. Haywood, "Initial Experiments With the Cross-Impact Matrix Method of Forecasting," Futures, Vol. 1, No. 2, 1968. and J. P. Martino, op. cit.

that can affect population. Most of these he admitted to himself he would not have recognized had he tried to make the forecast by himself. Nor would he have had much feeling for the strengths of connections of these factors to population if he had taken his own approach.

At that point, Stan remembered a discussion he had had one time over friendly cocktails with Ralph Wallstreeter, a neighbor of his back in New Jersey. Ralph worked in the research section of a big stock brockerage firm in New York. His job was to make forecasts of stock prices at various future points in time. Ralph had degrees in statistics and economics, and he used the tools he had learned in these disciplines quite often. "But" he told Stan, "I have long since found that there is no single forecasting technique I can use to make the necessary predictions. I try several, and in the process I usually find that I eventually become so familiar with the behind-the-scenes reasons why a stock fluctuates, that I then can make the forecast independently of, and I think better than with, the techniques. You definitely need to use the techniques, but it's the forced systematic learning experience they generate that is the key to their real benefit."

Stan now felt the confidence that Ralph must have felt in those unique instances when he felt he finally "knew" the factor to be predicted. The Stone Gulch forecasting efforts had left him somewhat skeptical of individual techniques but absolutely certain that the overall effort had been worthwhile. A wide range of possible futures had been generated, explored, analysed, and evaluated. And now he didn't feel bad when he placed his "informed quesstimate" on the application form. And he vowed to himself to keep monitoring Stone Gulch's situation in case some of the more radical events Prof. Plum and the SCRAP team had suggested did come true. By doing this, Stan hopefully could respond in time to avoid any major problems.[21]

Several weeks later Stan received SCRAP's report. It described in glowing terms the great successes the team had had in helping the unsophisticated folks in Stone Gulch meet their pressing forecasting needs. Stan had to chuckle at the audacity of some of these technical experts. But he remembered Ralph Wallstreeter again, and went home for his cocktail hour.

[21] For further information on breakthroughs monitoring for them see J. P. Martino, op.cit. and R. C. Davis, "Organizing and Conducting Technological Forecasting in a Consumer Goods Firm," in J. R. Bright and M. E. F. Schoeman, op. cit.

TABLE 4. Computations To Develop Linear Regression Relating Population to Time in Rurbania

Column	(1)	(2)	(3)	(4)	(5)
	Year (since 1900)	Population (thousands)			
Symbol	(x)	(y)	(x^2)	(y^2)	(xy)
	0	35	0	1225	0
	10	37	100	1369	360
	20	37	400	1369	720
	30	42	900	1764	1260
	40	44	1600	1936	1760
	50	53	2500	2809	2650
	60	60	3600	3600	3600
Total	210	308	9,100	14,072	10,350

$$\text{Slope} = \frac{7(10{,}350) - (210)(308)}{7(9100) - (210)^2} = \frac{72{,}450 - 64{,}680}{63{,}700 - 44{,}100} = \frac{7770}{19{,}600} = 0.396$$

$$\text{Intercept} = \frac{308 - (0.396)(210)}{7} = 32.12$$

$$\text{Correlation} = \frac{7770}{\sqrt{[19{,}600]\,[7(14{,}072) - (308)^2]}} = \frac{7700}{\sqrt{71.34 \times 10^6}} = \frac{7700}{8446} = 0.912$$

Population (thousands) in 1975 = 0.396(75) + 32.12 = 61.82
(75 years since 1900)
= 61,820 people

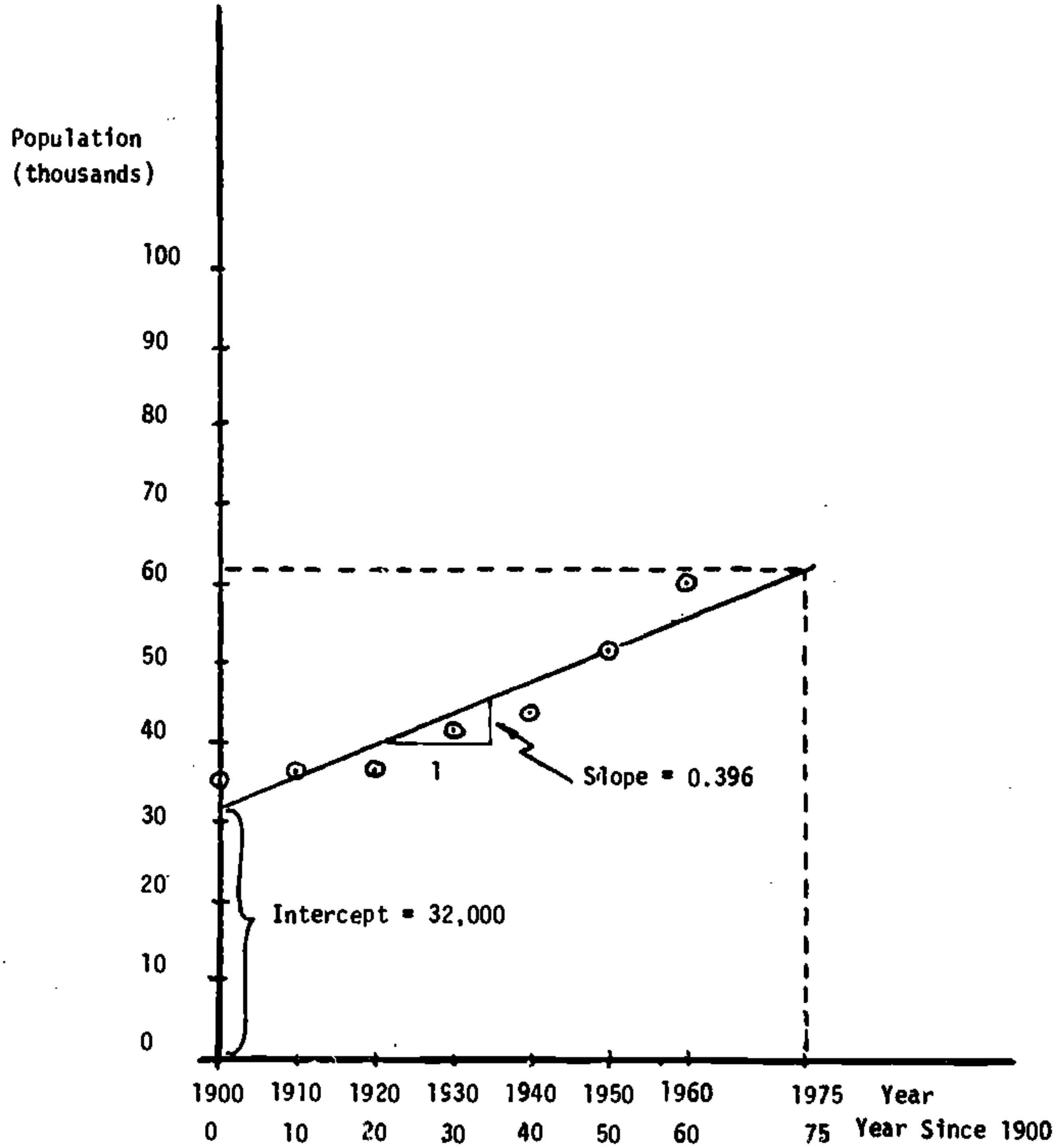

FIGURE 1. Linear Regression Relation Population To Time: Rurbania

85

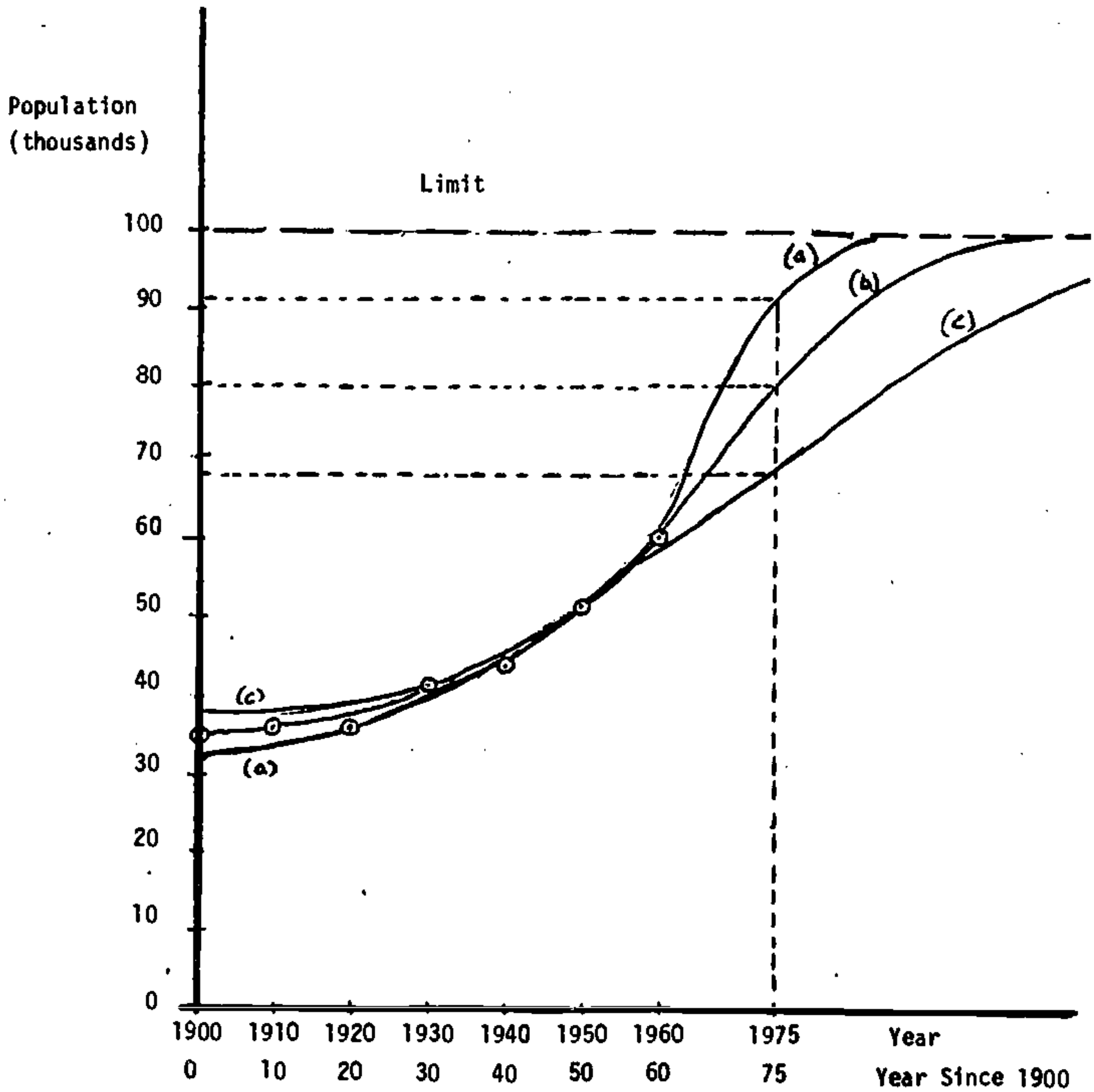

FIGURE 2. Sample Gompertz - Type Curves Relating Population To Time: Rurbania

CITY COMPARISON: RURBANIA VS. GREENVILLE, S. C.[a]

Both cities are located in the South, in or near the Appalachian Mountains. Both also are along major Interstate highways. Each appears to be a regional commercial center with a major university within its city limits. Greenville, however, is more industrialized and experienced a much higher growth rate between 1900 and 1950 than Rurbania. This probably is related to textile manufacturing, which grew rapidly in the area.

The population of Greenville in 1950 was 58,161 as compared to 52,631 for Rurbania. Both cities experienced growth rates between 1950 and 1960 of about 12%. Rurbania had a dwelling unit increase during this same time period of 14.7% as compared to an 18.4% rise in the number of households in Greenville.

Greenville differs from Rurbania in that it has more females than males and also about double the 1960 Black population percentage (30% vs. 16.7%). Further, the former area has experienced a steady increase in the Black population through 1960 as compared to a fluctuating rate for the latter.

The actual number of farms was not obtained from the Census. In 1950, however, Greenville had only 35 persons listed as farmers or farm managers as compared to 1,957 farms for Rurbania. Moreover, while wage and salary workers were grouped together in the Census figures, indications are that because of the generally rapid growth in Greenville and a steady rise in low income people, there probably is a much larger wage-earner labor force in that city than in Rurbania.

The 1970 Census reveals that the total population of Greenville decreased by 7.5% from 1960. This was comprised of an 11% drop in the White population and a 3.7% decrease in the Black. The number of households, however, increased fairly substantially during this period, perhaps indicating that a large group of unrelated persons had been added to the city's population. This may have been due to the addition of students to Census counts, a change in city boundaries, and concurrence with the national trend toward smaller families.

Greenville appears to have suffered from its dominance by textiles as the main component of its economic base during the 1960s. Rurbania's diversity and rather slow overall growth indicates a more diverse and flexible economy. On the other hand the settings still have many similarities and, based on the figures in Table 4, Rurbania may have grown only from 66,000 to 68,000 by 1975. The reason for the increase as compared to Greenville's decrease is that, unlike Greenville, most Southern cities reversed their decreasing population trends in the late 1960s and early 1970s. Rurbania's more diverse economy probably also forced change in that direction.

---

[a]This analogy was drawn by John Harvin, a graduate student in Urban and Regional Planning at Virginia Tech.

TABLE 5. Selected Census Data For Greenville, South Carolina

Characteristics	Year							
	1900	1910	1920	1930	1940	1950	1960	1970
Population	11,860	15,741	23,127	29,154	34,734	58,161	66,188	61,208
Males						27,311	30,544	27,955
Females						30,850	35,639	33,253
Blacks						16,095	19,717	19,145
Households						16,466	15,980	19,886
Farmers and Farm Managers						35		
Wage & Salary Earners						30,820	28,045	

Sources: U. S. Bureau of the Census, Census of Population, South Carolina, Washington, D. C. (Various years).

TABLE 6. Population and Land Area For Selected Cities

City	1960 Land Area (sq. mi.)	Year							
		1900	1910	1920	1930	1940	1950	1960	1970
Berkeley, CA	9.7	13,214	40,434	56,036	82,109	85,547	113,805	111,000	117,000
Columbia, SC	106.2	21,108	26,319	37,524	51,581	62,396	87,000	97,000	114,000
Durham, NC	NA	6,679	18,241	21,719	52,037	60,195	71,311	78,302	95,438
Jackson, MS.	46.5	7,816	21,262	22,817	48,282	62,107	98,000	144,000	154,000
Lansing, MI.	21.2	16,485	31,229	57,327	78,397	78,753	92,000	108,000	132,000
Raleigh, NC	44.9	13,643	19,218	24,418	37,379	46,896	66,000	94,000	122,000
South Bend, IN	23.8	35,999	53,684	70,983	104,193	101,268	116,000	132,000	126,000
Chapel Hill, NC	NA	1,099	1,149	1,483	2,699	3,654	9,177	12,573	25,535
Athens, GA	NA	10,245	14,913	16,748	18,192	20,650	28,180	31,355	44,342

Sources: U.S. Bureau of the Census, Statistical Abstract of the United States Washington, D. C. (various years).
U.S. Bureau of the Census, 1970 Census of Population, (North Carolina and Georgia), Washington, D. C., 1970.

TABLE 7. Pertinent Events and Facts and Associated With Rurbania (1961 to 1976)

Date	Event or Fact Description
1962	$13.6 million in construction. Retail sales up 14% per year at suburban shopping center; 3% elsewhere in city.
1963	2,514 acres of county annexed, including shopping center.
1963-73	Economy of nation (and State) doing well (low unemployment, inflation)
1965	University has 6,600 students, 4,190 undergraduate and 2,410 graduate.
1967	General Assembly approves $81 million bond issue for higher education.
1968	51 acres of county annexed.
1969	New city hall completed.
1970	University has 9,735 students, 5,769 undergraduate and 3,966 graduate. City population is 76,660, with 1,500 more males than females. Two-thirds of residents native to state. Maintenance of farms as estates; increases in horses as farm animals. Women enter university on undergraduate level.
1971	Local community college opens - 1,500 students. Same students protest over Viet Nam War.
1972	7,540 people in manufacturing (triple from 1950). Mostly small, clean industries. 2,130 people in health services.
1973	$42 million spent by tourists; 322 firms employ 1,929 people catering to tourists. 21 motels with 1,260 rooms. 47,765 air departures; 525,000 visit Monticello. 6,000 faculty and staff at university. $53 million in wages. Students spend $19.1 million.
1974	University finishes $34.5 million in 14 construction projects. $3.5 million downtown mall constructed. Open land (agricultural, recreation, etc.) taxed at less than market value.
1975	University has 14,382 students, 9,358 undergraduate and 5,024 graduate. Population reaches 87,000.

Sources:

J. H. Moore, Albemarle: Jefferson's County, University Press of Virginia, Charlottesville, 1976.

E. Woods, The History of Albemarle County, C. J. Carrier, Bridgewater, Virginia, 1964.

TABLE 8. A Rough Comparison of Technological Forecasting Techniques

Technique	COMPARISON FEATURE							
	1. Accuracy	2. Quality of Ideas	3. Cost	4. Time Period Required	5. Data Requirements	6. Individual Knowledge Needed	7. Group Knowledge Needed	8. Participant Benefits
1. Regression	High if past factors operative	Very Low	Low	Very Low	Very Low	High	NA	None
2. Gompertz	High if past factors operative	Very Low	Low	Very Low	Very Low	Very Low	NA	None
3. "Genius"	Varied	Medium	Medium	Low	Low	Very High	NA	None
4. Committee	Medium	Medium	Medium	Medium Low	Low	Medium	High	Fairly High
5. Analogy	Fair	Above Average	Medium	Medium	Fairly High	Medium	NA	None
6. Delphi	Fairly High	Fairly High	Medium	Medium	Low	Fairly High	High	Fairly High
7. Gaming	Fair	Fairly High	Medium	Medium	Medium	Fairly High	High	High
8. Morphological Analysis	Medium	Medium	Low	Low	Fairly Low	Very High	NA	None
9. Relevance Tree	Varied	Very High	Medium	Medium	Fairly High	Very High	NA	None
10. Probe	Fairly high if factors "discrete"	Below Average	Medium	Medium	Medium	Very High	NA	None
11. Cross Impact	High if factors factors "discrete"	Low	Above Average	Low	Fairly	Very High	NA	None

VI.4.47

TABLE 9. Major Points To Consider In The Forecasting Process

(1)	Do not forecast unless you have to. Forecasting is hazardous at best, yet is almost a necessity.
(2)	Make several forecasts and compare results. Use different techniques and different scenarios (including the most likely (base case)).
(3)	Decide which factors need to be forecasted, which ones will seriously affect these, and which ones are under your (i.e., your agency's) control.
(4)	Decide which groups of people will be impacted by, and which groups will affect, the factor being forecasted.
(5)	Decide on the geographic area (and possibly subareas) for which forecasts are needed.
(6)	Choose measures for each factor (some of which will be qualitative in nature).
(7)	Decide on the time period(s), remembering that the longer the period, the less the certainty.
(8)	Choose an allowable level of uncertainty.
(9)	Decide which forecasting techniques(s) or model(s) is most appropriate. Try to use as much "proven" theory as possible in this effort.
(10)	Do a post evaluation (several years later).

APPENOIX

FORTRAN Computer Programs

for

PERT NETWORK

CROSS IMPACT ANALYSIS

~~SIMPLE LINEAR REGRESSION~~

and, indirectly,

GOMPERTZ and REED-PEARL CURVES

```
C     ***********************************************************************
C     *
C     *              ***  PERT  NETWORK  ***
C     *
C     * THIS PROGRAM WILL DETERMINE THE CRITICAL PATH IN A PERT NETWORK
C     *  AND WILL PROVIDE THE INFORMATION NECESSARY TO DETERMINE THE
C     *
C     *  PROBABILITY OF COMPLETING EACH EVENT ON OR BEFORE THE SCHEDULED
C     *  COMPLETION TIME.
C     *
C     * TO CONSERVE STORAGE SPACE, THIS PROGRAM MAKES USE OF AN NX 7
C     * MATRIX CALLED C IN ORDER TO STORE
C     *     A(I,J) ACTIVITY FROM EVENT I TO EVENT J
C     *                J IS STORED IN C(K,2)
C     *                I IS STORED IN C(K,1)  (K=1,2,...,N)
C     *   AT(I,J)  OPTIMISTIC COMPLETION TIME FOR ACTIVITY (I,J) IN C(K,3)
C     * MT(I,J)  MOST LIKELY COMPLETION TIME FOR ACTIVITY (I,J) IN C(K,4)
C     * BT(I,J)  PESSIMISTIC COMPLETION TIME FOR ACTIVITY(I,J) IN C(K,5)
C     * ET(I,J,)  ESTIMATED MEAN COMPLETION TIME FOR ACTIVITY (I,J)
C     *          IN C(K,6)
C     *        ET(I,J)= (AT(I,J)+4*MT(I,J)+BT(I,J))/6
C     *  SIG(I,J)  ESTIMATED VARIANCE OF COMPLETION TIME OF ACTIVITY(I,J)
C     *           IN C(K,7)
C     *        SIG(I,J)=((BT(I,J)-AT(I,J))/6)**2
C     *
C     *  THIS PROGRAM IS DESIGNED
C     *
C     *     TO READ
C     *   CARD 1 COLS 2-72 TITLE DESCRIPTION OF THE PROBLEM USING ANY
C     *                          CHARACTERS ON KEYPUNCH
C     *                          ** COLUMN 1 MUST BE LEFT BLANK **
C     *   CARD 2 COLS 1-5 M MAXIMUM NUMBER OF EVENTS ON NETWORK(I5)
C     *               6-10 N MAXIMUM NUMBER OF ACTIVITIES ON NETWORK
C     *                               (INCLUDING DUMMY)  (I5)
C     *   CARDS 3 TO N+2 COLS 1-10 C(K,1)  I OF A(I,J)
C     *                      11-20 C(K,2)  J OF A(I,J)
C     *                      21-30 C(K,3)  AT(I,J)
C     *                      31-40 C(K,4)  MT(I,J)
C     *                      41-50 C(K,5)  BT(I,J)
C     *    PUNCH ONE CARD FOR EACH OF THE N ACTIVITIES (5F10.0)
C     *  CARD N+3  SD(J)  SCHEDULED COMPLETION TIME FOR EVENT J
C     *                   (J=1,2,...,M)  PUNCH IN FORMAT (8F8.0)
C     *                   USING AS MANY CARDS AS NECESSARY.
C     *                   SET SD(1)=0.=SD(M).  PROPER VALUE FOR SD(M)
C     *                   WILL BE FILLED IN BY PROGRAM.
C     *    TO SOLVE MORE THAN ONE PROBLEM AT A TIME, REPEAT THE
C     *    READ SEQUENCE, AND STACK THE DATA ONE BEHIND THE OTHER
C     *
C     *    TO CALCULATE AND PRINT
C     *      ET(I,J)  MEAN COMPLETION TIME (C(K,6))
C     *    SIG(I,J)  VARIANCE OF COMPLETION TIME OF EACH ACTIVITY (C(K,7))
C     *    TE(J)  EARLIEST EXPECTED COMPLETION TIME OF EVENT J
C     *    TL(I)  LATEST ALLOWABLE EVENT COMPLETION TIME FOR EVENT I
C     *    SD      SCHEDULED COMPLETION TIME FOR ENTIRE PROJECT (TL(M))
C     *    SE(J)  SLACK TIME FOR EACH EVENT J
C     *    SIGTE(J) SUM OF VARIANCES OF ACTIVITY TIME IN PATH USED TO
```

```
C    *              CALCULATE TE(J)
C    *     CPATH(I) CRITICAL PATH
C    *     X(K)     CRITICAL VALUE OF CUMULATIVE N(0,1) DISTRIBUTION
C    *              TO DETERMINE THE PROBABILITY OF COMPLETING EVENT K
C    *              ON OR BEFORE THE SCHEDULED COMPLETION TIME
C    *   SOURCE:  BILLY E. GILLETT, INTRODUCTION TO OPERATIONS RESEARCH,
C    *            MCGRAW-HILL, 1976
C    *
C    ******************************************************************
      DIMENSION C(100,7),CPATH(100),SIGTE(100),SD(100)
      DIMENSION TE(100),TL(100),SE(100),X(100),TITLE(18)
      INTEGER CPATH,FLAG(100)
    5 READ(5,10,END=2000)TITLE
   10 FORMAT(18A4)
      WRITE(6,6)TITLE
    6 FORMAT('1',18A4 //)
      READ(5,15)M,N
   15 FORMAT(2I5)
      DO 25 I=1,N
      READ(5,20)(C(I,J),J=1,5)
   20 FORMAT(5F10.0)
      FLAG(I)=0
   25 CONTINUE
      READ(5,27)(SD(I),I=1,M)
   27 FORMAT(8F8.0)
C    ******************************************************************
C    *   STEP 1
C    *      CALCULATE ESTIMATED MEAN COMPLETION TIME OF ACTIVITY ET(I,J)
C    *      CALCULATE ESTIMATED VARIANCE OF COMPLETION TIME FOR EACH
C    *             EVENT SIG(I,J)
C    ******************************************************************
      DO 30 I=1,N
      C(I,6)=(C(I,3)+4*C(I,4)+C(I,5))/6
      C(I,7)=(C(I,5)*C(I,5)-2*C(I,5)*C(I,3)+C(I,3)*C(I,3))/36
   30 CONTINUE
      WRITE(6,35)
   35 FORMAT(9X,'I',9X,'J','    AT(I,J)    MT(I,J)    BT(I,J)    ET(I,J)    S
     1IG(I,J)'/)
      DO 40 I=1,N
   40 WRITE(6,45)(C(I,J),J=1,7)
   45 FORMAT(7F10.3)
C    ******************************************************************
C    *     STEP 2
C    *      CALCULATE EARLIEST EXPECTED COMPLETION TIME FOR EVENT J TE(J)
C    ******************************************************************
      TE(1)=0
      SIGTE(1)=0
      DO 50 J=2,M
      TMAX=0
      SIGMAX=0
      DO 55 K=1,N
      IF(C(K,2).NE.J) GO TO 55
      TE(J)=TE(C(K,1))+C(K,6)
      SIGTE(J)=SIGTE(C(K,1))+C(K,7)
      IF(TE(J).LE.TMAX) GO TO 55
```

```
      TMAX=TE(J)
      SIGMAX=SIGTE(J)
   55 CONTINUE
      TE(J)=TMAX
      SIGTE(J)=SIGMAX
   50 CONTINUE
C    *********************************************************************
C    *      STEP 3
C    *      CALCULATE LATEST ALLOWABLE COMPLETION TIME FOR EVENT J TL(J)
C    *********************************************************************
      TL(M)=TE(M)
      SD(M)=TL(M)
      DO 60 IF=2,M
      I=M-IF+1
      TMIN=100000.
      DO 65 KF=1,N
      K=N-KF+1
      IF(C(K,1).NE.I) GO TO 65
      TL(I)=TL(C(K,2))-C(K,6)
      IF(TL(I).GE.TMIN) GO TO 65
      TMIN=TL(I)
   65 CONTINUE
      TL(I)=TMIN
   60 CONTINUE
C    *********************************************************************
C    *      STEP 4
C    *      CALCULATE SLACK TIME FOR EACH EVENT J SE(J`
C    *********************************************************************
      DO 70 J=1,M
   70 SE(J)=TL(J)-TE(J)
      WRITE(6,75)
   75 FORMAT(  // 5X,'EVENT J',10X,'TE(J)',10X,'TL(J)',10X,'SE(J)')
      DO 80 J=1,M
   80 WRITE(6,85)J,TE(J),TL(J),SE(J)
   85 FORMAT(/ 7X,I5,3F15.3)
C    *********************************************************************
C    *      STEP 5
C    *             FIND ACTIVITIES ON CRITICAL PATH
C    *********************************************************************
      DO 90 K=1,N
      I=C(K,1)
      J=C(K,2)
      IF(ABS(TL(I)-TE(I)-SE(M)).GT..0001) GO TO 90
      IF(ABS(TL(J)-TE(J)-SE(M)).GT..0001) GO TO 90
      IF(ABS(TE(J)-TE(I)-TL(J)+TL(I)).GT..0001.OR.ABS(TL(J)-TL(I)-C(K,6)
     1).GT..0001) GO TO 90
      FLAG(K)=1
   90 CONTINUE
      CPATH(1)=1
      KP=1
      DO 100 K=1,N
      I=C(K,1)
      J=C(K,2)
      IF(FLAG(K).EQ.0) GO TO 100
      IF(I.NE.CPATH(KP)) GO TO 100
      KP=KP+1
      CPATH(KP)=J
  100 CONTINUE
```

96

```
      WRITE(6,105)(CPATH(I),I=1,KP)
  105 FORMAT( // 5X,'CRITICAL PATH',14I4)
C     ***********************************************************************
C     *     STEP 6
C     *  CALCULATE CRITICAL VALUE OF CUMULATIVE N(0,1) DISTRIBUTION
C     *   TO DETERMINE PROBABILITY OF COMPLETING EVENT BEFORE
C     *    SCHEDULED COMPLETION TIME
C     ***********************************************************************
      DO 110 K=2,M
  110 X(K)=(SD(K)-TE(K))/SQRT(SIGTE(K))
      WRITE(6,111)
  111 FORMAT(  // 5X,'EVENT',13X,'TE',13X,'SD',10X,'SIGTE',13X,'X')
      DO 115 K=2,M
  115 WRITE(6,120)K,TE(K),SD(K),SIGTE(K),X(K)
  120 FORMAT(/ 7X,I5,4F15.3)
      GO TO 5
 2000 STOP
      END
```

INPUT DATA

```
   STONE GULCH PERT
     9    11
 1.        2.        3.        4.        5.
 1.        3.        5.        6.        7.
 1.        5.        7.        8.        9.
 1.        4.        6.        7.        8.
 2.        7.        1.        2.        3.
 3.        6.        1.        2.        3.
 5.        6.        3.        4.        5.
 4.        7.        1.        2.        3.
 6.        7.        0.5       1.        1.5
 7.        8.        2.        3.        4.
 8.        9.        0.5       1.        1.5
 1975.     1979.     1981.     1982.     1983.     1984.     1986.     1988.
 1990.
```

OUTPUT

I	J	AT(I,J)	MT(I,J)	BT(I,J)	ET(I,J)	SIG(I,J)
1.000	2.000	3.000	4.000	5.000	4.000	0.111
1.000	3.000	5.000	6.000	7.000	6.000	0.111
1.000	5.000	7.000	8.000	9.000	8.000	0.111
1.000	4.000	6.000	7.000	8.000	7.000	0.111
2.000	7.000	1.000	2.000	3.000	2.000	0.111
3.000	6.000	1.000	2.000	3.000	2.000	0.111
5.000	6.000	3.000	4.000	5.000	4.000	0.111
4.000	7.000	1.000	2.000	3.000	2.000	0.111
6.000	7.000	0.500	1.000	1.500	1.000	0.028
7.000	8.000	2.000	3.000	4.000	3.000	0.111
8.000	9.000	0.500	1.000	1.500	1.000	0.028

EVENT J	TE(J)	TL(J)	SE(J)
1	0.0	0.0	0.0
2	4.000	11.000	7.000
3	6.000	10.000	4.000
4	7.000	11.000	4.000
5	8.000	8.000	0.0
6	12.000	12.000	0.0
7	13.000	13.000	0.0
8	16.000	16.000	0.0
9	17.000	17.000	0.0

CRITICAL PATH 1 5 6 7 8 9

EVENT	TE	SD	SIGTE	X
2	4.000	1979.000	0.111	5925.000
3	6.000	1981.000	0.111	5925.000
4	7.000	1982.000	0.111	5925.000
5	8.000	1983.000	0.111	5925.000
6	12.000	1984.000	0.222	4183.242
7	13.000	1986.000	0.250	3946.000
8	16.000	1988.000	0.361	3281.607
9	17.000	17.000	0.389	0.0

```
C     ************************************************************************
C             *** CROSS IMPACT ANALYSIS ***
C     ALL DATA RIGHT JUSTIFIED
C     UP TO 30 EVENTS ALLOWED, OTHERWISE MUST CHANGE DIMENSIONS
C     *****
C     FOLLOWING FORMAT IS USED FOR INPUTING DATA
C     DATA CARD 1
C          COLS. 1-5    NUMBER OF EVENTS
C          COLS.6-10   NUMBER OF TIMES THROUGH MONTE CARLO ROUTINE
C          COLS. 11-15  STARTING YEAR (E.G. 1975)
C          COLS. 16-20  ENDING (HORIZON) YEAR (E.G. 1990)
C     *****
C     DATA CARD 2   (NOT MORE THAN ONE CARD)
C     DATA FORMAT FOR READING CROSS IMPACT MATRIX:
C          FIRST, NUMBER OF THE EVENT (I FORMAT)
C          SECOND, DATE (YEAR) OF THE EVENT (I FORMAT, SHOULD BE,
C            E.G. 1981)
C          THIRD, PROBABILITY OF EVENT OCCURING AT ALL (F FORMAT)
C                    (ONE DIGIT ONLY)
C          FOURTH, STRENGTH (INCLUDING MODE) OF INTERACTION OF THE EVENT
C                    WITH EACH OTHER EVENT
C               MODE IS + = ENHANCING    STRENGTH IS FRACTION
C                       - = INHIBITING
C                                                  (ONE DIGIT ONLY)
C          FIFTH, PREDECESSOR RELATIONSHIP FOR THE EVENT WITH EACH OTHER
C                    EVENT (I FORMAT)
C                    0 = IMMATERIAL
C                    0 = IMMATERIAL
C                    1 = LIKELY PREDECESSOR
C                    2 = NECESSARY PREDECESSOR
C     ****************  NOTE  ********************
C     THE MODE, STRENGTH, AND PREDECESSOR CHARACTERISTICS FOR EACH EVENT
C     WITH EVERY OTHER EVENT SHOULD BE READ TOGETHER.  FOR EXAMPLE, FOR
C     EVENT 2 WITH 3, IT MIGHT BE -32, WHICH INDICATES AN INHIBITING MODE,
C     A STRENGTH OF 0.3, AND A PREDECESSOR RELATIONSHIP OF 2.
C     *****
C     DATA CARD 3
C          DATA FOR EACH EVENT IN THE FORMAT OF THE PRECEDING CARD.
C     *****
C     DATA CARD 4  (ONE FOR EACH EVENT)
C          COLS. 1-3    EVENT NUMBER
C          COLS. 6-29   NAME OF EVENT
C     *****
C     SUBROUTINE RANDU MAY ALREADY BE DEFINED IN THE FORTRAN LIBRARY.
C     IF SO, IT MAY BE DELETED FROM THE END OF THE PROGRAM.
C     ****
C     SOURCE:  FAZIL T. NAJAFI, GRADUATE STUDENT, CIVIL ENGINEERING,
C              VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY,
C              BLACKSBURG, VIRGINIA, SPRING, 1976
C     ************************************************************************
      DIMENSION PNP(30),S(30,30),NA(30),IFORM1(18),PN(30),NAME(8,30)
      DIMENSION ITEST(30),NP(3),NEC(30),IMM(30),EH(30),DELTA(30)
      INTEGER P(30,30),LIK(30),EO(30),DATE(30)
      DATA IX/65539/
      DATA EH/30*0./
```

```
      READ(5,2031) NE,NT,NSY,NHY
 2031 FORMAT(4I5)
      WRITE(6,2036) NE,NT,NSY,NHY
 2036 FORMAT(//2X,'NO. OF EVENTS =',I3,/2X,'NO. OF TRIALS =',I5/2X,'STAR
     1TING YEAR =',I5,/2X,'HORIZON YEAR =',I5//)
      READ(5,2035) IFORM1
 2035 FORMAT(18A4)
      WRITE(6,2037) IFORM1
 2037 FORMAT(2X,'FORMAT FOR DATA IS',3X,18A4)
      T=NHY-NSY
      DO 1 K=1,NE
    1 READ(5,IFORM1) EO(K),DATE(K),PN(K),(S(K,L),P(K,L),L=1,NE)
      DO 703 K=1,NE
  703 READ(5,2032) EO(K),(NAME(L,K),L=1,6)
 2032 FORMAT(I3,2X,6A4)
      M = 1
      N = 9
 199  IF(N.GT.NE) N=NE
      WRITE(6,202) (L,L=M,N)
  202 FORMAT(1H1,'IF THE VERTICAL EVENTS HAPPEN,'/' THEN THE HORIZONTAL
     1EVENTS CHANGE PROBABILITY'//1H ,'FIRST DIGIT = STRENGTH, 0.0--1.0
     2'/1H ,'SECOND DIGIT = PREDECESSOR,  0--IMMATERIAL, 1--LIKELY, 2--
     3NECESSARY',/1H0,9X,'I'/1H ,9X,'N'/1H ,1X,'E',7X,'I'/1H ,1X,'V'
     4,2X,'D',4X,'T'/1H ,1X,'E',2X,'A',4X,'I'/1H ,1X,'N',2X,'T',4X,'A'
     5/1H ,1X,'T',2X,'E',4X,'L',9I6/)
      DO 201 K=1,NE
      IF(N.GT.NE) N = NE
      WRITE(6,200) EO(K),DATE(K),PN(K),(S(K,L),P(K,L),L=M,N)
  200 FORMAT(I3,I5,2X,F3.1,20(F5.1,I1))
 201  CONTINUE
      IF(N.EQ.NE) GO TO 203
      M = N + 1
      N = N + 9
      GO TO 199
 203  CONTINUE
      DO 3 I=1,3
   3  NP(I) = 0
      IQ=1
  52  IF(IQ.GT.NE) GO TO 55
      DO 6 M=IQ,NE
      DO 4 L=1,NE
      IF(P(M,L).EQ.2) GO TO 17
   4  CONTINUE
      DO 5 L=1,NE
      IF(P(M,L).EQ.1) GO TO 18
   5  CONTINUE
      NP(3) = NP(3) +1
      IMM(NP(3)) = EO(M)
   6  CONTINUE
  55  DO 14 IT = 1,NT
      I = 0
      NS = 0
      IFIN = 0
      DO 10 L=1,NE
      PNP(L)=PN(L)
  10  ITEST(L) = 0
```

109

```
11   CALL RANDU(IX,IY,Z)
     IX = IY
101  IF(NS.EQ.0) GO TO 104
     K=(Z*NS)+1.0
     IF(K.GT.NS) K=NS
     J=NA(K)
     NS=NS-1
     IF(K.EQ.(NS+1)) GO TO 103
     DO 102 M=K,NS
102  NA(M)=NA(M+1)
103  ITEST(J)=1
     GO TO 112
104  I=I+1
     IF(I.GT.3) GO TO 111
     IF(NP(I).EQ.0) GO TO 104
     IF(I-2) 109,105,107
105  NS=NP(2)
     DO 106 M=1,NS
106  NA(M)=LIK(M)
     GO TO 101
107  NS=NP(3)
     DO 108 M=1,NS
108  NA(M)=IMM(M)
     GO TO 101
109  NS=NP(1)
     DO 110 M=1,NS
110  NA(M)=NEC(M)
     GO TO 101
111  IFIN=1
112  IF(IFIN.EQ.1) GO TO 14
     CALL RANDU(IX,IY,Z)
     IX=IY
     IF(Z.LE.PNP(J)) GO TO 100
     GO TO 11
100  EH(J)=EH(J)+1.
     K=0
 53  KQ=K+1
     IF(KQ.GT.NE) GO TO 11
     DO 12 K=KQ,NE
     IF(S(J,K).NE.0.0) GO TO 13
12   CONTINUE
     GO TO 11
 13  Q=DATE(J)
     TM=DATE(J)-NSY
     TF = (T-TM) / T
     IF(Q.EQ.0.) TF=1.0
     IF(T.LE.TM) GO TO 53
     A = S(J,K) * TF * (-1.0)
     PNP(K) = (A * PNP(K)**2) + ((1.0 - A) * PNP(K))
     GO TO 53
14   CONTINUE
     DO 16 L=1,NE
     TN=NT
     EH(L)=EH(L)/TN
     DELTA(L) = EH(L) - PN(L)
16   CONTINUE
```

```
      GO TO 19
17    NP(1) = NP(1) + 1
      NEC(NP(1)) = EO(M)
      IQ=M+1
      GO TO 52
18    NP(2) = NP(2) + 1
      LIK(NP(2)) = EO(M)
      IQ=M+1
      GO TO 52
 19   WRITE(6,20) NT,NE
 20   FORMAT(1H1,'LISTING OF EVENTS IN ORDER PRESENTED',2X,I6,' TRIALS',
     1I6,' EVENTS',/,1H0,12X,'EVENT',15X,'INITIAL',7X,'DELTA',8X,'FINAL'
     1,/,1H ,30X,'PROBABILITY',   2X,'PROBABILITY', 2X,'PROBABILITY')
      DO 75 I=1,NE
 75   WRITE(6,21)  I,(NAME(K,I),K=1,6),PN(I),DELTA(I),EH(I)
 21   FORMAT(1H ,I3,1X,6A4,3F12.3/)
      STOP
      END
      SUBROUTINE RANDU(IX,IY,YFL)
      IY=IX*65539
      IF(IY)5,6,6
  5   IY=IY+2147483647+1
  6   YFL=IY
      YFL=YFL*.4656613E-9
      RETURN
      END
```

INPUT DATA

```
    8  100 1975 1990
(I3,1X,I4,1X,F1.1,2X,8(F3.1,I1))
  1 1979 5        30                  40  50      40
  2 1982 5    72                      42  82      82
  3 1984 5   -61 -60                 -20 -20  71 -20
  4 1983 5   -20 -30  41             -20 -30  41 -20
  5 1987 5        10                      72      92
  6 1985 5        10                  82          92
  7 1982 5   -50 -50  92 -20 -30 -30         -40
  8 1990 5                            20  41
  1   COAL SLURRY PIPELINE
  2   ENVR SUIT SETTLED
  3   NAT DEM FOR COAL
  4   OFFSHORE OIL DIS
  5   MIGRATION
  6   15000 JOBS
  7   NAT ENERGY CONSUMPTION
  8   50000 POPULATION
```

OUTPUT

NO. OF EVENTS = 8
NO. OF TRIALS = 100
STARTING YEAR = 1975
HORIZON YEAR = 1990

FORMAT FOR DATA IS (I3,1X,I4,1X,F1.1,2X,8(F3.1,I1))

IF THE VERTICAL EVENTS HAPPEN,
THEN THE HORIZONTAL EVENTS CHANGE PROBABILITY

FIRST DIGIT = STRENGTH, 0.0--1.0
SECOND DIGIT = PREDECESSOR, 0--IMMATERIAL, 1--LIKELY, 2-- NECESSARY

EVENT	DATE	INITIAL	1	2	3	4	5	6	7	8
1	1979	0.5	0.00	0.30	0.00	0.00	0.40	0.50	0.00	0.40
2	1982	0.5	0.72	0.00	0.00	0.00	0.42	0.82	0.00	0.82
3	1984	0.5	-0.61	-0.60	0.00	0.00	-0.20	-0.20	0.71	-0.20
4	1983	0.5	-0.20	-0.30	0.41	0.00	-0.20	-0.30	0.41	-0.20
5	1987	0.5	0.00	0.10	0.00	0.00	0.00	0.72	0.00	0.92
6	1985	0.5	0.00	0.10	0.00	0.00	0.82	0.00	0.00	0.92
7	1982	0.5	-0.50	-0.50	0.92	-0.20	-0.30	-0.30	0.00	-0.40
8	1990	0.5	0.00	0.00	0.00	0.00	0.20	0.41	0.00	0.00

LISTING OF EVENTS IN ORDER PRESENTED 100 TRIALS 8 EVENTS

	EVENT	INITIAL PROBABILITY	DELTA PROBABILITY	FINAL PROBABILITY
1	COAL SLURRY PIPELINE	0.500	-0.040	0.460
2	ENVR SUIT SETTLED	0.500	-0.100	0.400
3	NAT DEM FOR COAL	0.500	0.080	0.580
4	OFFSHORE OIL DIS	0.500	0.020	0.520
5	MIGRATION	0.500	0.030	0.530
6	15000 JOBS	0.500	0.060	0.560
7	NAT ENERGY CONSUMPTION	0.500	0.070	0.570
8	50000 POPULATION	0.500	0.050	0.550

```
C     ************************************************************************
C     *                                                                      *
C     *             ***  SIMPLE LINEAR REGRESSION ***                        *
C     *                                                                      *
C     * THIS PROGRAM IS DESIGNED                                             *
C     *                                                                      *
C     *    TO READ                                                           *
C     *       CARD 1 COLS  2-72   TITLE  DESCRIPTION OF THE PROBLEM          *
C     *                                  USING ANY CHARACTERS ON             *
C     *                                  KEYPUNCH ** COLUMN 1 MUST BE        *
C     *                                  LEFT BLANK **                       *
C     *       CARD 2 COLS  1- 5    N  TOTAL # OF OBSERVATIONS  (I5)          *
C     *                    6-10    K  # OF UNIQUE VALUES OF THE              *
C     *                               INDEPENDENT VARIABLE  (I5)             *
C     *       CARDS 3 TO T  K SETS OF CARDS, ONE SET FOR EACH IND. VALUE     *
C     *          CARD A  COLS   1-10  NI # OF OBSERVATIONS AT X(I) (I10)     *
C     *                        11-20  X(I) INDEPENDENT VALUE  (F10.0)        *
C     *          CARD B   Y(I,J)  J=1,...,NI  OBSERVATIONS AT X(I)           *
C     *                                       PUNCH 7 TO A CARD IN           *
C     *                                       7F10.0 FORMAT.  IF NI>7,       *
C     *                                       CONTINUE ON NEXT CARD.         *
C     *           TO SOLVE MORE THAN ONE PROBLEM AT A TIME, REPEAT THE       *
C     *           READ SEQUENCE, AND STACK THE DATA ONE BEHIND THE           *
C     *           OTHER                                                      *
C     *                                                                      *
C     *    TO CALCULATE                                                      *
C     *       SUMX     TOTAL SUM OF VALUES OF INDEPENDENT VARIABLE           *
C     *       SUMY     TOTAL SUM OF VALUES OF DEPENDENT VARIABLE             *
C     *       SUMYI    SUM OF THE VALUES OF THE DEPENDENT VARIABLE           *
C     *                AT EACH VALUE OF THE INDEPENDENT VARIABLES            *
C     *       SUMX2    TOTAL SUM OF SQUARES OF THE INDEPENDENT VARIABLE      *
C     *       SUMY2    TOTAL SUM OF THE SQUARES OF THE DEPENDENT             *
C     *                VARIABLE                                              *
C     *       SUMXY    TOTAL SUM OF THE PRODUCTS OF THE INDEPENDENT          *
C     *                VARIABLE WITH THE CORRESPONDING DEPENDENT             *
C     *                VARIABLE                                              *
C     *       XBAR     MEAN OF THE INDEPENDENT VARIABLE                      *
C     *       YBAR     MEAN OF THE DEPENDENT VARIABLE                        *
C     *       YBARK(I) PARTIAL MEANS OF THE DEPENDENT VARIABLE WHEN          *
C     *                MULTIPLE OBSERVATIONS ARE INVOLVED                    *
C     *       BHATO BHAT1  LEAST SQUARES ESTIMATES OF THE PARAMETERS IN      *
C     *                    THE MODEL  Y=BETA0 + BETA1*X + EPSILON            *
C     *       SSQM     SUM OF SQUARES FOR THE MEAN                           *
C     *       SSQDR    SUM OF SQUARES DUE TO REGRESSION                      *
C     *       SSQAR    SUM OF SQUARES ABOUT REGRESSION                       *
C     *       SSQLF    SUM OF SQUARES DUE TO LACK OF FIT                     *
C     *       SSQPE    SUM OF SQUARES DUE TO PURE ERROR                      *
C     *       RMS      REGRESSION MEAN SQUARE                                *
C     *       SQUARE   RESIDUAL MEAN SQUARE                                  *
C     *       LFMS     LACK OF FIT MEAN SQUARE                               *
C     *       ERRMS    PURE ERROR MEAN SQUARE                                *
C     *       FVAL     REGRESSION MEAN SQUARE / RESIDUAL MEAN SQUARE         *
C     *       FLOF     LACK OF FIT MEAN SQUARE / ERROR MEAN SQUARE           *
C     *       RSQR     PART OF SUM OF SQUARES ABOUT THE MEAN ACCOUNTED       *
```

```
C   *                    FOR BY THE PRESENCE OF B1 IN THE MODEL                *
C   *       STERR        STANDARD ORROR OF REGRESSION                          *
C   *       STDEV        STANDARD DEVIATION                                    *
C   *       MAPD         MEAN ABSOLUTE PERCENT DEVIATION                       *
C   *       MAPE         MEAN ABSOLUTE PERCENT ERROR                           *
C   *       T            T STATISTIC = SQRT OF FVAL                            *
C   *                                                                          *
C   *     TO PRINT                                                             *
C   *        ANALYSIS OF VARIANCE TABLE                                        *
C   *        XMEAN, YMEAN, INTERCEPT, SLOPE, R, RSQR, MAPD, MAPE,              *
C   *        STD. ERR OF REG., STD. DEV., T                                    *
C   *                                                                          *
C   * THE PROGRAM, AS WRITTEN, DOES NOT ALLOW MORE THAN 100 VALUES,           *
C   * OR MORE THAN 15 OBSERVATIONS AT A GIVEN X(K).  TO CHANGE THESE          *
C   * LIMITS, CHANGE THE CORRESPONDING DIMENSION STATEMENTS.                  *
C   * SOURCE:  BILLY E. GILLETT, INTRODUCTION TO OPERATIONS RESEARCH,         *
C   *             MCGRAW-HILL, 1976                                            *
C   *             MODIFIED BY CARL WILSON AND JOHN DICKEY, VPI & SU            *
C   *                                                                          *
C   ************************************************************************
      DIMENSION X(100),Y(100,15),NYOBX(100),YBARK(100),TITLE(18)
      DIMENSION YHAT(100)
      REAL LFMS,MAPDN,MAPEN,MAPD,MAPE
C  READ DATA
   95 READ(5,96,END=2000)TITLE
   96 FORMAT(18A4)
      WRITE(6,97) TITLE
   97 FORMAT('1',18A4,//)
      READ(5,100)N,K
  100 FORMAT(2I5)
      DO 110 I=1,K
      READ(5,115)NI,X(I)
  115 FORMAT (I10,F10.0)
      READ(5,116)(Y(I,J),J=1,NI)
  116 FORMAT(7F10.0)
      NYOBX(I)=NI
  110 CONTINUE
C  PRINT OUT THE DATA AS A CHECK
      WRITE(6,111)
  111 FORMAT(6X,'K   N(I)    X(K)',7X,'Y(K,1)',4X,'Y(K,2)',4X,'Y(K,3)',
     *4X,'Y(K,4)',4X,'Y(K,5)',/)
      DO 113 I=1,K
      NI=NYOBX(I)
      WRITE(6,112)I,NI,X(I),(Y(I,J),J=1,NI)
  112 FORMAT( 5X,I2,2X,I2,1X,6F10.3,(/24X,5F10.3))
  113 CONTINUE
      WRITE(6,144)
  144 FORMAT(/1X,72('_')/)
C     ********************************************************************
C     * CALCULATE SUMMATIONS NECESSARY FOR AN ANALYSIS OF VARIANCE       *
C     ********************************************************************
```

```
C  INITIALIZE SUMMATIONS
      SUMX=0.0
      SUMY=0.0
      SUMX2=0.0
      SUMY2=0.0
      SUMXY=0.0
      SUMYI=0.0
      BNUM=0.0
      BDEN=0.0
C  CALCULATE SUMMATIONS AND AVERAGES
      DO 120 I=1,K
      SUMYI=0.0
      NI=NYOBX(I)
      SUMX2=SUMX2+NI*X(I)*X(I)
      SUMX=SUMX+NI*X(I)
      DO 125 J=1,NI
      SUMXY=SUMXY+X(I)*Y(I,J)
      SUMY2=SUMY2+Y(I,J)*Y(I,J)
      SUMY=SUMY+Y(I,J)
      SUMYI=SUMYI+Y(I,J)
  125 CONTINUE
      YBARK(I)=SUMYI/NI
  120 CONTINUE
      XBAR=SUMX/N
      YBAR=SUMY/N
C  SET FLAG FOR REPEATED OBSERVATIONS
      DO 121 I=1,K
      IF(NYOBX(I).NE.1) GO TO 122
  121 CONTINUE
      IFLAG=0
      GO TO 123
  122 IFLAG=1
  123 CONTINUE
C  CALCULATE VALUES FOR AOV TABLE
      DO 130 I=1,K
      DIFF=X(I)-XBAR
      BNUM=BNUM+NYOBX(I)*DIFF*YBARK(I)
      BDEN=BDEN+NYOBX(I)*DIFF*DIFF
  130 CONTINUE
      BHAT1=BNUM/BDEN
      BHAT0=YBAR-BHAT1*XBAR
      SSQM=N*YBAR*YBAR
      SSQDR=BHAT1*BHAT1*BDEN
      SSQAR=SUMY2-SSQM-SSQDR
      RMS=SSQDR/1
      N2=N-2
      SQUARE=SSQAR/N2
      STERR=SQRT(SQUARE)
      STDEV=SQRT((SSQAR+RMS)/(N-1))
      FVAL=RMS/SQUARE
      T=SQRT(FVAL)
      MAPDN=0.0
      DO 133 I=1,K
      NOY=NYOBX(I)
      DO 133 J=1,NOY
      MAPDN=MAPDN+(ABS(Y(I,J)-YBAR))/YBAR
  133 CONTINUE
      MAPD=MAPDN*100/N
```

```
      MAPEN=0.0
      DO 134 I=1,K
      YHAT(I)=BHAT0+BHAT1*X(I)
      NOY=NYOBX(I)
      DO 134 J=1,NOY
      MAPEN=MAPEN+(ABS(Y(I,J)-YHAT(I)))/YHAT(I)
  134 CONTINUE
      MAPE=MAPEN*100/N
      RSQR=SSQDR/(SUMY2-SSQM)
      R=SQRT(RSQR)
C  PRINT TABLE IF NO REPEATED OBSERVATIONS
      IF(IFLAG.EQ.0) GO TO 150
      SSQPE=0.0
      DO 135 I=1,K
      NI=NYOBX(I)
      DO 135 J=1,NI
      SDIF=Y(I,J)-YBARK(I)
      SSQPE=SSQPE+SDIF*SDIF
  135 CONTINUE
      SSOLF=SSQAR-SSQPE
      K2=K-2
      LFMS=SSOLF/K2
      NE=N-K
      ERRMS=SSQPE/NE
      FLOF=LFMS/ERRMS
      GO TO 160
C     ******************************************************************
C     * PRINT ANALYSIS OF VARIANCE TABLE                               *
C     ******************************************************************
  150 WRITE(6,155)
  155 FORMAT(13X,'ANALYSIS OF VARIANCE TABLE WITH NO REPEATED OBSERVATIO
     *NS')
      WRITE(6,148)
  148 FORMAT(1X,72('_')/)
      GO TO 170
  160 WRITE(6,165)
  165 FORMAT(13X,'ANALYSIS OF VARIANCE TABLE WITH REPEATED OBSERVATIONS'
     *)
      WRITE(6,148)
  170 CONTINUE
      WRITE(6,175)
  175 FORMAT(2X,'SOURCE VARIATION   DF        SUM SQUARES        MEAN SQUA
     *RES       CAL.F.')
      WRITE(6,147)
  147 FORMAT(1X,72('_'))
      WRITE(6,180)N,SUMY2
  180 FORMAT(13X,'TOTAL',2X,I3,2X,F16.4)
      WRITE(6,147)
      WRITE(6,185)SSQM
  185 FORMAT(14X,'MEAN     1   ',F16.4)
      WRITE(6,147)
      WRITE(6,190)SSQDR,RMS,FVAL
  190 FORMAT(10X,'R(B1|B0)'/
     *1X,'DUE TO REGRESSION     1',2X,F16.4,2X,F16.4,2X,F10.5)
      WRITE(6,147)
      WRITE(6,195)N2,SSQAR,SQUARE
  195 FORMAT(9X,'RESIDUAL'/
```

```
     *2X,'ABOUT REGRESSION',2X,I3,2X,F16.4,3X,F16.4)
      WRITE(6,147)
      IF (IFLAG.EQ.0) GO TO 210
      WRITE(6,200)K2,SSOLF,LFMS,FLOF
  200 FORMAT(7X,'LACK OF FIT',2X,I3,2X,F16.4,3X,F16.4,3X,F10.5)
      WRITE(6,147)
      WRITE(6,205)NE,SSOPE,ERRMS
  205 FORMAT(8X,'PURE ERROR',2X,I3,2X,F16.4,3X,F16.4)
      WRITE(6,147)
  210 CONTINUE
      WRITE(6,215)XBAR,YBAR
  215 FORMAT(/10X,'XMEAN =',F12.4,10X,'YMEAN =',F12.4/)
      WRITE(6,225)BHATO,BHAT1
  225 FORMAT(10X,'INTERCEPT =',F12.4,10X,'SLOPE =',F14.6/)
      WRITE(6,230)R,RSQR
  230 FORMAT(10X,'R =',F12.4,10X,'R**2 =',F12.4/)
      WRITE(6,235)MAPD,MAPE
  235 FORMAT(10X,'MAPD =',F12.4,10X,'MAPE =',F12.4/)
      WRITE(6,240)STERR,STDEV
  240 FORMAT(4X,'STD. ERROR OF REG. =',F12.4,10X,'STD. DEV. =',F12.4/)
      WRITE(6,245)T
  245 FORMAT(10X,'T = SQUARE ROOT OF CAL. F. =',F12.4//)
      GO TO 95
 2000 STOP
      END
```

INPUT DATA

```
STONE GULCH REGRESSION
   6     6
         1         0.
       9.
         1        10.
      11.
         1        20.
      12.
         1        30.
      11.
         1        40.
      11.
         1        50.
    10.
```

OUTPUT

STONE GULCH REGRESSION

K	N(I)	X(K)	Y(K,1)	Y(K,2)	Y(K,3)	Y(K,4)	Y(K,5)
1	1	0.0	9.000				
2	1	10.000	11.000				
3	1	20.000	12.000				
4	1	30.000	11.000				
5	1	40.000	11.000				
6	1	50.000	10.000				

ANALYSIS OF VARIANCE TABLE WITH NO REPEATED OBSERVATIONS

SOURCE VARIATION	DF	SUM SQUARES	MEAN SQUARES	CAL.F.
TOTAL	6	688.0000		
MEAN	1	682.6667		
R(B1|B0) DUE TO REGRESSION	1	0.2286	0.2286	0.17909
RESIDUAL ABOUT REGRESSION	4	5.1052	1.2763	

XMEAN = 25.0000 YMEAN = 10.6667

INTERCEPT = 10.3810 SLOPE = 0.011429

R = 0.2070 R**2 = 0.0429

MAPD = 7.2917 MAPE = 7.3305

STD. ERROR OF REG. = 1.1297 STD. DEV. = 1.0328

T = SQUARE ROOT OF CAL. F. = 0.4232

GOMPERTZ AND PEARL-REED CURVES

The preceding sample linear regression program can be employed to establish S-shaped curves of the Gompertz and Pearl-Reed (logistic) varieties. The equation for the Gompertz is:

$$y = Le^{be^{-kt}}$$

where L is the limit, e is the base of the natural logarithms (2.712), t is time, and b and k are parameters. The latter two are established by running a simple regression of ln ln (L/y) versus t. The resulting slope is -k (the slope will always be negative, so k itself is always positive) and the intercept will equal ln b. Experience indicates for both the Gompertz and Pearl-Reed that you should use t = 10, 20, 30, etc. instead of 1910, 1920, 1930... in performing the regression and subsequent calculations. You then take the anti ln of the resulting intercept to get b and set up the specific Gompertz equation. Note that the R^2, MAPE, and standard error shown on the obtained printout are <u>not</u> for the original Gompertz equation but for the ln ln (L/y) vs. t equation. If you want the "true" values for these statistics, you will have to plug each t value into the Gompertz equation, solve for the corresponding y's (denoted by $\hat{y}$), then rerun a regression of y vs. $\hat{y}$.

The equation for the Reed-Pearl curve is:

$$y = \frac{L}{1 + ae^{-bt}}$$

To get the parameters a and b, you must regress $\ln\left[(L/y) - 1\right]$ versus t.

The resulting slope will be b and the intercept ln a. Similar procedures as for the Gompertz then would be carried out to get a, the appropriate R^2, MAPE, and standard error of regression.

For further information, see:

J. P. Martino, Technological Forecasting for Decision-Making, (New York: American Elsevier, 1972), pp. 111-119.